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MATERIÁLOVOTECHNOLOGICKEJ FAKULTY
SLOVENSKEJ TECHNICKEJ UNIVERZITY
V BRATISLAVE SO SÍDLOM V TRNAVE

Mimoriadne číslo
2013

RESEARCH PAPERS

FACULTY OF MATERIALS SCIENCE AND TECHNOLOGY
SLOVAK UNIVERSITY OF TECHNOLOGY IN TRNAVA

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Upon the decision of the Faculty management, this special issue contains selected papers of IDS 2013.

The papers were reviewed.

FACULTY OF MATERIALS SCIENCE AND TECHNOLOGY SLOVAK UNIVERSITY OF TECHNOLOGY IN TRNAVA

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CONTRIBUTIONS TO IMPROVE ONLINE LEARNING THROUGH ADAPTIVE HYPERMEDIA TECHNIQUES

Javier ABRAHAM-CURTO

ABSTRACT

The personalization of learning through the automatic adaptation of the educational process, especially for the contents, is regarded as an important and necessary step for the improvement of education in the future. It is believed that through individualization get improved efficiency, increased speed and quality of learning for students and by automating the process, improved efficiency, better resource utilization, scalability of the process learning. To achieve this goal we have developed different strategies. One of them are looking for Adaptive Hypermedia Systems adjust all contents in a atuomática to the characteristics of each user.

KEY WORDS

Adaptive Hypermedia System, user modelling, educational dataminig, learning analytics

INTRODUCTION

In basics, the way of teaching has not changed. It continues to emphasize the figure of the teacher, who has some knowledge, together with a certain skills and teaching techniques, transmitting them to a group of students. Also, to consider that the student has acquired a certain knowledge there are some exercises and / or tests that must pass.

With the arrival of the Information Technology (IT) training and, more specifically, the eLearning was considered that it would produce a revolution in education. As time has verified these changes have not really affected the learning process rather has implicated a progress in the ability to access the educational resources regardless of the spatial and temporal. This is that students can access from anywhere, provided that availability of a device with an Internet connection. Similarly, these processes have allowed teachers to distribute their content to more students and track more or less detailed, which is the use of students perform on them.

Notably, thanks to technology, the inclusion of certain tools such as forums, chats, blogs, video, computer-assessment tests, etc. allow students to interact among themselves and with

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the teachers, so that it is reproduce the process of interaction and feedback from classroom education, as necessary during the training process.

Basically, without addressing the complexity, quality and standard of materials and teachers, these formations are under the paradigm "the same education for all students" which is based on the assumption that students come to training with certain knowledge, similar, and must acquire a minimum knowledge through a predetermined classes and materials and pass some tests, which are the same for everyone.

However, it is possible to understand what are the limitations and disadvantages of this system, and it is equally possible to understand the enormous benefits that a system would adjust the training to the individual characteristics of each student, taking into account their prior knowledge, their way of learning and skills, adapting the different materials to each student and not forcing students to adapt materials. This would allow students to progress and learn more efficiently and students realize their full potential, which could mean a huge improvement in the development of knowledge, science and, ultimately, society.

Why still using this paradigm? We can find several answers: (1) education system has worked well for results obtained based on available resources (2) Not found another best possible apply to the real world. For over 20 years has been considered to have the potential IT to individualize the learning process in a more or less automated. With this premise began to develop a new area of research, Adaptive Hypermedia Systems (AHS). An AHS can be defined as the system that builds a model of the goals, preferences and knowledge of each user, and uses it to set the user interaction, in order to adapt the content to their needs (Brusilovsky 1996). Although there are dozens of developments of all types of educational SHA and the large number of researchers and resources have been devoted, not all of them have gone from being prototypes or experimental developments, used on a small scale, in terms of reduced courses content and / or students. Currently there is none with a real and complete application in the field of education.

To understand the full scope of the concept adaptive system, it is important to differentiate the adaptive adaptable concept, and the necessity of the existence of a user model. Is adaptable system that allows the user, through an appropriate interface, can manually set certain options or features of the system directly or indirectly, while an adaptive system that adaptation process performed automatically or semi-automatically, without intervention by the user. There is also the possibility that one system can have both characteristics, i.e.: be adaptable and adaptive simultaneously.

Another important concept is that of user modeling, which is based on user characteristics represented in a User Model and User Model (UM). From a general point of view one can differentiate the adaptation to user data, the usage data and environment data. The data point to the target user adaptation. Usage data is data on the user interaction can be used to influence the process of adaptation. Data environment includes all aspects that are not related to the behavior or characteristics of the user (Kobsa 2001).

We can consider several causes of these difficulties in the implementation of AHS in the field of education, such as: (1) the complexity and cost of adaptive content development, (2) difficulty in determining the user's current knowledge / student (3) lack of appropriate platforms, adaptive capacity, to distribute content.

In order to resolve some of these difficulties and / or limitations and to better understand the individual learning process, since the beginning of this century, we have been starting to use the analysis of information systems that generate web-based education, primarily the Learning Management Systems or Learning Management System (LMS). This information

can come from different sources: (1) provided by the user, (2) the results of the test, practice tests, (3) the activity logs (log files), with which it can be determined properly configured what resources you used, how many times you have used, how long it has been in every one of them and (4) even with the help of specialized tracking software, which has performed actions in each resource (mouse movements and clicks, if has rectified an answer, etc.). Obviously for each session of each user on each system can generate a huge amount of data and, by linking the data of all users, they become totally unmanageable for people to analyze directly. Therefore, they began to use different data mining techniques to find patterns that could help analyze and understand this data in order to improve the learning process in general, and, among other things, to model each much more user automatically, efficiently and effectively.

To answer this need to analyze these data, we developed two different research communities: Educational Data Mining (EDM) and Learning Analytics and Knowledge (LAK). Both reflect the emergence of the approaches based on the analysis of educational data to understand and improve the learning process. An analysis of the similarities and key differences between these areas can be found in the work "Learning Analytics and Educational Data Mining: Towards Communication and Collaboration" (Siemens 2010), which includes the following definitions: According to the International Educational Data Mining Society (IEDMS) "EDM is a discipline that seeks to develop methods to explore educational data, and use these methods to better understand students and the way in which they learn." According to the Society for Learning Analytics Research "is a measurement LAK, capture, analysis and reporting of data on students and their context, for understanding and optimizing learning and the environments in which this happens." The similarities between EDM and LAK overlapping suggest numerous research areas there between, besides the fact that practically required for development of the same data sets. However, having different roots and some important differences. Most importantly, this proposed thesis is the fact that mainly focuses LAK inform and empower instructors and students, while EDM is focused more towards adapting automated or semi-automated.

Another characteristic of these research communities is that they are composed of researchers from different disciplines such as computer science, teaching scientists, specialists in psychometrics, etc. Due to the short time they have developed, we can consider that the analysis of educational data through data mining technology is an emerging field that is still in an early stage of development and immature. However, the boom of its application in sectors other than education, such as finance, marketing, health. That is why it is considered to investigate the application of data mining techniques in educational environments presents significant opportunities for innovation and implementation in educational systems of the future.

Specifically, for the development of the thesis, we propose the implementation of the main AI techniques and data mining to propose a dynamic user model that can be implemented in an educational AHS. This is intended to analyze the various data sources currently used for user modeling and whether educational environments may include other data sources that have not been used to date in order to optimize the modeling. Once established the user model is intended to make a proposal of architecture of a generic educational AHS can be used simply and fully operational in a real educational environment.

Knowledge Background

For a system to be considered adaptive hypermedia should meet three criteria: (1) be a hypertext or hypermedia system, (2) having a user model and (3) being able to adapt the hypermedia using this model (Brusilovsky 1996). To perform an adaptation the system must be able to respond to the six main issues:
What can we adapt? (What?)
What do we adapt? (Why?)
Why do we need to adapt? (Why?)
Where can we apply adaptation? (Where?)
When can we apply adaptation? (When?)
How can we adapt? (How?)

Despite all the research and developed systems, there is still no consensus on what is the ideal architecture for adaptive systems. Each new development introduces new components, new interfaces, new techniques for adaptation, etc. In search of a generalization of the AHS has tried to develop a model that could serve as reference standard. Among the most notable include: Tower Model, AHAM, "Munich" Model, Gahm and LAOS. (Knutov, De Bra et al. 2009)

The UM is a feature of the AHS. In an educational AHS has been doing modeling based on certain characteristics of the user, such as:

1. Knowledge
2. Interests
3. Objectives and tasks
4. Background
5. Personal Characteristics
6. Workbench.

The development of User Modeling can be done in two ways: (1) based on the characteristics of the user and (2) based on stereotypes. The first is based on making a UM for each user based on their own individual characteristics, is most often used in most AHS. The second is based on a set of user groups that meet certain characteristics and include each user in one of these groups called stereotypes, so many UM only exist as clusters are taken into the system. This is the oldest form of user modeling. To model the user's knowledge and developments in educational AHS is normally used an approach called overlay or overlay, which requires the establishment of a prior domain model or domain model (DM) and the UM builds from the back the DM, adding the values that reflect the user's knowledge level of each of the concepts (Brusilovsky, Millán 2007). Regarding the application of data mining in education or Educational Data Mining (EDM), we can highlight the work "Educational Data Mining: a Survey form 1995 to 2005" (Romero, Ventura 2007) and "Educational Data Mining : A Review of the State of the Art "(Romero 2010) as the most comprehensive survey to date. In the latter paper argues that there are many possible applications of data mining in educational environments. Among the investigated and we find:

1. Data analysis and visualization
2. Provide feedback to support instructors
3. Recommended for students
4. Predicting the performance of students
5. Student Modeling
6. Detection of undesirable behaviors of students
7. Grouping students

8. Analysis of social networks
9. Develop concept maps
10. Construction courses
11. Planning and organization

It also suggests several lines of future research:

1. Development of data mining tools easier to use by educators
2. Integration with eLearning systems
3. Standardization of data and models
4. Adjust the data mining algorithms traditional take into account the educational context.

Knowledge Contribution

While the application of data mining techniques in user modeling AHS is not new, if it is to provide new solutions more efficient and effective in the face of their inclusion in real environments.

The definition and design of a dynamic user model using such techniques as well as the definition and design of a fully functional educational AHS can help lay the foundation for a new generation of educational AHS, focusing on its applicability and usability, rather than experimentation and research.

It is estimated that, overall, the progress they have been developing different data mining techniques, it is possible to achieve the proposed objectives, or at least, to establish a clear and concrete are the specific reasons that have prevented achieve those objectives, face to allow the development of new lines of research. From an educational perspective, being able to implement a fully functional educational AHS that is able to adapt content based on a dynamic user model simply, can make a revolution that will allow students to develop their potential so many more effective and efficient.

Finally, from an economic standpoint, can make the change in the business model of online training, because since the contents are quickly outdated and easily replicable and have lost a very significant amount of its value, so people are less likely ever to pay for some content. However, being able to use a system that adapts content to each user can add value in terms of learning more in less time (efficiency), it would be very difficult to replicate by individual user and by other organizations, what people would be willing to pay for use and could be a competitive advantage for the company or organization that achieved satisfactorily implement.

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REFERENCES

1. BRUSILOVSKY, P. 1996. Methods and Techniques of Adaptive Hypermedia. *User Modeling and User-adapted Interaction,* **6**(2-3), pp. 87-129.

2. BRUSILOVSKY, P. and MILLÁN, E. 2007. *User Models for Adaptive Hypermedia and Adaptive Educational Systems.* Springer Berlin / Heidelberg.
3. KNUTOV, E., DE BRA, P. and PECHENIZKIY, M. 2009. AH 12 years later: a comprehensive survey of adaptive hypermedia methods and techniques. *New Rev.Hypermedia Multimedia,* **15**(1), pp. 5-38.
4. KOBSA, A. 2001. Generic user modeling systems. *User modeling and user-adapted interaction,* **11**(1), pp. 49.
5. ROMERO, C. 2010. Educational data mining: a review of the state of the art. *IEEE Transactions on Systems, Man, and Cybernetics, Part B: Cybernetics,* **40**(6), pp. 601.
6. ROMERO, C. and VENTURA, S. 2007. Educational data mining: A survey from 1995 to 2005. *Expert Systems with Applications,* **33**(1), pp. 135-146.
7. SIEMENS, G. 2010. Learning analytics and educational data mining: towards communication and collaboration.

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DATA PORTABILITY AMONG PROVIDERS OF PLATFORM AS A SERVICE

Darko ANDROCEC

ABSTRACT

Platform as a service model has certain obstacles, including data lock-in. It is expensive and time-consuming to move data to the alternative providers. This paper presents data storage options in platform as a service offers and identifies the most common data portability problems between various commercial providers of platform as a service. There are differences among their storage models, data types, remote APIs for data manipulation and query languages. Representing data models of platform as a service and data mappings by means of ontology can provide a common layer to achieve data portability among different cloud providers.

KEY WORDS

data portability, platform as a service, Cloud Computing

INTRODUCTION

Cloud Computing is a new paradigm for the provision of computing infrastructure, platform or software as a service (4). The most comprehensive definition of Cloud Computing is provided by NIST: "Cloud computing is a pay-per-use model for enabling available, convenient, on-demand network access to a shared pool of configurable computing resources (e.g. networks, servers, storage, applications, services) that can be rapidly provisioned and released with minimal management effort or service provider interaction" (11). Platform as a service is a Cloud model where providers offer virtualized servers and associated services for running existing applications or developing and testing new ones (16).

However, this new business model for the provision of computing infrastructure has certain obstacles, including provider lock-in. The aforementioned problem is characterized by expensive and time-consuming migration of application and data to alternative Cloud providers, the inability or limited ability to connect to computing resources, applications and data outside the selected Cloud Computing service, and the dependence on a specific programming language used by the selected Cloud Computing vendor. Currently, each Cloud

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provider develops its own specific technology solutions, remote application programming interfaces (APIs), and some even create new programming languages. If Clouds are not interoperable, it is difficult or even impossible to achieve collaboration among computing resources of different Cloud service providers, and possible migration to another provider is a complex and an expensive task. There are three main models of Cloud Computing: infrastructure as a service, platform as a service, and software as a service. The focus of this work is on issues of data portability among various offers of platform as a service.

The rest of the paper is structured as follows. In the next section, I list related work on Cloud Computing interoperability. After that, I present possible storage models for platform as a service layer. Thereafter, I identify the most common data interoperability problems in platform as a service model. Finally, I conclude and propose some solutions to found data interoperability problems.

RELATED WORK

Cloud Computing interoperability has recently become very active research field. Rodero-Merino et al. (18) propose a new abstraction layer for infrastructure as a service. This layer is closer to the service lifecycle and it provides automatic deployment, definition and management of services. Ajith and Maximilien (2) described their own Altocumulus middleware to homogenize different Cloud solutions and the associated Cloud best practice model. Bernstein and Vij (3) present their InterCloud Directories and Exchanges mediator to enable connectivity and collaboration among Cloud vendors. They define their Cloud Computing resources ontology by means of the Resource Description Framework (RDF). Merzky, Stamou and Jha (13) demonstrate a proof-of-concept of application-level interoperability among different Clouds and Grids by means of the SAGA-based implementation of MapReduce. They developed a range of Cloud adaptors for SAGA. MapReduce is a programming framework developed within Google and is used to simplify data processing across massive data sets, and SAGA is a programming interface which provides the ability to develop distributed applications in an infrastructure independent way. Ranabahu and Sheth (17) present the usage of well-established semantic technologies to overcome vendor lock-in issues in Cloud Computing. They distinguish four types of semantics for an application: data semantics (definitions of data structures, their relationships and restrictions), logic and process semantics (the business logic of the application), non-functional semantics (e.g. access control and logging) and system semantics (deployment descriptions and dependency management of the application). Buyya, Ranjan and Calheiros (5) present the vision, challenges and architecture of a utility-oriented federation of Cloud Computing environments. They advocate the creation of a federated Cloud Computing environment that supports dynamic expansion or contraction of capabilities. The reference architecture for semantically interoperable Clouds (RASIC) was proposed by Loutas et al. (12). The architecture's main aim is to enable the design, deployment and execution of services on top of semantically interlinked Cloud Computing offerings.

Promising research activities, related to Cloud Computing interoperability, are carried out in the European research projects: Mosaic (15), Cloud4SOA (6), Contrail, VisionCloud, REMICS, and MODAClouds. However, data portability issue among platform as a service providers is still unresolved.

STORAGE FOR PLATFORM AS A SERVICE

There are two main storage models in platform as a service: NoSQL and relational databases. NoSQL is next generation database that has some of the following characteristics: non-relational, distributed, open source and horizontally scalable (14). More characteristics that often apply to this paradigm are: schema-free, easy replication support, simple API, eventually consistent / BASE (not ACID), a huge amount of data and more (14). Relational databases can be run on the cloud as a virtual machine images or as a services. These databases are difficult to scale, but cloud providers attempt to address this issue. Now we will look at three prominent platform as a service offers (namely, Google App Engine, Microsoft Azure and Salesforce) and describe in detail their storage models.

Google App Engine has three options for data storage: App Engine Datastore, Google Cloud SQL and Google Cloud Storage. The App Engine Datastore is a schemaless object datastore (9). The primary data repository for this offer is High Replication Datastore where data is replicated across multiple data centers using Paxos algorithm. The data store holds data objects named entities; each entity has one or more properties of one of supported data types; and each entity is identified by its kind and key. Google Cloud SQL (10) enables you to create, configure and use relational MySQL databases in Google's cloud. It has almost all of the capabilities and functionality of MySQL (1). The Google Cloud Storage is an experimental service that provides storage for big objects and files (up to terabytes in size).

There are three main storage offerings on the Azure platform (7): Local Storage, Windows Azure Storage, and SQL Database. Local Storage provides temporary storage for a running application and it represents a directory that can be used to store files. Windows Azure Storage consists of blobs (storage of unstructured binary data), tables (a schemaless collection of row like entities, each of which can contain up to 255 properties) and queues (storage for passing messages between applications) that are accessible by multiple applications. SQL Database is based on SQL Server technology and provides relational database for the Azure platform.

In Salesforce, an organization is the equivalent of a database, but with built-in user identity and security (8). Objects are similar to tables in relational databases, they contain fields and records. Objects are related to other objects by using relationship fields, such as lookup and master-detail relationships, instead of primary and foreign keys. There are two types of objects: standard objects (predefined, created automatically by Salesforce) and custom objects (objects that you create in your organization).

IDENTIFIED DATA PORTABILITY PROBLEMS

The first identified problem is a difference between data storage models of various commercial providers of platform as a service. For example, it is difficult or even impossible to move data from a NoSQL model of one provider to a SQL model of another platform as a service provider. Even if we choose the same models (e.g. SQL) in two various offers, these models will still have significant differences due to provider's design and used technology. For example, each provider supports their own set of data types. Data types differ in name, value space, permitted range of values, precision of data etc. Some offers also have predefined standard objects or tables, e.g. Salesforce list standard objects in their documentation (some object/table names are reserved) and it also adds some standard fields to any new custom object (object created by user).

Data import or export is often complicated. Most providers offer only basic CSV or XML exports (list of columns and row data), and from them you can't determine data types, primary keys, possible relationships between tables (e.g. foreign keys) etc. You must use remote APIs of cloud providers to get that information. APIs are not standardized, so you need to cope with different functions, input and output parameters and different means to access remote API functionalities (for example, by using libraries for programming languages and/or SOAP or REST web services). Various platform as a service providers also use their own versions of data query languages. Salesforce provides the Salesforce Object Query Language (SOQL) and Salesforce Object Search Language (SOSL). Google Query Language (GQL) is a language for retrieving entities or keys from the Google App Engine data store, and its syntax is similar to that of SQL. SQL Azure uses T-SQL as the query language.

CONCLUSION

Cloud Computing is a new paradigm for the provision of computing infrastructure, platform or software as a service that enables significant cost reduction and flexibility. This is a strong motive for many organizations from the public and private sector to turn to Cloud Computing services. Lack of established Cloud Computing standards still presents a challenge to organizations interested in cloud services. When an organization chooses a specific cloud service provider, it also gets the vendor's specific protocols, standards and tools, making a potential future migration complex and costly. The focus of this paper is on issues of platform as a service data portability.

I found that there are two main storage models in platform as a service offers: NoSQL and relational databases. The first identified data portability problem is a difference among data storage models of various commercial providers of platform as a service. The storage models of three prominent platform as a service providers (Google, Salesforce and Microsoft) are presented in the third section. Furthermore, each provider supports their own set of data types that differ in name, value space, permitted range of values, precision of data etc. The next issue lays in the fact that platform as a service providers use their own data query languages. Remote APIs for data manipulation are not standardized, and most providers offer only basic CSV or XML exports.

The data portability problems can be solved by using unified model and mapping. I Plan to develop an ontology that identifies remote API operations for data manipulation and data mappings among the heterogeneous APIs. The synonymous API operations of various platform as a service vendors can have different types and numbers of input and output parameters. Furthermore, platform as a service offerings often use proprietary and non-standard databases (relational and non-relational). Representing these data models by means of ontology can provide a common layer for information exchange.

REFERENCES

1. About Google Cloud SQL, https://developers.google.com/cloud-sql/docs/introduction, Accessed 20.02.2013.
2. AJITH, R., MAXIMILIEN M. 2009. A Best Practice Model for Cloud Middleware Systems. Proceedings of the Best Practices in Cloud Computing: Designing for the Cloud workshop in ACM SIGPLAN International Conference on Object-Oriented Programming, Systems, Languages, and Applications (OOPSLA). Orlando FL, USA. pp.41-51.

3. BERNSTEIN, D., VIJ, D. 2010. Intercloud Directory and Exchange Protocol Detail using XMPP and RDF. In *The 6th World Congress on Services*. Miami, USA, pp. 431-438.
4. BUYYA R., YEO C S., VENUGOPAL S., BROBERG J., BRANDIC I. 2009. Cloud computing and emerging IT platforms: Vision, hype, and reality for delivering computing as the 5th utility, Future Generation Computer Systems, Amsterdam, Netherlands, pp. 599-616.
5. BUYYA, R., RANJAN, R., CALHEIROS R.N. 2010. InterCloud: Utility-Oriented Federation of Cloud Computing Environments for Scaling of Application Services. In: *Proceedings of the 10th International Conference on Algorithms and Architectures for Parallel Processing*. Germany, Springer.
6. D1.2 Cloud4SOA Cloud Semantic Interoperability Framework. 2.6.2011, http://www.cloud4soa.eu/sites/default/files/D1.2_Cloud4SOA%20Cloud%20Semantic%20Interoperability%20Framework.pdf, Accessed 14.05.2012.
7. Data Storage Offerings on the Windows Azure Platform, http://social.technet.microsoft.com/wiki/contents/articles/1674.data-storage-offerings-on-the-windows-azure-platform.aspx, Accessed 20.02.2013.
8. Database.com Workbook, 2013, http://www.salesforce.com/us/developer/docs/workbook_database/workbook_database.pdf, Accessed 20.02.2013.
9. Datastore overview, https://developers.google.com/appengine/docs/java/datastore/overview, Accessed 20.02.2013.
10. Google Cloud SQL, https://developers.google.com/cloud-sql/, Accessed 20.02.2013.
11. LINTHICUM, D. S. 2009. Cloud Computing and SOA Convergence in Your Enterprise, Addison-Wesley, New York, USA.
12. LOUTAS, N., PERISTERAS V., BOURAS T., KAMATERI E., ZEGINIS D. 2010. Towards a Reference Architecture for Semantically Interoperable Clouds. In: *2010 IEEE Second International Conference on Cloud Computing Technology and Science*, pp. 143-150.
13. MERZKY, A., STAMOU, K., JHA, S. 2009. Application Level Interoperability between Clouds and Grids. Workshops at the Grid and Pervasive Computing Conference, pp. 143-149.
14. NoSQL, http://nosql-database.org/, Accessed 20.02.2013.
15. PETCU, D., MACARIU, G., PANICA S., CRACIUN C. 2012. Portable Cloud applications—From theory to practice. Future Generation Computer Systems.
16. Platform as a service definition, 2010, [online], http://searchcloudcomputing.techtarget.com/definition/Platform-as-a-Service-PaaS
17. RANABAHU, A., SHETH, A. 2010. Semantics Centric Solutions for Application and Data Portability in Cloud Computing. In: *2nd IEEE International Conference on Cloud Computing Technology and Science*, pp. 234-241.
18. RODERO-MERINO, L., VAQUERO, L.M., GIL, V., GALAN, F., FONTAN, J., MONTERO, R. S., LLORENTE, I.M. 2010. From infrastructure delivery to service management in clouds. Future Generation Computer Systems 26, pp. 1226-1240.

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GENERALIZED CONSTRUCTION OF TWO-DIMENSIONAL QUASI COMPLETE COMPLEMENTARY CODES

Monika DÁVIDEKOVÁ

ABSTRACT

Authors in (1) proposed generating method of two-dimensional (2D) quasi orthogonal complete complementary codes (QOCCC) with element order N^2. This construction is based on one-dimensional (1D) complete complementary codes (CCC) introduced in (2). New constructions of CCC with shorter 1D-CCC element length were published recently (3-4). In this paper former construction is generalized for using any recent 1D-CCC for input which results in 2D-CCC with element of smaller order. Parameter dependences of 2D-QOCCC on 1D-CCC parameters and advantages of QOCCC are discussed.

KEY WORDS

Quasi orthogonal complete complementary code, QOCCC, complete complementary code, CCC, two-dimensional.

INTRODUCTION

Complete complementary codes (CCC) found application in many different areas, such as physics, astronomy, radar technology, navigation, image processing and telecommunication systems. Golay in (5) published complementary codes in connection with optical infrared, multi-slit spectrometry first. Later further complementary sequences were developed in (6-9). Authors of mentioned papers were concerned mostly about autocorrelation properties of those sequences. First who proposed sets of sequences with ideal autocorrelation and cross-correlation were Tseng and Liu (10). Later these sequence sets were called Complete Complementary Codes (CCC) (7-9). Generating of CCCs is still a vivid area of research. Latest framework for a systematic construction was published recently (4).

In (1) authors proposed construction of two-dimensional quasi orthogonal complete complementary codes (2D-QOCCC) with element order of N^2 where on input 1D-CCC (2) with sequence length of N^2 was used. In this paper original method is generalized to accept on input any of recent 1D-CCCs (2-4). This leads to construction of 2D-QOCCC with elements of smaller order than N^2. Parameter dependencies of 2D-QOCCC on 1D-CCC input code are discussed in this paper later. Benefits of it are also briefly described.

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Paper is organized as follows: Introduction to CCC is given in section II and III for 1D and 2D cases, respectively. In section IV generalized construction is presented. In section V parameter dependence is demonstrated. In section VI advantages of proposed construction are summarized. Conclusion is given in VII.

CCC DEFINITIONS

For the convenience of the reader before defining CCC known definitions of discrete aperiodic cross-correlation function is given (11):

$$C_{p,r}(s)=\begin{cases}\sum_{u=0}^{T-1-s} a_u^{(p)} a_{u+s}^{(r)}, & 0\le s\le T-1\\ \sum_{u=0}^{T-1+s} a_u^{(p)} a_{u+s}^{(r)}, & 1-T\le s<0\\ 0, & |l|\ge T\end{cases} \quad [1]$$

where s denotes shift, T denotes period of equally long distinguish sequences ($a_j^{(p)}$) and ($a_j^{(r)}$) of p-th and r-th users consisting of coordinates +1 and -1. $C_{p,r}$ denotes discrete aperiodic autocorrelation function if $p=r$.
Signature is a collection of sequences assigned to one user where autocorrelation function computed through all sequences has ideal property: it is zero for any nonzero shift.
Two signatures are said to be mutually orthogonal if every two complementary sets in the collections are mates of each other.

In CCC sequences of signatures are to be transmitted via independent channels (12). This allows computing auto- and cross-correlation on receiving end independently for each channel and then to sum up results to obtain overall cross- and autocorrelation. In this way it is possible to achieve ideal cross- and autocorrelation properties.

Because CCCs are formed by more sequences, original definition from (11) has to be slightly modified for CCC:

The *aperiodic autocorrelation* function $\rho_{\mathbf{c}^{(i)}}$ of L long sequence $\mathbf{c}^{(i)}$ is defined as:

$$\rho_{\mathbf{c}^{(i)}}(\tau)=\sum_{l=0}^{L-1}\mathbf{c}^{(i)}(l).\left[\mathbf{c}^{(i)}(l+\tau)\right]^{*}; \quad [2]$$

where τ denotes the shift.
The *aperiodic cross-correlation* function $\rho_{\mathbf{c}^{(i)},\mathbf{c}^{(j)}}(\tau)$ between two different sequences $\mathbf{c}^{(i)}\in C$ and $\mathbf{c}^{(j)}\in C$ where $i\neq j$:

$$\rho_{\mathbf{c}^{(i)},\mathbf{c}^{(j)}}(\tau)=\sum_{l=0}^{L-1}\mathbf{c}^{(i)}(l).\left[\mathbf{c}^{(j)}(l+\tau)\right]^{*}; \quad [3]$$

Let's denote *i*-th *signature* in a set *C* of *N* signatures as:

$$\mathbf{c}^{(i)}=(\mathbf{c}_1^{(i)}\quad \mathbf{c}_2^{(i)}\quad \ldots\quad \mathbf{c}_E^{(i)});\quad i=1,2,\ldots N, \quad [4]$$

where each sequence:

$$\mathbf{c}_k^{(i)}=(c_{k,1}^{(i)}\quad c_{k,2}^{(i)}\quad \ldots\quad c_{k,L}^{(i)});\quad k=1,2,\ldots E, \quad [5]$$

is a *k*-th *element* of it with length L. Each element is a vector in which coordinates are symbols $\left|c_{k,j}^{(i)}\right| = 1$.

The CCC possesses ideal aperiodic auto- and cross-correlation properties. In other words (2) and (3) are equal to zero except for zero shift of aperiodic autocorrelation (2).
Numerous construction methods which lead to CCC with different parameters were recently published, namely the length of elements *L* alternates e.g. N^2, 2^mN or *N* for maximal number of signatures *N* using (2), (3) and (4), respectively, where *N* is power of two. In some applications it is desirable to minimize *L* (4) keeping *N* maximal.

2D-CCC

Let $\mathbf{C}$ be a complex matrix of order P made of complex numbers c_{ij} whose absolute values $\left|c_{ij}\right| = 1$:

$$\mathbf{C} = \begin{bmatrix} c_{11} & c_{12} & \dots & c_{1P} \\ \dots & & & \\ c_{P1} & c_{P2} & \dots & c_{PP} \end{bmatrix} \quad [6]$$

M_{2D} sets of N_{2D} matrices

$$\left\{\mathbf{C}_1^{(1)}, \mathbf{C}_2^{(1)}, \dots \mathbf{C}_{N_{2D}}^{(1)}\right\}, \dots \left\{\mathbf{C}_1^{(M_{2D})}, \mathbf{C}_2^{(M_{2D})}, \dots \mathbf{C}_{N_{2D}}^{(M_{2D})}\right\} \quad [7]$$

compose a 2D-CCC of order M_{2D} if their autocorrelation and cross-correlation are ideal where functions are defined in Appendix A (18) and (19), respectively. A set of N_{2D} matrices $\left\{\mathbf{C}_1^{(i)}, \mathbf{C}_2^{(i)}, \dots \mathbf{C}_{N_{2D}}^{(i)}\right\}$ is termed *i*-th signature of 2D-CCC. A matrix $\mathbf{C}_j^{(i)}$ is termed the *j*-th element of *i*-th signature.

CONSTRUCTION OF 2D-QOCCC

Let $\mathbf{C}_{n_{2D}}^{(k_{2D})}$ denote the n_{2D}-th element of the k_{2D}-th signature of the new 2D-QOCCC. It is a matrix with order P. Let $\mathbf{c}_{n_{2D},i}^{(k_{2D})}$ denote its *i*-th row $i = 1,2,\dots,P$, $P = L$.
Each element of 2D-QOCCC signature is composed of rows obtained using following equation:

$$\mathbf{c}_{n_{2D},i}^{(k_{2D})} = \mathbf{c}_{n_{2D}}^{[(k_{2D}-1) \bmod M_{1D}]+1} \times c_{v,i}^{(f)} \quad [8]$$

$$f = [(k_{2D} - t) \bmod M_{1D}] + 1 \quad [9]$$

$$v = \left[\left(\left\lfloor \frac{k_{2D}-1}{M_{1D}} + 1 \right\rfloor - 1\right) \bmod N_{1D}\right] + 1 \quad [10]$$

$$t = t + 1 \text{ for } (k_{2D} - 1) \bmod M_{1D}^2 = 0 \quad [11]$$

$$-N_{1D} + 1 \le t \le 0 \quad [12]$$

$$k_{2D} = 1,2,\dots,M_{1D}^2 N_{1D} \quad [13]$$

$$n_{2D} = 1,2,...,N_{1D} \quad [14]$$

where $\lfloor x \rfloor$ is the greatest integer, which is equal or smaller than x, M_{1D} and N_{1D} denote number of signatures and elements of inputted 1D-CCC, respectively.

Borders and equation are generalized in comparison to original method (1) which uses solely 1D-CCC with element length N^2 (2) for input and generates 2D-QOCCC with element order of N^2. Recently new 1D-CCCs with different lengths were proposed (3-4) which could not be used as input for former method with given algorithm and borders in (1). This generalized construction accepts any 1D-CCC on input. Furthermore, it is not necessary to input all 1D-CCC signatures. The resulting 2D-QOCCC constructed by inputting a non-optimal 1D-CCC will increase in number of signatures and elements according to conditions described in section IV. Optimal CCC denotes CCC where number of signatures is equal to number of elements of each signature.

PARAMETERS

Given construction generates 2D-QOCCC increased in number of signatures with unmodified number of elements of each signature if compared with 1D-CCC. Number of signatures, elements and element order of 2D-QOCCC generated according to proposed construction depend on parameters of inputted 1D-CCC as follows:

$$M_{2D} = M_{1D}^2 N_{1D} \quad [15]$$

$$N_{2D} = N_{1D} \quad [16]$$

$$L_{2D} = L_{1D} \times L_{1D} \quad [17]$$

where M, N, L are number of signatures, elements and element‘s length for 1D and 2D, respectively.

For recently published 1D-CCC constructions, table 1 shows resulting parameters of 2D-QOCCC.

PARAMETERS Table I

reference	*1D- CCC parameters*			*2D-QOCCC parameters*		
	Signatures	*Elements*	*Length*	*Signatures*	*Elements*	*Order*
2.	M	N	N^2	$M^2.N$	N	N^2xN^2
3.	M	N	2^mN	$M^2.N$	N	2^mNx2^mN
4.	M	N	N	$M^2.N$	N	NxN

where M, N, L are number of signatures, elements and element‘s length for 1D-CCC, respectively.

ADVANTAGES

In (1, 13) a Multicarrier CDMA (MC-CDMA) using 2D-CCC and 2D-QOCCC are proposed in two dimensional time-frequency domain. Considering smaller order of 2D elements *N*-times, 2D channels can be narrowly allocated, thus the available frequency domain can be used effectively for transmission of more signatures.

Each signature in MC-CDMA application can be used for one user, thus the maximal number of concurrently communicating users is given by number of signatures.

Each obtained element of order *N* in MC-CDMA application has to be transmitted via separate channel (1), e.g. frequency-time zone in 2D introduced in (13) where by unchanged number of channels the 2D-QOCCC needs *N*-times less channels than 2D-CCC for transmissions of equal number of users. The only one restriction is that QOCCC does not retain fully ideal correlation property. This property is only slightly disregarded which means that the cross-correlation property is non-zero for some possible shifts which can be prevented by forbiding these shifts by used protocol. These non-zero values occur for some vertical shifts within the zero horizontal shift, solely when both signatures have odd or even indexes *(k)*, e.g. 1 and 3 or 2 and 4 etc. Remaining cross-correlation values are zero values, thus ideal.

2D-QOCCC enables achievement of higher spectral efficiency than 2D-CCC with the same order by avoiding unideal cross-correlation vertical shifts. Number of avoided shifts is considerably small if compared with increase of possibly used spectral efficiency.

CONCLUSION

In this paper generalized construction of 2D-QOCCC was presented. This construction can be applied on any recently published 1D-CCC. Generated 2D-QOCCC will increase in number of signatures in comparison to 1D-CCC with retain of unchanged number of elements of each signature according to conditions shown in section IV. Using presented construction and inputting the recently proposed 1D-CCC (3), the 2D-QOCCC with element order *N* can be generated where achieved order is *N*-times lower than the original proposed in (1).

APPENDIX A

$$\boldsymbol{\rho}(\mathbf{C},o,p)=\begin{cases}\frac{1}{M.N}\sum_{k=1}^{M-o}\sum_{l=1}^{N-p}\mathbf{c}_{kl}.\mathbf{c}^{*}_{(k+o)(l+p)} & for\ o=0,1,\ldots M-1;\ p=0,1,\ldots N-1\\ \frac{1}{M.N}\sum_{k=1}^{M-o}\sum_{l=1-p}^{N}\mathbf{c}_{kl}.\mathbf{c}^{*}_{(k+o)(l+p)} & for\ o=0,1,\ldots M-1;\ p=-N+1,\ldots -1\\ \frac{1}{M.N}\sum_{k=1-o}^{M}\sum_{l=1}^{N-p}\mathbf{c}_{kl}.\mathbf{c}^{*}_{(k+o)(l+p)} & for\ o=-M+1,\ldots -1;\ p=0,1,\ldots N-1\\ \frac{1}{M.N}\sum_{k=1-o}^{M}\sum_{l=1-p}^{N}\mathbf{c}_{kl}.\mathbf{c}^{*}_{(k+o)(l+p)} & for\ o=-M+1,\ldots -1;\ p=-N+1,\ldots -1\end{cases}; \quad [18]$$

$$\boldsymbol{\rho}(\mathbf{C}^{(x)},\mathbf{C}^{(y)},o,p)=\begin{cases}\frac{1}{M.N}\sum_{k=1}^{M-o}\sum_{l=1}^{N-p}\mathbf{c}^{(x)}_{kl}.\mathbf{c}^{(y)*}_{(k+o)(l+p)} & for\ o=0,1,\ldots M-1;\ p=0,1,\ldots N-1\\ \frac{1}{M.N}\sum_{k=1}^{M-o}\sum_{l=1-p}^{N}\mathbf{c}^{(x)}_{kl}.\mathbf{c}^{(y)*}_{(k+o)(l+p)} & for\ o=0,1,\ldots M-1;\ p=-N+1,\ldots -1\\ \frac{1}{M.N}\sum_{k=1-o}^{M}\sum_{l=1}^{N-p}\mathbf{c}^{(x)}_{kl}.\mathbf{c}^{(y)*}_{(k+o)(l+p)} & for\ o=-M+1,\ldots -1;\ p=0,1,\ldots N-1\\ \frac{1}{M.N}\sum_{k=1-o}^{M}\sum_{l=1-p}^{N}\mathbf{c}^{(x)}_{kl}.\mathbf{c}^{(y)*}_{(k+o)(l+p)} & for\ o=-M+1,\ldots -1;\ p=-N+1,\ldots -1\end{cases}; \quad [19]$$

where $\mathbf{c}^{*}_{ij}$ is the complex conjugate of $\mathbf{c}_{ij}$.

REFERENCES

1. FARKAŠ, P., TURCSÁNY, M. 2003. Two-dimensional quasi orthogonal complete complementary codes. In: *Mobile Future and Symposium on Trends in Communications, 2003. SympoTIC '03. Joint First Workshop*, pp. 37- 40, 26-28.
2. SUEHIRO, N. 1982. Complete Complementary Code Composed of N-Multiple Shift Orthogonal Sequences. *Transaction IEICE*, vol. J65-A, pp. 1247-1255.
3. ZHANG, C., HAN, C., LIAO, Y., LIN, X., HATORI, M. 2005. Iterative Method for Constructing Complete Complementary Sequences with Lengths of 2^mN. *Tsinghua Science and Technology*, **10**(5), pp. 605-609.
4. CHENGGAO, H., SUEHIRO, N., HASHIMOTO, T. 2011. A Systematic Framework for the Construction of Optimal Complete Complementary Codes. *Information Theory, IEEE Transactions,* **57**(9), pp. 6033-6042.
5. GOLAY, M. J. E. 1949. Multislit spectrometry. In *J. Opt. Sot. Amer.,* vol. 39, p. 437.
6. TURYN, R. 1963. Ambiguity Function of Complementary Sequences. *Information Theory IEEE Transaction*, vol. IT-9, pp. 46-47.
7. TAKI, Y., MIYAKAWA, H., HATORI, M., NAMBA, S. 1969. Even-shift Orthogonal Sequences. *IEEE Transactions Information Theory*, 1969, vol. IT-15, pp. 295-300.
8. SIVASWAMY, R. 1978. Multiphase Complementary Codes. *IEEE Transaction, Information Theory*, vol. IT-24, pp. 546-552.
9. FRANK, R. L. 1980. Polyphase Complementary Codes. *IEEE Transaction, Information Theory*, vol. IT-26, pp. 641-647.
10. TSENG, C. C., LIU, C. L. 1972. Complementary Sets of Sequences. *IEEE Transaction, Information Theory*, vol. IT-18, pp. 664-652.
11. PURSLEY, M. 1977. Performance Evaluation for Phase-Coded Spread-Spectrum Multiple-Access Communication--Part I: System Analysis. Communications, IEEE Transactions, 25(8), pp. 795- 799.
12. HSIAO-HWA C., JUN-FENG Y., SUEHIRO, N. 2001. A multicarrier CDMA architecture based on orthogonal complementary codes for new generations of wideband wireless communications. *Communications Magazine, IEEE*, **39**(10), pp.126-135.
13. TURCSANY, M., FARKAS, P., DUDA, P., KRALOVIC, J. 2006. Performance evaluation of two-dimensional quasi orthogonal complete complementary codes in fading channels. In: *Mobile Future, 2006 and the Symposium on Trends in Communications. SympoTIC '06. Joint IST Workshop*, pp.84-87.

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2013 Special Number

A PROPOSAL OF A MULTI-AGENT SYSTEM FOR ADAPTING LEARNING CONTENTS TO USER COMPETENCES, CONTEXT AND MOBILE DEVICE

Antonio GARCIA-CABOT

ABSTRACT

E-learning has been a revolution in recent years in the training field. This, combined with the increased use of the mobile devices has caused the emergence of the m-learning. Hence new problems have appeared in the training field, such as showing correctly some learning contents in a mobile device that has restricted features or taking into account the learner's context in the learning process, because the learner can be anywhere. Because of this, this paper proposes a new multi-agent system for adapting the learning contents to the learner's competences, to the learner's context and to his/her mobile device. The paper also describes in detail the prototype developed for testing the proposed design.

KEY WORDS

Adaptation, multi-agent system, mobile device, context, competences

INTRODUCTION

E-learning has been a revolution in recent years in the training field. It has been based on the use of Information and Communication Technologies, and its most important characteristic is offering distance learning and training. This characteristic is frequently underlined as the main advantage of these systems, however, in traditional e-learning the minimum requirement of hardware continues being a personal computer (PC), therefore this is not an absolutely independence in location. This independence is not yet accomplished with the use of a laptop because a really independence in time and location means learning where and when a learner wants and having access to the learning contents (1).

For these reasons the mobile learning (m-learning) has emerged, an evolution of e-learning based on the use of mobile devices. An advantage of this system is the availability of these devices, because most of the population has a mobile device (2), e.g. phone, Personal Digital Agent (PDA), etc. in their hand or in their pocket during most of the day. Therefore, m-learning could be an important tool for the continuous learning.

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But m-learning presents also some challenges and difficulties:

- There are many types and models of mobile devices with different operating systems, this means that not all devices support the same files and formats. Therefore not all devices could show the same learning contents, it depends on its features. For example, if there is a learning content in a video format and there is a learner with a mobile device that does not support video, the learning content could not be opened.
- The nature of these mobile devices (possibility of use in wherever) means that a learner can learn in different situations and conditions (context) (5). For this reason, each learner has a different context when he/she use his/her mobile device for the training. In the other hand, there are some learning contents which are not appropriated for certain contexts (e.g. a very long text when a learner is surrounded by people and noise).
- Learners have different competences acquired previously and it would be interesting to adapt the learning contents to these competences (4) because this would optimize the learning process (3).

This paper presents the design of a multi-agent system which is able to (1) adapt learning contents to different types of mobile devices and (2) the contexts of the learners, and also to (3) adapt the subjects and courses to the competences of the learners.
Section 2 describes the proposed system for solving the problem indicated in the introduction. Section 3 shows the obtained results of implementing the proposed solution and finally in Section 4 conclusions and future work are discussed.

THE DESIGNED MULTI-AGENT SYSTEM

The main aim of this work is proposing a new design of a multi-agent system (Figure 1) able to adapt the learning contents to the learner's context, to his/her mobile device and to his/her competences. Five different agents have been designed for carrying out this task, whose work collaboratively making up a multi-agent system.

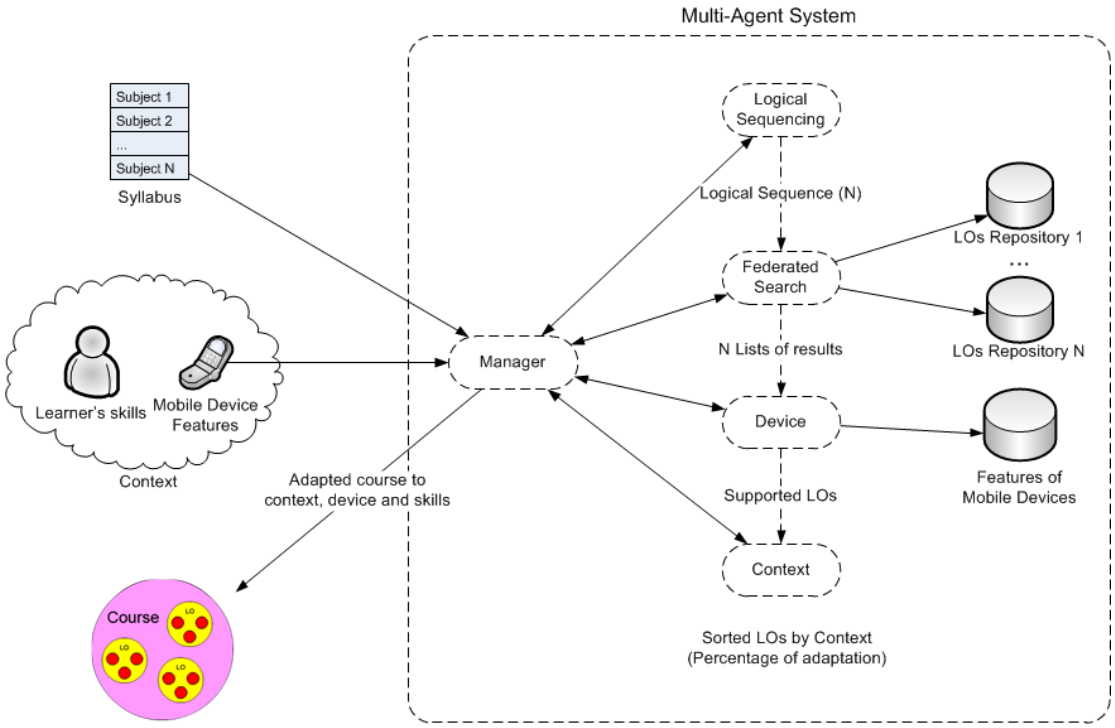

***Fig. 1** Designed multi-agent system*

The designed system has three elements as inputs: the learner's competences, the features of his/her mobile device, his/her current context and the learner's syllabus. The output will be an adapted course (a set of learning objects) to these parameters.

Each of the agents is explained below with their inputs and outputs.

Logical Sequencing Agent

The logical sequencing agent establishes a sequence of the topics or subjects that the learner has in his/her syllabus. This problem is represented as a Permut-CSP (Constraint Satisfaction Problem) (4) where the topics/subjects are the elements for permuting and their prerequisites and the competences obtained are the restrictions.

The inputs of this agent are the competences of the learner and his/her syllabus. The output is a sequence with the plan adapted to the learner.

Federated Search Agent

This agent performs a federated search in different learning objects repositories with each element of the result sequence of the previous agent. The specification SQI (Simple Query Interface) (6) is used for searching in different learning repositories, the titles of the subjects/topics of the syllabus are used as keywords for the search. After searching in the learning repositories a list of learning objects is created with the results for each subject/topic, removing the duplicated Los (Learning Objects).

For example, for a sequence of N elements (topics or subjects), this agent would return N lists of learning objects (one for each topic or subject).

Only the LOs packaged with a LOM (Learning Object Metadata) file are kept in the lists (the remaining of the LOs are discarded) because the next agents use this file for obtaining information about the LO.

Device Agent

The main aim of this agent is filtering the learning objects that the learner's mobile device does not support, e.g., if a mobile device does not support Flash format, all learning objects in Flash format are removed from the list.

The inputs of this agent are the results obtained by the previous agent and the features of the learner's mobile device. These features are searched in WURFL (Wireless Universal Resource FiLe) using the User-Agent when the learner connects with the system. Once his/her mobile device is located in WURFL some features of this mobile device are obtained, e.g., the screen resolution can be found in the 'resolution_width' and 'resolution_height' fields; the fields 'bmp', 'jpg', 'png', 'gif', etc. with true/false values represent if the mobile device shows or does not show this images format.

On the other hand, in the LOM file there is a field that shows the format of the LO, this field is called 'format' and it is within the 'technical' category, according to the specification 'this data element shall be used to identify the software needed to access the learning object'. The possible values are defined by the MIME (Multipurpose Internet Mail Extensions) standard, e.g., 'image/gif', 'text/html', 'video/mpeg', etc.

Each LO format is compared with the allowed formats of the learner's mobile device, discarding those incompatible learning objects.

Context Agent

Once all learning objects are supported by the learner's mobile device, these learning objects are sorted by context.

Each learning object is designed for a specific context, represented using IEEE LOM (Learning Object Metadata) (7), using the field number 5.6 'Context' of the specification. The possible values of this field are each specific contexts categorized by Kim *et. al* (8), e.g., 'hand: one, emotion: low', etc., in CSV (Comma Separated Values) format.

On the other hand, the learner's context is obtained from the learner through a questionnaire.

Taking into account the learner's context and the contexts of the LOs, the number of matches can be obtained, e.g., a learner could have a low level visual distraction and a specific learning object could be designed for low level visual distraction, this is a match.

Once the number of matches is established for each learning object the percent of adaptation to the context can be obtained as follows:

$$Adaptation\ Context\ Percentage = \frac{\#\ matches\ with\ the\ learner's\ context}{\#\ total\ of\ specific\ contexts\ of\ the\ LO} * 100$$

This percent is calculated for each learning object and later the LOs are sorted by this percent in descending order. The first LO in the list will be the most adapted to the learner.

The sorted list is showed to the learner with the coefficient of adaptation of each LO, so he/she can choose one different from the most adapted.

Manager Agent

The main aim of this agent is to manage the other agents because they are not aware of the others. It is the responsible of establishing the agents' inputs and outputs for running correctly. All agents are called by this manager agent and when they ends their execution the manager agent receives the results and it invokes the next agent (if it would be necessary).

This agent also has the aim of interacting with the learner and it is also responsible of invoking the execution of an specific agent if any parameter of the learner is changed, e.g., if the learner changes his/her mobile device it is necessary a new execution of the 'Device Agent' for filtering again the learning objects, or if the learner's context is changed the 'Context Agent' should sort again the list of the LOs.

The execution's sequence of the four main agents (sequencing, federated search, device and context) has been established based on the probability of changing, e.g., the learner's context should be probably more changing than his/her mobile device because the learner can move between different places or he/she can change some component of his/her context while the mobile device could be the same in all situations.

RESULTS

A prototype has been developed using the Java web technology. This prototype implements all agents using web-services as communication.

As example, the lessons of the subject entitled ‘Usability’ of the Master in Web Software Engineering program of the University of Alcalá have been selected for using this prototype. This subject is composed of fourteen lessons, nine of which are mandatory lessons and five are optional lessons.

Each lesson of this syllabus is represented with its prerequisites and competences obtained as a state-diagram showing the precedence and requirements of each lesson.

In the first screen of the prototype the learner can choose his/her context and competences (what knowledge he/she has got). The type of mobile devices is detected automatically using the HTTP headers, specifically the ‘User-Agent’. Later the mobile device model is searched using WURFL.

Next to this, the sequence of lessons is showed after the ‘Logical Sequencing Agent’ execution, showing which is the lesson most adapted to his/her competences. The first element of the sequence is recommended to the learner.

Once the learner selects a specific lesson the ‘Manager Agent’ invokes the execution of the rest of agents (Federated Search, Device and Context Agent). The Federated Search Agent searches in different repositories with the chosen lesson, and these results are filtered by the Device Agent taking into account the mobile device used by the learner.

Next, the learning objects allowed by the mobile device are sorted using the context selected by the learner and the percentage of adaptation is calculated.

The learning object with more adaptation percentage is the most adapted to the learner’s context. Finally the learner chooses one of them and it is showed.

CONCLUSIONS AND FUTURE WORK

A system for adapting learning contents to the learner’s competences, to the learner’s context and to his/her mobile device has been designed. This system presents some advantages with respect to other similar systems: it has been designed as a multi-agent system, allowing to delimit the functionality of each agent and being easily expandable with new functionality if it would be necessary. On the other hand, the system takes into account a complex learner’s context, according to context categorization of Kim *et al*. (8), showing the learning contents to the learner in an accurate way and showing the percentage of adaptation of each learning content. In addition, the system filters the learner contents based on mobile devices features, removing the learning contents that cannot be showed.

On the other hand, a disadvantage has been detected in this system: it may be necessary to adapt the learning contents to the mobile devices changing its graphical interface, e.g., if a learning content is in HTML format but it is designed for a large screen, it would be interesting to adapt it to a small screen by transforming its appearance. Although this could be solved by incorporating to the proposed system a new agent capable of transforming the learning contents using transformation languages, such as XSLT (Extensible Stylesheet Language Transformations) language for texts or other transformation mechanisms between different file formats, e.g., WAV to MP3, etc.

For demonstrating the system viability a prototype has been developed, so the next step is testing this system in a real case. For testing the system in a real case an experiment with students will be carried out in the 'Usability' subject of the Master in Web Software Engineering program. Two groups of learners will be created, an experimental group which will use the new system and another group, which will use a traditional e-learning system. This experiment will allow to demonstrate if the learners perform better, i.e., they have better grades in the exam, and if they are more motivated for learning than with traditional e-learning systems.

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REFERENCES

1. L. F. MOTIWALLA. 2007. Mobile learning: A framework and evaluation. *Computers & Education*, 49, 581–596.
2. A. BECKER. 2007. Electronic commerce: concepts, methodologies, tools and applications. Premier Reference Source, p. 2522.
3. L. de-MARCOS, R. BARCHINO, J. J. MARTÍNEZ AND J. A. GUTIÉRREZ. 2009. A new method for domain in-dependent curriculum sequencing: A case study in a web engineering master program. *J. of Engineering Education*, **25**(4), pp.632-645.
4. L. de-MARCOS, J. - J. MARTINEZ, J. - A. GUTIERREZ, R. BARCHINO, J. - R. HILERA, S. 2011. Oton and J.-M. Gutierrez, Genetic algorithms for courseware engineering. *International Journal of Innovative Computing, Information and Control*, **7**, (7(A)), pp. 3981-4004.
5. T. LEMLOUMA, N. LAYAÏDA. 2003. Adapted Content Delivery for Different Contexts. Applications and the Internet.
6. SQI: Simple query interface, European Committe for Standarization, ftp://ftp.cenorm.be/PUBLIC/CWAs/e-Europe/WS-LT/cwa15454-00-2005-Nov.pdf, 2005.
7. IEEE 1484.12.1: Learning Object Metadata (LOM), IEEE Standards Association, New York, 2002.
8. H. KIM, J. KIM, Y. LEE, M. CHAE & Y. CHOI. 2002. An Empirical Study of the Use Contexts and Usability Problems in Mobile Internet. In: *Proceedings of the 35th Hawaii International Conference on System Sciences*.

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INTRODUCTION TO HUMAN AGE ESTIMATION USING FACE IMAGES

Petra GRD

ABSTRACT

Age estimation is one of the tasks of facial image classification. It can be defined as determination of a person's age or age group from facial images. This paper gives an overview of recent research in facial age estimation. Along with an overview of previous research on this topic, descriptions of basic age estimation models are given: anthropometric model, active appearance model, aging pattern subspace and age manifold.

KEY WORDS

biometrics, face recognition, facial aging, age estimation, craniofacial morphology, aging pattern subspace, age manifold, active appearance

INTRODUCTION

Age estimation is an important task in facial image classification. For research purposes, definitions of basic terms are given. Age estimation in this study is defined as age of a person based on his or hers biometric features, precisely on the basis of two-dimensional facial images (1). Facial characteristic points can be defined as a standard reference points on human face used by scientists in order to recognize a person's face, or in this case, to estimate the age of a person (2). Morphology by itself is a study of form (3). Therefore, the craniofacial morphology is a study of shape of the face and skull. Changes in texture of face are defined as changes in face associated with skin and muscle elasticity (4). The aging process affects structure and appearance of a person in many ways. The changes that occur are related to craniofacial morphology and face texture. Certain features of craniofacial morphology appear only in people of certain age and change during the aging process. Changes in skin texture usually occur in adulthood.

There have been many research on craniofacial morphology of individuals from different aspects. One of these studies is the one conducted by Patterson et al. (5). They propose using aging function based on AAM (Active Appearance Model), which is based on the use of PCA (Principal Component Analysis) method. In 1994 Kwon and Lobo (6) proposed theory and practical calculation for age classification of face images. Their calculations are based on craniofacial morphology and wrinkle analysis. Combining the analysis of the face ratios and

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wrinkle analysis, faces are classified in three different classes. Geng et al. (7) presented the AGES (Aging Pattern Subspace) method for age estimation. The basic idea is to model the aging pattern, which is defined as a sequence of images sorted in time order, by constructing a representative subspace. The proper aging pattern for a previously unseen face is determined by the projection in the subspace that can reconstruct the face image with minimum error, while the position of the face image in that aging pattern indicates age.

Besides these, many other studies concerning age estimation have been conducted (8), (9), (10), (11), (12), (13), (14), (15), (16), (17), (18), (19), (20), (21), (22), (23).

There are some problems in age estimation, and one of those problems is ethics of age estimation, especially in age estimation of children. Existing methods, such as skeletal and dental age estimation are invasive and according to European Council Directive 97 / 43 / Euratom people have the legal right to object a medical age estimation (30). In a study of alternative reception arrangements at the port of Dover in England, unaccompanied children were placed under the care of the Social Service Department for a period of 7 days, during which the age assessment was carried out. In subsequent interviews, the children expressed annoyance of having participated in a process that they did not understand and which they experienced as hostile (31).

AGE ESTIMATION

Age estimation can be defined as determination of a person's age or age group. Person's age can be determined in many ways, but this research is concerned with age estimation based on two-dimensional images of human subjects.

According to Geng et al. (4), there are several types of age:

- Chronological age is defined as the number of years a person has lived
- Appearance is the information about age, defined by person's appearance
- Perceived age is defined by other people who define it on the basis of a person's appearance
- Estimated age is the age defined by computer based on persons appearance

Appearance age is usually very close to the actual or chronological age. The objective of age estimation is that estimated age is as close to appearance age as possible.

FACIAL CHANGES DURING GROWTH AND AGING

Geng et al. (4) in their work on the automated age estimation recognized two stages of facial aging. The first phase is the early years, defined as the years from birth to adulthood. At this stage, most of the changes are caused by changes in craniofacial growth:

- Chin becomes more prominent
- Cheeks are spread over a larger area
- Characteristics of the face increase and cover the interstices
- Forehead falls back, reduces the free space on the surface of the skull

In addition to changes caused by craniofacial growth, minor changes in the skin occur (4):

- Facial hair become denser and change color
- Skin color changes

The second phase of the aging face, recognized by Geng et al. (4) is during adulthood. Adulthood is defined as the time from the end of growth to old age. The main changes in this stage are changes in skin texture. Skin becomes thinner, darker, less elastic and more leathery. Also, wrinkles, under chin, sagging cheeks and lowered bags under the eyes appear. But there is also some small craniofacial growth at this stage, mainly changes in the shape of the face, but most of the craniofacial growth occurs at an early age of the individual.

FACIAL REPRESENTATION MODELS

There are many different models for facial representation. Models recognized in (4), (24), (23) are:

- Anthropometric Model
- Active Appearance Model
- Aging Pattern Subspace
- Age Manifold.

Anthropometric model

Facial Anthropometry is the science of measuring the size and proportions of the human face (25).

The main idea of this model is to consult research related to craniofacial growth and development. Craniofacial research theory uses a mathematical model for description of a person's head from birth to adulthood: $\Theta' = \Theta$, $R' = R\,(1 + k\,(1-\cos\Theta))$ where Θ is the angle formed by the vertical axis, R is the radius of the circle, k is a parameter which increases with time, and (R', Θ') circuit growth over time (26). Farkas gave an overview of facial anthropometry. He defined facial anthropometric as measures taken from 57 characteristic points of the face taken over years (27). For age estimation, distances and ratios between characteristic points are commonly used, instead of using a mathematical model, because it is difficult to measure face profile on the two-dimensional face images (23).

Computations in this model are based on the craniofacial development theory. Changes in the appearance of face caused by the growth and texture samples are sufficient to categorize faces in several age groups. This model is suitable for a rough age estimation, but not for detailed classification (15).

Anthropometric model is based on rations of the human face, as shown in Figure 1.

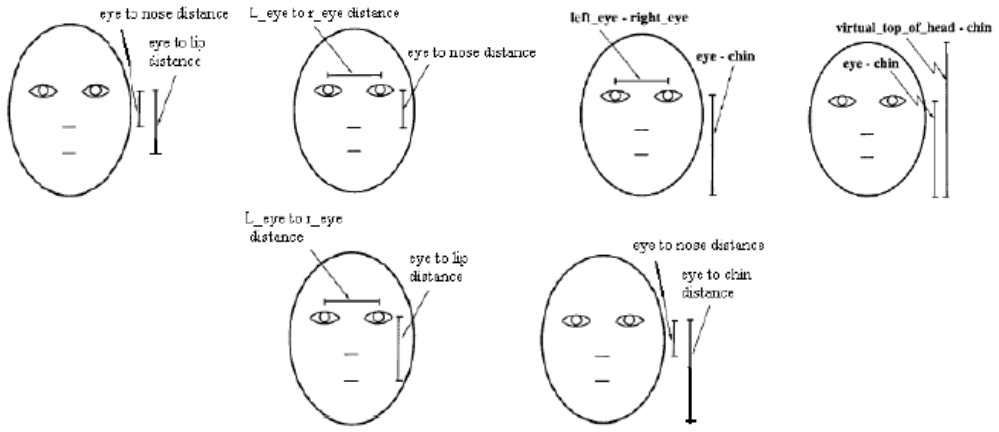

Fig. 1 *Ratios on human face (11)*

This model is useful for the classification of people in minors and adults, but it cannot distinguish between adults of different age (4), for example, young adults and seniors. This is the main reason why Kwon and Lobo (6) used wrinkle analysis to distinguish between young adults and elderly.

Anthropometric model is useful for younger people, but not for adults. In practice, it can only be used for en face images for measuring facial geometry, because the distances and ratios are calculated from two-dimensional images of individuals that are sensitive to the positions (23). This model takes into account only geometry of face, without information about the texture.

Active appearance model

This model was proposed in 1998. by Cootes et al. (39). Using facial images, statistical shape model and intensity model are learned separately. In 2002 The AAM has been expanded to facial aging (28) suggesting an aging function defined by age = f (b), to explain the variation in years. *Age* is the age of a person in the picture, *b* is a vector containing 50 parameters learned from AAM, and *f* is an aging function. The function defines the relationship between person's age and facial description parameters (23). There are different forms of an aging function. Some examples of such functions are: quadratic aging function, linear aging function, cubic aging function and others.

Unlike anthropometric model, AAM is not oriented only to younger people, but deals with assessment of the age of people of all ages. It works in a way that takes into consideration not only the geometry of human face, but its texture also. In this way the age of a person can be estimated more accurately (23).

Aging pattern subspace

Instead of using every face image separately aging pattern subspace model uses a sequence of facial aging images to model the aging process. This model was developed by Geng et al. (4) and named AGES (AGing pattErn Subspace). Aging pattern is defined as a sequence of facial image of a person, sorted by time.

AGES works in two steps. The first step is a learning step, the second step is the age estimation step (23). In the first step, PCA is used to obtain the subspace representation. The difference from the standard PCA approach is that there are probably no images for each year for each aging pattern. So EM (Expectation-Maximization) is used as a method of iterative learning to minimize error in reconstruction. Error while reconstruction is defined as the difference between the available images of the face and the face reconstructed images (23). In the second step, the test face image needs to find a pattern of aging that suits that image, and the exact position of the year in the sample. Position year returned is the estimated age of a person in the test image (23).

To cope with incomplete data, due to difficulties in data collection, the aging pattern subspace models the sequence of a person's aging face images by learning subspaces. Age of the person being tested is determined by the projection in the subspace that can best reconstruct the face image (15).

Methods based on aging functions view age estimation as a classification problem: face images are data, and the goal is the age of a person in the picture. According to (4) aging pattern is a sequence of images sorted by age.

The emphasis of this model is the use of facial images of a person at different ages to define the aging pattern.

Age manifold

Instead of learning the specific aging pattern for each person, it is possible to learn the common pattern of aging for more than one person at different ages. For each age, more than one facial image is used for age representation. Each person can have several face images in one age or in an age range (23). Therefore, this model is more flexible than AGES model, and it is much easier to collect a larger number of samples (facial images) and create a larger database.

This model uses a manifold embedding technique for learning a low-dimensional aging trend for many facial images of the same age. The only requirement of this model is that the sample size for learning is large enough so that embedded manifold can be taught with statistical sufficiency (29).

COMPARISON OF ALGORITHMS

There are a large number of algorithms and some of them have been described in the introduction of this paper. To compare these algorithms, Mean Absolute Error (MAE) is used in most of these papers. MAE is defined as average absolute error between estimated and chronological age (32). The lowest the MAE the more accurate the algorithm is. Most commonly used database also used in this comparison is FG-NET database. Algorithms by MAE can be seen in Table 1 (33).

ALGORITHMS BY MAE Table 1

Algorithm	MAE
K-nearest neighbor	8,24
Support Vector Machines	7,25
Local feature of face image and regression	6,85
Aging Pattern Subspace	6,77
Nonlinear Aging Pattern Subspace	6,18
Ranking with uncertain labels	5,33
Metric learning and Gaussian Process Regression	5,08
Manifold learning and locally adjusted robust regression	5,07
Regression Patch Kernel	4,95
Active Appearance Model	4,37
Enhanced bio-inspired features	3,17

CONCLUSION

Age estimation of humans using their facial images is by itself insufficiently researched, but it is widely applicable and has great potential: determining the age of immigrants or asylum seekers in situations where there are no documents proving the person's age, for places on the Internet where entrance is permitted only to persons older than 18 years, in order to improve the face recognition systems (most of the systems are sensitive to changes during aging), searching for missing persons over many years, the human-computer interaction based on age, for the purpose of predicting persons aging, and in the fight against pedophilia (removing images of minors from various portals or personal computers). The above are just some of the possible uses of a person's age estimation, and with further development of new technologies, there will be more.

This paper gives an overview of the field of facial age estimation. Along with an overview of previous research on this topic, description of basic age estimation models is given: anthropometric model, active appearance model, aging pattern subspace and age manifold. Future research will regard age estimation from a classification point of view. First step will be classification of individuals in a small number of classes based on their facial images, and later, an exact age classification will be researched.

REFERENCES

1. Facial age estimation, http://www.scholarpedia.org/article/Facial_Age_Estimation, accessed 13.02.2013
2. Facial landmarks http://face-and-emotion.com/dataface/anatomy/landmarks.jsp, accessed 13.02.2013
3. Definition of Morphology, http://www.medterms.com/script/main/art.asp?articlekey=4432, accessed 13.02.2013
4. Geng Xin, Fu Yun, Smith-Miles Kate. 2010. Automatic Facial Age Estimation, Tutorial at PRICAI.
5. E. Patterson, K. Ricanek, M. Albert, E. Boone. 2006. Automatic representation of adult aging in facial images. *Proceedings of the 6th IASTED International Conference on Visualization, Imaging, and Image Processing*, pp.171-176.
6. Young H. Kwon, Niels da Vitoria Lobo. 1999. Age Classification from Facial Images, Computer Vision and Image Understanding, **74**(1), pp. 1–21.
7. Xin Geng, Zhi-Hua Zhou, Kate Smith-Miles. 2007. Automatic age estimation based on facial aging patterns. *IEEE Transactions on pattern analysis and machine intelligence*, **29**(12).
8. Sydney R. Coleman, Rajiv Grover. 2006. The Anatomy of the Aging Face: Volume Loss and Changes in 3-Dimensional Topography, Aesthetic surgery journal.
9. Karl Ricanek Jr et al. 2008. Craniofacial aging. *Wiley Handbook of Science and Technology for Homeland Security*.
10. Feng Gao, Haizhou Ai. 2009. Face Age Classification on Consumer Images with Gabor Feature and Fuzzy LDA Method, Advances in Biometrics. In: *Third International Conference, ICB*, Alghero, Italy, Proceedings, pp 132-141.
11. Andreas Lanitis. 2009. Facial Biometric Templates and Aging:Problems and Challenges for Artificial Intelligence, AIAI.
12. Ramesha K et al. 2010. Feature Extraction based Face Recognition, Gender and Age Classification. *International Journal on Computer Science and Engineering*, **02**(No.01S), 14-23.
13. E. Patterson; K. Ricanek; M. Albert; E. Boone. 2006. Automatic representation of adult aging in facial images. In: *Proceedings of the 6th IASTED International Conference on Visualization, Imaging, and Image Processing*, pp.171-176.
14. Pettersson Olle. 2007. Implementing LVQ for Age Classification, Master of Science Thesis.
15. Yun Fu, Ye Xu, Thomas S. Huang. 2007. Estimating human age by manifold analysis of face pictures and regression on aging features. In: *International Conference on Multimedia and Expo*, pp.1383-1386.
16. Xin Geng, Zhi-Hua Zhou, Kate Smith-Miles. 2007. Automatic age estimation based on facial aging patterns. *IEEE Transactions on pattern analysis and machine intelligence*, **29**(12).

17. Guodong Guo, Yun Fu, Charles R. Dyer. 2008. Image-based Human Age Estimation by Manifold Learning and Locally Adjusted Robust Regression. *IEEE Transactions on Image Processing*, **17**(7).
18. Kazuya Ueki, Masakazu Miya, Tetsuji Ogawa i Tetsunori Kobayashi. 2008. Class Distance Weighted Locality Preserving Projection for Automatic Age Estimation. In: *2nd IEEE International Conference on Biometrics: Theory, Applications and Systems*.
19. Khoa Luu, Karl Ricanek Jr., Tien D. Bui, Ching Y. Suen. 2009. Age Estimation using Active Appearance Models and Support Vector Machine Regression. In: *3rd International Conference on Biometrics: Theory, Applications, and Systems*, pp.1-5.
20. Pavan Turaga, Soma Biswas, Rama Chellapa. 2010. The Role of Geometry in Age Estimation. In *IEEE International Conference on Acoustics Speech and Signal Processing*, pp. 946-949.
21. Yi-Wen Chen, Meng-Ju Han, Kai-Tai Song, Yu-Lun Ho. 2010. Image-Based Age-Group Classification Design using Facial Features. In: *International Conference on System Science and Engineering*, pp.548-552.
22. Amrutha Sethuram, Karl Ricanek, Eric Patterson. 2010. A Hierarchical Approach to Facial Aging. In: *IEEE Computer Society Conference on Computer Vision and Pattern Recognition Workshops*, pp.100-107.
23. Yun Fu, Guodong Guo, Thomas S. Huang. 2010. Age Synthesis and Estimation via Faces: A Survey. In *IEEE Transactions on Pettern Analysis and Machine Intelligence*, **32**(11).
24. Guodong Guo, Guowang Mu, Yun Fu, Thomas S. Huang. 2009. Human Age Estimation Using Bio-inspired Features. In: *IEEE Conference on Computer Vision and Pattern Recognition*, pp.112-119.
25. A. Montagu, A Handbook of Anthropometry (1960)
26. T.R.Alley. 1998. Social and Applied Aspects of Perceiving Faces. Lawrence Erlbaum Assoc.
27. L.Farkas. 1994. *Anthropometry of head and face*. Raven Press.
28. A. Lanitis, C.Taylor, T. Cootes. 2002. Toward Automatic Simulation of Aging Effects on Face Images. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, **24**(4), pp. 442-455.
29. Y.Fu, T.S.Huang. 2008. Human Age Estimation with Regression on Discriminative Aging Manifold. *IEEE Transactions on Multimedia*, **10**(4), pp. 578-584.
30. Hjern, A, Brendler-Lindqvist, M, & Norredam, M 2012, 'Age assessment of young asylum seekers'. *Acta Paediatrica*, 101, 1, pp. 4-7, Academic Search Complete, EBSCOhost, viewed 9 April 2013.
31. Watters C. 2005. Avenues of Access and the Parameters of Care: reflections on Reception Procedures for Unaccompanied Asylum- seeking Children at a Port of Entry. The Asylum-Seeking Child in Europe Goteborgs Universitet, Centrum for Europaforskning.
32. G.Guo, Y.Fu, T.Huang, C.Dyer. 2008. Locally Adjusted Robust Regression for Human Age Estimation. *IEEE Workshop on Application of Computer Vision*.
33. Mohamed Y. El Dib, Hoda M. Onsi.2011. Human Age Estimation Framework Using Different Facial Parts. *Egyptian Informatics Journal*, 12, pp. 53-59.

RESEARCH PAPERS
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2013 Special Number

SIMULATION OF PHOTON PROPAGATION IN TISSUE USING MATLAB

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ABSTRACT

This paper deals with the light transport, photon trajectory and its radiation in tissue. A model based on Monte Carlo simulation has been implemented in Matlab to get inside into photon interaction with tissue. The project is aimed to non-invasive pulse oximetry measurement of fetal oxygen saturation in the maternal abdomen. One of the fundamental challenges is to ensure a sufficient penetration depth which covers maternal and fetal tissue. This contribution investigates the photon trajectories and analyse the number of photons which stayed in tissue and their radiation distribution. The principle and photon propagation rules, needed for simulation, are presented in this article. Finally the results are compared with literature.

KEY WORDS

Monte Carlo simulation, photon propagation, tissue, light transport

INTRODUCTION

Optical technique is a useful analysis method in biomedical diagnosis. The simulation of light transport provides statements about the photon interaction with tissue. In the case of fetal pulse oximetry, it will be possible to evaluate the light distribution and the penetration depth under different conditions without the need of suitable patients. These parameters are important for further investigations, for instance simulating pulse curve shapes or determining the oxygenation of arterial blood. For this reason this paper deals with the fundamental photon propagation rules and the radiation in tissue.

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THE PHOTON PROPAGATION RULES

The implemented algorithm is based on Wang and Jacques steady-state light transport model which was written a in a standard language C [WaJa92]. The single steps of the implementation are described in the following.

Figure 1 shows the schematic of the Cartesian coordinate system which describes the model. The z-coordinate represents the depth of the tissue, where the x- and y-direction are assumed as infinity wide.

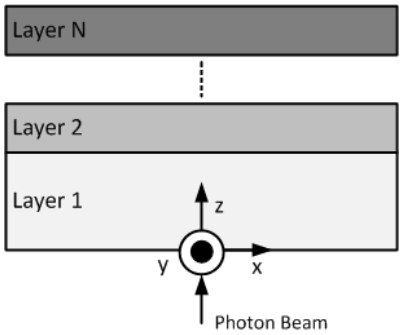

Fig. 1 *Schematic of the Cartesian coordinate system, which describes the implemented simulation model, the y axis points outwards [WaJa92]*

Launching a photon

The start position of each photon is determined by the coordinates $x, y, z = 0,0,0$ and the initial direction is orthogonal to the tissue surface, which is given by $\mu_x, \mu_y, \mu_z = (0,0,1)$. When the photons penetrate into the tissue, some specular reflectance at the surface will occur. The specular reflectance R_{sp} can be described by

$$R_{sp} = \frac{(n_1 - n_2)^2}{(n_1 + n_2)^2}$$

and the photon weight will be decreased by R_{sp}

$$W = 1 - R_{sp}$$

Moving the photon

After photon injection the step size s will be calculated by using the equation:

$$s = \frac{-\ln(\xi)}{\mu_t},$$

where μ_t is an interaction coefficient equals the sum of the absorption coefficient μ_a and scatter coefficient μ_s. The parameter ξ is a random variable, which is uniformly distributed over the interval $(0,1)$. A decision has to be made, which distinguishes whether the step size s is long enough to reach a boundary or not.

If the photon didn't reach a boundary the position of the photon will be updated by:

$$x \leftarrow x + \mu_x \cdot s$$
$$y \leftarrow y + \mu_y \cdot s$$
$$z \leftarrow z + \mu_z \cdot s$$

Absorption and scattering of the photon

By moving a photon inside the tissue the photon weight is decreasing due to absorption. The amount of photon weight loss is defined by:

$$\Delta W = W \cdot \frac{\mu_a}{\mu_t}$$

The photon weight is then updated by:

$$W \leftarrow W - \Delta W$$

For scattering the photon, the azimuth $\psi \in [0, 2\pi)$ and deflection angle $\theta \in [0, \pi)$ have to be taken into account. The final photon directions are computed by the following equation:

$$\mu_x' = \frac{\sin\theta}{\sqrt{1-\mu_z^2}}\ \mu_x\,\mu_z\cos\psi - \mu_y \sin\psi\ + \mu_x\cos\theta$$
$$\mu_y' = \frac{\sin\theta}{\sqrt{1-\mu_z^2}}\ \mu_y\,\mu_z\cos\psi - \mu_x \sin\psi\ + \mu_y\cos\theta$$
$$\mu_z' = -\sin\theta\cos\psi\ \ \sqrt{1-\mu_z^2} + \mu_z\cos\theta$$

For the special case, that the incident angle is orthogonal to the surface of the tissue, the photon direction is following the formulas:

$$\mu_x' = \sin\theta\cos\psi$$
$$\mu_y' = \sin\theta\sin\psi$$
$$\mu_z' = \mathrm{SIGN}(\mu_z)\cos\theta$$

$$\mathrm{SIGN}\ x\ = \begin{cases} -1 \text{ if } x < 0 \\ 0 \text{ if } x = 0 \\ 1 \text{ if } x > 0 \end{cases}$$

Finally the photon direction is updated:

$$\mu_x \leftarrow \mu_x'$$
$$\mu_y \leftarrow \mu_y'$$
$$\mu_z \leftarrow \mu_z'$$

Reflection and transmission at a boundary

If the step size is long enough to hit the boundary, then the photon moves to the boundary. Subsequently the program decides whether the photon escapes the tissue or is internally reflected. This depends on the angle of incidence α_i and the angle of transmission α_t. The internal reflectance $R(\alpha_i)$ is then calculated by Fresnel's formula:

$$R\ \alpha_i\ = \frac{1}{2}\ \frac{\sin^2\ a_i - a_t}{\sin^2\ a_i + a_t} + \frac{\tan^2\ a_i - a_t}{\tan^2\ a_i + a_t}\ .$$

The finally decision is realized by comparing the internal reflectance with a random number. After this step the absorption and scattering will computed correspondingly (see [WaJa92] for more details).

Photon Termination

A photon is terminated if it escapes the tissue or if the photon weight decreases below a defined threshold inside of the tissue. In the case that the photon weight is lower than the threshold, the current photon gets a further chance in m (e.g., $m = 10$) for surviving with a weight of mW [WaJa92]. The photon is terminated if it does not survive the so called roulette:

$$W = \begin{cases} mW & \text{if } \xi \leq 1/m \\ 0 & \text{if } \xi > 1/m \end{cases}$$

VERIFICATION OF RESULTS

Simulations were done for three different cases to verify the implemented algorithm. The results of these scenarios were compared with other results from literature [Giov55, Huls80, PKJW89 and WaJa92].

The first simulation includes ten runs with 50,000 photon packets and the investigated slab has the following optical properties:

OPTICAL PROPERTIES OF THE SLAB
OF THE FIRST SIMULATION Table 1

	n	μ_a	μ_s	g	d
medium	1	10 cm^{-1}	90 cm^{-1}	0.75	0.02 cm

Table 2 shows the results of the computed total diffuse reflectance R_d and total transmittance T_t. The simulation results are consistent with the data from literature.

Furthermore we determined the average number of photons which goes through the tissue. Overall 41,848 of 50,000 photon packets escaped the tissue by transmittance in this simulation and the average absorption was 0.2418.

COMPARISON OF THE FIRST SIMULATION RESULTS Table 2

Source	R_d Average	T_t Average
Van de Hulst [Huls80]	0.09739	0.66096
Wang and Jacques [WaJa92]	0.09734	0.66096
Prahl et al. [PKJW89]	0.09711	0.66159
Matlab	0.09734	0.66100

For the second simulation, we investigate ten simulations with 5,000 photon packets. The optical properties were determined as follows:

OPTICAL PROPERTIES OF THE SLAB
OF THE SECOND SIMULATION Table 3

	n	μ_a	μ_s	g
medium	1.5	10 cm^{-1}	90 cm^{-1}	0

We computed the average of the total diffuse reflectance in the semi-infinite turbid medium. The comparison with literature is shown in Table 4. The relative error is 0.76 % between the conducted simulation and the investigations of Giovanelli [Giov55].

In this simulation, 2,599 photons were absorbed by tissue and the value of average absorption was 0.4466.

COMPARISON OF THE SECOND SIMULATION RESULTS

Table 4

Source	Reflectance R_d Average
Giovanelli [Giov55]	0,26000
Wang and Jaques [WaJa92]	0,25907
Prahl et al. [PKJW89]	0,26079
Matlab	0,25803

The final verification was realized with one simulation run of multi-layered tissues. There were 100,000 photon packets and the specific optical properties of three layers are shown in Optical properties of three layers for last simulation Table 5. The refractive indices of the top and bottom ambient media are both set to 1. Average absorption was 0.4310 and number of absorbed photons was 42,415.

OPTICAL PROPERTIES OF THREE LAYERS
FOR LAST SIMULATION Table 5

	n	μ_a	μ_s	g	d
medium above	1				
layer 1	1.37	1	100	0.90	0.1
layer 2	1.37	1	10	0	0.1
layer 3	1.37	2	10	0.70	0.2
medium below	1				

The total diffuse reflectance and total transmittance of a slab of turbid medium and the comparison is shown in Comparison of the third simulation results Table 6.

The standard error is 0.0012.

COMPARISON OF THE THIRD SIMULATION RESULTS Table 6

Source	Reflectance R_d	Transmittance T_t
Gardner [GaWe92]	0,2381	0,0974
Wang and Jacques [WaJa92]	0,2375	0,0965
Matlab	0,2341	0,0934

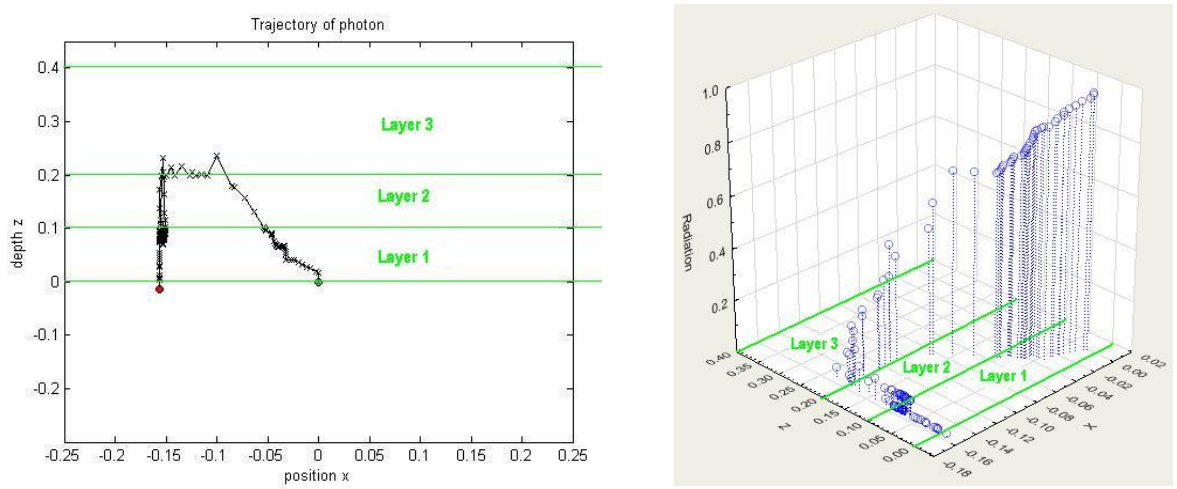

Fig. 2 *Trajectory of a single photon in cm (left) and radiation distribution of the single photon (right)*

Fig. *2* shows the photon interaction with the tissue for a single photon. These results are based on the multi-layered tissue simulation where the corresponding parameters are given by Optical properties of three layers for last simulation Table 5. The starting point of the photon is indicated with a green point at coordinates (0; 0). Termination occurred when the last significant fraction of remaining photon weight escaped from tissue at the position indicated by the red point at the coordinates (-0.156; -0.013) with a residual weight of 0.011143.

CONCLUSION

We investigated the reflectance and transmittance of photons in tissue for verification our results. The calculated values were compared with the available experimental data which shows an overall agreement. In addition, we looked into photon track inside the turbid medium and its radiation. The results reported in this paper provide fundamental knowledge for further investigations in view of non-invasive pulse oximetry.

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REFERENCES

[BoWo99] BORN, M. and E. WOLF. 1999. *Principles of optics*. Cambridge University Press, Cambridge, 7th edition.

[GaWe92] C. M. GARDNER, A. J. WELCH. 1992. *Improvements in the accuracy and statistical variance of the Monte Carlo simulation of light distribution in tissue*. In S. L. Jacques: *Proc. SPIE 1646, Laser-Tissue Interaction III*, pp. 400-409.

[Giov55] GIOVANELLI, R.G. 1955. *Reflection by Semi-infinite Diffusers*. Optica Acta: International Journal of Optics, **2**(4): 153-162.

[Hech02] E. HECHT. 2002. *Optics. 4th Edition*. Addison Wesley Longman, Inc., USA, 4th edition.

[Huls80] H. van de Hulst. 1980. *Multiple Light Scattering, Vol. 2*. New York, Academic Press.

[PKJW89] PRAHL, S.A., M. KEIJZER, S.L. JACQUES, and A.J. WELCH. 1989. *A Monte Carlo Model of Light Propagation in Tissue*. SPIE Institute Series, 5: 102-111.

[WaJa92] WANG, L., and JACQUES, S. L. 1992. *Monte Carlo Modeling of Light Transport in Multi-layered Tissues in Standard C*. University of Texas, Houston.

[Witt77] WITT, A. N. 1977. *Multiple Scattering in Reflection Nebulae. I. a Monte Carlo approach*. Astrophysical J. Supp. Series, 35: 1-6.

RESEARCH PAPERS
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2013 Special Number

SMART HOME AND ERDERLY PEOPLE

Andrej STRAŠIFTÁK, Dušan MUDRONČÍK, Michal ELIÁŠ

ABSTRACT

In this article we purport how advances from the device and technological side have not necessarily been matched with a similar level of development in processing of the information recorded within the living environment from an algorithmic or 'intelligent' perspective.

KEY WORDS

Smart House, self-control, home automation, inteligent control

INTRODUCTION

Smart Homes have become firmly established as an active research area with potential for huge social and economic benefits..The use of Smart Homes to support independent living refers here to the possibility of designing an intelligent monitoring system that can detect when an undesirable situation may be developing (e.g., hazard, security threat, etc). Although all people can be involved in such undesirable situations, elderly people and people with health problems require more exhaustive monitoring when they are not accompanied by a healthcare professional. It is possible for someone exhibiting early stages of cognitive impairments to, for example, begin to cook a meal, forgot they have started this activity and subsequently proceed to leave the house or take a bath/shower.. We have focused on improving the level of support offered by devices which are readily available from a commercial perspective and can be deployed with a simple user interface. 'Sensor' is a keyword in this area. Smart Homes can be much more intelligent than they currently are.

SMART HOME SCENARIO

We consider a model for a Smart Home based on a residential care institution for erderly people. The environment is one of shared community care where approximately several individual one-person apartments are contained within the same building each offering high technology solutions to promote independent living for the elderly. At the core of the environment is a central monitoring facility which has the ability to detect all sensor and alarm events concurrently from each apartment. We will focus on just one apartment. Figure 1 depicts the llayout of a person's apartment.

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SENZORS

In this Section we provide a brief description of the sensors in the aforementioned scenario. Not all of them have to be present in a Smart Home and on the other hand new sensors can be incorporated.We focus here on a subset of sensors which are commercially available, affordable and combined can offer an autonomous living environment while maintaining the privacy of the inhabitant.

The environment has motion sensors in the following locations which have the ability to identify the whereabouts of the person (kitchen, livingroom, toilet, reception, bedroom, outside (right below front door)).

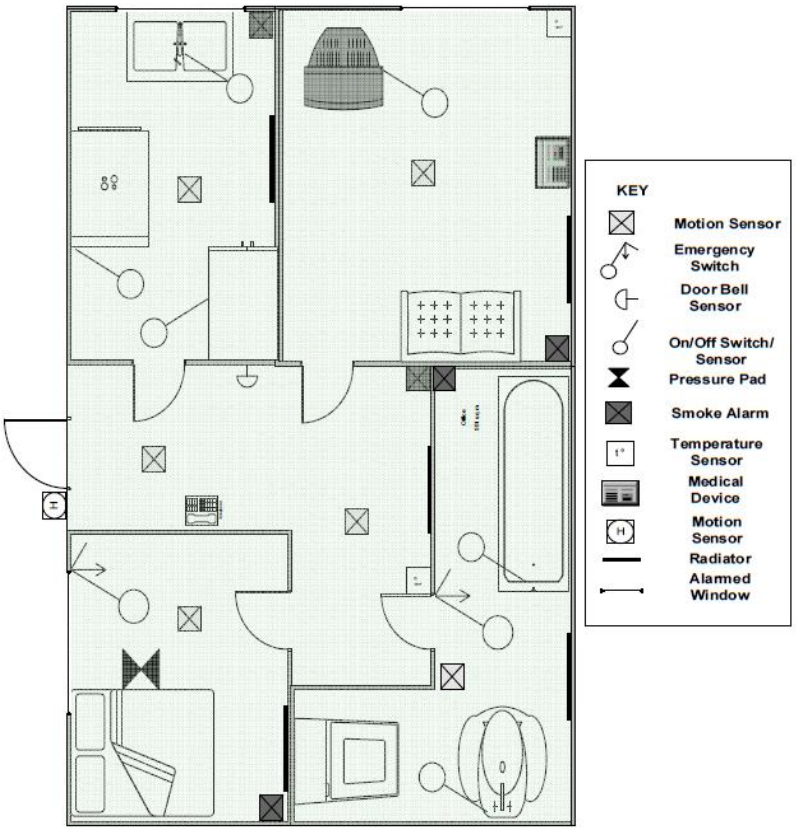

Fig. 1 *Layout of apartment*

In addition, it is assumed the person wears an electronic tag. Such a tag communicates with sensors on the doors to each room and has the ability to complement the aforementioned location sensors. The environment will have smoke alarms in all rooms.

The Smart Home will have control or monitoring abilities over the following common domestic appliances:

1. cooker
2. tv
3. fridge
4. kitchen tap
5. bathroom sink tap
6. bath tap
7. air conditioning
8. doorbell
9. phone
10. emergency pull cord switch
11. temperature sensor
12. radiators
13. bed

All the above will operate in a toggle fashion i.e. can only be active/non active. There is also a difference between items 1-7 and 8-13. The first group are also equipped with switches so that they can be remotely deactivated if needed.

SENZORS AT WORK

An example of a possible sequence of primitive events for our case study would be: *at_kitchen_on, cooker_on, cooker_off, alarm_kitchen_on, alarm_kitchen_off, at_living_on, tv_on, tv_off, doorbell_on, inbed_on, at_outside_on.*

From the initial state, a possible sequence of primitive events (preceded by their instant of occurrence) arriving at the system would be:

0 at kitchen on	*1 cooker on*
2 at reception on	*3 no event*
4 at toilet on	*5 tapSinkBathroom on*
6 no event	*7 tapSinkBathroom off*
8 no event	*9 at reception on*
11 at bedroom on	*11 inbed on*
12 no event	*13 no event*
...	...

Events with suffixes ‘ on’ and ‘ off’ represent sensors changing values from ‘off’ to ‘on’ and viceversa. One special event we considered is the absence of an event at a given point in time, we denote this as no event. These represent that at a particular time no sensor changed its value. The fact that no sensor changed its value does not mean nothing happened inside the house but instead nothing that can be captured by the sensors. In order to develop the necessary approaches to process all of the information from these sensor elements and provide a means of support it is necessary to consider the possible activities that a person may undertake during normal and abnormal conditions. The key parameter is primarily to assess the current location of the person in the living environment. Once this has been realized, it is then possible to determine if the sequence of actions the person becomes involved in are ‘normal’ or ‘abnormal’. The diversity of the types of information generated by the sensors provides a number of dimensions to the information which can be generated for a person. These can be considered to be (a) their whereabouts (b) their interaction with appliances and (c) the duration of these events. Hence, with such information, rules may be modeled and used to discriminate between normal conditions and potentially hazardous situations when an alarm condition should be raised.

SMART HOMES AS DYNAMIC SYSTEMS

We can make an abstraction of a Smart Home and look at it as a system that starting in an initial state can then evolve through different states as events occur inside. Each state is defined by the place the person is in, which devices and alarms are activated, e.g. the temperature of the room. Each of these parameters are discrete values, either boolean ‘on’-‘off’ or within ranges like those used for temperatures. It is important to mention here from a computational point of view that all the constituent parts of the theory (houses, sensors, possible events, possible states and time spanning since the initial state until the current time of use) can be defined as finite sets. The sequence of events can potentially develop ad infinitum but from a practical perspective it would not make much sense to take the complete history and the possible ‘sequence to be’. In reality what happens is that we look at a specific window in time to assess the history and another limited window to assess the possible future sequence in order to infer what may be the case in the next minutes. We do not consider if the cooker was left on by mistake one year ago and we do not try to infer if it will be left on by mistake in one year’s time. Once the initial state has been defined on the basis of the layout of the house, the sensors available and their initial values, subsequent states will be produced as events are triggered and their effects are recorded. Lets suppose a tenant is allocated one such

house. The event of the door being opened triggers the anti-burglar sensor attached to the door. This will update the system to the next state where the front door is open. The movement sensor in the reception area will also detect movement and that event will trigger an update to a new state where movement in that room is explicitly included. While the tenant is walking through the front door the movement sensor in the reception area will stay on. Eventually, if for example the patient enters the living room area then the movement sensor in the reception area will go off and the sensor in the living room will go on detecting movement of the person entering the room. Movement sensors have to be strategically located; this posses the first practical challenge relating to the interaction between sensors and the reasoning system. Lets imagine two contiguous rooms like the living room and the reception area. Each one will have a movement sensor, have an overlapping area of detection then when a person is moving in that particular area the system will believe they are in both areas simultaneously and automated analysis may become very difficult or at least it may decrease substantially the options the system can consider. On the contrary if there is a transition area such that it does not belong to any of the two regions then there may be important events/states that can pass unnoticed to the system, like the person staying in that area for a long time, e.g., alzheimer patients can stay in the same place for a prolonged duration during a time of crisis. Occasionally the system can enter into loops. This is neither good nor bad and can be more or less frequent depending on how many moving objects there are inside the house, how many sensors there are and how sensitive they are. For example, imagine a state where the patient is sitting quietly in the living room on one side of the sofa watching TV, the movement sensor in the living room is off. Lets call this state S1. Then the patient/tenant moves to the other side of the sofa activating the movement sensor. After a short period where the patient remains reasonably inactive in the new location the sensor will go off again. Lets call this state S2. If no other sensors are triggered then the state of the house from the system's perspective, i.e., from outside and based on sensor values, will be exactly the same as in S1. Based on these notions further analysis of possible evolutions of the environment under consideration can be made. These analysis can be made before the system is built as an initial approximation during the modelling stage. Alternatively they can also be used once the system is in operation to reason about the way the system itself is evolving, or may evolve, during real-time monitoring of activities in order to undeunderstand the context and decide how to react appropriately.

A POSSIBLE SCENARIO

Imagine the following sequences of events developing one after the other in sequence:
at_living_ on,
at_reception_on,
at_kitchen_on,
cooker_on,
at_reception_on,
at_bedroom _on,
inbed_on,
...

These roughly depict a person moving from the living room to the kitchen to turn the cooker on and then going to bed. It is a common and normal sequence of activities. There are, however, potentially interesting issues in this sequence which depends on other aspects of the activities considered. For example, staying in bed for 'too long'. To address those issues we need to consider explicitly the time when the events occurred, lets suppose we have:

0 at_living_on,
3 at_reception_on,
5 at_kitchen_on,
8 cooker_on,
10 at reception_on,
13 at bedroom_on,
15 inbed_on,
...

The reader can assume that at times when no meaningful event has been detected, for example at time 2, a default event no event is recorded by the system to keep track of the activities developed in the house. Also we omitted repetitions of events in the list above but a more realistic depiction of the scenario will have more information as movement sensors will be stimulated several times in sequence when a person is walking and also multiple sensors can be activated simultaneously. Hence a closer depiction of the information recorded in our scenario will be as follows:

0 at_living_on,
1 at_living_on,
2 at_door_reception-living_on,
3 at_reception_on,
4 at_door_reception-kitchen_on,
5 at_kitchen_on,
6 at_kitchen_on,
7 at_kitchen_on, cooker_on,
8 at_kitchen_on, cooker_on,
9 at_door reception-kitchen_on, cooker_on,
10 at_reception_on, cooker_on,
11 at_reception_on, cooker_on,
12 at_door_reception-bedroom_on, cooker_on,
13 at_bedroom_on, cooker_on,
14 at_bedroom_on, cooker_on,
15 at_bedroom_on, cooker_on, inbed_on,
...

Notice that in the list above at door reception-kitchen on and at reception on correspond to what we generically described as MDR and TDRK, respectively, in figure 2. Some sensors can be assumed to persist in an ‘on’ status once they have been activated, e.g. the cooker being on unless it is turned off, whilst other sensors tend to persist in an ‘off’ status, e.g. a movement sensor will be ‘on’ only while movement is detected. Also it is worth mentioning that although we considered a way to attach temporal references to events in this section and to states in figure 2 which resemble instants we do not intend to suggest that this is a mandatory way to associate time with events and states.

CONCLUSION

We present our view in this article which relates to the fact that much more needs and can be performed in terms of equipping Smart Home systems with advanced reasoning capabilities. Increasing the functionality of the available hardware with computational intelligence techniques will have the resultant effect of increasing the complexity of contexts to be understood, increasing the capabilities of the system to identify interesting situations, for example hazards, and to offer the ability of the system to react in a more appropriate way in terms of the quality of judgment.

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REFERENCES

1. VALEŠ, M. 2008. *Inteligentní dům*. Brno: Vydavatelství ERA. ISBN 978-80-7366-137-3
2. MAENHAUT, P.J. & coautors*: Self-Learning Smart House Control*, [online] http://users.atlantis.ugent.be/jenelis/tmp/FinalDocuments/Group4/sa_final_document_group04_DRAFT.pdf
3. VAINIO, A. M., VALTONEN, M., VANHALA, J. *Learning and adaptive fuzzy control system for smart home* [online] http://www.students.tut.fi/~valtone8/Learning%20and%20adaptive%20fuzzy%20control%20system%20for%20smart%20home.pdf
4. STRAŠIFTÁK, A. 2012. Data collection in self-learning smart house. In: *International Doctoral Seminar 2012*: Proceeding, pp. 432-437. ISBN 978-80-8096-164-0
5. PRÚCHA, J. Chytré bydlení, 2012. Dostupné na internete: http://www.insighthome.eu/Chytre-bydleni/pdf.html

MATERIALS ENGINEERING

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COATING OF Cr-V LEDEBURITIC STEEL WITH CrN CONTAINING 7 % OF Ag

Pavel BÍLEK, Peter JURČI, Mária HUDÁKOVÁ, Jana BOHOVIČOVÁ

ABSTRACT

Samples made from Vanadis 6 PM ledeburitic tool steel were surface machined, ground and mirror polished. Prior the deposition, they were heat treated to a hardness of 60 HRC. CrAg7N-coatings were deposited by magnetron sputtering technique, using pure Cr and Ag targets, in a composite low pressure nitrogen/argon atmosphere and at a temperature of 500 °C. The coatings have an average thickness of 4.3 μm. They grew in a very well visible columnar manner, but, individual silver agglomerates were visible along the columnar crystals, also. The average size of silver agglomerates lies well below 50 nm, e.g. one can suggest that they are capable to be solved and release the Ag atoms to be migrated to the free surface during thermal exposition. The coatings had a good adhesion on the surface – the first critical loads, established by scratch-testing method, ranged between 30 and 39 N.

KEY WORDS

CrN-Ag coatings, Surface morphology, Nanohardness, Young´s modulus, adhesion

INTRODUCTION

Chromium nitrides (CrN) have been extensively investigated in the applications of protective coatings due to their high hardness, good wear resistance as well as excellent corrosion and high temperature oxidation resistance (1-5). They gained great scientific interest and industrial popularity due to those properties in copper machining, aluminium die casting and forming, and wood processing (6). However, in many applications, the requirements on coated material surface cannot be met by such a single coating. A further development to adapt some of their properties to a desired value for specific applications is to produce composite coatings, where different material properties are combined and some new desired properties could be created (7-9).

The effect of self-lubrication has gained a great scientific importance in last few years. The main idea to develop self-lubricating and multi-purpose coatings is based upon the fact that commercially available lubricants (sulphides, oxides, graphite) exhibit considerable

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shortcomings and cannot be used effectively in tooling applications over sufficiently wide temperature range (10-12). Soft noble metals on the other hand, posse stable chemical behaviour and can exhibit self-lubricating properties due to their low shear strength. Noble metal particle bring several benefits to the layer properties compared to metal oxides or graphite. They are stable up to relatively high temperatures, have low hardness and do not behave as abrasive particles. A common disadvantage of noble metals is their high cost, but this can be optimized to an acceptable level. Self-lubricating effect is based on incorporation of small amount of noble metals, mostly silver, into the basic CrN-film. Silver is completely insoluble in CrN and forms nano-particles in basic CrN-compound. Silver containing transition metal nitrides films have been extensively studied in recent years (13).

The current paper deals with the development of adaptive nanocomposite CrAgN coatings on the Vanadis 6 Cr-V ledeburitic tool steel. It describes and discusses the microstructure and the basic coating characteristics like hardness, Young´s modulus and adhesion for coating with 7 % content of silver.

EXPERIMENTAL

The substrate material was the PM ledeburitic steel Vanadis 6 with nominally 2.1 % C, 1.0 % Si, 0.4 % Mn, 6.8 % Cr, 1.5 % Mo and 5.4 % V and Fe as a balance and soft annealed to a hardness of 21 HRC.

The samples used for the investigation were plates with dimensions of 50 mm x 10 mm x 10 mm, heat treated (austenitized at a temperature of 1050 °C, quenched in flow of nitrogen gas and double tempered for 2 hours at temperature 530 °C) to final hardness of 60 HRC and then finely ground and polished with diamond suspension up to a mirror finish.

The conditions for CrN/Ag-coatings were reported elsewhere (14). The output power on the Cr cathode was 5.8 kW and that on the Ag cathode was 0.21 kW.

The measurement of roughness was carried out on mirror finish samples and on samples with coatings by laser scanning confocal microscope Zeiss LSN 700. The analyses of the substrate microstructure, PVD-coatings investigation and the fractography were carried out using a JEOL JSM-7600F field emission scanning electron microscope (SEM) in BE-detection regime. Energy dispersive spectroscopy (EDS) was done on the same device at an accelerating voltage of 20 kV and standard working distance of 15 mm. For the examinations of the substrate, standard metallographic specimens were prepared and etched with Villela-Bain reagent. PVD layers were prepared for observation via a special method based on deep cooling of the samples in liquid nitrogen and subsequent breaking.

The nanohardness and the Young´s modulus (E) values of the coatings were determined using the instrumented nanoindentation test under a normal load of 60 mN using a Nanohardness tester TTX 2 CSM Instruments equipped with a Berkovich indenter. The indentation depth was kept to 10 % of the coating thickness to minimize the substrate effect. Fifteen measurements were made and the mean value and the standard deviation were then calculated.

The adhesion of the coating was examined using a CSM Revetest scratch-tester. The scratches were made under a progressively increasing load from 1 N to 100 N, with a loading rate of 50 N/min. A standard Rockwell diamond indenter with a tip radius of 200 μm was used. Five measurements were made on each specimen and the mean value and standard deviation of adhesion represented by the L_{c1}, L_{c2}, L_{c3} and L_{c4} critical loads, respectively, was calculated. The critical loads were determined by recording the signal of acoustic emission as well as by viewing the scratches on the SEM micrograph. The L_{c1} critical load corresponding

to the occurrence of the first inhomogeneities in the coating. The L_{c2} and L_{c3} corresponding to another damages on the edge of the track. And finally the L_{c4} critical load was determined as the load when all of the coating was removed from the substrate.

RESULTS AND DISSCUSSION

The microstructure of the substrate material after applied heat treatment is shown in Fig. 1. The material consists of a matrix with fine carbides uniformly distributed throughout the matrix. SEM micrograph (Fig. 1a) shows that the matrix is formed with fine tempered martensite. The EDS-maps of chromium and vanadium (Fig. 1b and 1c) show that the carbides are of two basic types. Large particles, having a size up to 2 µm, are the M_7C_3 carbides, and the finer formations are the MC carbides. It was recently establish at (15,16) that M_7C_3 phase is chromium based that underwent dissolution in the austenite during heat processing, being responsible for the saturation of the austenite with carbon and alloying elements, which leads to high hardness of as-heat-treated material. Almost whole amount of MC phase remained undissolved. After the heat treatment, the average hardness of the material was 60 ± 0,3 HRC and the roughness of surface before and after deposition was Ra < 0.01 µm.

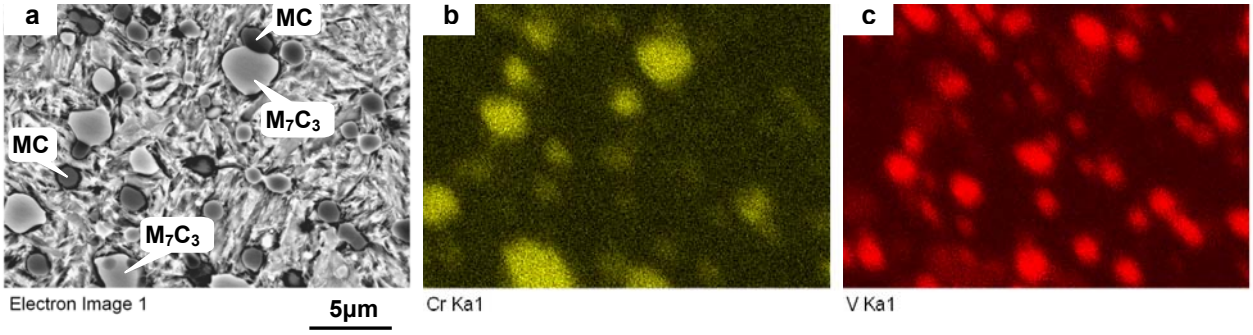

Fig. 1 *Microstructure of PM ledeburitic steel Vanadis 6 substrate after heat treatment: a-overview (SEM-BSE), b-EDS map of chromium from Fig. 1a, c-EDS map of vanadium from Fig. 1a.*

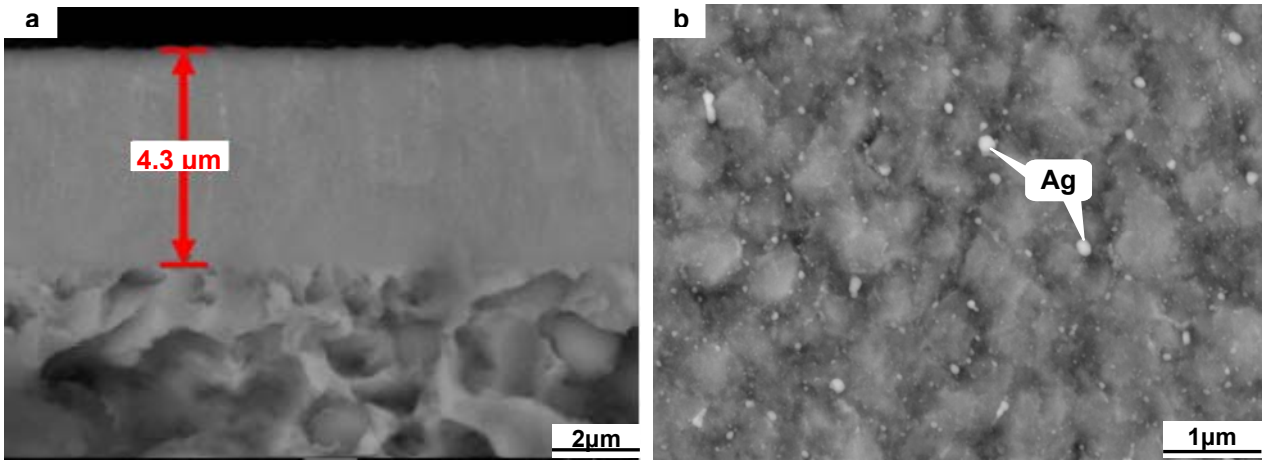

Fig. 2 *SEM micrographs showing the microstructure of CrAg7N coating: a-fracture, b-surface overview with Ag particles.*

The thickness of CrAg7N coating was 4.3 µm (Fig. 2a). The film grew in a well visible columnar manner. This type of layer growth is typical for magnetron-sputtered CrN films at a

wide range of processing parameters, as reported previously (17). This result is in a good agreement with reported results at (14). The addition of 7 % Ag into the CrN does not change the commonly known columnar morphology of such types of films and in addition, the thickness of the film was practically the same as that of the pure CrN and coatings with 3 % of Ag (14). SEM micrograph in Fig. 3a, made from the fracture of coating in the BE-detection regime, and corresponding EDS mapping of Cr, respectively Ag, Fig. 3b, respectively Fig. 3c show that silver forms individual grains along columnar manner and on the surface (Fig. 2b) at higher concentration. The average size of silver agglomerates lies well below 50 nm. Various authors have reported (18, 19) that individual silver agglomerates along the columnar crystals are capable to be solved and release the Ag atoms to be migrated to the free surface during thermal exposition and it could be responsible for self-lubrication effect (Fig. 3b and 3c).

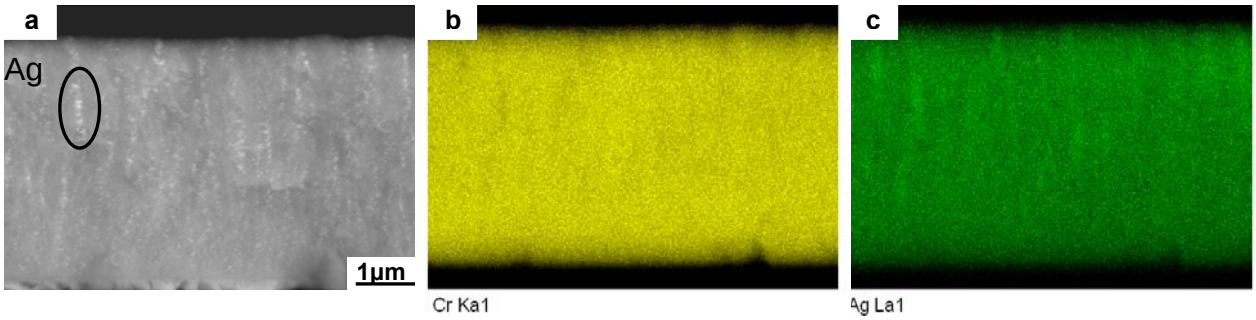

Fig. 3 *SEM micrograph of fracture of CrAg7N coating: a-detail with Ag particles, b-EDS map of chromium from Fig. 3a, c-EDS map of Silver from Fig. 3a.*

The nanohardness of CrAg7N coating was 16.17 ± 1.93 GPa. This value is comparable to early reported results (14) for pure CrN and coating with 3 % of Ag, how it is see in Table 1. Silver is very soft and could cause softening of the coating. However, no substantial effect of Ag addition on hardness was observed.

Similar behaviour can be found for measurement of Young´s modulus *E*, Table 1. With addition 7 % of Ag in CrN coating Young´s modulus little increase, but this difference could be explains by standard deviation of measurement and higher deposition temperature in comparison with previously work (14). However, this slight increase in E is rather surprising because normally, a decrease of E is expected with an Ag – addition. Further examinations are required to better clarify this phenomenon.

MECHANICAL PROPERTIES DETERMINED FROM NANOINDENTATION MEASUREMENTS, VALUES FOR CrN AND CrAg3N ARE FROM PREVIOUS WORK

Table 1

Coating	Hardness (GPa)	Young´s Modulus (GPa)
CrN	16.79 ± 1.49	244 ± 15
CrAg3N	15.97 ± 1.44	241 ± 9
CrAg7N	16.17 ± 1.93	263 ± 17

After the scratch test, the failure of CrAg7N coating is with semi-circular tensile cracking (Fig. 4a), results documented Table 2. The coatings show a very brittle behaviour. Even at the beginning of track are many cracks visible, but the coating is stable and has a good adhesion. The first inhomogeneities accompanied with the signal of acoustic emission occurred at a load 34.5 N (L_{c1}),(Fig. 4b). With increasing load more damages on the edge of track are visible, L_{c2} (Fig. 4c) and at load 52.9 N (L_{c3}) (Fig.4c) occurred break substrate through the coating on

the edge of the track. At the load 79 N all coating is remove from surface of substrate as documented SEM micrograph in BE-detection regime (Fig. 5a). Corresponding EDS maps of chromium (Fig. 5b), silver (Fig. 5c), iron (Fig. 5d) and vanadium (Fig. 5e) show an interface where CrAg7N coatings crossing to substrate, steel Vanadis 6. On the surface of coating after exposure are visible crushed particles of Ag (Fig. 5f), which are probably responsible for better friction properties.

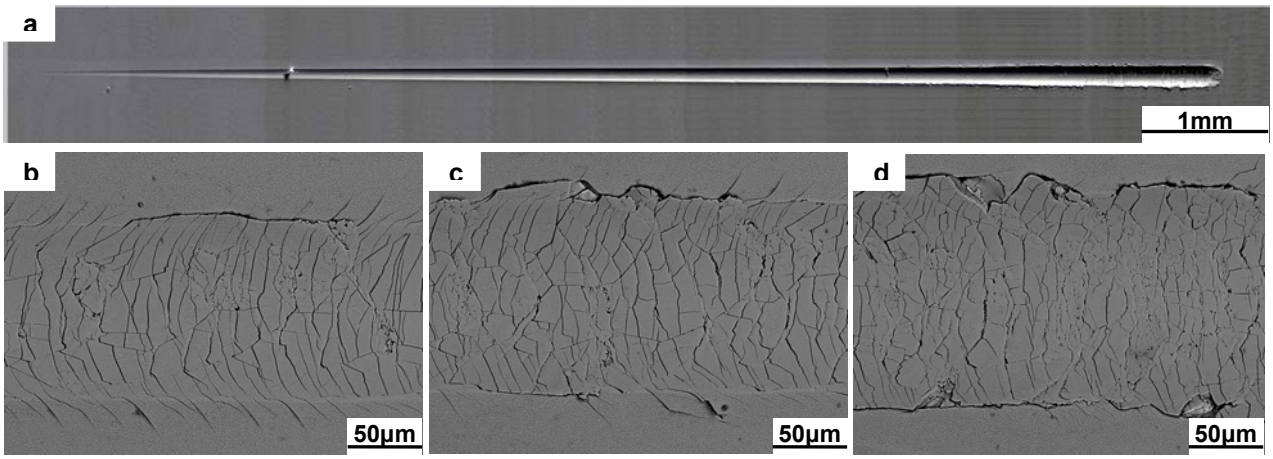

Fig. 4 *Electron microscopy showing the failures after scratch testing: a-overview, b-L_{c1}, c-L_{c2}, d-L_{c3}.*

ADHESION PROPERTIES DETERMINED FROM SCRATCH TEST Table 2

Coating	L_{c1} (N)	L_{c2} (N)	L_{c3} (N)	L_{c4} (N)
CrAg7N	*34.52±3.31*	*44.36±1.58*	*52.85±1.62*	*79.04±2.19*

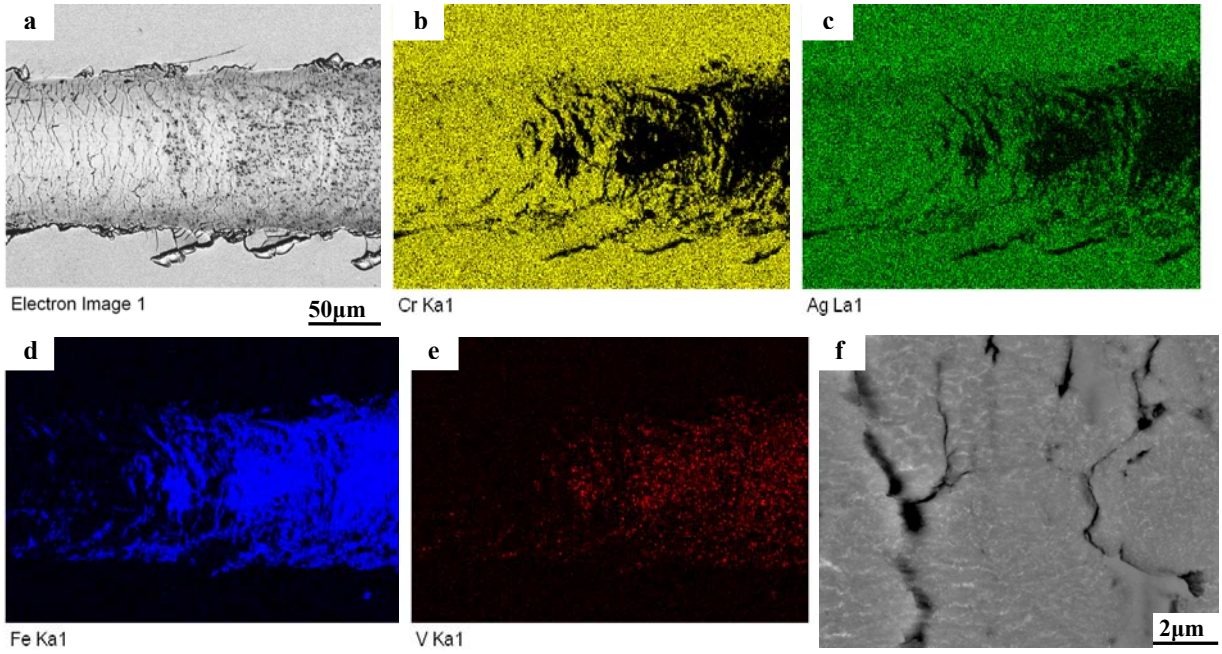

Fig. 5 *Electron microscopy showing the failures after scratch testing: a-L_{c4}, b-EDS map of chromium from Fig. 5a, c-EDS map of silver from Fig. 5a, d-EDS map of iron from Fig. 5a, e-EDS map of vanadium from Fig. 5a, f-surface after test.*

CONCLUSIONS

The effect of magnetron-sputtered CrAg7N-coatings on the mechanical behaviour of ledeburitic tool steel has been evaluated and an evaluation of the mechanical properties of the substrate/coating complex was done. The main findings can be summarized as follows: Coating deposited on the substrate grew in a typical columnar manner and had a thickness 4.3 μm. On the surface of coating and along the columnar crystal were visible individual silver particles with the size below 50 nm.

The addition of 7 % of Ag into the CrN film does not influence the hardness of the CrN negatively. On the other hand, the Young´s modulus has been established to be slightly higher than that of CrN or CrAg3N, which can be considered as rather surprising, because an opposite effect could has been expected.

The adhesion of CrAg7N film can be evaluated as very good. This can be attributed to a good capability of the soft Ag particles to absorb the plastic energy, which makes it more resistive against delamitation.

CrAgN coating of PM Cr-V ledeburitic steel Vanadis 6 is very promising way to increase its tribological properties at intermediate temperature. The addition of 7 % of silver brings good adhesion properties without effect on hardness of coatings. More tribological test of that coating is required.

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REFERENCES

1. BERTRAND, G., SAVALL, C., MEUNIER, C. 1997. *Surface and Coatings Technology 96,* p. 323 – 329.
2. XU, J., UMEHARA, H., KOJIMA, I. 2001. *Applications of Surface Science 201,* p. 208 – 218.
3. PRADHAN, SK. et al. 2005. *Surface and Coatings Technology 200,* p. 141-145.
4. HAN, S. et al. 2000. *Surface and Coatings Technology 133 – 134,* p. 460 – 465.
5. MERCS, D. et al. 2005. *Surface and Coatings Technology 200,* p. 403-407.
6. GAHLIN, R. et al. 1995. *Surface and Coatings Technology 76/77*, p. 174 – 180.
7. HAUERT, R., PATSCHEIDER, J. 2000. *Advanced Engineering Materials 2*, p. 247-259.
8. ZHANG, S. et al. 2003. *Surface and Coatings Technology 167,* p. 113-119.
9. HOVSEPIAN, PE., MUNZ, WD. 2003. *Vacuum 69*, p. 27-36.
10. MULLIGAN, C.P., BLANCHET, T.A., GALL, D. 2010. Wear 269, p. 125-131.
11. AOUADI, S.M., et. al. 2009. *Surface and Coatings Technology 203*, p. 1304 – 1309.
12. EDEMIR, A. 2005. *Surface and Coatings Technology* 200, p. 1792 – 1796.
13. AUOADI, S.M., et al. 2006. *Surface and Coatings Technology* 201, p. 418-422.
14. JURČI, P., DLOUHÝ, I. 2011. *Applied Surface Science*, p.10581-10589.
15. JURČI, P., et al. 2004. *Materiali in Tehnologije* 38, p. 13 - 19.

16. BÍLEK, P., SOBOTOVÁ, J., JURČI, P. 2011. *Materiali in Tehnologije 45,* p. 489-493.
17. SHELL, N., et al. 2003. *Thin Solid Films, 426*, p.100-110.
18. BASNYAT, P., et al. 2007. *Surface and Coatings Technology, 202*, p. 1011-1016.
19. MULLOGAN, C.P., et al. 2010. *Surface and Coatings Technology, 204,* p.1388-1394.

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2013 Special Number

APPLICATION OF NANOTECHNOLOGY FOR ANTI-FRICTION COATINGS

Marco ENGER, Pavel BLAŠKOVITŠ

ABSTRACT

Different slide-active coatings for thermoplastic surfaces, based on a new binder technology, were investigated for their use as slide element in the automobile interior. The main focus of this paper is the determination of the sliding behaviour of the coated thermoplastics in direct comparison to the uncoated variants. The coatings showed clearly different slide motion properties concerning their friction coefficient and stick-slip behaviour. In a direct comparison with the currently used polymers a clear improvement of slide properties could be achieved.

KEY WORDS

slide-active coatings, thermoplastics, friction, solid lubricants, stick-slip, nano-structured particles

INTRODUCTION

Thermoplastic materials are indispensable for many technical applications as they combine many important properties. They can be easily processed and feature a low specific weight. Additionally, their physical properties can be adapted for specific applications. The application of plastics in the car industry is immense and is growing continuously with increasing comfort, safety standards and quality requirements. Especially plastics have established themselves in the car interior for example as dashboards, levers or cover parts (1, 2).

For these components thermoplastic polymers such as ABS, PC, polymer blends or reinforced polymer blends for components requiring a higher material stiffness are often used. Due to danger of contamination there is no possibility to use conventional lubricants (greases and oils). Under dry friction conditions these polymers show a high stick-slip tendency and have high friction level, which can cause disturbing noise emission and also stiff movement of the different plastic components (3-6).

A solution to improve the frictional behaviour of these thermoplastics is dry lubrication with solid lubricants. Solid lubricants are materials which are able to separate two contacting

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surfaces in relative movement to improve their friction and wear behaviour. If solid lubricants are used, the question arises how these materials can be fixed to the contacting surfaces. Anti-friction coatings are a possibility for the fixation of these materials. In general anti-friction coatings consist of a solid lubricant, a binder and a solvent.

Fig. 1 *Friction behaviour of various amorphous thermoplastics*

Within this research thesis new anti-friction coatings should be developed on the basis of a new binder technology (Silixane) for thermoplastic surfaces. The present paper shows some research results of the last years. Some of the results were also published on other conferences and scientific journals.

EXPERIMENTAL DETAILS

Coating systems

Various slide-active coatings based on the new Silixan binder technology (7, 8) were prepared for this study and applied on different polymeric surfaces. The binder system was slide-modified with typical solid lubricants (PTFE, h-BN, graphite) at different concentrations. The main steps of the coating process are described below. First, the fine solid lubricant particles (PTFE, h-BN, graphite) were homogeneously dispersed in a system containing a Silixan binder and a solvent. Second, the substrate surfaces were pre-treated (degreased and roughened) to improve the adhesion behaviour between coating and substrate. Third, the mixture was applied onto the specimen surfaces by spray application (spray gun). Finally, the coatings were cured in a furnace at a temperature of 80 °C for one hour. The coating process is the same for all coatings. Table 1 gives an overview of the composition of the investigated coatings.

COMPOSITION OF THE DIFFERENT COATING SYSTEMS

Table 1

Solid	Concentra	Size	Bind
PTFE	10/20/40%	4 µm	Silixan
Graphite	10/20/40%	8 – 28	Silixan
h-BN	10/20/40%	3 µm	Silixan

Silixan binders are currently used for nano-based scratch-resistant coatings. The innovative characteristic of the new binder class is the creation of nano-scaled SiO_2-particles during the curing phase. Figure 2 shows a structural model of a hardened Slilixan binder system. The particles distribute homogenously in the binder. They build a strengthening phase in the cured coating system (9) which could have a positive effect on the tribological properties.

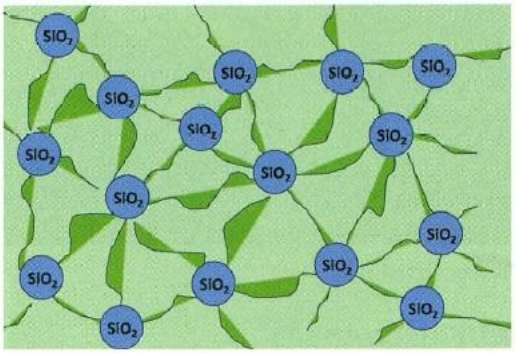

Fig. 2 *Structural model of a hardened binder system with nano-structured formation between hard glass-like and soft polymer-like zones (9)*

In (10) the influence of nanostructed SiO_2-particles on the sliding behaviour of anti-friction coatings was investigated. Therefore, conventional anti-friction coatings were modified with SiO_2-particles in terms of powder at different concentrations. The results showed the positive influence of SiO_2 nano-scaled particles on the tribological property profile of anti-friction coatings. Primarily, a significant increasing of the coating durability could be achieved with those particles.

Within the framework of this paper, portfolios of this new class of binders are to be extended regarding their application as binder for slide-active coatings.

Test matrix

For estimating the suitability of the new developed slide-active coatings for the application as slide element, an extensive test program is needed.

Adequate adhesion between coatings and plastic surfaces is essential for the subsequent function as sliding element. Therefore, the bond strength as well as the resistance against mechanical influences will be investigated with the cross-cut and scratch test.

The main focus of the investigation is the tribological characterisation of the coating systems in direct comparison to typical used uncoated thermoplastics.

The investigation of the friction behaviour was run on the Universal-Micro-Tribometer (UMT). The following factors of influence were tested:

- Various p,v-values
- Solid lubricant concentration.

The schematical illustration of the test device is given in figure 3. The test configuration was ball on disk. The temperature and the humidity of the atmosphere were nearly constant during the complete test matrix.

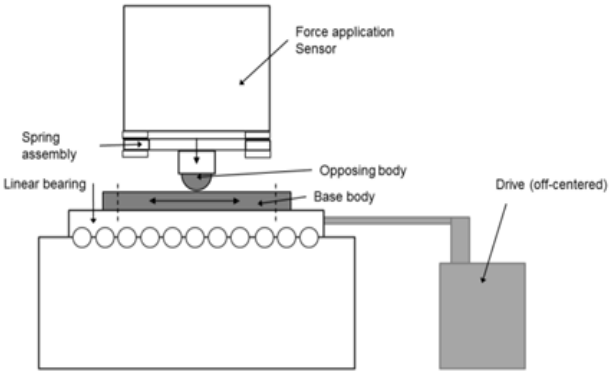

Fig. 3 *UMT test rig (ball on disc configuration)*

RESULTS AND DISCUSSION

Particle dispersion

The first investigation step was the determination of the particle dispersion of the different slide-active particles in the Silixan matrix. Inhomogeneous particle dispersion can have a negative influence on the adhesive and cohesive as well as on the sliding properties. The results are given in the following micrographs.

The PTFE particles distribute homogenously in the matrix. No influence of the particle concentration is observable. The graphite particles distribution is very homogeneously independent form the particle fraction in the matrix. For the BN particles a significant particle agglomeration in the matrix is given with the highest agglomeration rate for the lowest solid lubricant concentration (Figure 4, 5 and 6).

Fig. 4 *Particle dispersion of the PTFE-particles in the matrix: a: 10 % PTFE, b: 40 % PTFE*

Fig. 5 *Particle dispersion of the graphite-particles in the matrix: a: 10 % graphite, b: 40 % graphite*

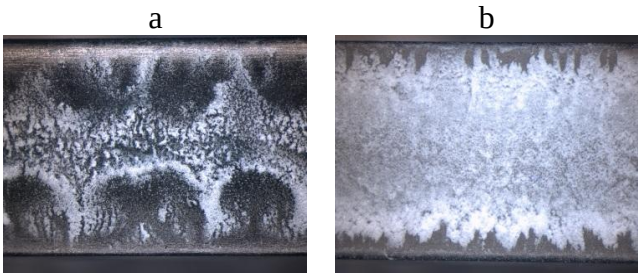

Fig. 6 *Particle agglomeration of the BN-particles in the matrix: a: 10 % BN, b: 40 % BN*

Furthermore, a cross-linking catalyst was used to reduce the agglomeration of the BN particles in the polymeric matrix resulting in a better particle distribution. However, the BN particle agglomeration cannot be completely eliminated.

Bond strength and scratch resistance

Adhesion behaviour

Adequate bond strength between coating and substrate is an important property of the coating for the further use as slide element. To get a first information about the bond strength of the coating systems different thermoplastic (PCABS, ABS, PC, PCABS+GF) materials with various topographies (R_z = 0,5 to 16 µm) were coated with slide-modified Silixan binders. The adhesion between the substrate and the coating systems were measured with the cross-cut test (DIN EN ISO 2409). The cut surfaces were examined with a scanning electron or a digital microscope to more clearly detect a possible coating failure (e. g. coating delamination).

The following figures show the surface analysis for a PCABS substrate with two representative topographies coated with a PTFE-system. No laminar coating failure is observable. Only in the areas of the "cuts" is a marginal damage of the coating apparent.

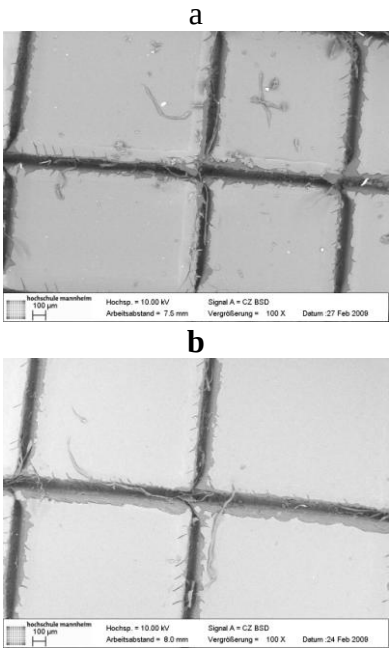

Fig. 7 *Overview cross-cut: a: polished polymer surface, b: blasted substrate surface*

The complete results of the influence of the surface topography on the bonding strength of the coatings are given in table 2. All coatings in the test showed a good bond strength independent from the topography that argue for a good chemical (covalent bonding) and mechanical bonding between binder and the substrate surface. This suggests that a sufficient adhesion between binder and base substrate is given. All coatings show similar adhesion behaviour determined with cross-cut test. No coating failed in the cross-cut test through insufficient bond strength.

INFLUENCE OF THE SUBSTRATE TOPOGRAPHY
ON THE ADHESION BEHAVIOUR
(PTFE COATING APPLIED ON PCABS) Table 2

Substrate topography		Bonding strength
Polished	R_Z =< 1	Rating 5: no peeling or removal
Grinded	R_Z = 1	Rating 5: no peeling or removal
	R_Z = 3	Rating 5: no peeling or removal
Blasted	R_Z = 5	Rating 5: no peeling or removal
	R_Z = 8	Rating 5: no peeling or removal
	R_Z = 16	Rating 5: no peeling or removal

Scratch test

In the scratch test, an indenter is moved over the coated surface under continuously increasing load with a constant slide velocity. The scratching point produces an increasing elastoplastic deformation of the coating-substrate systems until a coating failure (coating chipping and spalling, coating flaking, coating breakthrough or distinctive cracking) occurs which can have an adhesive or cohesive nature.

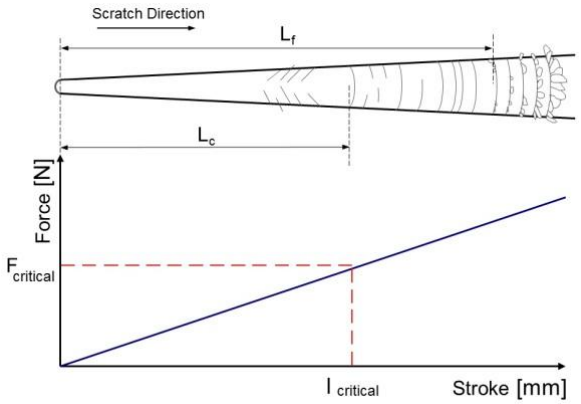

Fig. 8 *Schematic illustration of the scratch test method*

The point at which an incipient or a complete coating failure occurs can be read off directly by using SEM analysis. The corresponding forces which are responsible for the coating failures can be derived directly from the linear relationship between applied force and travelled distance and are named as critical load L_c or failure load L_f (Figure 8). The test parameters were: maximum load = 7,5 N, distance = 10 mm, duration of the test is 1 min.

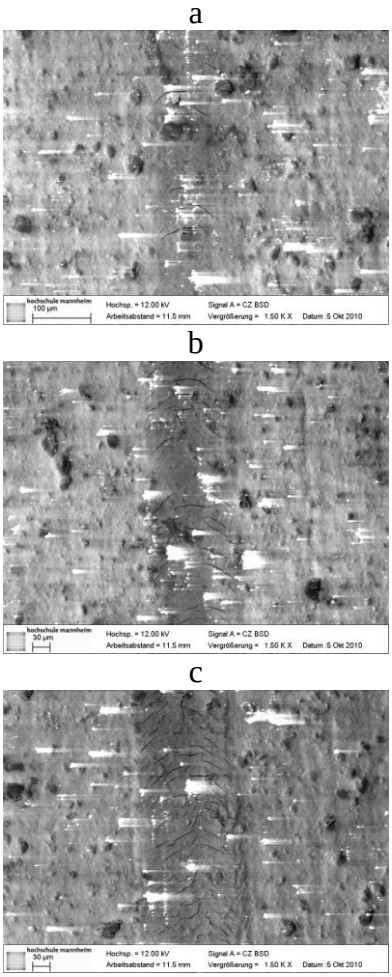

Fig. 9 *SEM-analysis of the scratch track of a BN based coating applied on PCABS: a: load = 1 N, b: load = 1,6 N, c: load = 2,2 N*

Detailed investigations of the scratch tracks are carried out on the scanning electron microscope. Figure 9 represents exemplary SEM micrographs of a BN-based coating applied on PCABS substrate. An extensive plastic deformation of the substrate coating composite is visible in the SEM micrographs, which increases with an increasing load. In spite of the significant plastics deformation of the coating and substrate no coating failure is detectable. This indicates good bond strength between coating and substrate.

Furthermore, cracking was established in the scratch track at a critical load induced by the deformation of the soft substrate. If the coating cannot deform accordingly it will crack. Thereby the typical crack patterns are observable: angular cracks, conformal cracking and tensile cracking. Conformal and tensile cracks are typical for coatings which remain fully adherent on the substrate. The damage increases significantly with increasing load, and a distinctive crack network is formed. No complete coating failure (e. g. coating chipping or a coating breakthrough) is observable. All investigated coatings show similar behaviour.

On the basis of the SEM-analysis the critical failure load was defined for each coating. In this context the critical load represents the load at which a distinctive crack network is visible in the scratch track. The results are given in the following bar diagram (Figure 10).

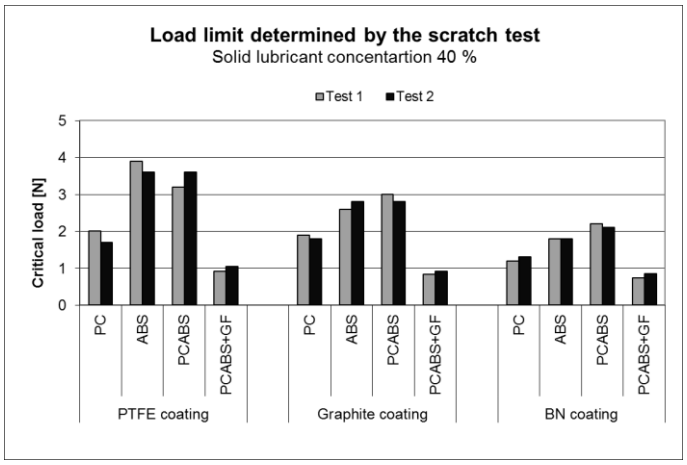

Fig. 10 *Critical load determined with the scratch test*

The BN coating system shows the earliest failure of the investigated coating systems. The values for the critical load range between 1,3 and 2,2 N. The highest resistance against mechanical influences was performed by the PTFE-based coating system. For the PTFE coating the average value for the critical load is 1,7 to 3,7 N. The critical load (1,8 to 2,9 N) of the graphite system lies between the other two coating systems. The substrate materials possess a significant influence on the scratch resistance of the coatings. The highest critical loads were determined for the PCABS and ABS substrate. Applied on substrates with a lower deformability (PC, PCABS+GF) all coatings show a premature coating failure.

Tribological behaviour

Friction behaviour

The next tests encompass the tribological behaviour of the coatings under oscillating friction conditions. The results are shown in the figure 11. The given values represent an average of a minimum of three replicate measurements. The error bar indicates the corresponding maximum and minimum measured value. During the tests, the main parameters were chosen as follows: constant slide velocity of 10 mm/s, the normal load varied from 1 and 3 N, corresponding to the maximum Hertzian contact stress 30 and 45 MPa.

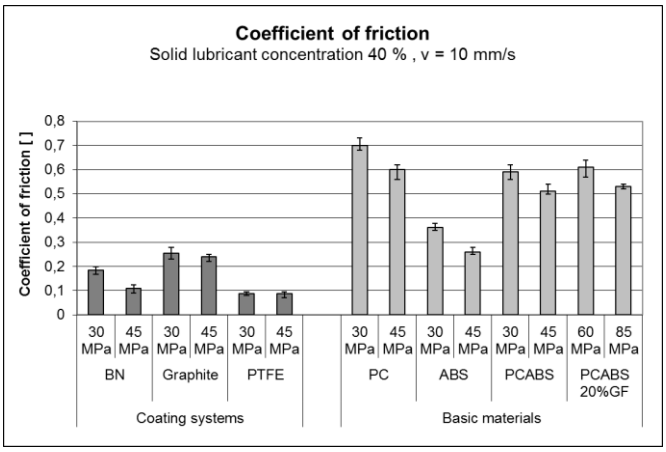

Fig. 11 *Friction behaviour*

The BN coating shows a very low friction level for each investigated p,v-value. The PTFE coating system features a good sliding performance for the complete p,v-spectrum. The graphite based system exhibits a higher coefficient of friction than the other two coating systems. All coatings show a decreasing coefficient of friction with higher loads. The coefficient of friction for uncoated samples is much higher. These findings suggest the three coatings can effectively reduce the friction level under oscillating movement.

Long-term behaviour

To be able to make a statement about the long-term behaviour of the different coating systems an endurance test was carried out for two specific p,v-values (contact stress = 45(85) MPa, velocity = 20(50) mm/s, duration = 48 h). The results are illustrated in figure 12 and 13.

For the description of the durability of the coatings two times are necessary. First, the instant of time at which the coating system is completely intact (steady-state coefficient of friction). This point also defines the time at which the first discontinuities such as short-term peaks in the coefficient of friction curves and/or an increase of the friction coefficient to a higher level can be identified, which are indicators for a partial coating failure. Second, the elapsed time till the coating failed through a complete breakthrough.

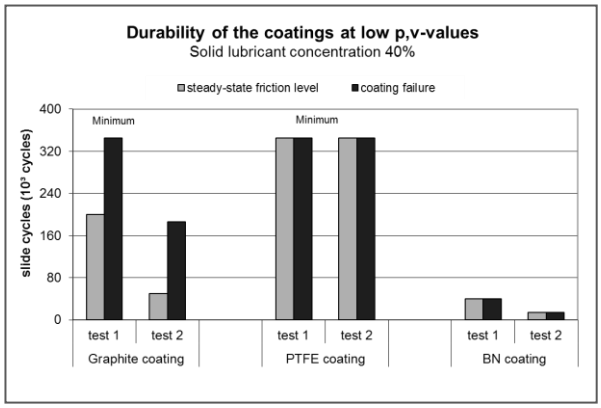

Figure 12 *Durability at low p,v-values*

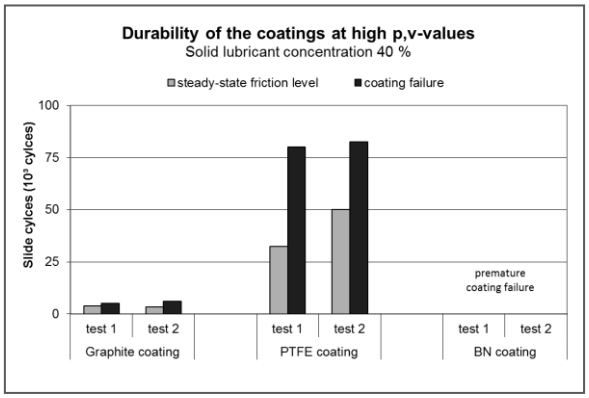

Fig. 13 *Durability at high p,v-values*

The PTFE coating shows the best long-term behaviour. The graphite coating also exhibits good durability for the low p,v-combination. The BN based coating performs an insufficient durability for both investigated p,v-values. All coatings show a significant reduction of their durability for an increasing collective stress. As in all coating systems, the same pre-treated

substrate is used and all parameters of the coating process are the same. The different durabilities can be ascribed to the influence of the various solid lubricants. The BN coating builds two phases during the curing phase, which cause a degradation of the adhesive and cohesive properties of the coating leading to a premature coating failure.

Influence of the solid lubricant concentration

The friction and wear behaviour of slide-active coatings depends strongly on the coating composition. In particular, the fraction of the solid lubricant can have a significant influence on the tribological properties.

The variation of the friction level of the different coating systems against the solid lubricant concentration is shown in the following diagram.

The solid lubricant concentration does not significantly affect the friction behaviour of PTFE and graphite based coating systems. Both coating systems possess a constant tribological performance independent from the used solid lubricant fraction in the coating matrix. For the BN modified coating a significant influence of the solid lubricant on the sliding behaviour is given. The BN coating shows a premature coating failure for the lower solid lubricant concentrations due to the high agglomeration rate of the BN particles in the polymeric matrix.

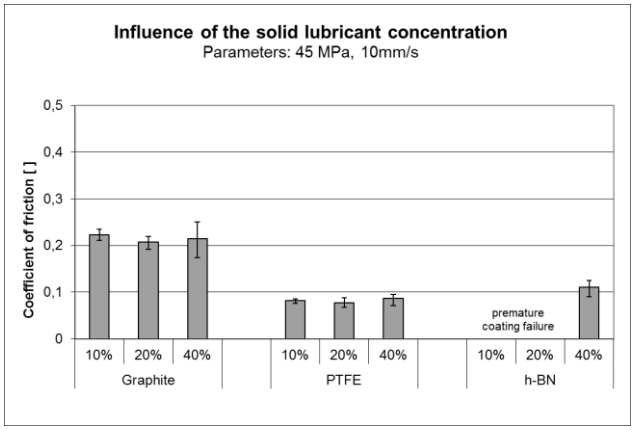

Fig. 14 *Influence of the solid lubricant concentration*

CONCLUSION

Within this work different slide-active coatings for thermoplastic surfaces, based on a new binder technology, were developed to improve the sliding behaviour of thermoplastic surfaces. These coatings were slide-modified with typical solid lubricants (h-BN, PTFE, graphite) at different concentrations. The first focus of the investigations was the determination of the adhesion behaviour as well as the behaviour against mechanical influences. The friction properties under oscillating movement conditions against different parameters were investigated. Furthermore, the long-term behaviour of the coating was determined. The coatings showed clearly different slide motion properties concerning their friction as well as the long-term behaviour. All coating substrate composites possess good bond strength determined with the cross-cut test. All coatings feature a good resistance to mechanical influences. The results of the friction and wear tests showed that these coatings can effectively reduce the stick-slip tendency and the friction level of amorphous thermoplastics and can also improve their wear resistance. The PTFE coating possesses the best friction behaviour. The endurance test performed on the coatings reveal different wear

lives for each coating. The best long-term behaviour was shown from the graphite and PTFE based coatings.

REFERENCES

1. T. L. HENSEL. 2004. *Globale Marketingstrategien für technische Kunststoffe*. Ticona GmbH, Kelsterbach.
2. Kunststoffe im Automobil: Einsatz und Verwendung. Verband Kunststofferzeugende Industrie e.V. (VKE), Frankfurt/Main
3. N. S. EISS, J. HANCHI. 1998. Stick-Slip friction in dissimilar polymer pairs used in automobile interiors. Tribology international: the technology of lubrication, wear prevention and friction control.
4. N. S. EISS, B. P. McCANN. 1993. Frictional Instabilities in Polymer-Polymer Sliding. Tribology Trans. 36.
5. N. S. EISS, J. HANCHI. 1998. Friction Instabilities in Plastics Used in Automotive Interiors. Industrial and Automotive Lubrication. 11th International Colloquium.
6. H. ENDO, E. MARUI. 2004. Fundamental studies on friction and wear of engineering polymers: Industrial Lubrication and Tribology.
7. S. SEPEUR, N. LARYEA. 2008. Silixane – Basis für die Lacke der Zukunft.
8. S. SEPEUR, N. LARYEA, F. GROSS, S. GOEDICKE. 2008. Nanotechnologie: Grundlagen und Anwendungen. Farb und Lack Edition. Vincentz Network.
9. N. LARYEA, S. SEPEUR, C. THURN, M. Mönkemeyer. 2010. Damit das Auto noch lange glänzt: Hochkratzfeste Klarlacke mit neuem Bindemittelkonzept, Farbe und Lack, Ausgabe 7.
10. R. ZECHEL, S. HARTL, P. STAUB. 2010. High-Performance Verschleißschutz mit nanopartikelhaltigen Gleitlacken, 51. Tribologie Fachtagung: Reibung, Schmierung und Verschleiß: Forschung und praktische Anwendungen, Band 2.
11. W. STEHR. 2002. Stick-Slip Verhalten von Polymeren. 13th International Colloquium Tribology, TAE-Esslingen.

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INHOMOGENEITIES IN THE STRUCTURE OF HIGH TEMPERATURE SUPERCONDUCTING LAYER

Pavol KONOPKA, Marcela PEKARČÍKOVÁ, Michal SKARBA, Jozef JANOVEC

ABSTRACT

Superconducting layer in coated conductor was investigated to assess the inhomogeneities present in its structure and to get better insight into the effect of inhomogeneities on degradation of electric properties. In the investigation scanning electron microscopy, energy-dispersive X-ray spectroscopy, electron backscattered diffraction, and laser scanning confocal microscopy were used. The results obtained showed good correlation between the density of inhomogeneities across the tape width and the degradation of current transport properties determined by measurements of the current density

KEY WORDS

high temperature superconductor, characterization of structure, inhomogeneities

INTRODUCTION

One of the most important issues related to the development of new energy sources is production of electromagnetic coils which will provide strong magnetic fields in a nuclear fusion reactor. The coils will be most probably made of high temperature superconducting tapes enabling the electricity conduction in a micrometer thick ceramic layer. High temperature superconducting coated conductor (Fig. 1) is a complex structure consisting of several layers. The most important (functional) layer is the mentioned high temperature superconductor (HTS). Investigated tapes consist of high temperature superconductor containing rare earth elements (RE) in the crystal lattice. This type of superconductor is referred to as (RE)BCO (where (RE)BCO means (RE)$Ba_2Cu_3O_{7-y}$, RE = Y_XGd_{1-X}) with orthorhombic crystal lattice.

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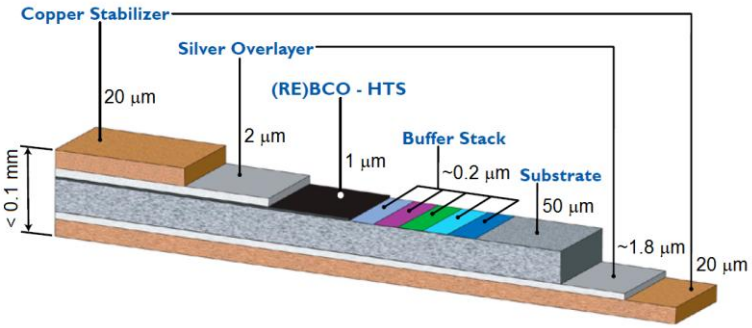

Fig. 1 *Schematic illustration of coated conductor (1)*

SAMPLE PREPARATION

Prior to planar surface investigation of high temperature superconducting layer, it is necessary to remove the copper and silver overlayers. This was done by selective chemical etching using iodine. The etchant attacks only metal layers (copper and silver overlayer), while the high temperature superconducting layer remains untouched. There are several advantages of this approach. The selective chemical etching provides large uncovered area (the size of uncovered area is basically unlimited) and the localization of uncovered area is controllable. Furthermore, there is no mechanical damage of the uncovered area because the etching stops exactly at the top of the surface layer. By the use of selective chemical etching (Fig. 2), surface morphology and chemical composition of the HTS layer is preserved. In Fig. 2 two kinds of shapes can be identified: needle-like and polygonal structures.

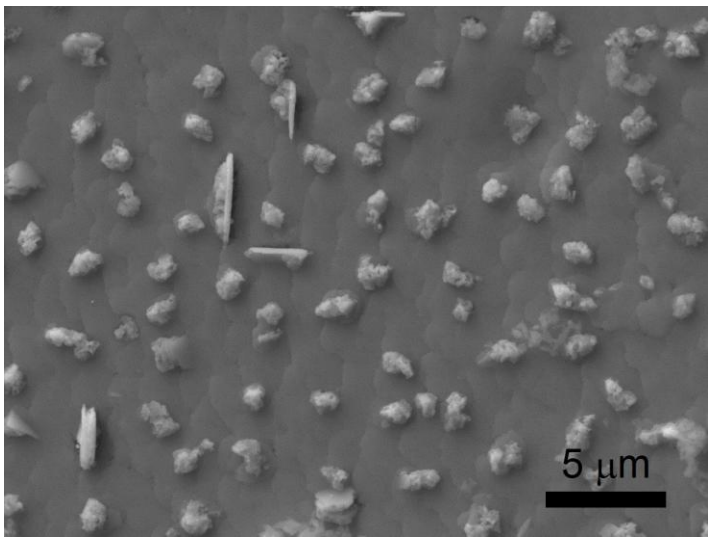

Fig. 2 *Uncovered high temperature superconducting layer prepared by selective chemical etching, secondary electron imaging (SEI) mode*

RESULTS AND DISCUSSION

SEM investigation of coated conductor

Investigation using scanning electron microscope (SEM) JEOL JSM7600F revealed inhomogeneities in the structure of HTS layer. As it was previously reported in (2), the presence of such inhomogeneities (also known as outgrowths) is typical for good crystalline quality of HTS layer. These particles in HTS layer have generally another orientation than

superconductor matrix and they are classified as a-, or b-axis oriented grains (a-, b-axis is parallel to surface normal) or secondary shaped particles other than (RE)BCO phase (3). In addition to the size, number density and homogeneity of outgrowths are time and temperature dependent (3). The energy dispersive X-ray spectroscopy (EDX) line scan (Fig. 3) guided through outgrowths shows the chemical composition of outgrowths is rather complex. RE elements show an increase in the intensity in white parts of outgrowths and the black parts contain predominantly Cu. Minima in the barium, yttrium and gadolinium concentration profiles indicates that the chemical composition of black parts of outgrowths might be as simple as Cu_XO (x = 1 or 2). However, to confirm this hypothesis some additional high resolution measurements, for example by TEM, in cross-sectioned samples are necessary.

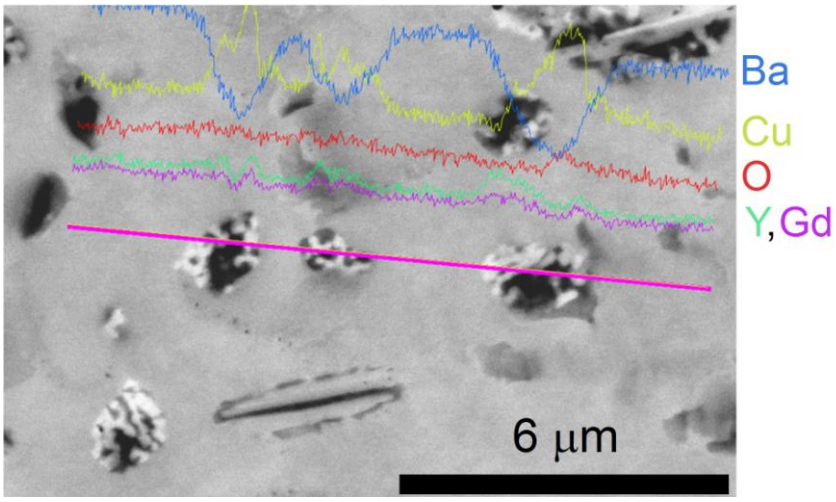

Fig. 3 *The EDX line scan of outgrowths, SEM backscattered electron imaging (BEI) mode*

The concentration of elements (Fig. 4) is better observable in cross-section of coated conductor. EDX mapping showed depleted areas of barium in superconducting layer and rich areas of copper corresponding with position of outgrowths in the SEM micrograph.

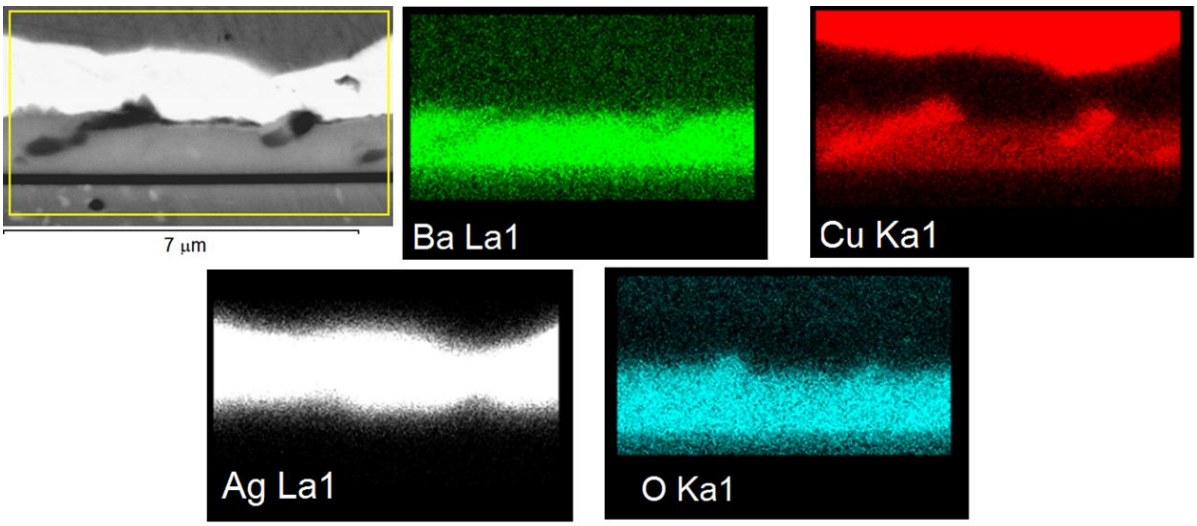

Fig. 4 *The EDX maps of coated conductor in cross-section, SEM micrograph was obtained in BEI mode*

Correlation between results of electric and structural measurements

The SEM micrograph in Fig. 4 (top left) shows that outgrowths penetrate deeply in to the superconducting layer but rarely touch the buffer stack. These outgrowths have different chemical composition and crystal orientation as the bulk part of superconductor and may affect the electro-magnetic properties of coated conductor. We suspect that the presence of outgrowths have major influence on the degradation of current transport properties localized mostly at the tape edges (Fig. 5). The profile of critical current density showing a degradation of the current transport properties at the conductor edges (Fig. 5a) is in good agreement with the profile of surface areas (Fig. 5b).

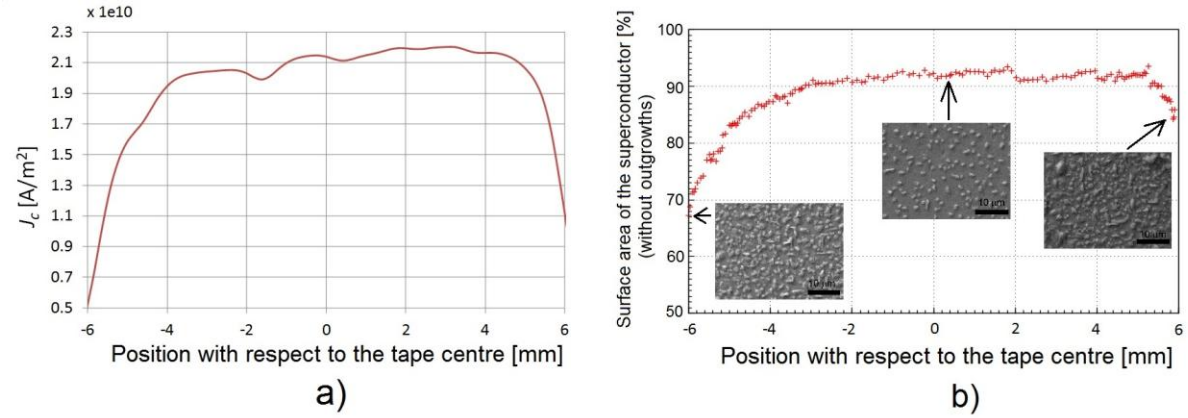

Fig. 5 *a) Profile of a critical current density; b) profile of a surface area of the superconductor (without outgrowths), both as a function of a position across the tape width (0 = center of the tape) (4)*

Laser scanning confocal microscopy

From the point of view of experimental surface characterization, the surface roughness due to the presence of outgrowths is an undesirable feature. Fig. 6 depicts surface micrographs of HTS layer obtained by the use of laser scanning confocal microscope ZEISS LSM 700. These micrographs show that the outgrowths have height about 1 μm and are still too high and unsuitable to allow for crystal structure analysis by EBSD where very smooth surface is required.

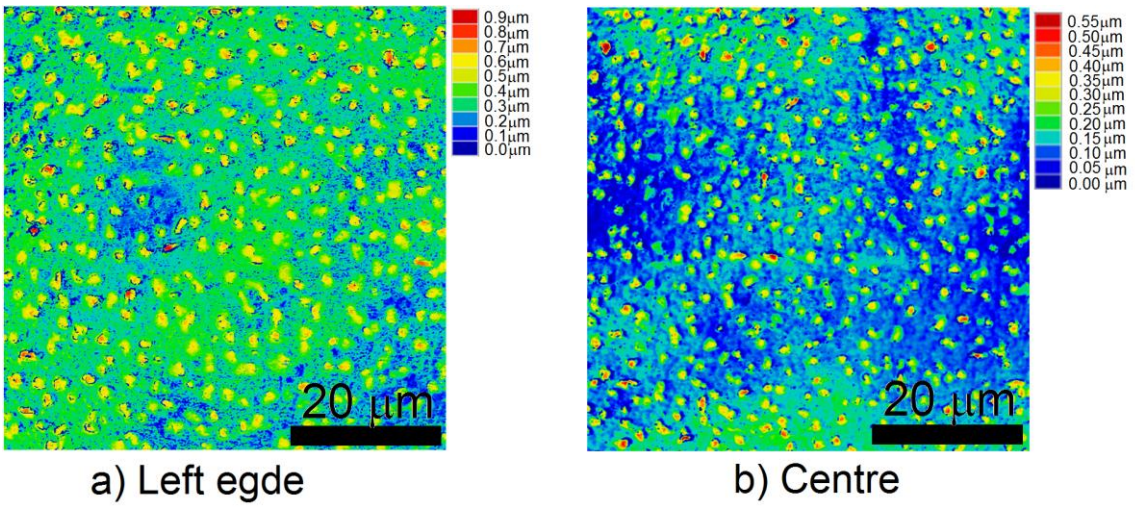

Fig. 6 *Surface height map obtained by means of laser scanning confocal microscope; height of outgrowths are indicated by various colours*

Electron backscattered diffraction of coated conductor

The analysis of cross-section in coated conductor using EBSD (accelerating voltage 20 kV, recording using 4x4 binning on a Nordlys II camera for 30 ms) shows clearly different crystallographic orientation in (RE)BCO outgrowth-free regions (the superconducting layer itself), in outgrowths and in neighbouring regions of outgrowths (Fig. 7). The EBSD technique was performed manually as point by point measurement, because automatic EBSD mapping was unable to distinguish between a-, b- and c-axis oriented superconductor.

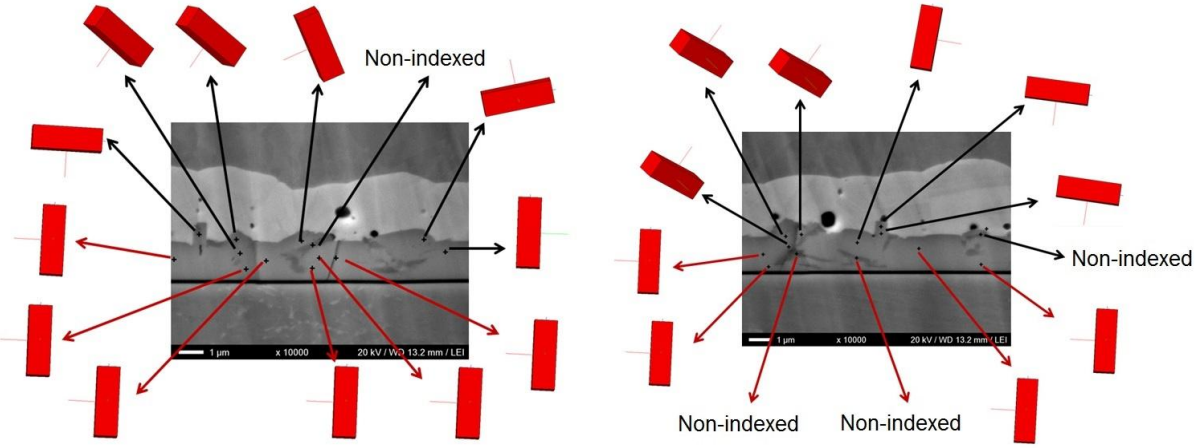

Fig. 7 *Crystallographic orientation in (RE)BCO superconductor by EBSD*

EBSD technique reveals that the (RE)BCO superconductor has almost identical (001) crystallographic orientation (red arrows in Fig. 7) as it was expected for good quality of HTS tape. Neighbouring regions of outgrowths indicates different orientation than (RE)BCO superconductor (black arrows in Fig. 7). Rotated lattice scheme (in red color) indicates different orientation than it is the expected (001) orientation. It was not possible to index outgrowths, dark areas in superconducting layer, black arrows marked as "Non-indexed" in Fig. 7, because of overlapping of two different electron backscattered patterns (EBSP) or obtaining of the EPSP from unknown phase, probably copper (I or II) oxide.

CONCLUSION

The SEM measurements showed inhomogeneities in the structure of the HTS layer. The observed outgrowths were found to have rather complex chemical composition. They might be formed by simple copper oxide (Cu_XO; black parts of outgrowths). Moreover, three regions were identified by EBSD: outgrowths-free region (superconductor), neighbouring region of outgrowths and outgrowths. This technique confirmed the expected orientation of superconductor – (001). Neighbouring region of outgrowths (white parts of outgrowths) shows different orientation than the surrounding superconductor. It was shown by EBSD that the latter region is the superconductor with different orientation. It was not possible to index some outgrowths, because they are formed with unknown phase, probably copper oxide.

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REFERENCES

1. Available on internet (*http://www.superpower-inc.com*)
2. KREISKOTT, S., GETTA, M., MÖNTER, B., PIEL, H., PUPETER, N. 2003. High Jc films on biaxially textured Ni with oxide buffer layers deposited using evaporation and sputtering technique. *Physica C*, 383. 306-314. ISSN 0921-4534
3. HAN, Z., SELINDER, T., I., HELMERSSON, U. 1994. Formation of Cu rich particles on the surface of $YBa_2Cu_3O_{7-x}$ thin film grown by in situ offaxis sputtering. *Journal of Applied Physics*, 75. 2020-2025. ISSN 1089-7550
4. GÖMÖRY, FEDOR - ŠOUC, JÁN, ING - PARDO, ENRIC - SEILER, EUGEN - SOLOVIOV, MYKOLA - FROLEK, ĽUBOMÍR - SKARBA, MICHAL - KONOPKA, PAVOL - PEKARČÍKOVÁ, MARCELA - JANOVEC, JOZEF. 2013. AC Loss in Pancake Coil Made From 12 mm Wide REBCO Tape. *IEEE Transactions on Applied Superconductivity*, **23**(3). ISSN 1051-8223

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2013 Special Number

COMPARISON OF OXIDATION RESISTANCE OF TiAlN MONOLAYER COATING AND ITS nACo3 NANOSTRUCTURED VERSION

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Kristián ŠALGÓ, Jana BOHOVIČOVÁ, Jozef SONDOR

ABSTRACT

The contribution deals with comparison of oxidation resistance of classical TiAlN monolayer coating and its advanced high hard nanostructured and multilayered nACo3 version at elevated temperatures. Both coatings were deposited onto AISI M36 high speed steel using unique LAteral Rotating Cathodes process (LARC®). "In – situ" X-Ray diffraction analysis was employed for determination of the beginning of oxides creation and phase detection at different heating temperatures. Scanning electron microscopy fitted with EDX analysis was used for observation of fracture areas and measurements of coatings and oxide layers thicknesses as well. Determination of chemical composition of coatings surfaces and elemental linescans through the coatings and oxide layers were performed using EDX analysis. All measurements of these coatings were carried out not only before but also after the thermal annealing.

KEY WORDS

TiAlN, nACo3, LARC®, In – Situ XRD analysis, SEM, LSM

INTRODUCTION

Nowadays, thin wear resistant hard coatings are widely applied on cutting and forming tools to improve their lifetime and performance, enhance productivity, and enable some new engineering applications as well. Hard coating deposition has now become a routine processing step in tools industry. Currently, a wide range of PVD hard coatings are available for a variety of applications (1, 2). Due to the increasing lifetime and the cutting speed, the nanocomposite coatings are pushing the machining technology towards new horizons (3). The study of TiAlN based coatings has deserved special attention. TiAlN is shown to have an excellent property in high speed cutting performance, such as oxidation resistance, mainly

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because Al_2O_3 is formed on the interface between tool and work pieces at high cutting speeds (4). Ti atoms are partly replaced by Al atoms in TiN, from this reason the hardness of TiAlN increases (1, 2, 3). Nanostructured nACo3 coating consists of nanocrystallic grains with average size of 3 nm that are embedded in amorphous Si_3N_4 matrix. This coating offers higher hardness, oxidation resistance and lower thermal conductivity in comparison with TiAlN monolayer coating (5, 6). During nACo3 nanocomposite PVD deposition, the TiAlN or TiN nanocrystals are dispersed in the growing amorphous Si_3N_4 matrix and the growth of nanocrystals is limited. When the external pressure is applied, the dislocations are motion – impeded by amorphous parts (7, 8), the hardness and toughness of the nACo3 coating are increased. With the increase of the silicon content in the nACo3 nanocomposite coating, the crystal size decreased. When the Si content is increased to 6.0 %, the coating exhibits a super hardness as well as an excellent fracture hardness and adhesion strength (9). Small amount of Si increases the mechanical property of TiAlN coating, on the contrary, an excess Si decreases it, because the excessive Si forms a weak phase.

EXPERIMENTAL PROCEDURE

TiAlN monolayer coating and its nanocrystallic version that is called nACo3 were deposited by a PLATIT π80 lateral rotating cathodes arc system onto M36 high speed steel substrate. This steel is very suitable for production of tools that are designated to use in application of turning, milling and drilling hard machinable and high strength materials. The chemical composition of this steel is given in table 1.

CHEMICAL COMPOSITION OF AISI M36 HIGH SPEED STEEL Table 1

Chemical composition of AISI M36 HSS (wt. %)									
C	**Si**	**Mn**	**P**	**S**	**Co**	**Mo**	**Cr**	**V**	**W**
0.90	0.45	0.45	0.035	0.035	7.50	5.00	4.00	1.90	5.50

The PLATIT π80 deposition unit consists of two lateral rotating elemental cathodes, Ti (or Cr) and Al, and a rotating carrousel sample holder. This system has two major advantages over the conventional planar vacuum arc deposition systems. The first advantage comes from the unique lateral cathode rotation, which results in a maximum effective cathode surface and longer cathode lifetime. The second advantage comes from the Virtual Shutter function, which makes it possible for in situ cathode cleaning before coating deposition without plasma interruption. This feature results in superior adhesion strength and smooth surface of the as deposited coatings. Coatings were fabricated at LISS, a.s. Company in Rožnov pod Radhoštěm, Czech Republic. Coatings deposition was carried out in a flowing pure nitrogen atmosphere under a working pressure of 1.5 Pa. Ti/Al cylindrical target with Ti:Al atomic ratio of 1:1 was performed for evaporation of TiAlN coating. The second Al/Si cathode was employed during the deposition of nACo3 coating. Mirror polished M36 HSS disks with diameter of 10 mm were used as base materials. Before loading into the deposition chamber, these substrates were ultrasonically cleaned in a series of alkaline solutions. Next, they were washed with deionized water, blown dried by nitrogen gas and further dried in an oven at 100 °C. The pre cleaned substrates were then mounted on the carrousel substrate holder that rotates at a speed of 12 rpm during deposition. Prior to deposition, the substrates were bombarded by high energy ions to remove any traces of surface contamination and the native oxide layer. During deposition, a negative DC bias of−70 V was applied to the substrates and the deposition temperature was controlled at around 480 °C. Oxidation resistance and phase transformations that could occur inside these coatings during the heating process were studied using PANalytical Empyrean diffractometer that is fitted with PIXcel^{3D} detector and Anton

Paar DHS 1100 heating chamber. Parameters of XRD analysis were chosen with respect to coatings thicknesses (from 3 to 4 μm). From this reason, the Grazing Incidence XRD was performed due to suppress diffraction peaks achieved from the base material. Co anode with wavelength of 0.178897 nm was used as a source of radiation. These parameters were utilized during the analysis: U = 40 kV, I = 30 mA and step size of 0.01°/ 20 s. The specimens were heated up with heating rate of 30 K/min^{-1} and dwell time on each temperature stage was 10 min. Fracture areas of samples before and after thermal annealing were observed with high resolution field emission gun JEOL JSM 7600 F scanning electron microscope. All specimens were cleaned in acetone using ultrasonic energy before the observation. Specimens were observed in regime of backscattered electrons. Parameters of observation were: U = 20 keV, I = 2 nA and WD = 15 mm. The chemical composition of coatings surfaces were detected with X-Max 50 mm^2 EDX SDD detector. The elemental linescans through the coatings and oxide layers were achieved using the same detector as well.

RESULTS AND DISCUSSION

XRD patterns of TiAlN and nACo3 coatings achieved before and during the annealing process are documented in Fig. 1 a) and b). The structure of as deposited TiAlN mono coating consists of $TiAlN_2$ phase that is characterized with cubic unit cell with lattice parameter of 4.19 Å. The diffraction peak at the value of Bragg angle of 102° could be considered as a contribution of base material (ferrite) to the whole diffraction pattern. Diffraction peaks of TiN adhesion layer appears at Bragg angles of 50°, 40°, 100° and 124°. The phase transformation from ferrite to austenite occurred at the temperature of 900°C. The beginning of oxides layers formation was recorded at the temperature of 900°C as well. Above this temperature, the Al_2O_3 and TiO_2 oxides were detected.

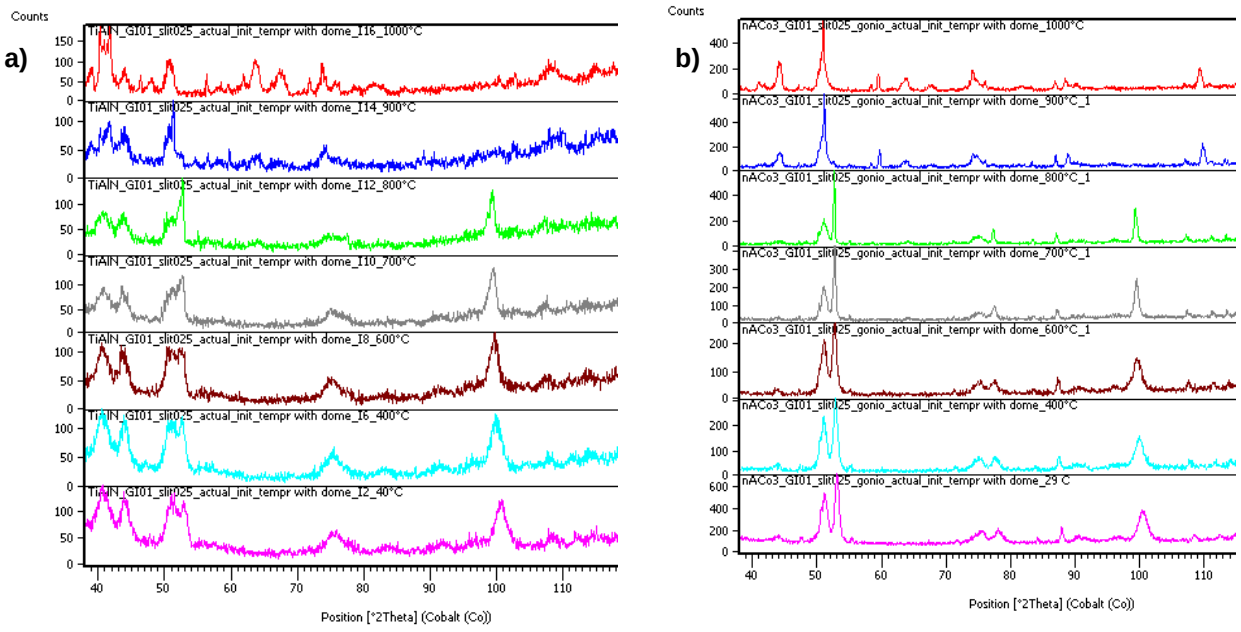

Fig. 1 *Diffraction patterns of a) TiAlN coating at elevated temperatures, b) nACo3 coating at elevated temperature*

The structure of nACo3 coating consists from $TiAlN_2$ phase before the thermal heating. The presence of amorphous Si_3N_4 matrix could not be detected due to its amorphous nature. The structure was stable until the temperature of 800 °C. The creation of first oxides was

observed at the temperature of 800 °C. Slight diffractions of Fe correspond to the contribution of substrate to the total diffraction pattern of the coating. TiO_2, SiO_2 and Al_2O_3 are the mainly oxides that were detected.

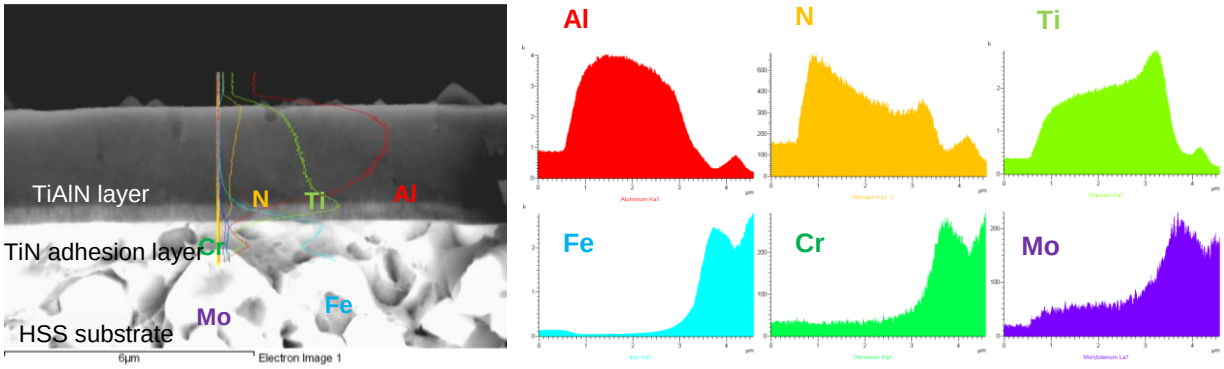

Fig. 2 *Fracture area of TiAlN coating before thermal heating and its chemical composition through the coating*

Structure of TiAlN fracture area monolayer before thermal annealing is given in Fig. 2. The presence of microparticles on the coating surface was proved. The thickness of TiAlN monolayer measured with SEM reached value of 2.76 µm. SEM also reveals that the monolayer consists of functional TiAlN layer and TiN adhesion layer. TiN interlayer was evaporated onto surface of base material due to improve the adhesion between TiAlN coating and AISI M36 substrate. The thickness of TiN adhesion layer was about 0.38 µm. The TiAlN coating is characterized by columnar crystal growth. Increase of Ti content from the top of the coating towards base material was documented by EDX linescan analysis across TiAlN coating – substrate interface. The intersection between the Ti and Al concentrations can be considered as the interface between TiAlN coating and TiN adhesion layer. Ti content reached its maximum value at the half of the adhesion layer.

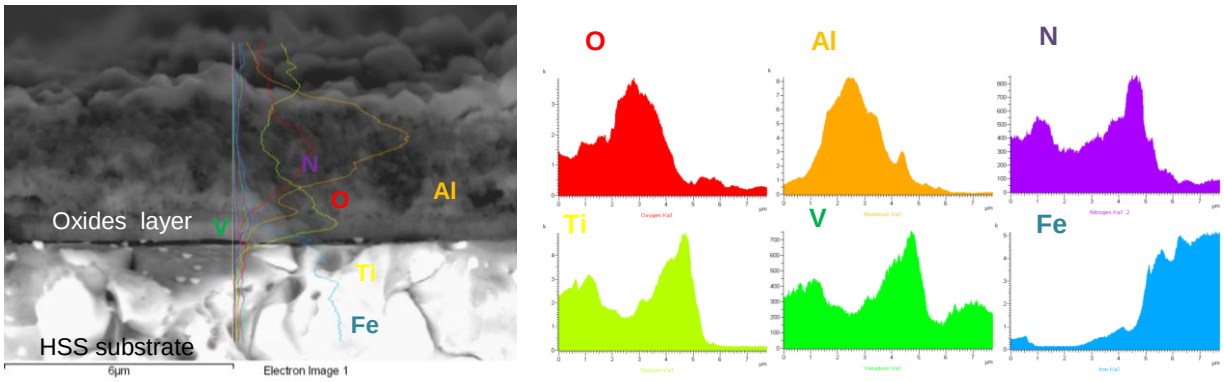

Fig. 3 *Fracture area of TiAlN coating after thermal heating and its chemical composition through the coating*

Structure of TiAlN coating fracture area after the heating process at the temperature of 1000 °C is documented in Fig. 3. SEM micrograph confirmed the presence of oxide layers created on the coating surface and failure of adhesion between the coating and base material. In this case, the thickness of TiAlN layer increased from 2.76 µm to 4.00 µm. It is caused by the oxide layers formation. Fig. 3 illustrates the course of concentration change of chemical elements across the TiAlN coating - base material interface after the oxidation process. Oxide

layers presented on the coating surface were mainly created from Al_2O_3 oxide. Diffusion of Vanadium from the substrate to TiN adhesion layer occurred. It assumed that the Vanadium substituted Ti atoms and caused the increasing of TiN adhesion layer lattice parameter. This could be a reason of lack of adhesion between the coating and substrate.

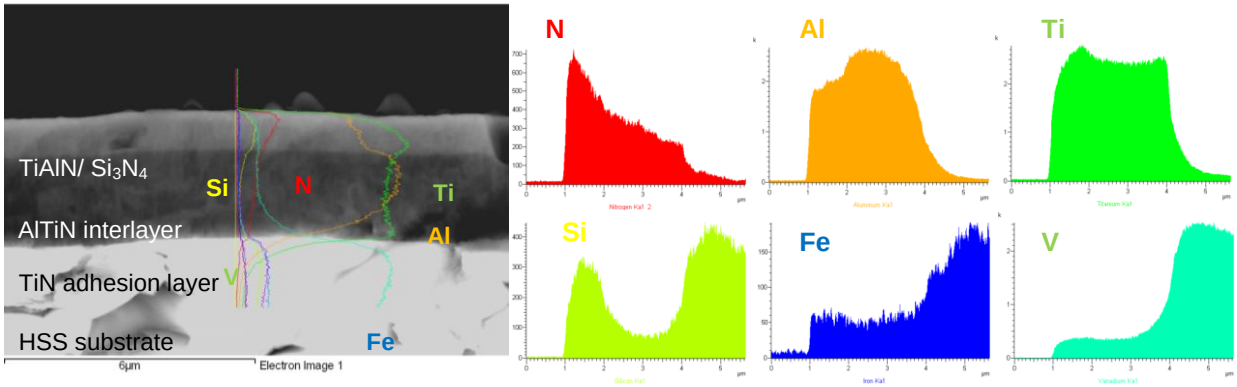

Fig. 4 *Fracture area of nACo3 coating before thermal heating and its chemical composition through the coating*

Fig. 4 illustrates the structure of nACo3 coating fracture area before the thermal heating process. The nACo3 coating belongs to the group of triple coatings. It means that, the coating consists from functional nanocrystallized TiAlN grains that are embedded in amorphous Si_3N_4 matrix. TiN adhesion layer was deposited onto substrate surface to improve adhesion between the coating and substrate. Connection between TiAlN/Si_3N_4 and TiN adhesion layer is realized using AlTiN interlayer. This interlayer improves the toughness of the coating. In this case, the columnar crystal growth was observed as well. The thickness of triple coating measured with SEM was approximately 3.13 µm. The thicknesses of individual layers are following: TiN adhesion layer is 0.14 µm, AlTiN interlayer is 2.03 µm and TiAlN/Si_3N_4 layer is 0.98 µm. The course of concentration change of elements across the interface of evaporated nACo3 coating to base material is documented in Fig. 4 as well. Constant growth of Si with its local maximum in the middle of the TiAlN/Si_3N_4 layer and constant decrease of N in the coating towards the interface were observed. Ti/Al ratio was changing through the functional coating and interlayer.

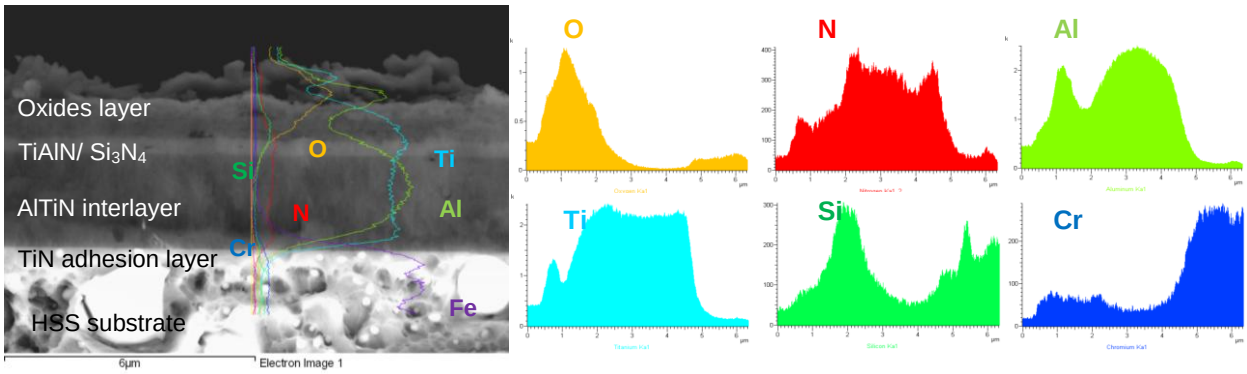

Fig. 5 *Fracture area of nACo3 coating after thermal heating and its chemical composition through the coating*

Structure of nACo3 coating fracture area after the heating process at the temperature of 1000 °C is documented in Fig. 5. The oxide layers on the coating surface were also observed. Based on EDX analysis we can assume that the oxides are dominantly created by Ti, Si and Al elements. The thickness of nACo3 coating increased from 3.13 µm to 3.49 µm.

CONCLUSIONS

The article dealt with the comparison of oxidation resistance of classical type of TiAlN monocoating and its new advanced nanocrystallic nACo3 version. “In situ” XRD analysis revealed the fact, the oxidation resistance of nACo3 coating is better than TiAlN. In addition, TiN adhesion layer lost its function after the thermal annealing of TiAlN coating. In the case of all coatings, the coating thicknesses increased after heating. It was caused by the formation of oxide layers. Formation of Al_2O_3 oxide layer on the surfaces of both coatings could lead to improve their wear resistance.

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REFERENCES

1. CHIM, Y. C., DING, X. Z., ZENG, X. T., ZHANG, S. 2009. Oxidation resistance of TiN, CrN, TiAlN and CrAlN coatings deposited by lateral rotating cathode arc. *Thin Solid Films*, **517**, pp. 4845 – 4849.
2. DING, X. Z., TAN, A. L. K., ZENG, X. T., WANG, C., YUE, T., SUN, C. Q. 2008. Corrosion resistance of CrAlN and TiAlN coatings deposited by lateral rotating cathode arc. *Thin Solid Films*, **516**, pp. 5716 – 5720.
3. PODGURSKY, V., NISUMAA, R., ADOBERG, E., SURZHENKOV, A., SIVITSKI, A., KULU, P. 2010. Comparative study of surface roughness and tribological behavior during running in period of hard coatings deposited by lateral rotating cathode arc. *Wear*, **268**, pp. 751 – 755.
4. DING, X. Z., ZENG, X. T., LIU, Y. C. 2011. Structure and properties of CrAlSiN Nanocomposite coatings deposited by lateral rotating cathode arc. *Thin Solid Films*, **519**, pp. 1894 – 1900.
5. PODGURSKY, V., ADOBERG, E., SURZHENKOV, A., KIMMARI, E., VILJUS, M., MIKLI, V., HARTELT, M., WÄSCHE, R., ŠÍMA, M., KULU, P. 2011. Dependence of the friction coefficient on roughness parameters during early stage fretting of (Al,Ti)N coated surfaces. *Wear*, **271**, pp. 853 – 858.
6. ARNDT, M., KACSICH, T. 2003. Performance of new AlTiN coatings in dry and high speed cutting. *Surface and Coatings Technology*, **163 – 164**, pp. 674 – 680.
7. MO, J. L., ZHU, M. H., LEYLAND, A., MATTHEWS, A. 2013. Impact wear and abrasion resistance of CrN, AlCrN and AlTiN PVD coatings. *Surface and Coatings Technology*, **215**, pp. 170 – 177.
8. CHANG, Y. Y., WANG, D. Y. 2007. Characterization of nanocrystalline AlTiN coatings synthesized by a cathodic arc deposition process. *Coatings and Surface Technology*, **201**, pp. 6699 – 6701.
9. LIU, A., DENG, J. X., CUI, H. B., CHEN, Y. Y., ZHAO, J. 2012. Friction and wear properties of TiN, TiAlN, AlTiN and CrAlN PVD nitride coatings. *Journal of Refractory Metals and Hard Materials*, **32**, pp. 82 – 88.

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STRUCTURE ANALYSIS OF Zn-Al-Mg COATING ON STEEL WIRE

Kristián ŠALGÓ, Martin KUSÝ

ABSTRACT

The corrosion resistance of zinc coatings is determined primarily by the thickness of the coating but varies with the severity of environmental conditions. In case of zinc-based alloys for steel coating the phase type and its quantity developed upon solidification determines corrosion resistance as well. In this paper the phase quality and evolution along thickness of the Zn-Al-Mg coating layer was studied by x-ray diffraction analysis. During investigation the coating was removed in controlled manner in several steps. Each individual step of removal was followed with x-ray diffraction measurement and subsequent analysis of x-ray diffraction patterns.

KEY WORDS

zinc coatings, hot-dipping, corrosion resistance, zinc-based alloys, x-ray diffraction

INTRODUCTION

The usage of zinc coatings for the corrosion protection of ferrous substrates is very widespread (1, 2). To improve corrosion resistance of wires, the coating can have the addition of 5% Al which could be further increased to 10% for improved corrosion protection (3). Galvanizing forms a metallurgical bond between the zinc and the underlying steel creating a barrier that is part of the metal itself. During galvanizing, the molten zinc reacts with the iron in the steel to form a series of zinc/iron alloy layers (4). Zinc is anodic to iron and steel and as a result in the case of galvanic corrosion zinc becomes the anode, while the ferrous substrate becomes the cathode and does not corrode. Hot-dipping involves immersion of the steel in a bath of molten zinc or Zn-based alloys. Hot-dip galvanized coatings comprise essentially pure zinc provided controlled amounts of aluminium or silicon are added to the molten zinc bath to suppress the formation of zinc–iron intermetallic phases (5). Addition of Al causes formation of the inhibition layer which is still not well understood. One reason for the lack of detailed information on the formation of the inhibition layer is that the Fe-AI Iayer on commercial product is often too thin to be observed in cross-section using light optical microscopy or conventional SEM and XRD analysis (6). Diffraction experiments presented in this contribution examine whole thickness of the coating including inhibition layer which allowed assigning the layer with corresponding phases.

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EXPERIMENTAL DETAILS

An experimental material used for this study was a steel wire substrate with 6.5 mm diameter coated with Zn-5Al-0.5Mg. Dipping process started with pickling performed in HCl followed by water rinsing in water and drying. Hot dipping process was executed in two stages – double dip coating. The first stage comprised immersion of the steel substrate in zinc bath held at 450°C. In the second stage the substrate was dipped in a Zn-5Al-0.5Mg alloy bath held at 450°C. After immersion, the wire was drawn up from the bath vertically to allow for solidification in cooling water. Coatings exhibit total thickness ranging from 60 to 90 μm. Reaction layer thickness varied from 5 to 25 μm.

General microstructure overview was obtained using Zeiss Axioscope light microscope. Electron microscopy was carried out using a Jeol JSM7600EF scanning electron microscope with back scattered electron detector. All observations as well as chemical microanalysis were performed at 15 kV accelerating voltage and 89 μmA probe current. Local chemical composition was detected using an Oxford Instruments EDX analyser coupled with the scanning electron microscope.

Observation of depth resolved phase evolution in the coating was executed using x-ray diffraction analysis (XRD). Each series of XRD measurements started with the stripping of the wire in 1.5% HCl in ethanol or 10ml HNO_3 in 30ml of water (6). Sample cleaning in water and weighting was executed after each stripping step. A Metler Toledo balance with precision of 0.1 mg was used to determine exact weight of the sample. In total 9 stripping steps summarized in Tab. 1 were applied to the wire.

XRD measurement was performed using a Panalytical Empyrean x-ray diffractometer in Theta-2Theta geometry. Characteristic $CoK\alpha_{1,2}$ radiation filtered by Fe was used during scattering experiment. Co mirror was used to generate primary parallel beam on incident arm. Detector arm was equipped with 0.27° parallel plate collimator and scintillation detector. X-ray diffraction data were analysed with the Panalytical search-match program Xpert High Score Plus.

STRIPPING STEPS AND CORRESPONDING LAYER THICKNESSES Table 1

Strip step	Layer thickness (μm)	Strip step	Layer thickness (μm)	Strip step	Layer thickness (μm)
1.step	5.774	4.step	4.2	7.step	1.244
2.step	4.64	5.step	7.323	8.step	2.249
3.step	5.393	6.step	6.894	9.step	80

RESULTS

Light microscopy images presented in Fig.1 show cross-section of three different coating layer microstructures on one investigated sample. Columnar microstructure is displayed in Fig. 1a. It is typical for regions with high cooling rate due to direct contact with the cooling water. The columnar grains grew in one direction because of rapid heat removal. Regions of wire without effective cooling with direct water sprout were showing a dendritic microstructure (Fig.1b). Small areas with mixed microstructure were frequently observed between the two mentioned regions (Fig. 1c).

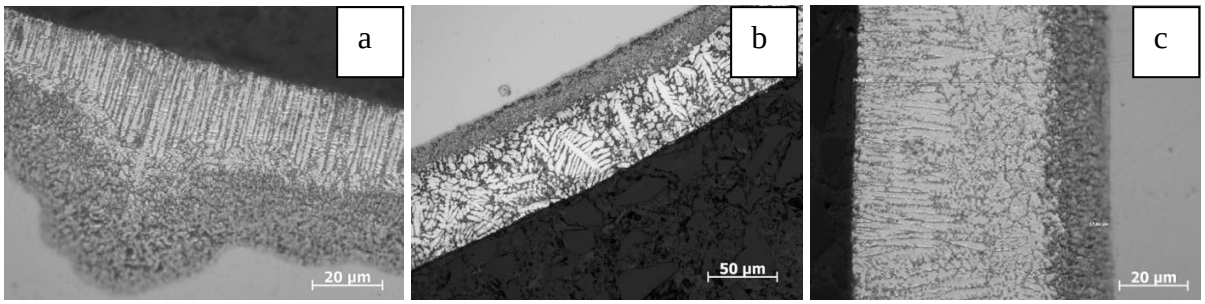

Fig. 1 *Typical microstructures of the ZnAlMg coating: a) Columnar microstructure, b) dendritic microstructure, c) mixed microstructure*

Further microstructural analysis continued with scanning electron microscopy examination. Two regions of interest were chosen. First, labelled by polar angle 0° with characteristic solidification microstructure is shown in Fig. 2a. Second region of interest was found at 90° and microstructure is documented in Fig. 2b.

Both regions were characterized using EDX line scan of chemical elements across the total coating thickness. Analysis focused on major chemical constituents of the coating: Zn, Al, Mg and Fe. Same features were observed in both line scans. Zn, Al and Mg are observed in alloy layer while Fe only in reaction and inhibition layer.

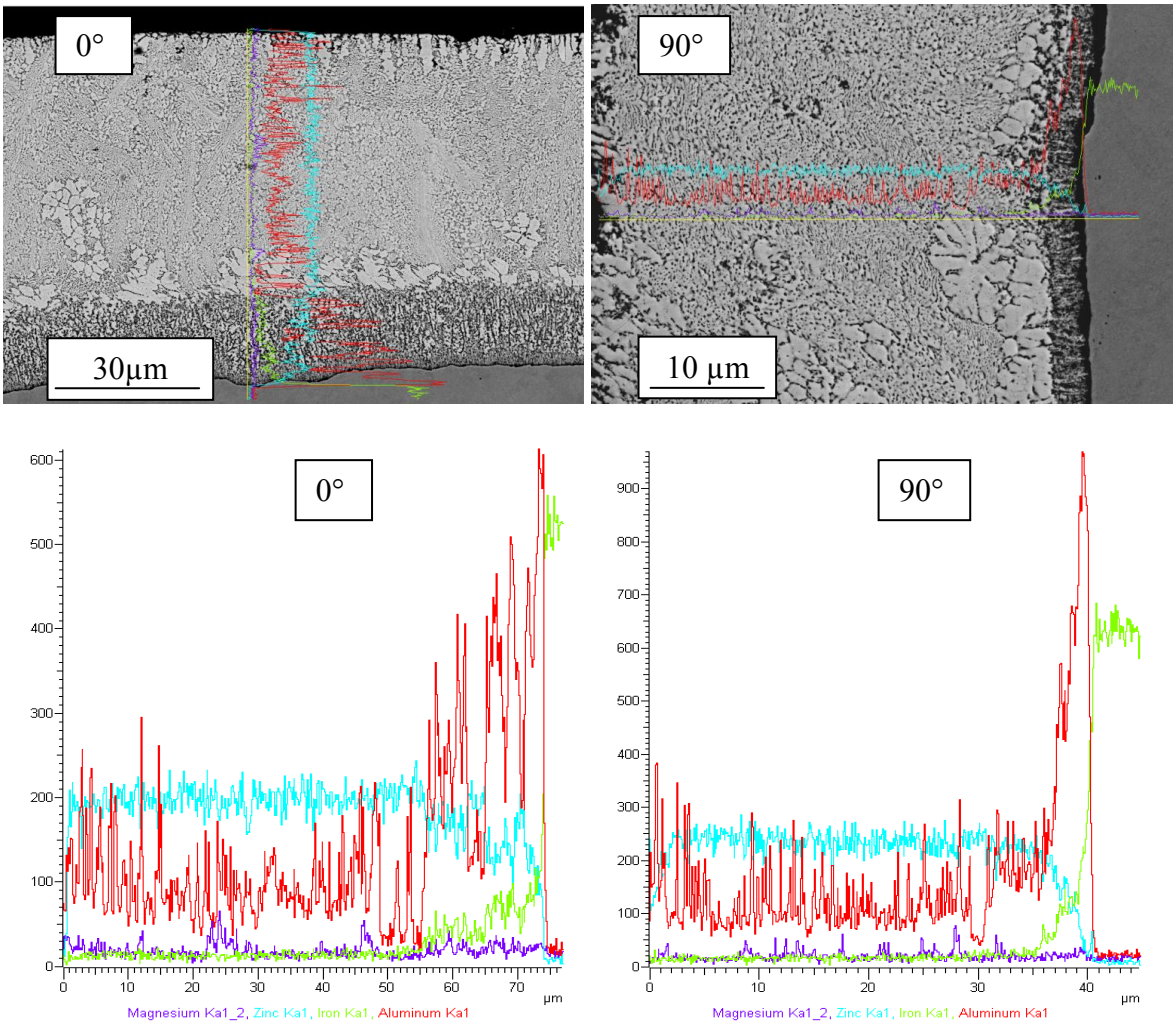

Fig. 2 *Solidification microstructure of the coating taken at polar coordinates 0° and 90° with corresponding EDX line profiles of chemical elements*

Series of XRD patterns taken from the experiment of a step-wise removal of ZnAlMg coating formed on a steel wire is shown in fig. 3. Thickness of each layer removed from the coating is listed in the table 1. Step-wise removal by chemical dissolution of the double-dip coating showed that phase composition of alloy layer remains stable over its entire thickness. Changes are observed close to the reaction as well as inhibition layer. Presence of Mg rich phases becomes less pronounced. Further removal of reaction layer reveals the inhibition layer adhering directly to the steel, where mainly Al_3Fe intermetallic phase was identified.

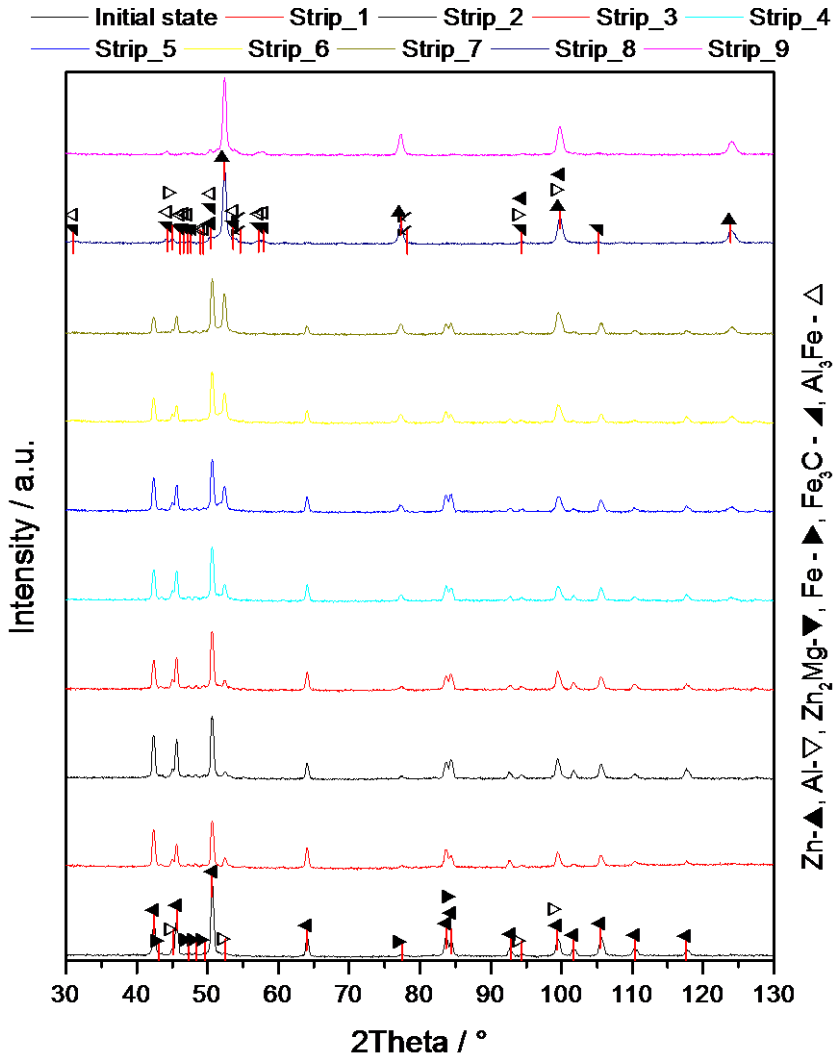

Fig. 3 *Series of XRD patterns taken during step-wise chemical stripping of ZnAlMg coating layer*

DISCUSSION and CONCLUSIONS

Steel wire coated with Zn-5Al-0.5Mg alloy using double dip technology was studied. Microstructural analysis revealed presence of 3 different solidification microstructures: dendritic, columnar and mixed microstructure. Coated sample was found uniformly coated. The entire coating layer could be divided into three sub-layers: alloy layer, reaction layer and inhibition layer.

All three layers were characterized using SEM in particular utilizing local characterization of chemical composition by EDX analysis. Stable concentrations of main alloy constituents were found across the alloy layer. Phase changes indicated by chemical

analysis were expected in vicinity of reaction layer. In this region x-ray diffraction analysis shows decrease in quantity of Zn_2Mg as reaction on decreasing Mg content. On the contrary, Al content increases which in return forms higher amount of Al rich solid solution. As it was shown in chemical line scans Al tends to build up a thin Al rich layer in close vicinity of the base steel. This layer is considered as an inhibition layer where Al forms intermetallic phases. According to McDevitt et.al. (6) this layer is a mixture of Al_5Fe_2 and Al_3Fe phases. Our study confirms using Al_3Fe present in inhibition layer. This is in contrast with previous studies where only Al_5Fe_2 was detected by XRD.

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REFERENCES

1. PISTOFIDIS, N., VOURLIAS, G., KONIDARIS, S., PAVLIDOU, E., STERGIOU, A., STERGIOUDIS, G. MATER LETT, **61**(4-5), 2007, pp. 994-997.
2. DE BRUYCKER, E., ZERMOUT, Z., DE COOMAN, B. C. 2007. *Materials Science Forum*, **539-543**, pp. 1276-1281.
3. SUGIMARU, S., NISHIDA, S., NISHIKAWA, Y., YOSHIMURA, K., TANAKA, S., YOSHIE, A., USHIODA, A. 2004. *Wire Journal International*, Vol. **37**, pp. 60-64.
4. Hot-Dip Galvanizing for Corrosion Protection of Steel products. American Galvanizers Association, 2000.
5. HOSKING, N.C., STRÖM, M.A., SHIPWAY, P.H., RUDD, C.D. 2007. *Corrosion science* 49, pp. 3669-3695.
6. MCDEVITT, E., MORIMOTO, Y., MESHII, M. 1997. ISIJ International, **37**(8), pp. 776-782.

INFORMATION AND COMPUTATIONAL SCIENCES AND APPLIED INFORMATION TECHNOLOGY AND AUTOMATION IN INDUSTRY II

RESEARCH PAPERS
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2013 Special Number

FAULT TREE ANALYSIS OPTIMIZED BY GENETIC ALGORITHMS

Adriána LIBOŠVÁROVÁ, Peter SCHREIBER

ABSTRACT

This paper deals with possibilities of using genetic algorithms in design of costs optimization, which are needed to reach given reliability of technical system, respectively system reliability optimization by given amount of investment costs. In following chapters, there is a described design of new method, which will be later implemented in application and verified on an example.

Causal relationships between system failures and elements faults can be detected by analytic approach, when at first the undesired system fault is identified and its reasons are progressively detected. The reliability of system and its elements is analyzed using method FTA (fault tree analysis) and system is represented by fault trees. In order to optimize costs, respectively reliability, the genetic algorithms are used.

KEY WORDS

ault tree analysis, fault tree, event, gate, genetic algorithms, population, objective function, selection, crossover, mutation

INTRODUCTION

Systems have become an inseparable part of modern life; they consist of functionally bound and dependent subsystems, which serve for different purposes. It is necessary to monitor and to analyze systems even after their implementation into service. Some systems can be too expansive, what increases a complexity in the system analysis. One of the most important monitored factors is safety, i.e. reliability of the systems. Risk analysis and safety increase is applied already in the system development phase (Janíček 2009). Thanks to, the risks of possible accidents and hazards can be eliminated or reduced.

With the developing technologies and systems implementation also appears the risk of danger. In some cases, the risk of accidents can be eliminated by appropriate measures, and it allows preventing at least some types of failure. But it is not always possible in the real world. It is necessary to regard so called supporting risks already before the system implementation and to strive to mitigate them. In these cases, the compromises are made between acceptation of the system benefits and rejection because of real accident risk, which the given system

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presents. The essence of security and key to effective risk management is to properly recognize and analyze hazards. Just their correct identification helps in the design and construction of the systems to be safe for the people and the environment. And for this purpose the various techniques and tools are developed and constantly improving (Ericson 2005, Janíček 2009).

FAULT TREE ANALYSIS

Fault tree analysis is a technique, which serves to analyze probability of technical system failure, potential risks detection and design of suitable preventive measures, which should increase system reliability. This method is regarded as deductive, because it is based on logical decomposition of certain dangerous undesired event subsequently through partial to elemental events. The undesired events can be understood as failures. They significantly influence functionality, an economics, a safety or other required properties of system (Vincoli 2006).

The method FTA is based on principle of strict structuring. It is a graphical expression of individual fault states, which can occur in given system and cause its failure by specific combinations. The model is characterized by tree structure and its creation is based on rules of Boolean algebra, logic and probability theory. The created diagram is called fault tree (FT) and it is a basic element of this analysis technique (Ericson 2005).

The fault tree is a diagram, which illustrates graphically and logically different ways, how a system can fail. The certain combinations of elements faults result in a creation of primary undesired event. Under the term "undesired event", it is considered each event, which is for safety inappropriate and undesired, respectively it characterizes danger, hazard or another fault state (Ericson 2005). Fault tree describes how the events follow each other and how they are mutually dependent. The events hierarchy and logical links between events are created by using so called logical gates, especially "AND" and "OR" gates. Together with fault events, they represent relationships "cause-effect". Subsequently the constructed fault tree can be qualitatively or quantitative evaluated. The choice of suitable type of evaluation depends on various factors such as established requirements (Dunn 2002).

FTA is very extended and favorite analysis technique in practice. It can be used not only preventative to examine the system design, but also to investigate occurred problems. This method is applied on complex technical systems, whose current state is dependent on earlier time and outside influences. FTA is useful in all industry areas, which deal with safety and reliability question, for example in nuclear power, aviation, cosmonautics, etc. (Ericson 2005).

In practice, the question of finance is also solved in addition to the level of reliability security. The system reliability is set and influenced by the amount of invested money. The investments are needful to build security, to ensure service, but also for any necessary repairs due to failures. Since finance amount is limited mater, the highest possible system safety should be ensured with a certain amount of investment, alternatively the given system reliability should be achieved at minimum costs. As optimization mechanism of analysis technique FTA, genetic algorithms can be used.

PROCEDURE OF PROCESS

The first step involves constructing fault tree of a selected part of the technical system, which is analyzed through FTA. The tree has m leaf nodes u_1 - u_m, each of them represents a

primary event or subsystem. Each node i has an associated reliability s_i and corresponding amount of investment n_i which is needed to achieve it. The achieved reliability is functionally dependent on maintenance costs. This dependence is generally expressed as function $s_i = g_i(n_i)$ and is shown in figure 1. These relevant data are known in advance, so the constructed fault tree can be quantitatively evaluated from primary events up to the top undesired event.

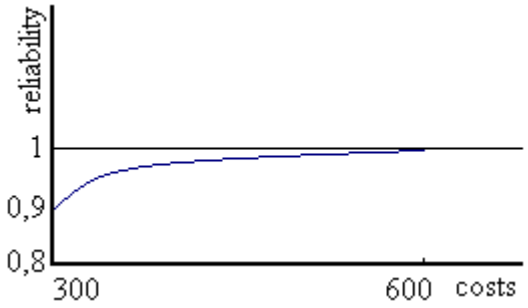

Fig. 1 *Reliability dependence on costs*

Using Boolean algebra relations allows calculating reliability of given tree – system part, generally $S = f_1(s_1, s_2, ..., s_m)$. In given reliability, system maintenance costs are calculated as sum of all costs of subsystems maintenance $N = f_2(n_1, n_2, ..., n_m) = \Sigma\, n_i$.

After correct construction and evaluation of the complete fault tree, genetic algorithms are appropriately applied to optimize. Optimization can be done in terms of:

- achieving certain system reliability with minimal financial investment,
- achieving the maximum possible system reliability with given amount of investment.

FAULT TREE REPRESENTATION IN ACCORDANCE WITH GA

Data on system elements reliability and the associated costs are known through calculation, historical experience or are available from the supplier (Janíček 2009). The important information consists in their representation. These data tend to be written to real numbers format.

In terms of genetic algorithms methodology, it is possible to work with real numbers. The following figure illustrates the example of fault tree with registered reliabilities of primary fault events.

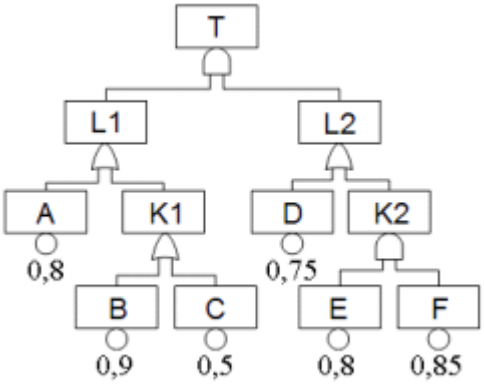

Fig. 2 *Example of FT representation and reliability evaluation*

The value that belongs to one node of the tree corresponds to one gene and all values together represent one individual (figure 3).

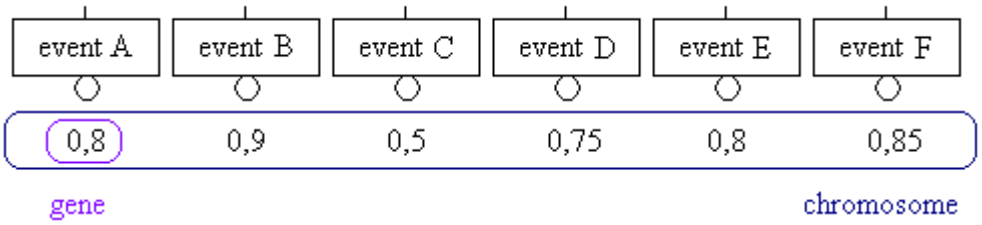

Fig. 3 *Example of chromosome and its genes in fault tree*

DESIGN OF GENETIC ALGORITHM

On the basis of fault tree analysis and its quantitative evaluation, the chromosome is available. Then the whole population is created by modifying alleles of given chromosome to the other values of the appropriate domain. Each population will consist of 100 individuals.

In the next step objective function is chosen. Its form depends on the established purpose of the genetic algorithm, i.e.:

1. with limited financial sources to achieve maximum reliability of the technical system, i.e.:
   - to maximize reliability, i.e. OF_1: reliability $\rightarrow$ maximum,
   - the genes are represented by values of financial investments of individual nodes N_i.
2. to achieve the given system reliability with minimum costs, i.e.:
   - to minimize costs, i.e. OF_2: costs $\rightarrow$ minimum,
   - the genes are represented by reliabilities of individual nodes S_i.

Then by using the fitness function, all individuals are rated for suitability and success (Hynek 2008). By each created solution, of the top undesired event occurrence probability (or system reliability) and also invested costs in the concrete measures are simultaneously calculated. By calculating costs, it is necessary to control, if maximum possible amount of investment is not exceeded. For example, if significantly increased system reliability is achieved at specific combination of costs of individual nodes, but investment amount needed in order preventive measures is also exceeded. In this case, the solution is unsuitable and its fitness is automatically equal to zero.

Selection, respectively choice of individuals into reproductive process is done through the roulette. In this selection mechanism, the individuals with a higher valuation have higher probability of selecting, but also for weak individuals, there is a little chance of becoming parents and providing their genetic material (Hynek 2008).

The next step is the applying genetic operators on the appropriate solutions - crossover and mutation. By multiple crossover, two chromosomes are divided at random, but the same position and behind each odd division point will exchange parts of their chains (figure 4) (Kvasnička 2000).

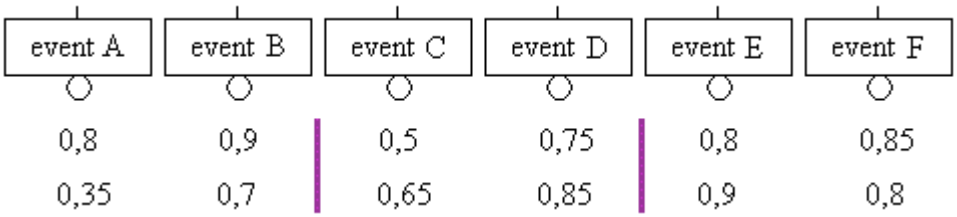

Fig. 4 *Crossover of parent chromosomes*

After crossover, a mutation is applied on new offspring. Through this operator, the gene value is changed to another random, but allowed value of the domain, which belongs to the specific primary event (Kvasnička 2000).

The last step is to form a new population, to which the genetic algorithm process will be repeated again. In this case, it is appropriate to use elitism, through which 6 of the best valued individuals from the previous generation enter in the new population, along with 94 new individuals generated by the described crossing and mutation process.

If for the last *k* algorithm iterations only slight or no change occurs in the potential solutions in comparison with previously the most successful solution, the cycle would not be repeated (Hynek 2008). Fulfillment of this designed terminating condition terminates the whole process of the genetic algorithm.

CONCLUSION

This paper provides an interesting aspect of using genetic algorithms in conjunction with FTA in practice in commercial areas (e.g. reduction of serious accidents occurrence, compliance with safety standards, etc.). There is a described design of methodology how to optimize maintenance of system represented by fault tree.

The genetic algorithm design by itself consists of the compilation of objective function, the choice of selection mechanism, the use of genetic operators and not least of the determination of terminating condition. In the course of individual cycles of iteration genetic algorithm process, there is an attempt for every solution to achieve its optimum depending on the chosen objective function. The best and satisfactory solutions are subjected to reproductive process - crossover and mutation. By the correct design it is possible to reach that every additional population of solutions contains better or at least as good solutions as the previous generation. The proposed approach will be processed in the usable application, through which its functionality will be tested on a practical example.

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REFERENCES

1. AVEN, Terje. 2008. *Risk Analysis*. Chichester: John Wiley & Sons Ltd. ISBN 978-0-470-51736-9

2. DUNN, William R. 2002. Fault Tree Analysis. In: *Practical Design of Safety-Critical Computer Systems*. Solvang: Reliability Press, s. 166 – 174. ISBN 0-9717527-0-2
3. ERICSON II., Clifton A. 2005. *Hazard Analysis Techniques for System Safety*. Hoboken: John Wiley & Sons, Inc. ISBN 978-0-471-72019-5
4. HAUPT, R. L., HAUPT, S. E. 1998. *Practical Genetic Algorithms*. New York: John Wiley & Sons, Inc. ISBN 0-471-18873-5
5. HYNEK, Josef. 2008. *Genetické algoritmy a genetické programování*. Praha: Grada Publishing, s.r.o. ISBN 978-80-247-2695-3
6. JANÍČEK, F., KOVÁCS, Z. 2009. *Spoľahlivosť v elektroenergetike*. Bratislava: Renesans, s.r.o. ISBN 978-80-89402-12-0
7. JANKOVIĆ, Mladen. Genetic Algorithm Library. 2012 [cit. 2013-01-21]. Dostupné na internete: http://www.codeproject.com/Articles/26203/Genetic-Algorithm-Library
8. KVASNIČKA, V., POSPÍCHAL, J., TIŇO, P. 2000. Genetický algoritmus (GA). In: *Evolučné algoritmy*. Bratislava: STU, s. 31 – 57. ISBN 80-227-1377-5
9. SEKAJ, Ivan. 2004. Riešenie problémov pomocou genetických algoritmov. *Automatizace*, **47**(9), 552 – 555.
10. SCHREIBER, P., VAŽAN, P., TANUŠKA, P. Production optimization by using genetic algorithms and simulation model of production system. In: *Annals of DAAAM and Proceedings of DAAAM Symposium*. - 22-25th October 2008, Trnava, Slovakia, ISSN 1726-9679, ISBN 978-3-901509-68-1, pp. 1229-1230
11. ŠTRBO, M., TANUŠKA, P., GESE, A. The proposal of preliminary hazard analysis for safety-critical control systems. In: *INFOKOM-5*. - ISSN 2219-293X. - Infokommunikacionnyje technologii v nauke, proizvodstve i obrazovanii : 5. meždunarodnaja naučno-techničeskaja konferencija, Kislovodsk, Stavropoľ, 2 - 6 maja 2012. - Stavropoľ : Severo-Kavkazskij gumanitarno-techničeskij insitut, 2012, s. 162-167, časť 1
12. VINCOLI, Jeffrey W. 2006. Fault Tree Analysis. In: *Basic Guide to System Safety*. Hoboken: John Wiley & Sons, Inc., s. 139 – 151. ISBN 978-0-471-72241-0

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IMPACT OF DATA CHARACTERISTICS ON FEATURE SELECTION TECHNIQUES PERFORMANCE

Dijana ORESKI

ABSTRACT

Feature selection is a step in knowledge discovery in databases which takes away most of the time of the entire process. Therefore, the effective implementation of feature selection significantly improves the overall process. This paper suggests examining data characteristics before applying feature selection and hypothesize that data characteristics significantly affect feature selection techniques performance. Our experimental comparison of five previously used feature selection techniques reveals significant difference in feature selection techniques performance when dealing with data sets of different characteristics.

KEY WORDS

feature selection, data characteristics, classification accuracy

INTRODUCTION

Very often data sets contain a large number of features, which can influence the performance of the entire learning in classification. Large dimensionality of the database can be reduced by using appropriate techniques. These techniques fall into two groups: those that transform the fundamental meaning of the features (feature extraction techniques) and those that preserve the semantics. Feature selection techniques belong to second group (which selects a small set of features on the basis of the evaluation function) and they are in the focus of this paper. Feature selection is a very active and fruitful area of research in machine learning, statistics and data mining (Ramaswami and Bhaskaran, 2009). In the process of knowledge discovery in databases preparation of data takes away 60% - 95% of the time (De Veaux, 2005). Feature selection, the most important part of this step, refers to the problem of selection of features that give the highest predictive information with respect to the output. The main objective of carrying out the feature selection is to select a subset of input features in order to remove features that are not relevant and do not provide predictive information, and finally, achieving high classification accuracy (Ramaswami and Bhaskaran, 2009). Feature selection, in theory and in practice, proved to be effective in increasing the efficiency of learning, forecasting accuracy and reducing complexity of the results (Koller and Saham, 1996).

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On different data sets different techniques respond differently and differ in the accuracy of classification. This paper explores the relation of the data set characteristics and performance of the feature selection techniques. For this purpose, research presented here compares five feature selection techniques on two data sets of different characteristics. The paper is organized as follows. The second section defines feature selection whereas third section provides a theoretical overview of the feature selection techniques that will be used in empirical research and discusses the characteristics of the data important for classification task. Fourth section describes the research and discusses the obtained results. The last chapter concludes the work.

RELATED WORK

Feature selection can be defined as follows. „Suppose F is the given set of original features with cardinality n (where n symbolizes the number of features in set F), and $\overline{F}$ is the selected feature subset with cardinality $\overline{n}$ (where $\overline{n}$ symbolizes the number of features in set F), then $\overline{F} \subseteq F$. Also, let $J((\overline{F})$) be the selection criterion for selecting feature set $\overline{F}$. We assume that a higher value of J indicates a better feature subset. Thus, the goal is to maximise $J()$. The problem of feature selection is to find a subset of features $\overline{F} \subseteq F$ such that „(Chrysostomou, 2009)

$$J(\overline{F}) = \max_{Z \subseteq F, |Z| = n} J(Z) .$$

Dash and Liu define four steps of feature selection process: generating subset, subset evaluation, stopping criterion and validation (Dash and Liu, 1997). A review of the literature showed that there are many approaches to the problem of feature selection. However, essentially all approaches include two key components: search strategy that explores the set of all subsets of features in a purposeful way and evaluation criterion. The most common classification of feature selection techniques is: filter and wrapper techniques. The main difference between those two approaches is in the evaluation of the subset. Wrapper approach evaluates subset within learning algorithm, whereas when applying filter approach feature selection and classification are separated. Filter approach very often uses heuristic in which evaluation function is not directly related to the effectiveness of a particular classifier. Instead, the result depends on the internal characteristics of the data. Features are evaluated according to criteria such as the distance measure, the Pearson correlation coefficient, entropy or other measures of information (e.g. Devijver and Kittler, 1982. or Guyon and Elisseeff, 2003). We can say that the filter techniques present a general approach to feature selection providing a solution suitable for a wide set of classifiers. The filter techniques are very fast, and as such are useful for high-dimensional problems where other methods are not competitive with respect to computational complexity. However, the selected optimal features do not necessarily guarantee the best performance of the classifier.

Wrapper techniques evaluate subset of features by estimating the accuracy of the learning algorithm. Search strategy use prediction accuracy as a function of leading the search for the best subset and is looking for those features that maximize accuracy. Of course, features are optimized for the previously selected algorithm, and very likely not optimal for another learning algorithm. Wrapper techniques require a lot of computation, because a large number of models of classification must be done during the process of searching for the best subset of

the attributes. Speed could be achieved by using efficient search strategy. But that search becomes almost impossible with increasing dimensionality, especially when working with a computer - intensive methods of learning. Wrappers often result with overtraining. Despite this, some authors (e.g. John et. al., 1994. or Kohavi and John, 1997) showed that the accuracy is better than in the case of filter techniques. Traditionally, feature selection techniques are evaluated based on the time that they need for the performance and quality of the selected subsets of attributes (Jain and Zongker, 1997). The methodology for the evaluation of the results is not standardized and varies from article to article. It is therefore very difficult to draw conclusions or make comparisons between feature selection techniques. As criteria for comparison of techniques classification performance and algorithm execution time mainly have been used previously. Jain and Zongker argue that the algorithm execution time is less important criterion than the final classification performance (Jain and Zongker, 1997). The most commonly used criterion is the error rate (or classification accuracy) of the selected learning algorithm, which was implemented using a set of features derived by feature selection technique. Thus, this is criterion used in research presented here.

Wrapper methods often produce more accurate results than the filter methods, but the execution time is much larger. Therefore, when dealing with problems consisting of several thousand features wrapper methods are not applicable. While some argue that the biggest disadvantage of filter methods is ignoring the impact on the accuracy of the selected subset on the learning algorithm (Guyon and Elisseeff, 2003). Other authors (e.g. Abe et al. 2006) independence of the feature selection techniques emphasize as an advantage because it is best to select a subset of features that gives good results for each classifier (Abe et. al. 2006). Research presented in this paper uses both, filter and wrapper techniques in evaluation.

METHODOLOGY DESCRIPTION

This section describes two main methodological aspects of research: feature selection techniques and characteristics of data set which was recognized in the previous research as important for task of classification

Five feature selection techniques are used in this research: *Relief*, *linear forward selection*, *information gain*, *gain ratio* and *voting* technique. Kira and Rendell introduce an algorithm *Relief* which assigns a relevance weight to each feature. Feature's weight represents ability of the feature to distinguish between class values. Features are ranked by weight and those that are higher than certain threshold are selected to form the final subset. A *linear forward selection* is a search where new features are added to a set one feature at a time. At each stage, the chosen feature is one that, when added to the current set, maximizes the objective. The algorithm terminates when the best remaining feature worsens the objective, or when the desired number of features is reached. *„Information gain* is a feature selection technique which provides a ranking for each feature describing the given training tuples. The feature with the highest information gain minimizes the information needed to classify the tuples in the resulting partitions and reflects the lowest degree of randomness or ‘‘impurity’’ in these partitions“ (Oreski, Oreski and Oreski, 2012). The information gain technique is biased toward tests with many outcomes. An extension to information gain is known as *gain ratio*, which attempts to overcome this bias. „It applies a kind of normalization to information gain using a ‘‘split information’’ value“ (Oreski, Oreski and Oreski, 2012).

Previous empirical studies have shown that the choice of optimal classifier in the process of knowledge discovery in databases depends on the data set employed (Michie, Spiegelhalter and Taylor, 1994). Van der Walt (Van der Walt, 2008) investigated the properties of data that influence classification performance and developed data measures that are specifically

defined to measure such data properties. These measures provide them to define the relationship between data characteristics and classifier performance. Measures were grouped into the following categories: standard measures, data sparseness measures, statistical measures, information theoretic measures, decision boundary measures, topology measures and noise measures. This research examines characteristics of two data sets included in the classification and performs feature selection in order to identify are there any differences in feature selection techniques performance when dealing with data sets of different characteristics.

RESEARCH DESCRIPTION

The comparisons were carried out in two datasets coming from the UCI Machine Learning Repository (http://archive.ics.uci.edu/ml/). Table 1 shows a summary of the characteristics of these datasets (*credit* and *spectf* data set) used in this paper to assess the performance of the five feature selection techniques: info gain, gain ratio, relief, linear forward selection and voting technique. In order to evaluate the performance of a feature selection techniques, the accuracy of the classifier (neural network) trained on those features selected by the aforementioned techniques will be compared.

DATA SETS CHARACTERISTICS Table 1

Data characteristic	Data set 1 (credit)	Data set 2 (spectf)
Standard measures	Number of features: 15 Number of instances: 690	Number of features: 45 Number of instances: 80
Data sparseness measures	Linear relationship	Exponential relationship
Statistical measures	Correlation:0,117 Normality: yes Homogeneity of covariance matrices: no	Correlation:0,223 Normality: no Homogeneity of covariance matrices: no
Information theory measures	Intrisnic dimensionality: 0,733	Intrisnic dimensionality: 0,355
Noise measures	Feature noise:0,267	Feature noise:0,644

As seen from table 1, presented data sets difeer significantly in number of instances and the level of data sparsity. Whereas first data set has low level of data sparsity and assumes linear relationship between features, second data set has high level of sparsity and assumes exponential relationship. Furthermore, data sets differ in the distribution (first data sets has normal distribution, whereas second does not have) and feature noise (second data set has significantly higher feature noise).

Five feature selection techniques were applied on described datasets. All techniques selected 9 features from first data set and 16 features from second data set. In the statistical evaluation of the feature selection techniques performance, we compare the achieved scores from classifier, neural networks, as follows.

Using the Friedman test we tested the null hypothesis stating that all feature selection techniques perform equally. The results of the tests showed that the Friedman statistic for equality of feature selection techniques performances has the p-value of 0.0021 for first data set and p-value of 0.0181 for second data. These results reject null hypothesis and indicates that the difference exist in the performance of feature selection techniques for both data sets. To analyze the performance differences, post-hoc Nemenyi test was performed in order to identify which technique provided better results by giving the p-values of the performance

comparisons between pairs of feature selection techniques. Results indicate that linear forward selection achieved significantly better compared to the other techniques on first data set**,** whereas Relief feature selection technique achieved significantly better accuracy on second data set.

CONCLUSION

This paper presented empirical evaluation of five feature selection techniques on two data sets. The emphasis was on the different characteristics of the used data sets, which has not been empirically evaluated in the previous research. Hypothesis of the research involved measuring of how feature selection techniques react on data sets which differ in their characteristics. The testing results have shown that linear forward selection performed best in terms of low number of features and high number of instances, low correlation and low feature noise. Relief feature selection technique achieved highest accuracy in the situation of higher number of features and lower number of instances, higher correlation and higher feature noise. This conclusion speaks in favor of hypothesis that feature selection techniques performance deeply depends on data characteristics and thus examining of data characteristics is necessary prior of applying of feature selection.

REFERENCES

1. ABE, N., KUDO, M., TOYAMA, J., SHIMBO, M. 2006. Classifier-independent feature selection on the basis of divergence criterion. *Pattern Analysis & Applications*, **9**(2), 2006, pp. 127.-137.
2. CHRYSOSTOMOU, K. 2009. Wrapper Feature Selection. In *J. Wang (Ed.), Encyclopedia of Data Warehousing and Mining*, Second Edition, pp. 2103-2108. Hershey, PA: Information Science Reference. doi:10.4018/978-1-60566-010-3.ch322
3. DEVIJVER, P. A., KITTLER, J. 1982. Pattern Recognition: A Statistical Approach. Prentice Hall.
4. De VEAUX, R., Predictive Analytics: Modeling the World, OR/MS Seminar, 2005. available at: *student.som.umass.edu/informs/slides/Predictive.pdf*
5. GUYON, I., ELISSEEFF, A. 2003. An introduction to variable and feature selection. *Journal of Machine Learning Research*, 3, pp. 1157–1182.
6. JAIN, A., ZONGKER, D. 1997. Feature selection: Evaluation, application and small sample performance. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, **19**(2), pp. 153–158, 1997.
7. JOHN, G. H., KOHAVI, R., PFLEGER, K. 1994. Irrelevant features and the subset selection problem. In *W. W. Cohen and H. Hirsh, editors, Proceedings of the 11th International Conference on Machine Learning*. San Francisco, CA, Morgan Kaufmann Publishers, pp. 121–129,
8. KOLLER, D., SAHAMI, M. 1996. Toward optimal feature selection. In *Proceedings of the Thirteenth International Conference on Machine Learning*, pp. 284–292.
9. MICHIE, D., SPIEGELHALTER, D.J., TAYLOR, C.C. 1994. *Machine learning, neural and statistical classification*. Ellis Horwood Limited, Hemel Hempstead.
10. ORESKI, S., ORESKI, D., ORESKI, G. 2012. Hybrid System with Genetic Algorithm and Artificial Neural Networks and its Application to Retail Credit Risk Assessment, Expert systems with applications, 39, pp. 12605–12617.
11. RAMASWAMI, M., BHASKARAN, R. 2009. A Study on Feature Selection Techniques in Educational Data Mining. *Journal of computing,* **1**(1), pp. 7- 11.

12. UCI Machine Learning Repository, available at: http://archive.ics.uci.edu/ml/
13. VAN DER WALT, C. 2008. *Data measures that characterise classification problems, Master Thesis*. University of Pretoria.

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BUSINESS APPLICATIONS ARCHITECTURE MODEL BASED ON SOFTWARE PRODUCT LINE APPROACH

Zdravko ROŠKO

ABSTRACT

Software product line architecture is one of the most important artifacts defined at the early stage of a product line development process. Since the rest of the products are developed based on the initial product line architecture, it is of high importance to ensure the architecture stability by enabling the software's evolution possibilities. Industrial evidence shows that companies spend more resources on maintaining and evolving their architecture and products than on the initial development of them. Hence, there is a need for flexible software architecture that stays stable as the requirements evolve. In this paper we propose a structural model, some architecture quality metrics, case-based reasoning methodology to predict the architectural stability and a feature model for business applications. The goal of the proposed architecture model is to develop a framework for business applications development and evaluating the stability of product line architectures in the face of changes in requirements.

KEY WORDS

software product lines, feature model, architecture, case-based reasoning, metrics

INTRODUCTION TO THE PROBLEM

Software reuse is the process of creating software applications from existing artifacts rather than building them from the scratch. Effective reuse requires a strategic vision that reflects the unique power and requirements of this technique (1). There are many software engineering technologies that involve some form of software reuse such as: application frameworks, design patterns, components, application generators, etc. Many organizations employ these technologies, and many are ready to take the next step towards more effective reuse of software.

Software product lines (SPL), in which; requirements, architecture, modeling and analysis, components, test cases, test data, test plans, documentation templates, and other software engineering artifacts, can be reused over a number of applications, is at the moment the most promising form of the software reuse (2). SPL is defined as a set of software-intensive systems, sharing a common, managed set of features that satisfy the specific needs

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of a particular market segment or mission and that are developed from a common set of core assets in a prescribed way (3). SPL development process consists of domain engineering process, (core assets development *for reuse*) and application engineering process (product development *with reuse*) that builds the final products, where construction of the reusable assets and their variability is separated from production of the product-line applications. SPL is mostly used by organizations that develop software for mobile phones, cars, electronic instruments, while information systems domain is not often considered as a potential base for developing SPL. Successful product lines have enabled organizations to capitalize on systematic reuse to achieve business goals and desired software benefits such as productivity gains, decreased development costs, improved time to market, higher reliability, and competitive advantage (4). Considering the costs, as stated by (5) SPL offer benefits when producing at least a certain number of products. Figure 1 (partially taken from (5)) illustrates the costs and distinct stages of producing one versus multiple products from the same product line. The solid line sketches the costs of developing the products independently, while the dashed line sketches the costs of developing the products using software product line engineering approach (6). The figure shows the case when less then four products are spawned from the same product line, where the price of product line engineering is relatively high, and the case whereas it is significantly lower for larger quantities of products being spawned from the sample product line (6). There is a break-even point, we call it „SPL early stage end“ at which the two lines intersect. It indicates that the costs are the same for both cases. As referred in (5) recent empirical experiences have shown that this break-even point is located at around 3 or 4 systems in the particular case of software engineering.

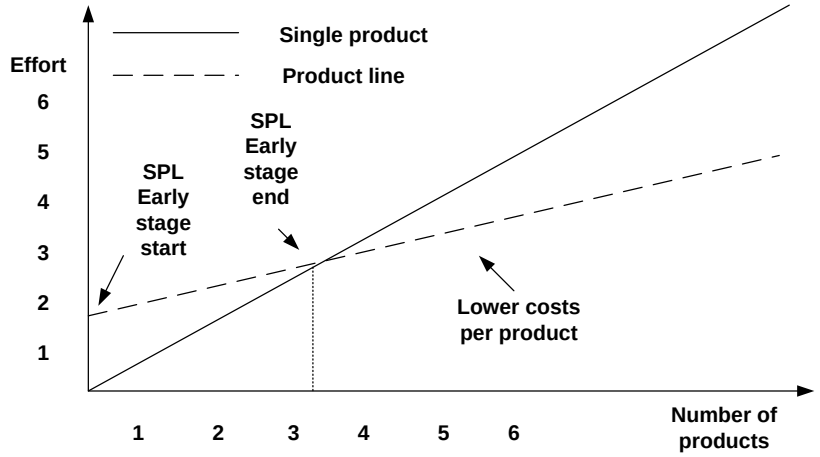

Fig. 1 *Costs of a SPL development*

Business applications are a kind of software that is used by business users to perform various business functions. Most of the business applications are interactive, they interact with a user through a user interface in order to read, process or change some persistent business data. The SPL for interactive applications defines, product line requirements, a software architecture and a set of reusable components. The existing frameworks such as Spring may sound like a solution for the problem, however it does not impose any specific programming model, it does not address all possible interfaces needed and it may lack a certain up to date features. Hence, making a product line architecture dependent on externally developed artifacts with not enough power to replace or change some of the key architecture features, is not a solution. One of the most important parts of a SPL is its architecture (PLA). The PLA plays a central role at the development of products from a SPL as it is the

abstraction of the products that can be generated, and represents similarities and variabilities of a product line (7). The PLA must consider the needs of the complete set of products in order to provide a framework for the development and reuse of new assets. These new assets have to be conceived with the required flexibility in order to satisfy the needs of the different products in the SPL (6). PLA consist of *frameworks* (Szyperski., 2002) as core assets, whose design captures recurring structures, connectors, and control flow in an application domain, along with the points of variation explicitly allowed among these entities (7). In this paper we use the term „SPL platform framework“ to represent the implementation of the generic architecture and components which are not business-specific but rather generic in the sense that they can be used by more than one business domain such as: banking, insurance, manufacturing, and etc. We propose a business application architecture model which includes:

- Business applications entities structural model
- Feature model for business applications
- Some „SPL Platform Framework Responsibility“ metrics for SPL stability
- Case-based reasoning methodology used to predict the architectural stability

BUSINESS APPLICATIONS ENTITIES STRUCTURAL MODEL

Today's interactive business applications consist of the three logical layers which have a distinct and specific responsibility: presentation, business logic and data access logic. Presentation layer's function is an interaction with the application's users which includes: various rendering of the data, data edits, data validation and formatting, data inter-dependency checks, and other user initiated actions. Business logic layer function is to process data entered by a user and/or data retrieved from the persistence data source. Business logic should stay free from dependencies on various data sources and let the variability mechanism of SPL to choose among different data sources. Data access logic layer function is to handle all interactions with the persistent data sources. The layered model does not imply that each layer should be in a separate address space, even thought in today's business application's environment the most of the time a three-tier model is used. Control and data can flow in both directions in layered systems. However, lower layers must not depend on functions provided by higher layers. Such a design avoids accidental structural complexity, and supports the use of lower layers in other applications independently of the higher layers (8). Table 1 shows that business domain specific components shared among different products spawned from the same product line are not a part of the SPL platform framework, but rather are part of the business-specific components but still belong to the domain engineering process.

PROPOSED PLA STRUCTURE Table 1

Prod 1	Prod 2	Prod 3	Prod 4
Business-specific components			
SPL Platform Framework (common services)			
External Components			
OS/Language Environment			

The structural model is the framework through which components, attributes, and inter-relationships within the system are expressed (9). The structural model enforces a consistency in the business applications structure by a set of constraints (e.g., the way a data is passed between layers, organization of the source code, the relationship between the source code

pieces). The Figure 2 shows the structural model for business applications we propose. The proposed model specifies: the kind of entities that will exist in the design (how do we package the entities), how the real world product (application) is mapped to the software entities (what is in a package) and the dependencies between the entities (how do packages relate to each another). Given a fact that most of the business applications are composed from a client part, which may be run in a separate address space, and a server part which may be run within an application server on the other address space, we assume that some of the software assets are shared between the two.

Client resources include the entities which are used by client part of an application while server resources include the entities used by server part of an application. Shared resources are the entities which are shared by client and server parts of an application. This structure does not impose a separation of client and server to the two separate address spaces, but indeed represent a variation point which can be used to compose an application as a one part to be run in one address space or as a two separate parts to be run in two distinct address spaces. The Figure 2 shows 13 distinct dependency relationships among different SPL structural entities. As we will show later some of them will be used as elements of the new proposed metric for stability of SPL platform framework.

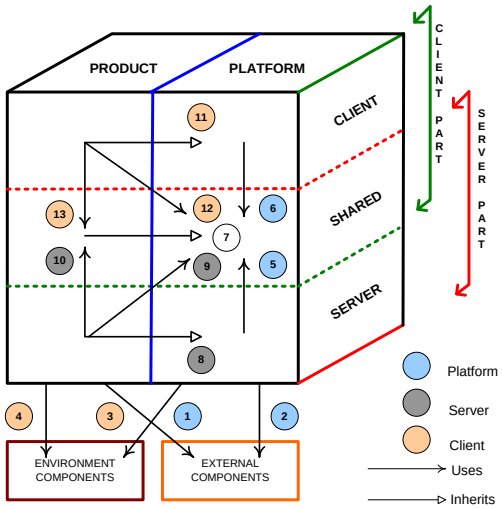

Fig. 2 *Proposed structural model and dependencies*

FEATURE MODEL FOR BUSINESS APPLICATIONS

Features are important distinguishing aspects, qualities, or characteristics of a family of systems (10). Features are use to depict the shared structure and behaviour of a set of similar products. Feature model for business applications is used for representing the possible configuration space of all the products of a product line in terms of its features. Business applications feature model is composed from the client and server models. Feature model for client (Figure 3) captures variability and commonality between the features of the different products available in a given domain.

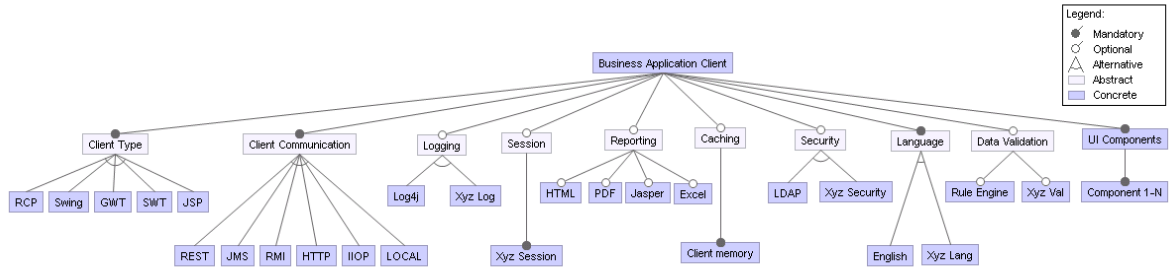

Fig. 3 *Client feature model*

Figure 4 shows server feature model. Not all possible configurations of the server features produce a valid server part of an application. For instance, a configuration of server part of an application that uses EJB as a type of business objects cannot use a non EJB transaction feature. Such restrictions are expressed in the form of integrity constraints. An example of these constraints is: *Business Object EJB EXCLUDES XYZ Transaction*. These constraints ensure the correct composition of product features in the various final business applications developed from this feature model.

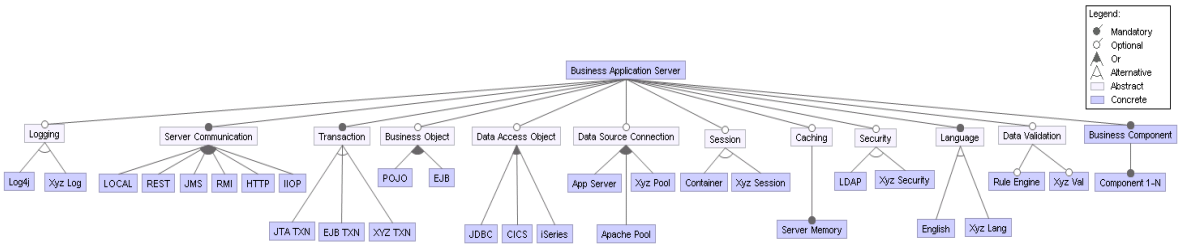

Fig. 4 *Server feature model*

PLATFORM FRAMEWORK RESPONSIBILITY METRICS

Software metrics to measure quality attributes of an architecture such as “Design Quality” metrics (11), metrics to measure structural soundness of product line architecture (12), PLA metrics (13), and complexity metrics for software product line architectures (7) do not address the quality of SPL platform framework responsibility. Within the context of SPL for business applications which is based on generic components, early indicators of the software product line architecture (PLA) quality attributes can be used in order to avoid low-quality products during the later stages of product development (14). We propose a „SPL Platform Framework Responsibility“ metrics which can be used as an early indicator of the future product's quality. A platform framework, is a group of components and services that provide a coherent set of functionalities through inheritance, interfaces and specific design patterns. The application development process should be concerned with the business requirements rather than with the low level APIs or external component's interaction rules. Platform framework needs to ensure the application development process independence by taking the responsibility to interact with external third-party components. By external components we refer to a non-development components developed by a third party organizations and used by the SPL platform framework or by a products spawned from it, illustrated in Figure 5. Referencing an external component directly from a business application product, makes the product less stable and harder to develop or change. The more external components a product relies on, the larger the likelihood to misunderstand or misuse

some of these services. Therefore, the product is more difficult to understand and develop, and thus likely to be more fault-prone. The product line platform framework should take as much as possible of the responsibility to interact with external components. We propose a five simple and intuitive architectural metrics as a measurement for SPL platform framework quality based on architectural elements dependency (14).

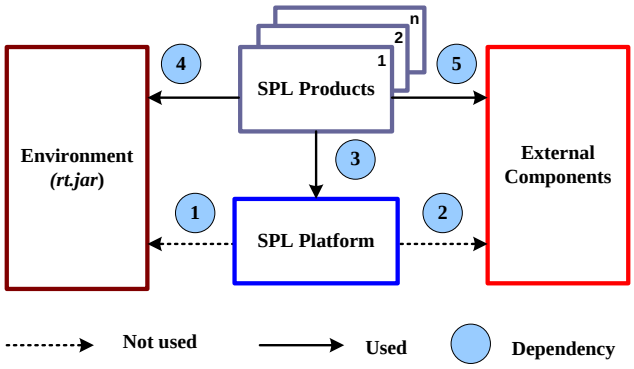

Fig. 5 *SPL Platform Framework Metrics*

As illustrated in Figure 5 there are 5 distinct high level dependency metrics of an SPL for business applications. SPL platform depends on its environment such as Java or .NET and on a number of external third-party components, while SPL products depend on its platform framework its environment and on a third-party external components. The proposed „SPL Platform Responsibility“ metric use the three dependencies metrics (Figure 5): D3: „Platform Afferent Coupling“ - the number of distinct references outside the platform that depend upon classes within the platform, D4: „Product Efferent Coupling“ - the number of distinct references inside the product that depend upon classes within environment components (e.g. Java RTE), D5: „Product Efferent Coupling“ - the number of distinct references inside the product that depend upon classes within external components. We can calculate the *Platform Responsibility* (PR) for a product line platform framework through the following equation:

$$PR = \sum_{i=1}^{n} \frac{D5_i + D4_i}{D3_i + D5_i + D4_i}.$$

The *PR* can be calculated for each product or for all of products spawned from the product line. *PR* = (D4+D5) / (D3+D4+D5): The range for this metric is from 0 to 1, where PR=0 indicates that SPL platform used by product makes the product more stable and protected from frequent changes to the external third party components, while the SPL platform serves the product by taking the responsibility to interact with external components. PR=1 indicates a completely irresponsible SPL platform.Table 4 shows the calculation of the *PR* for three products (P1, P2, P3).

MULTIPLE PRODUCT PR CALCULATION

Table 2

	D3	D4	D5	PR
P1	4	3	3	0,60
P2	4	3	0	0,43
P3	4	0	0	0,00
Total	12	6	3	0,43

The proposed metrics may be analyzed within the framework of measurement theory such as the Distance framework (15) and framework based on desirable properties which serves guidance provided to define proper measures for specific problem (16).

CASE-BASED REASONING USED TO PREDICT THE STABILITY

Predicting product design stability of software product lines for business applications, i.e., the ease with which a product evolves while it's design remains stable, can be used in order to plan product maintenance activities during the later stages of product's existence. A well designed product spawned from a software product line inherits most of the characteristics from the SPL platform framework but it also shares many similarities between other products. Product stability is a complex measure and its prediction is of high importance for any software maintenance planning. We propose an approach that uses the case-based reasoning (CBR) and k-nearest neighbour (k-NN) technique to predict the product stability. The application engineering process that uses and apply the stability prediction will help ensure that final product's maintenance is planned by using the most closest and similar cases from the historical case-library. Since there is a lack of knowledge about software evolution, we believe that CBR is an appropriate approach to the business application stability prediction problem. We hypothesize that two products (business applications) which show same or similar characteristics will also evolve in a similar way. Case repository for applications and its versions needs to have an appropriate structure which will enable the stability prediction. We propose to use the dependencies metrics explained earlier and a set of structural software metrics. Each metrics may be assigned a weight calculated by assigning the importance factor to each metric.

CONCLUSION

In this paper we propose some parts of an architecture model for software product lines in the field of information systems. We propose an entities structural model, feature model for business applications, a new metrics for measuring the „responsibility“ of a common platform framework and a case-based reasoning approach for predicting the stability of an architecture. Our future research is directed at the design of a complete architecture model based on a case study to help reduce the effort to maintain business applications.

REFERENCES

1. The Institute of Electrical and Electronics Engineers, „Guide to the Software Engineering Body of Knowledge,“ 2004. p. 120.
2. Z. ROŠKO. 2012. Strategy Pattern as a Variability Enabling Mechanism in Product Line Architecture.
3. L. N. Paul Clements, Software Product Lines: Practices and Patterns, 3 ed., Westford, MA: Addison-Wesley Professional, 2001, p. 608.
4. V. S. S. P. Kyo C. 2011. Kang. Applied Software Product Line Engeenering. *Taylor and Francis Group,* p.
5. G. B. a. F. J. v. d. L. Klaus Pohl. 2005. „Software Product Line Engineering:Foundations, Principles and Techniques,“ *Springer-Verlag,* pp. 12, 14, 15, 46, 62, 156, 157.

6. C. PARRA. 2011. Towards Dynamic Software Product Lines: Unifying Design and Runtime Adaptations.
7. M. G. J. C. M. Edson A Oliveira Junior. 2001. Empirical Validation of Variability-based Complexity Metrics for Software Product Line Architecture.
8. K. H. D. c. S. Frank Buschmann. 2007. Pattern-Oriented Software Architecture, zv. 4, p. 187.
9. J. Robert G. Crispen and Lynn D. Stuckey. 1994. STRUCTURAL MODEL: Architecture for Software Designers.
10. K. K. K. &. L. J. Lee. 2002. Concepts and guidelines of feature modeling for product line software engineering. *Lecture Notes in Computer Science*, pp. 62,77.
11. R. MARTIN. 1994. OO design quality metrics. An analysis of dependencies.
12. Rahman. 2004. Metrics for the Structural Assessment of Product Line Architecture.
13. N. M. a. A. v. d. H. Ebru Dincel. 2002. Measuring Product Line Architectures. *Software Product-Family Engineering*, pp. 151-170.
14. Z. ROŠKO. 2013. Assessing the Responsibility of Software Product Line Platform Framework for Business Applications. *CECIIS*.
15. G. a. G. D. ". a. f. f. s. m. c. D. R. R. 9. (. 1.-4. Poels, DISTANCE: a framework for software measure construction. *DTEW Research Report 9937*, pp. 1-47, 1999.
16. L. C. S. M. a. V. R. B. Briand. 1996. Property-based software engineering measurement. *Software Engineering, IEEE Transactions on 22.1*, pp. 68-86.
17. „An Industrial Case Study of Product Family Development Using a Component Framework“.
18. K. S. E. R. Frank van der Linden. 2010. Software product lines in action, the best industrial practice in product line engineering. *Springer*, p. 8.
19. D. G. Ebrahim Bagheri. 2011. Assessing the maintainability of software product line feature models using structural metrics.

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DEALING WITH MOBILE PLATFORMS FRAGMENTATION PROBLEM: ONTOLOGY ORIENTED APPROACH

Zlatko STAPIĆ

ABSTRACT

The available researches that referred mobile platforms fragmentation problem showed that current solutions, although many, converge into several groups that have common advantages and disadvantages and are based on the same principle: code ones, run anywhere. Thus, the new approach that would enable the developers to use native development environments was necessary. This paper introduces an ontology oriented approach that is based on methodological interoperability. Important assumption of the ongoing research presented in this paper is that during the development process the development team should use the same methodology and the same approach while developing for multiple mobile platforms. This will enhance this process with the artifacts reuse possibility according to the ontologically described knowledge.

KEY WORDS

mobile, development, methodology, fragmentation, interoperability, ontology

INTRODUCTION

One of the obstacles to efficient development of mobile applications is the lack of interoperability between different mobile platforms. The teams involved in developing applications for multiple platforms are faced with having to use platform specific development environments for each platform. This leads to the fact that artifacts created during development for one mobile platform, are not useful when developing for the second or any other target platform. This problem has been recognized by the professional and scientific communities which, over the past a few years, proposed several solutions. Although the proposed solutions are different in their implementation, they are based on a similar concept of developing one source code and its automatic transformation for various mobile platforms ("code once, run everywhere"). The results of these approaches, along with the well-known fragmentation problem (Agarwal et al., 2009) (Manjunatha et al., 2010) (Ridene et al., 2010), limit development teams to use only those features that are implemented in automated code generators or automated and target platform dependent adapters of mobile application.

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This paper will focus on the analysis of this problem and on proposal of a solution in a domain of methodological interoperability. The idea is to allow developer teams to use native development environments (that is, all their advantages for platform specific mobile application development), by raising the reusability and interoperability to a higher, methodological level. The paper is organized in following sections: at the beginning, the overview of existing solutions is given; the second section provides a brief look into a new ontology oriented approach of defining a methodological interoperability; and finally the conclusion with plans for future work is given.

EXISTING SOLUTIONS

The stated problem of fragmentation of mobile platforms, devices and programming languages has been an issue that the scientific and professional community is dealing with during the last several years. As presented in (Stapić et al., 2012) there are several, rather similar approaches that are being used by many authors. These approaches include the usage of mediatory transform engines, the usage of native application adapters, creation of extensions, APIs and middleware frameworks to existing languages and finally the usage of web technologies and web standards.

The usage of mediatory transform engines implies the process of generating the native code to run on multiple platforms (Maaløe and Wiboe, 2011) and is sometimes called a *cross-compilation* approach. As shown in Fig. 1 the generated native code would be packaged into a platform-specific (native) application package and distributed through usual distribution channels such as application stores. Additionally, this approach is sometimes relying on the usage of a domain specific language (DSL) and in some other cases it uses a cross-compilation between existing well-known programming languages.

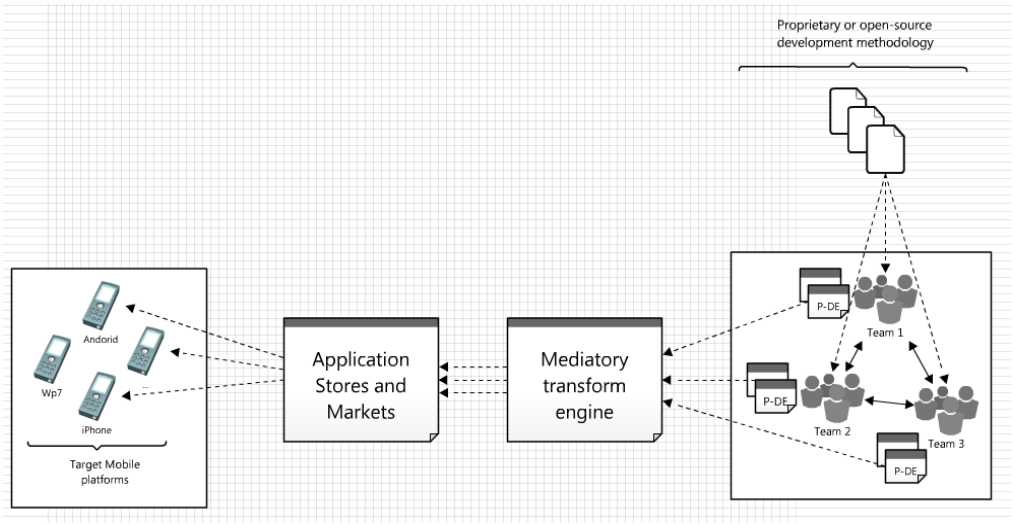

Fig. 1 *The use of mediatory transform engine (Stapić et al., 2012)*

There is an imerging number of projects that are based on this approach, and according to Stapić et al. (2012), some of the most influencial projects are MobiCloud (Manjunatha et al., 2010) from Kno.e.sis Research Group (2011), Rhodes from Rhomobile Inc. (2011), Amanquah & Eporwei code generator (Amanquah and Eporwei, 2009) et cetera.

The use of native application adapters is according to Agarwal et al. (2009) one of the two main techniques for handling the fragmentation in which the interfaces calls are wrapped

in a distinct modules which are then ported across the platforms. In this scenario (see Fig. 2), optimistically speaking, the interfaces calls in the original source code could be the same for all target platforms, but as argued in (Stapić et al., 2012) this is usually not the case.

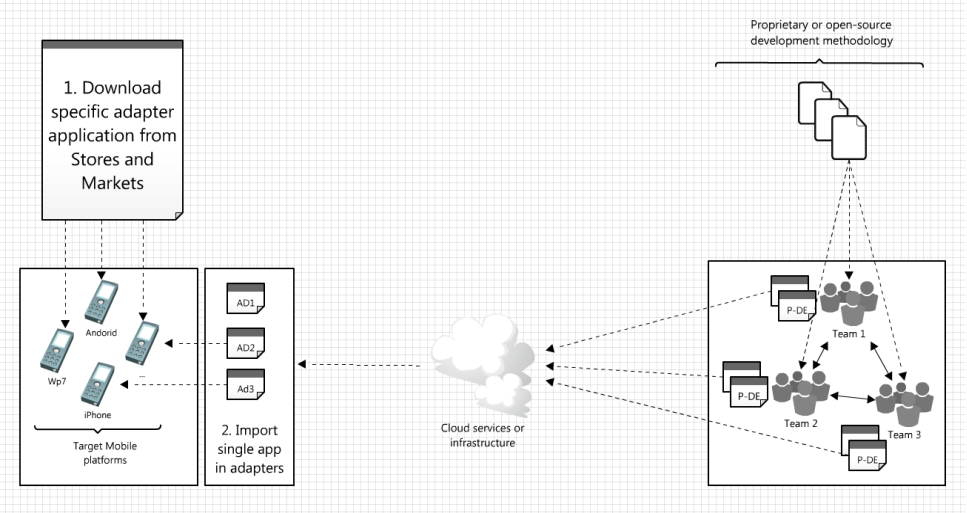

Fig. 2 *The use of native application adapters (Stapić et al., 2012)*

The influential projects from this group are MobiVine (Agarwal et al., 2009), Corona SDK (Fernandez, 2012), Sencha Touch (Rao, 2012), jQuery mobile (Bai, 2011) and for example PhoneGap which uses HTML5, CSS3 and JavaScript code and wraps it with platform specific adapter capable of calling the native target APIs. On the other side, there are numerous middlewares and frameworks developed in the simillar manner and some of them are presented in (Baloian et al., 2007), (Choi, 2012), (Choi et al., 2009), (Miravet et al., 2009), (Maaløe and Wiboe, 2011) et cetera. These extensions to existing languages aims to improve and make faster the overall multi-platform development process but are faced with the same disadvantages as other previously stated approaches.

As argued and discussed in (Stapić et al., 2012) all mentioned approaches have some advantages and some disadvantages and thus should be used only if project boundaries are clearly defined and state that a particular approach would result in acceptable solution. The conclusion from mentioned authors is that in specific cases none of the mentioned approaches is applicable and that new approaches that will provide the teams developing the multi-platform mobile applications with the full advantages of using the native APIs, the native test environments and the native generators of the executable code are necessary.

ONTOLOGY ORIENTED APPROACH

We can identify at least three dimensions in the space (S) of the possible approaches that could be taken while developing *multi-platform* mobile applications. Those dimensions are defined by methodologies (M), approaches (A) and target platforms (P). Thus, the space can be defined as S = {M, A, P} where each dimension can have several instances: M = {m_1, m_2, ... m_n}; A = {a_1, a_2, ... a_m}; P = {p_1, p_2, ... p_o}. Assuming that development team would use SAME methodology and SAME development approach, cardinality of defined sets could be defined as |M| = 1; |A| = 1; |P| > 1, and consequently the cardinality of set S as |S| = {(1, 1, n): n > 1}. Finally, the development process (DP) could be defined as set of sub-processes (ordered triplets), where each sub-process would result in mobile application developed for specific target platform, as DP = {SP_1, SP_2, … SP_n : $SP_i \in S$; SP_i = (m, a, p_i); $1 < n \leq |P|$; i =

{1, 2, …, n}; m ∈ M; a ∈ A; p ∈ P}. The important information given here is that the methodology and approach are NOT going to be changed during the execution of *n* development sub processes.

The research that is currently being performed is constructed by taking all mentioned constraints (of the existing solutions and of the domain defined in previous chapter) into consideration and is aiming to propose a different approach to solve the issues of multi-platform mobile applications development. The idea is to propose a solution based on a methodological interoperability by utilizing the ontologies and relying on previously stated assumption of usage of single methodology and single approach (|M| = 1; |A| = 1) during the development process.

While talking about interoperability, in this ontology oriented approach, the IEEE definition of interoperability (IEEE Computer Society., 1990) is adopted and extended and the interoperability is considered as "the ability of two or more systems, components, teams or team members to use and exchange the information and methodological artifacts that have been created during the mobile application development process". Additionally, although there are different types of interoperability, *semantic interoperability* is the knowledge-level interoperability which provides the interoperable systems with possibility to bridge the semantic conflicts (Park and Ram, 2004) and only semantic interoperability is in focus of this approach.

Finally, as ontology is defined as specification of a representational vocabulary for a shared domain of discourse and as it includes definitions of classes, relations, functions and other objects (Gruber, 1993), the ontology is considered as most appropriate tool to describe the mentioned methodological interoperability. Important concept related to ontology mapping of knowledge is *domain ontology* and it can be defined as a network of domain model concepts (topics, knowledge elements) that defines the elements and the semantic relationships between them (Brusilovsky et al., 2005). The use of domain ontologies is suitable to index all content regarding development methodology and this creates the solid bedrock in this approach. In the literature of ontology development, a number of ontology development methodologies (Lumsden et al., 2011) (Corcho et al., 2003) and ontology representation languages like LOOM, OCML or OWL are proposed, but the usage of specific ontology description language or specific ontology development methodology is not required.

CONCLUSION

The results of the efforts of the scientific and professional community to solve the mobile platforms fragmentation problem still have the important drawbacks which makes the paradigm "code ones – run anywhere" useless for mobile application development. The previous papers on this subject as well as short review given in this paper showed that new approach in solving this reusability-interoperability-and-development-efficiency problem is needed and also might be based on enabling the developers the usage of native development environments.

Combining the semantic similarities of artifacts that arise in such development process and taking into consideration the meaning of created artifacts should result in reusability and interoperability enhanced knowledge which is described with proper ontological description. In that way the future work based on this results could end up with an adaptive Web-based system, which will be able to select and recommend the most relevant content during the multi-platform mobile applications development process. Such system would in different aspects significantly improve the mentioned development process.

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REFERENCES

1. AGARWAL, V., GOYAL, S., MITTAL, S., MUKHERJEA, S., 2009. MobiVine: a middleware layer to handle fragmentation of platform interfaces for mobile applications. In: *Proceedings of the 10th ACM/IFIP/USENIX International Conference on Middleware*, *Middleware '09*. Springer-Verlag New York, Inc., New York, NY, USA, pp. 24:1–24:10.
2. AMANQUAH, N., EPORWEI, O.T.. 2009. Rapid application development for mobile terminals. In: *2nd International Conference on Adaptive Science & Technology (ICAST)*. Presented at the Technology (ICAST), Accra, Ghana, pp. 410–417.
3. BAI, G. 2011. *Jquery mobile first look*. Packt Pub Ltd, S.l.
4. BALOIAN, N., ZURITA, G., ANTUNEZ, P., BAYTELMAN, F. 2007. A Flexible, Lightweight Middleware Supporting the Development of Distributed Applications across Platforms, in: Computer Supported Cooperative Work in Design, 2007. CSCWD 2007. 11th International Conference On. pp. 92–97.
5. BRUSILOVSKY, P., SOSNOVSKY, S., YUDELSON, M. 2005. Ontology-based Framework for User Model Interoperability in Distributed Learning Environments, in: World Conference on ELearning, E-Learn. AACE, pp. 2851–2855.
6. Choi, M. 2012. A Platform-Independent Smartphone Application Development Framework. Computer Science and Convergence 787–794.
7. CHOI, Y., YANG, J.S., JEONG, J. 2009. Application framework for multi platform mobile application software development. In: *Advanced Communication Technology, 2009. ICACT 2009. 11th International Conference On*. pp. 208–213.
8. CORCHO, O., FERNANDEZ-LOPEZ, M., GOMEZ-PEREZ, A. 2003. *Methodologies, tools and languages for building ontologies. Where is their meeting point?* Data & Knowledge Engineering 46, 41–64.
9. FERNANDEZ, M.M. 2012. Corona SDK mobile game development beginner's guide: create monetized games for iOS and Android with minimum cost and code. Packt Pub., Olton, Birmingham [England].
10. GRUBER, T.R. 1993. A translation approach to portable ontology specifications. *KNOWLEDGE ACQUISITION* 5, 199–220.
11. IEEE Computer Society. 1990. IEEE standard computer dictionary : a compilation of IEEE standard computer glossaries, 610. Institute of Electrical and Electronics Engineers, New York NY USA.
12. Kno.e.sis Research Group, 2011. Welcome to Kno.e.sis [WWW Document]. URL http://knoesis.wright.edu/ (accessed 8.27.11).
13. LUMSDEN, J., HALL, H., CRUICKSHANK, P. 2011. Ontology definition and construction, and epistemological adequacy for systems interoperability: A practitioner analysis. *Journal of Information Science*, 37, 246–253.
14. MAALØE, L., WIBOE, M. 2011. Kamili - A Platform-Independent Framework for Application Development for Smart Phones (Bachelor thesis). Technical University of Denmark, Lyngby, Denmark.
15. MANJUNATHA, A., RANABAHU, A., SHETH, A., THIRUNARAYAN, K. 2010. Power of Clouds in Your Pocket: An Efficient Approach for Cloud Mobile Hybrid

Application Development. In: *2010 IEEE Second International Conference on Cloud Computing Technology and Science*, 496–503.
16. MIRAVET, P., MARÍN, I., ORTÍN, F., RIONDA, A. 2009. DIMAG: a framework for automatic generation of mobile applications for multiple platforms. In: *Proceedings of the 6th International Conference on Mobile Technology, Application & Systems, Mobility '09*. ACM, New York, NY, USA, pp. 23:1–23:8.
17. PARK, J., RAM, S. 2004. Information systems interoperability: What lies beneath? ACM TRANSACTIONS ON INFORMATION SYSTEMS 22, 595–632.
18. RAO, N. 2012. Sencha touch 1.0 mobile JavaScript framework: build web applications for Apple iOS and Google Android touchscreen devices with this first HTML5 mobile framework. Packt Publ., Birmingham; Mumbai.
19. Rhomobile, Inc. 2011. Smartphone Enterprise Application Integration, White paper [WWW Document]. URL http://tiny.cc/rhomobile (accessed 8.20.11).
20. RIDENE, Y., BELLOIR, N., BARBIER, F., COUTURE, N. 2010. A DSML For Mobile Phone Applications Testing, in: Proceedings of 10th Workshop on Domain-Specific Modeling in SPLASH. France.
21. STAPIĆ, Z., de-MARCOS, L., GUTIÉRREZ MARTÍNEZ, J.M. 2012. Approaches in Development of Multi-platform Mobile Applications: State of the Art. In: *Proceedings of IV International Conference on Application of Advanced Information and Communication Technologies. Presented at the ATICA 2012*, Universidad Técnica Particular de Loja, Loja, Ecuador, pp. 429–436.

RESEARCH PAPERS
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THE PROPOSAL OF THE PROCESS OF SAFETY ANALYSIS FOR COMPLEX DYNAMIC TECHNOLOGY SYSTEMS

Milan ŠTRBO, Pavol TANUŠKA, Augustín GESE

ABSTRACT

The aim of this article is the proposal of process of the safety analysis for complex dynamic systems in process of the proposal of control system for safety-critical processes. The method of safety analysis depends on various safety-critical states of system which are system are controlled by models. We propose to use the method SQMD for modeling these states. This method combines qualitative and quantitative methods of modeling states and takes advantage of both methods. The model of the proposal is shown in the diagram. The article includes detailed description of the tasks for each step of analysis.

KEY WORDS

complex dynamic system, qualitative model, quantitative model

INTRODUCTION

The automation of continuous-discrete technical processes greatly dependeds on the implementation functions of control and regulation. What more, it also depends on automatic control according to the operating rules. The engineering-technical applications are deployed to the monitor process which are often mathematical models, in order to obtain an accurate description of the technical equipment. However, especially for complex dynamic systems, the construction of a mathematical model for the control is associated with many difficulties. The main problem is that the parameters of the model are unknown and therefore for the analytical procedures must be used an estimate of state respectively an estimate of parameters. On the basis of these problems are also taken into account qualitative procedures for complex systems. The quality models may not be accurately reflect internal physical connections, in models are include only those situations when something "does". The qualitative model distinguishes these situations and allows the characterization of complex systems. The disadvantage of qualitative models is mainly the fact that the dynamic properties can not be at all or only very inaccurately described. However, this is a necessary condition for the control of dynamic properties of the system. For this reason, we propose to use for safety analysis of the complex dynamic systems the combination of both forms of the model, therefore the

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qualitative models for assessing the complexity of systems and quantitative (mathematical) models for description of the dynamics (Manz 2004).

THE DEVELOPMENT OF MODEL AND CONTROL OF PROCESSES

The question of using a combination of qualitative and quantitative modeling of controlled processes for safety analysis of complex systems is appropriate. SQMD is a method for modeling dynamic systems and it uses currently a combination of these two forms of modeling. The method uses a hybrid model for monitoring and detecting of real-time. The hybrid model includes qualitative and dynamic elements, and combines the advantages of both methods. Thus we can imagine on-line monitoring and diagnostics to detect and locate faults in complex dynamic systems. The main advantage of the safety analysis by method SQMD is easy modeling of complex dynamic systems.

The control of complex dynamic systems takes into account these objectives:
1 - Modeling,
2 - Observation,
3 - Error analysis.

The errors and failures of the hardware components, software errors or errors in the design that have not been taken into account for the operating conditions may cause a dangerous situations in the operation of technical processes. The role of an appropriate model of process is to provide a quantitative or qualitative measurable parameters in relation to the properties of the system and from these we can in real-time detect deviations during the process (Fröh 1996).

The models which should be deployed in controlling process often do not meet the requirements of a simple description of reality. With respect to the control process except for the description of the desired mode of the operation, it is necessary to identify all possible faults in the real process. In this way arise except models for the desired operating conditions also appropriate models for degraded modes of the operation. When checking are deployed the models for desired state, and these are compared these with the course of reality. As soon as a discrepancy is found between the model and reality, it is considered as an error. In this case, models of error operating modes determine the type and location of the error. An important task for the elaboration of the models is therefore taking into account all the possible errors in the model (Fröh 1996).

The tasks of the process control:
- examination of the current state from measured process signals and indication of the state for the operating personnel,
- examination of the failed subsystems caused by deviations from the regular operation and from these derived stimuli for actions performed by operating staff,
- output of the alarm messages for immediate outages,
- automatic protection of technical devices at hazardous or emergency situations,
- early detection of the emerging faults and outages (Laub 1999 b).

Figure 1 shows the principle of control loaded at the model. The process model is carried out on-line, i.e. parallel to the controlled process. Based on the input data is impossible to determine the behavior of the real process using output values (measured situation). This measured behavior is determined in parallel model with an associated of the same input data. The determined (calculated) situation are compared with measured and from this comparison are derived symptoms, characteristics or residues which are important to the detect errors (Laub 1999 a).

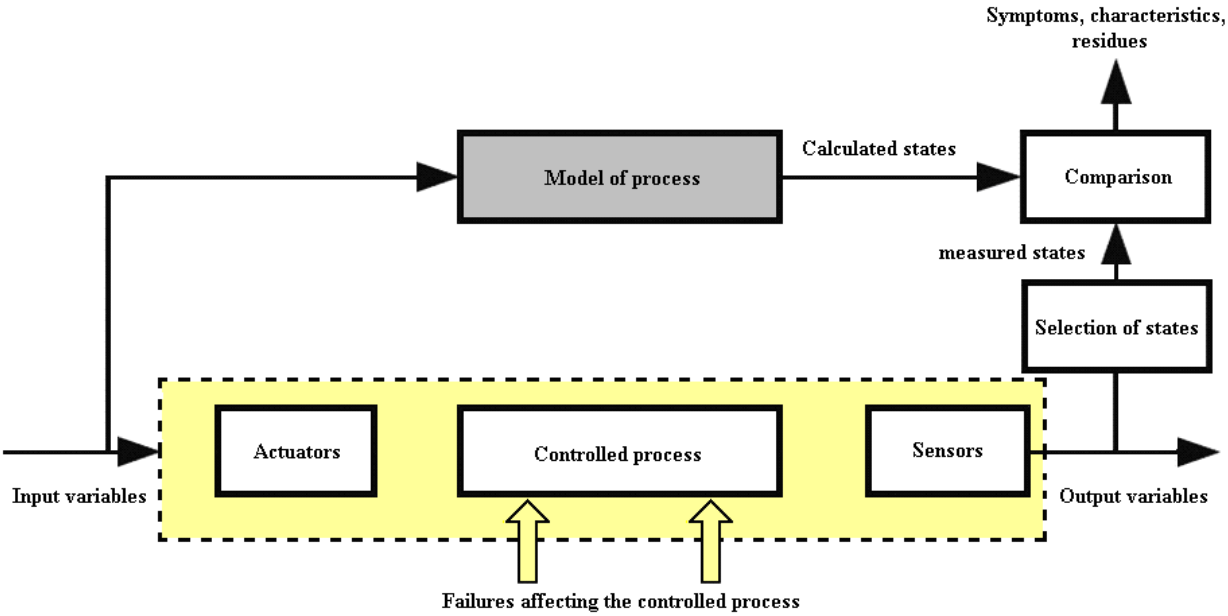

Fig. 1 *Principle of control based on the model of the real process. (Laub 1999 a)*

THE PROPOSAL

The overall proposal of the course of the safety analysis is shown in the figure 2. This process was divided into five steps. After the execution of each step of the analysis is performed verifying of achievements. The full contents of the tasks for various steps of the safety analysis is described later in this article.

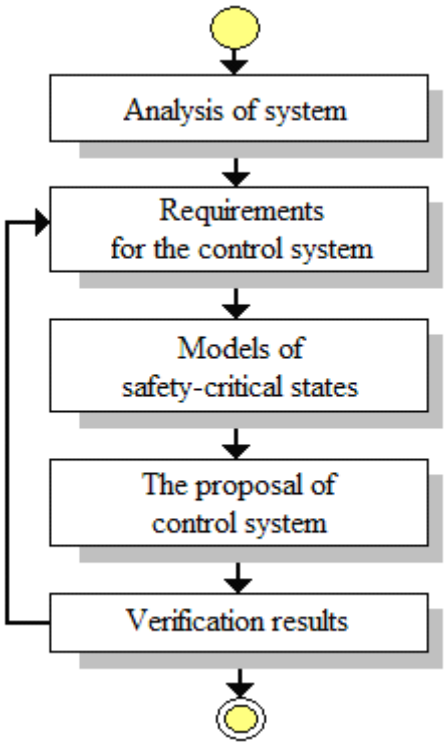

Fig. 2 *The proposal of process for safety analysis*

PROCESS OF SAFETY ANALYSIS

1. Analysis of system

The content of this step is to analyze the dynamic system with a focus on the implementation of the safety analysis. It means to become familiar with the system and its features and identify all possible states of the system during operation. It is necessary to analyze the actual terms and basic operating parameters respectively conditions. It is closely related to the analysis of limitations in individual states, analysis of deficiencies, analysis of risks and all available resources of the system. The selection and analysis of the operating states, which are safety-critical for a system, and determine whether these states are deterministic or stochastic. For the critical states is necessary to done the select of resources information. These will provide information to the operating personnel about the process of these states. It is also necessary to define the inputs for individual states, mutual relations between states and the characteristic of states on the output.

2. Requirements for the control system

The aim of this step is to establish requirements for the safety analysis respectively requirements for control process in terms of origin, course and evaluation of critical situations (faults). This can be understood as the determination of the individual requirements for hardware and software of the control system for safety-critical situations that we get an analysis of conditions obtained in step one. Each process has some set of the states. In this step, we will work only with safety-critical states. By detailed analysis of these states we obtain the requirements for measurement, control functions during the states or requirements of the actuators controllers. We must take into account all the relevant standards and the implementation safety-critical states to criteria of the SIL (Safety Integrity Level). The content of this step is also the selection and analysis methods of observation of the processes (estimate of the states). The Use of the Luenberger´s observer for deterministic states and Kalman´s observer (filter) for stochastic states, the determination of the methods and processes for safety analysis. It is necessary to the mention the Top-Down method, which allows us to decompose a system from a global perspective to the individual subprocesses.

3. The models of safety-critical states

In this step, we will describe the critical states of the system through models. The aim is to develop qualitative and quantitative models within the general description of the system. For the development of qualitative models of the individual processes we use fuzzy logic, possibly we can to use description through causal networks. Quantitatively, mathematical models we develop by using differential and difference equations. The structure of these models we can orient into UML diagrams. It is also necessary to carry out the synthesis of these models, evaluate their effectiveness and make the validation of these models. To verify the accuracy of models need to be verified it by simulation.

4. The proposal of the control system

The result of this step will be conceptual design of the structures system for safety analysis (control of process) of the dynamic process. It is important to evaluate all possible solutions, opportunities and strategies in terms of fulfillment expectations and in the terms of achieving the specific goals. We carry out the design and analysis of our solutions. In conclusion, we select the final solution which we have selected on the basis of certain criteria on system and we get a real design of hardware and software of control system.

5. The verification results

The obtaining of the solution will be verified by simulation. We compare the results obtained with the system requirements. We establish the criteria for validation and verification of the proposed solutions. Then we perform validation and verification solutions based on these criteria. Finally we evaluate the results obtained for long-term and for short term and also evaluate the effect of the proposed solutions with respect to future possibilities. If the validation process finds deficiencies in the proposed solutions, so the process of safety analysis returns to the step "Requirements for the control system".

CONCLUSION

The aim of this article was the proposal of the safety analysis in context of the risks in the process of development of the control systems for the complex dynamic technology systems. The proposal of the process is shown by activity diagrams in UML (Unified Modeling Language). Furthermore, we have reported a detailed description of the tasks for each step of the safety analysis. The process of the safety analysis begins with familiarizing yourself with the system on which is carried out the analysis. Then it goes through the requirements on the system, modeling of the individual states to the overall design of the control system for the system. In conclusion of our proposal does not lack verification of the results obtained.

REFERENCES

1. Susanne MANZ. 2004. *Entwicklung hybrider Komponentenmodelle zur Prozessüberwachung komplexer dynamischer Systeme*. Stuttgart: Forschungsbericht Institut für Automatisierungs- und Softwaretechnik, Universität Stuttgart.
2. Susanne MANZ. 2004. *Entwicklung hybrider Komponentenmodelle zur Prozessüberwachung komplexer dynamischer Systeme*. Stuttgart: Forschungsbericht Institut für Automatisierungs und Softwaretechnik, Universität Stuttgart.
3. P. FRÖHLICH. 1999. *Überwachung verfahrenstechnischer Prozesse unter Verwendung eines qualitativen Modellierungsverfahrens*. Stuttgart: Institut für Automatisierungs- und Softwaretechnik (IAS). Dissertation. Stuttgart: Universität Stuttgart.
4. LAUBER, P. GÖHNER. 1999. Prozessautomatisierung 1. Band 1, 3. Auflage. Berlin: Heidelberg, Springer-Verlag.
5. R. LAUBER, P. GÖHNER. 1999. Prozessautomatisierung 2, Band 2, 1. Auflage. Berlin Heidelberg: Springer-Verlag.

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WIFI ROAMING ACCESS POINT OPTIMUM ASSIGNMENT IN URBAN MULTI-SENSOR NETWORKS

Boris TOMAŠ

ABSTRACT

Urban sensor networks produce large amount of data including available WiFi networks information and current GPS location. We work on finding usable information in this WiFi "noise" in urban environments, envisioning the provision of efficient WiFi roaming during travel within the city. We identify the main challenges of such service, and discuss specific issue like finding the optimum sequence of WiFi AP for given route.

KEY WORDS

WiFi sequence, vertical offload, 3G offload, urban sensor networks

INTRODUCTION

In urban multi-sensor environment there is a large amount of gathered data. After that, this data needs to be synchronized with central database at the end of data gathering, but ideally would be the real time data synchronization. However, for the real time synchronization stable and constant Internet access is required. In urban environments there are many open access WiFi access points (hotspots) that provide free Internet access, let us assume that location of those devices is fairly constant, and for the sake of this paper this location is known using GPS technology. Exceptions are mobile hotspots on mobile devices and in special occasions dedicated hotspots for conferences, fairs, exhibitions,...

It is still difficult to make optimum and most efficient WiFi access point (AP) assignment for moving subject. The easiest assignment technique would be using strongest signal. In real life scenario this might not be the optimal assignment because moving object will exit coverage area very soon and new assignment would be necessary. Problem is how to choose optimum WiFi hotspot sequence for given travel path, this sequence should minimize amount of handshakes and maximize availability and path coverage.

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PROBLEM DEFINITION

Mobile object during movement in the urban sensor environment may require stable and constant internet access using existing WiFi infrastructure. Urban multi-sensor networks (UMN) like one described in (1) are usually implemented in the urban environments that do have many WiFi hotspots deployed around the area. Application that may use localization of AP is the assignment of WiFi AP to the roaming object in UMN (or any other network). This assignment would be necessary because of the offloading existing 3G networks with WiFi, is more efficient (2) Every time a moving object is changing its assigned AP it costs time because of authentication process and assignment procedure called handshaking which lasts for about 330ms (3). During this time vehicle travelling 80km/h can travel up to 7.3m which can be crucial for some applications using urban sensor networks. Sequence of WiFi AP is important because WiFi networks have relatively short range (comparing to GSM network relay stations). Finding the optimum sequence for the given route is one of the problems this paper solves. System that provides environment for the mentioned problem is made of:

- **Server**: Provides service for WiFi roaming objects in the environment. Server problem is that single roaming object may not know the route it is about to undertake, it is up to server to define route. Along with the route, server should provide optimum sequence of WiFi AP roaming object (Client) should be assigned to.
- **Client**: Consumes services provided by the server and assigns itself to the optimum WiFi AP to minimize handovers. Even for the given optimum sequence of WiFi AP, client still has a problem deciding when and where to initiate the physical WiFi switching, because some WiFi AP coverage areas, in a sequence, will overlap. Constant scanning for the available WiFi AP consumes client battery a lot and needs to be minimized.

RELATED WORK

There are several works being done to solve individual parts of the problem defined in section before.

- **3G offloading**
  3G offloading is the technique used to divert some traffic from 3G large networks to localized WiFi AP. "When WiFi is available, it is very likely (roughly 90%) that it outperforms 3G. Such out-performance is significant."(2) Many authors deal with the reasoning for 3G offloading and it is proven that it is better to use WiFi over 3G but there are some issues like WiFi switching (handoff) which may increase network delay (4)
- **WiFi handoff**
  It is referred to switching from one WiFi AP to another, this is called horizontal handoff. Also in scenario where 3G networks are overloaded offloading to the WiFi is considered one of the preferred solutions, this is called vertical handoff: "So, in the ideal case, 3G transfers would be replaced with more energy efficient WiFi transfers whenever possible" (5) The same author defines energy efficiency of WiFi networks that in reality use much less energy than 3G. It is also recognized that handoff procedure is time and resources consuming, so there are many different techniques defining AP assignment strategies/techniques (6):
  - **RSSI** – strongest signal first
  - **BRR** - highest exponentially average beacon reception ratio first.
  - **Sticky** - client is assigned to AP as long as there is connectivity.
  - **History** - best performance (based on historical measurements).
  - **BestBS** - best performance base station (BS) in future.

- **AllBSes** - uses all BS in vicinity. This technique is a part of special WiFi protocol proposal that is not yet being implemented in any today WiFi standard device.

Analysis using packet delivery measurements proved that the most efficient strategy is AllBSes, followed by BestBS then by History, first one is not applicable for this paper work because it deals with a new WiFi protocol proposal and this paper deals with existing WiFi technology. Regarding BestBS author states: "This method is not practical because clients cannot reliably predict future performance" (6), but analysing the past History strategy seems as most appropriate in the current case.

Another author identifies these baseline handoff policies (7):

- **Maintain until broken** - client is connected until connection is broken, equivalent to "Sticky" strategy mentioned before.
- **Always Strongest Signal** - equivalent to RSSI strategy mentioned before.
- **Averaged with Hysteresis** - time suppressing frequency of handoffs along with signal strength estimates.

"Driving on familiar routes provides the opportunity to learn and cache the relevant information about APs along a route, which can aid in quick connection establishment." (8) Using this huge amount of data, AP coverage is estimated using the fingerprinting technique to estimate the AP coverage. Later, appropriate AP selection can be made, this strategy is called Scripted handoff. This author also proposes several improvements to the AP handshake procedure at link and network layer to minimize the handoff duration.

PROPOSED SOLUTION

Solution for the problem is a new software system architecture that extends one described in (1).

- **Server**

  Server component of the architecture provides two new web-service methods with multiple overloads. All geographical inputs and outputs for the service methods are represented using OpenGIS standard for textual representation of geographical elements. Problem is that user provides unknown data input format, solution to this problem is providing service methods that require user to synthesize its data input in a structured form. Methods are:

  - ***string GetRoute(string start, string end)*** Method is used to calculate the shortest route for the given starting and ending point. Calculation is done using previous travels. Method returns appropriate OpenGIS compliant Linestring as string, using this simplified procedure:
    1. Find all trip paths(TP) that contain start and end point.
    2. Store TP segments, from start and endpoint on current TP, to a list.
    3. Find shortest TP segment in the list.

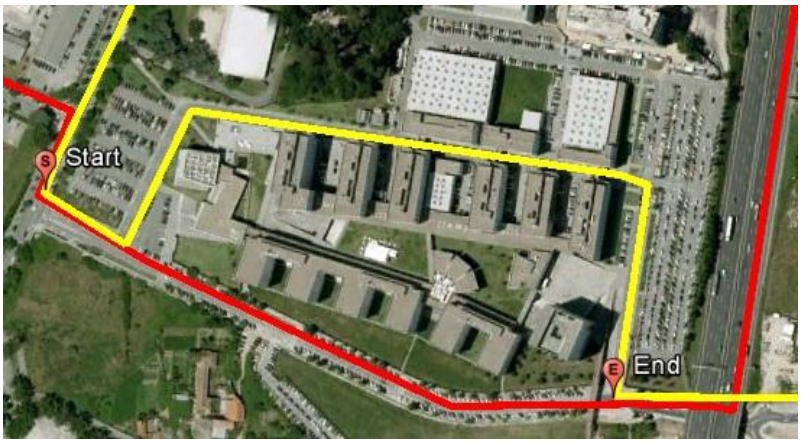

Fig. 1 *Shortest TP segment (Linestring) is the proposed shortest route for given start and end point*

- ***string GetAPSequence(string TravelPath, ReturnMode mode)***
  string GetAPSequence(string start, string end, ReturnMode mode)
  This method has two overloads whose signatures only differ by the input parameters. Methods use *ReturnMode* enumeration that defines available return modes:
  - *ReturnMode.MacOnly*: returns a string that is a comma separated list of MAC addresses.
  - *ReturnMode.MacExtended* : returns a string that is comma separated list of segments: "MAC address:latitude:longitude:radius"
  - *ReturnMode.KML*: returns a KML string that contains MAC address, location and coverage formatted for easy display in the geographical visualization tools like GoogleEarth.

  Other parameter of overloaded methods is input, in first case input is a list of path points *TravelPath*[1]. Path density is irrelevant, it will be taken as is, and all path segments will be represented as a straight line between start and end point of path segment.
  Second overloaded method takes start and end point as input. This means that the caller provides only start and end point for the roaming trip. Path for calculating optimum sequence of WiFi is calculated using the *GetRoute* method previously described. Method return value is a string to maintain easy scalability and compatibility between different clients. JSON or XML is not used to reduce data length by excluding description fields in mentioned data formats.

- **Client**
  Client component of this architecture has a task to call server services de-scribed before. After retrieval of service return data client makes the decision when and where to switch to another AP. As defined before scanning for the available WiFi consumes battery resources and should be minimized.
  There are two scenarios regarding relation between the current and the sub-sequent AP in the retrieved list of AP.
  - Overlapping
  - No overlapping – there is a gap in the returned sequence.

  If there is an overlap, client should begin WiFi scans near the ending edge of the coverage area of the currently assigned AP. If there is no overlapping, client should start WiFi scans near the beginning of the subsequent coverage area of WiFi AP. Definition of *near*: it is a

[1] OpenGIS compliant Linestring

parameter defined inside a client and can be changed by the client user. Its value is in meters and is set by default to 10m. If client is moving relatively fast then this value should increase or decrease in case of slow movement.
All WiFi scans should end after the successful assignment or user intervention (Cancelling)

- **WiFi AP sequence search**
  As defined before, problem is that the proper WiFi AP needs to be selected that way that the moving object remains the most time under coverage of single WiFi AP. This simple task should produce sequence that minimizes handovers between WiFi APs. This strategy is similar to History identified by Balasubramanian (6) Input data for this strategy are scan circles (described before), blue and green circles on Figure 2 and the travel path(TP) - desired route around the city, yellow line on Figure 2.

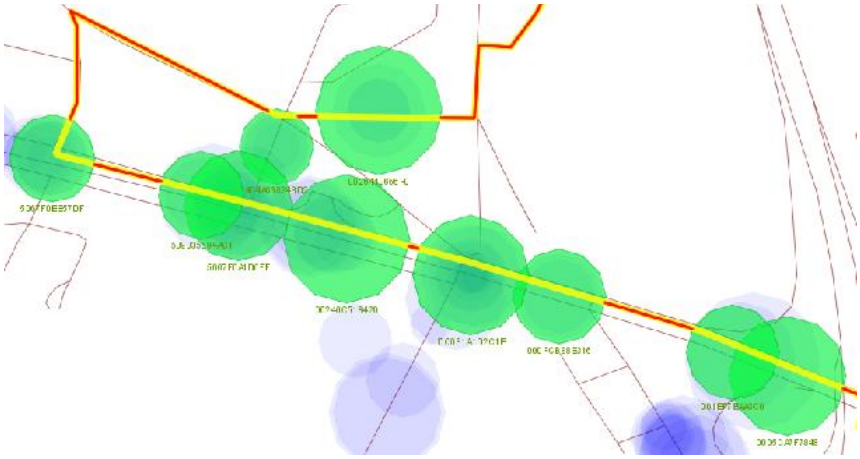

Fig. 2 *AP sequence search result, test case in Porto*

IMPLEMENTATION

This stage takes input TP in a form of Linestring[2]

e.g:

LINESTRING(8:599 41:167; 8:568 41:1788)

and returns the optimum sequence of WiFi AP mac addresses according to the previously described strategy. Order of the points in Linestring is important because it represents the orientation and direction. Each Linestring point is a place on Earth represented by latitude and longitude.

1. Get the list of all *(n)* the WiFi AP location estimation circles that intersect with *TP-*I_n
2. For each circle *(i)* calculate intersection with TP - (I_i), intersection is a line segment (or curved line segment) that has starting and ending point both on the circle and on TP.
3. Merge each intersection line segment start and end point with TP thus increasing the density of TP Linestring points.
4. Iterate through all the points X of TP and if X is not covered by currently selected WiFi AP then new WiFi AP selection is necessary.

[2] Simple object according to OpenGIS standard

5. Get the list of all intersections from I_n that contain point $X = I_x$
6. From the list I_x get the intersection that is the longest (length is measured from the point X up to the intersection end) = $\max(I_x)$
7. WiFi AP coverage circle containing the longest intersection ($\max(I_x)$) is the next selected AP.

Figure 2 shows the result of this algorithm. Selected AP are represented by their coverage estimation - green circles. TP is the yellow thick line. Red segments represent parts of TP that are not covered by any AP. Result is the list of WiFi AP MAC addresses according to Server service methods definitions.

ISSUES

While implementing this solution several issues arose that needed extra consideration.

- **Circle approximation**
  Having a circle as coverage estimation is a good for the geometrical approach that this work is using. However, this approach discards data, everything outside a circle is discarded. Alternative is using the probabilistic approach, which uses "fuzzy" circles (that implements channel model) to represent coverage area. Fuzzy means that there is a probability for each point of circle if there is or is not a WiFi AP or anything in between. Geometrical approach says that there is a 100% probability that WiFi is inside a circle, and 0% probability that WiFi AP is outside the circle. This may be an issue if it deals with one (or small number) of scans, if there is large amount of scans this error is averaged out. It is inconclusive which approach (geometric or probabilistic) would give better WiFi AP estimation.
- **GPS error**
  GPS position is imprecise, and GPS measurement is taken as static and correct which is not the case. "When your GPSr tells you the EPE is 40 feet, what it is really saying is "I am pretty sure I know where we are... give or take 40 feet"[3]
  This means that GPS devices provide the information how incorrect GPS measurement is.

STATISTICS ABOUT GPS ERRORS IN THE SYSTEM (in meters)

Table 1

min	max	avg	median	mode
2.0	248.00	110.128	71.92	10

From the Table 1 it can be seen that 10 is the most common value, this means that each measurement does not represent a single point P but a circle with *radius=10m*. Figure 3 shows the distribution of values of GPS error. It can be safely concluded that the error of 10m is appropriate. Assumption is that this small error will average out during time by the large amount of trials.

CONCLUSION

This paper describes solutions to the several specific problems, however there are different approaches that may provide different results. As a part of the future work one such approach is the probabilistic approach; instead of geometric analysis, calculation of probability

[3] http://www.cacheopedia.com/wiki/Estimated_position_error

is done using input data. It would be interesting to see the difference between geometric and probabilistic WiFi AP sequence determination. Part of the future work is a final implementation of this solution; it should be deployed as a web service that can be used in many applications.

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REFERENCES

1. J. G. P. RODRIGUES, A. AGUIAR, F. VIEIRA, J. BARROS, AND J. P. S. CUNHA. 2011. A mobile sensing architecture for massive urban scanning". In: *14th International IEEE Conference on Intelligent Transportation Systems (ITSC)*, pp. 1132-1137.
2. P. DESHPANDE, X. HOU, and S. R. DAS. 2010. Performance comparison of 3G and metro-scale WiFi for vehicular network access. In *Proceedings of the 10th annual conference on Internet measurement - IMC '10*, p. 301.
3. H.-S. PARK, S.-H. HAN, AND J.-D. KIM. 2009. Vehicular client roaming and location-based handoff through multiple WLAN APs in a container terminal. In: *Proceedings of the 2009 International Conference on Hybrid Information Technology - ICHIT '09*, pp. 465-472.
4. A. BALASUBRAMANIAN, R. MAHAJAN, and A. VENKATARAMANI. 2010. Augmenting mobile 3G using WiFi. In: *Proceedings of the 8th international conference on Mobile systems, applications, and services - MobiSys '10*, p. 209.
5. N. RISTANOVIC, J.-Y. LE BOUDEC, A. CHAINTREAU, and V. ERRAMILLI. 2011. Energy Efficient Offloading of 3G Networks. In: *2011 IEEE Eighth International Conference on Mobile Ad-Hoc and Sensor Systems*, pp. 202-211.
6. A. BALASUBRAMANIAN, R. MAHAJAN, A. VENKATARAMANI, B. N. LEVINE, and J. ZAHORJAN. 2008. Interactive wifi connectivity for moving vehicles. *ACM SIGCOMM Computer Communication Review*, **38**, p. 427.
7. A. GIANNOULIS, M. FIORE, and E. KNIGHTLY. 2008. Supporting vehicular mobility in urban multi-hop wireless networks. In: … *international conference on Mobile . . . .*
8. P. DESHPANDE, A. KASHYAP, C. SUNG, AND S. R. DAS. 2009. Predictive methods for improved vehicular WiFi access. In *Proceedings of the 7th international conference on Mobile systems, applications, and services - Mobisys '09*, p. 263.

ENVIRONMENTAL AND SAFETY ENGINEERING

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2013 Special Number

APPLICATION OF FTIR-ATR SPECTROSCOPY FOR DETERMINATION OF GLUCOSE IN HYDROLYSATES OF SELECTED STARCHES

Alica BARTOŠOVÁ, Maroš SOLDÁN, Maroš SIROTIAK,
Lenka BLINOVÁ, Anna MICHALIKOVÁ

ABSTRACT

Fourier transform infrared spectroscopy was evaluated as an easy and simple analytical method for determination of starch residues after enzymatic hydrolysis. Different starch sources were liquefaction by α-amylase enzyme Termamyl SC for 25 minutes in autoclave. In the next step were starches solutions enzymatically hydrolysed by enzyme pollulanase Promozyme® for 24 hours to 60°C water bath. Total glucose in starch hydrolysate was determined using Fourier Transformed Infrared Spectroscopy (FTIR) with ATR accessory with diamante crystal by recording the absorption of different carbohydrate in spectral range from 700 – 4000 cm^{-1}. Based on calibration curves of glucose the release of total glucose in hydrolysates was calculated.

KEY WORDS

starch, enzymatic hydrolyse, sugars, FTIR-ATR

INTRODUCTION

Biomass has become an alternative source for production of fuels because it is renewable and could reduce greenhouse gas emissions by replacing petroleum sources. Bioethanol as a biofuel is produced from sugar, starch or lignocellulose biomass. Current research has been focused on using starch biomass. In pre-treatment process starches are enzymatic hydrolysed to sugars and in next step are these sugars converted to ethanol.

The aim of this paper was to determinate sugars in hydrolysates of potato, corn and rice starches. These starches were enzymatic hydrolysed by α-amylase enzyme Termamyl used for liquefaction of starches and by enzyme pollulanase Promozyme® used for saccharification of starches solutions. The hydrolysis of corn starch may be considered as a first and key step in corn processing for bioethanol production. The main role of this step is to effectively provide the conversion of two major starch polymer components: amylose, a mostly linear a-D-(1–4)-

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glucan and branched amylopectin, a α-D-(1–4)-glucan, which has α-D-(1–6) linkages at the branch points, to fermentable sugars that could subsequently be converted to ethanol by yeasts or bacteria. Recent advances in the developing of termostable α-amylases, the starch liquefying enzymes which catalyse the hydrolysis of internal α-D-(1–4)-glucosidic linkages in starch in a random manner (1, 2) and effective glucoamylases (3, 4), the starch saccharifying enzymes which catalyse the hydrolysis of α-D-(1–4) and α-D-(1–6)-glucosidic bonds of starch from the non-reducing ends giving glucose as the final product, have led to commercial establishment of the so called 'two enzyme cold process'.

PRINCIPLES OF FTIR-ATR SPECTROSCOPY

Attenuated total reflection (ATR) has grown into the most widely practiced technique in infrared spectrometry. The reasons for this are fairly straightforward: the technique requires little or no sample preparation, and consistent results can be obtained with relatively little care or expertise. ATR is a technique whereby the sample is placed in contact with a sensing element, and a spectrum is recorded as a result of that contact. Unlike many other sampling techniques used in infrared spectrometry, radiation is not transmitted though the sample; consequently, the sample does not have to be thin enough to allow transmission of the incident radiation, with no band having an absorbance greater than 2.0 AU (5). When radiation passes from one transparent medium to another and the two media have different refractive indices, the angle at which the radiation is described by Snell´s low; that is,

$$n_1 sin\theta_1 = n_{21} sin\theta_2$$

where n_1 and n_2 are the refractive indices of the two transparent media, and θ_1 and θ_2 are, respectively, the angle of incidence and refraction with respect to the normal to the interface (5).

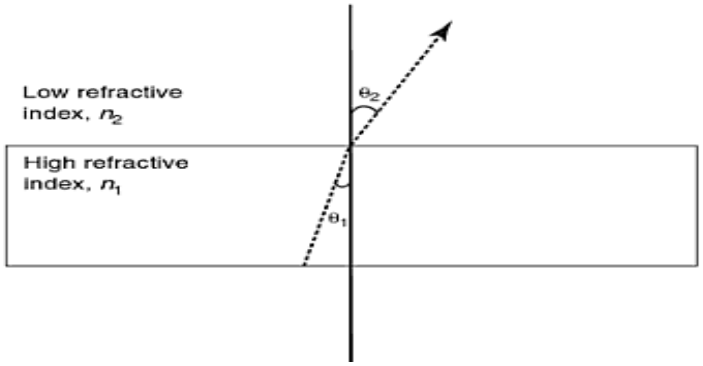

Fig. 1 *Shell´s law where the beam originates in the optically dense medium of refractive index n_1 and travels to the optically rare medium of refractive index n_2. The angles are measured with respect to the normal to the surface (5)*

MATERIAL AND METHODS

Samples of starches and enzymes

There are three samples of starch: corn starch and potato starch (Dr. Oetker) were obtained from a local grocery shop rice starch was earned from milling rice.

Termamyl 120L, a heat-stable α-amylase from *Bacillus licheniformiswas* used for corn meal liquefaction. Promozyme® is heat-stable debranching enzyme obtained from a selected

strain of Bacillus acidopullulyticus, and belongs to the group of debranching enzymes known as pullulanases. The enzymes were gift from Novozymes, Denmark.

Enzymatic hydrolyse

Solutions of starch were prepared; 15 g of each kind of starch were dissoluble in 50 mL of distilled water and adjusted by acetate buffer to pH 5.3 (2 mol/L CH_3COOH, 0.2 mol/L $C_3H_3O_2Na$). In the first step was adding 3 mL of α-amylase enzyme Termamyl for liquefaction in autoclave in temperature 119 °C for 10 minutes. After that, another 3 mL of enzyme Termamyl were add, solutions were autoclaved in temperature 119 for 8 minutes and bring to room temperature. After cooling down, in the second step, solutions were adjusted by acetate buffer to pH 4.2 and 7.5 mL (6) of enzyme pollulanase Promozyme® were added. Process of saccharification was taken 24 hours in temperature 60 °C in water bath. The spectra were recorded using a Varian Resolutions Pro and samples of starches were measured in the region 4000-700 cm^{-1}; each spectrum was measured 40 times. Resulting spectra of hydrolysates were corrected for background buffer absorbance.

Determination of infrared spectra by FTIR-ATR

Identification of starches and their hydrolysates were performed using an Infrared Fourier Transform Spectroscopy with ATR technique - Attenuated Total Reflectance (Varian 660 Dual MidIR MCT / DTGS Bundle) (Fig.2). Samples were directly applied to a diamante crystal of ATR and resulting spectra of them were corrected for background air absorbance. The spectra were recorded using a Varian Resolutions Pro and samples of starches were measured in the region 4000-700 cm^{-1}; each spectrum was measured 40 times.

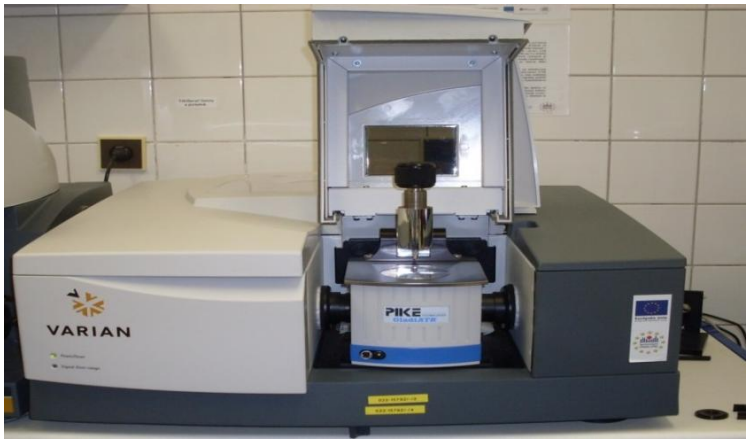

Fig. 2 *Infrared spectrometer Varian 660 MidIR Dual MCT/DTGS Bundle with ATR*

RESULTS

Determination of starches

In Fig. 3 are showed IR spectra of three samples of starches. The IR spectra obtained from native potato spectra showed at 1149 cm^{-1} C-O, C-C stretching with some C-OH contributions; 1076, 1077, 1049, 998, 991 , and 925 cm^{-1} (COH bending and CH_2-related modes) and 854,855, and 843 cm^{-1} (C-O-C symmetrical stretching and C-H deformation). A band near 946 cm^{-1} is interpreted as a skeletal mode indicating the α-1,4linkage of glucose molecules in starch amylose. The absorption band 855 cm^{-1} formerly identified in potato.

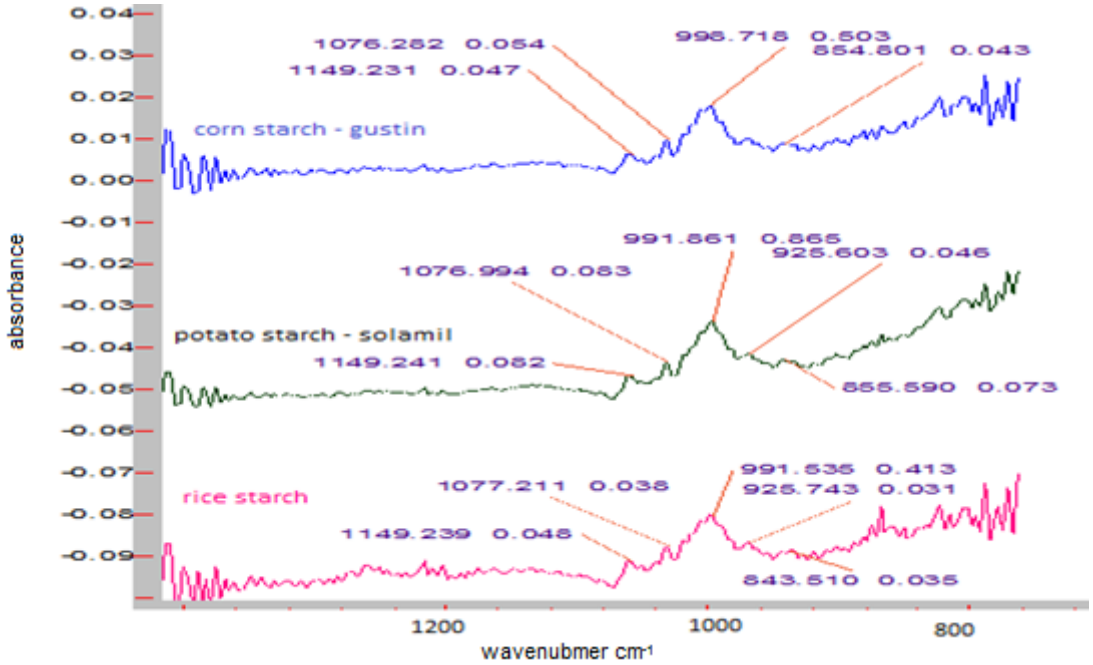

Fig. 3 *Spectrum of corn, potato and rice starch*

Determination of starch/glucose

The aim was hydrolysed starch to glucose and then quantitatively determined it by a calibration curve prepared from aqueous solutions of D-glucose pa concentrations of 2.5%, 5.0% 7.5% 10.0% 12.5%,15.0% 17.5%, 20.0%, 22.5% and 25%.

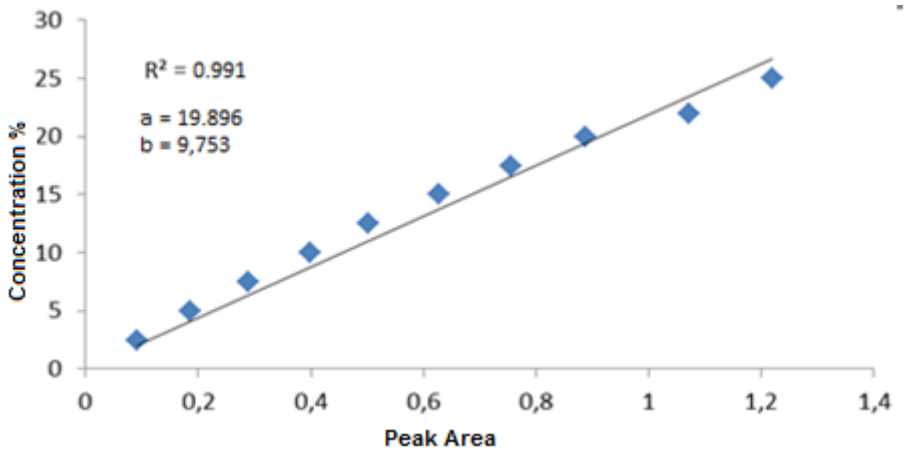

Fig. 4 *Concentration curve of glucose*

Calibration curve represents the dependence of the peak area on the concentration of glucose (Fig.4). Each sample was measured on an IR spectrophotometer of 4000-700 cm^{-1} and each spectrum was measured 40 times.

As can be seen in Fig. 5 the FTIR spectra of starch hydrolysates are well defined. There are showed intense fingerprint bands in the wavenumber range 1150-900 cm^{-1}. In this region, the specific absorption for each carbohydrate was identified. The characteristic bands of glucose have specific maxima at 1150, 1106, 1076 cm^{-1}, and the peak at 1029 cm^{-1} having the highest absorption. The most intense peak of glucose (1033 cm^{-1}) is characteristic to the C-O stretch vibration.

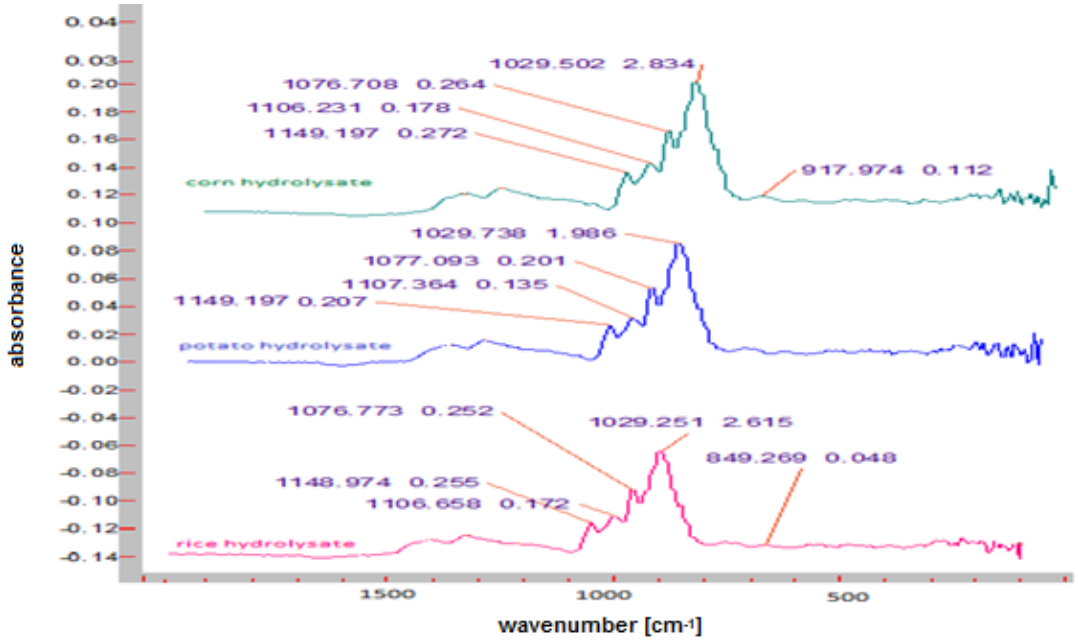

Fig. 5 *Spectra of corn, potato and rice hydrolysates*

PEAK AREAS OF STARCH HYDROLYSATES AND CONCENTRATION OF THEIR GLUCOSE Table 1

	Peak area	Concentration of glucose (%)
Potato starch$_{(n=3)}$	1.0565	22.78
Corn starch $_{(n=3)}$	0.9315	20.29
Rice starch$_{(n=3)}$	0.7315	16.31

Determination of concentration of glucose after enzymatic hydrolyse of starches was calculated from calibration curve conforms to equation in the form

$$c = 19.896 \times Peak\ area + 1.153.$$

Concentration of glucose of potato hydrolysate was 22.8%, corn hydrolysate was 20.29% and finally concentration in rice hydrolysate was 16.31%.

In Fig. 6 can by seen simple prove of hydrolyses of starch to glucose. Reaction of starch with Lugol´s iodine reagent yields a blue-black colour. A negative test is the brown-yellow colour. It means there are no more starches after enzymatic hydrolysates in these samples.

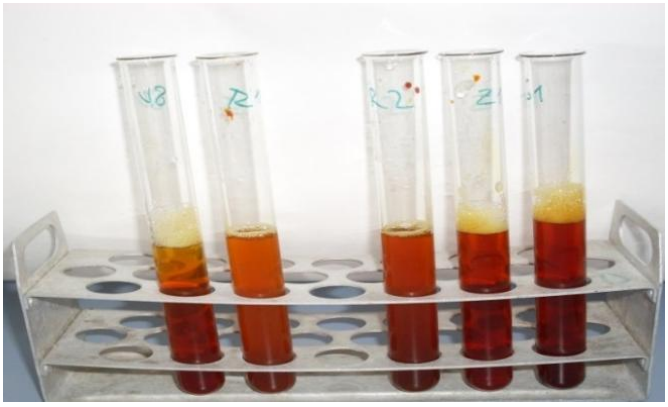

Fig. 6 *Lugol´s test of starches*

CONCLUSIONS

In this paper the FTIR spectroscopy as a non-destructive tool and useful method to determine glucose after hydrolyses of starch was applied. The time of FTIR analysis is considerably reduced compared to the classical methods. These results are promising and have a real analytical potential to supervise in routine procedure for determination sugars in natural carbohydrate polymers.

ACKNOWLEDGMENT

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REFERENCES

1. KONSOULA, Z., LIAKOPOULOU-KYRIAKIDES, M. 2004. Hydrolysis of starches by the action of ana-amylase fromBacillus subtilis. Process Biochem, 39: 1745–9.
2. HENKE, J.M., KLEPPER, G, SHMITZ, N. 2005. Tax exemption for biofuels in Germany: is bio-ethanol really an option for climate policy? Energy 2005; 30:2617–35.
3. TANRISEVEN, A., ULUDAG, Y.B., DOGAN, S. 2002. A novel method for the immobilization of glucoamylase to produce glucose from maltodextrin.Enzyme Microb Technol 30:406–9.
4. KEARSLEV, M. W., DZIEDZIC, S.Z. 1995. Starch Hydrolysis Products and Their Derivatives. Netherlands, Kluwer Academic / Plenum Publishers. ISBN:0751402699
5. GRIFFITHS, P.R. HASETH, J.A. *Fourier Transform Infrared Spectrometry*. Second Edition. Canada, Wiley. ISBN 978-0-471-19404-0
6. QUIGLEY, T.A., KELLY, C.T., DOYLE, E.M., FOAGARTY, F.M. Patterns of raw starch digestion by the glucoamylase of Cladosporium gossypiicolaATCC38026. Process Biochem 998;35:677–81.

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2013 Special Number

IGNITION TEMPERATURE OF DUST LAYER AND DUST CLOUDS OF WOOD PELLETS

Jozef HORVÁTH, Karol BALOG

ABSTRACT

In the production, transport, storage and use of wood pellets forming a flammable and explosive dust. To assess the fire risk of wood pellets was determined ignition temperature of dust layers and dust clouds. We used two commercially produced pellets from wood waste and wood and studied the dependence of ignition temperature on the thickness of dust layer and also observed the ignition temperature dependence of dust clouds from the weight and pressure of air in combustion chamber.

KEY WORDS

wood pellets, dust layer, dust clouds, ignition temperature

INTRODUCTION

The pellet is a circular shape with the diameter 6-8 mm and length 30 to 40 mm. It consists of biomass (wood, wood waste, sawdust, hay, straw) with-out chemical additives. The calorific value of wood pellets is from 18 to 19 MJ.kg (1). The production of pellets is used for the most of the mass in the form of wood sawdust with a minimum of wood dust, which deteriorates the strength of pellets. The moisture contents is nearly 10%. Biomass for production of wood pellets are dried and then compressed into form. The natural extractives and lignin found within the wood hold the pellets together. The process of making pellets is stamping so-called pelletization (1, 3, 6).

METHODS

Determination of the minimum ignition temperatures of dust layer and dust clouds is carried out according to STN EN 50281-2-1:2002 Electrical apparatuses for use in the presence of combustible dust. Part 2-1: Test methods - Methods for determining the minimum ignition temperatures of dust. To determine the ignition temperature of dust, we used powder samples with a diameter less than 500μm, and was prepared by sieve analysis.

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Fig. 1 *Sample B – pellets made of softwood with bark, Sample C – pellets made of softwood*

Preparation of samples of dust from wood pellets

Dust samples were prepared by grinding the pellets in a blender (Fig. 1). Dust sample B - pellets made of softwood with bark, Dust sample C - pellets made of softwood (Fig. 2).

Fig. 2 *Samples of dust from wood pellets*

For determining the minimum ignition temperature of dust clouds and dust layer by use of sieving machine, we obtain fractions of less than 500μm. Dust samples are stabilized before analysis in a desiccator for 24 hours at 24 °C and humidity 33% (5). The results of the analysis of samples are shown in Tab. 1.

THE PERCENTAGE FRACTIONS SIEVING DUST SAMPLES

Table 1

Sieve size (μm)	**Percentage by weight (%)**	
	Sample B	**Sample C**
> 500 μm	56,98	39,51
500 μm	24,98	27,5
250 μm	3,72	5,88
200 μm	4,42	7,37
150 μm	5,05	8,94
90 μm	1,65	2,2
< 71 μm	3,76	8,11
The losses	0,45	0,49

DETERMINATION OF THE MINIMUM IGNITION TEMPERATURE OF DUST LAYER

Determination of the minimum ignition temperatures of dust layer is carried out according to EN 50281-2-1:2002: Methods for determining the minimum ignition

temperatures of dust (Method A). It shall be considered that ignition of a dust layer has taken place when glowing and/or flaming burning observed or the measured temperature has achieved the value 450 °C or the measured temperature has exceeded by 250 °C the temperature of the heating plate (2, 4, 5). To determine the ignition temperature of dust layer samples were used with a particle size smaller than 500μm. The results of determining the minimum ignition temperature of dust layer from wood pellets are given in Tab. 2 and on Fig. 3 is the time-history of ignition of dust layer.

MINIMUM IGNITION TEMPERATURE OF DUST LAYER SAMPLE ACCORDING TO STN EN 50281-2-1:2002 Table 2

Sample of dust	**Ignition temperature (°C)**	
	Thickness of the dust layer 5 mm	**Thickness of the dust layer 12 mm**
B	340	310
C	350	310

			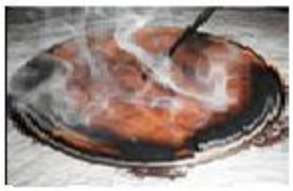
5 minutes	8 minutes	12 minutes	16 minutes
The location of the samples on a hot surface	Temperature increases on the sample surface	Smoldering on the sample surface and subsequent ignition	Smouldering and glowing of sample

Fig. 3 *Ignition time-history of dust layer when tested according to EN 50281-2-1:2002 on electrically heated plate*

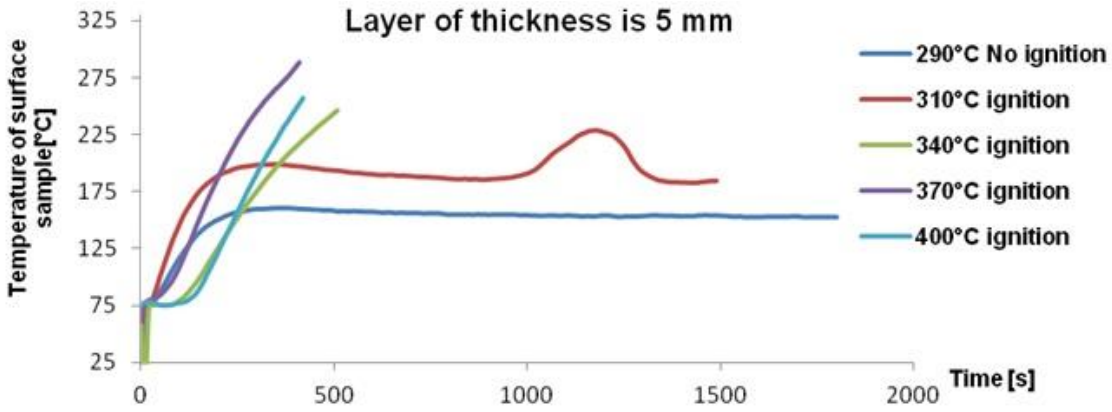

Fig. 4 *Temperature dependence of the surface dust samples from the time of exposure to hot surface (sample B)*

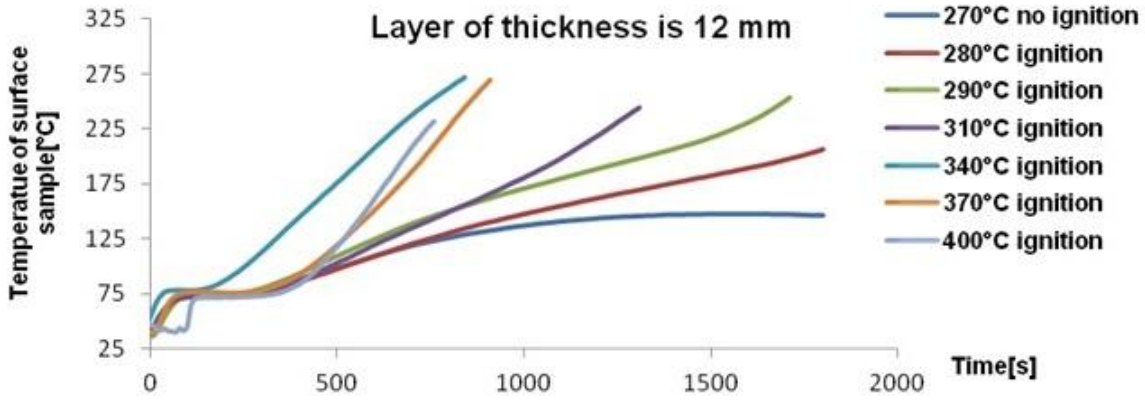

Fig. 5 *Temperature dependence of the surface dust samples from the time of exposure to hot surface (sample B)*

DETERMINATION OF THE MINIMUM IGNITION TEMPERATURE OF DUST CLOUDS

Determination of the minimum ignition temperatures of dust clouds is carried out according to EN 50281-2-1:2002: Methods for determining the minimum ignitio temperatures of dust. Method B: Dust clouds in the oven at a constant temperature (2, 5). For determining the ignition temperature of dust clouds according to the weight of the sample was used a different mass of dust (0.1 g - 0.5 g). We also observed the ignition temperature dependence of dust clouds from the pressure of air in combustion chamber (10 kPa - 50 kPa). The results of determining the minimum ignition temperature of dust cloud from wood pellets are given in Tab. 4 and Tab. 5. and on Fig. 6 is the time-history of ignition of dust cloud.

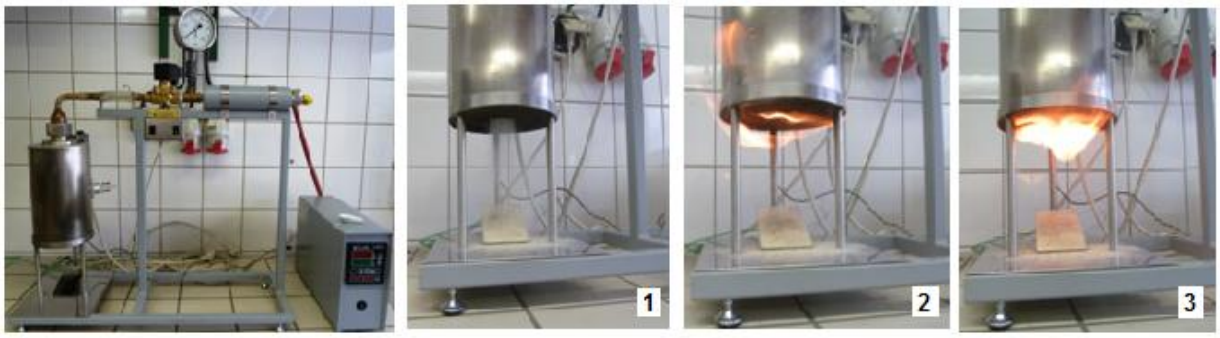

Fig. 6 *Ignition time-history of dust clouds when tested according to EN 50281-2-1:2002*

MINIMUM IGNITION TEMPERATURE OF DUST CLOUDS DEPENDING ON WEIGHT AND THE PRESSURE (SAMPLE B) Table 1

Weight (g)	0,1			0,2			0,3			0,5		
Pressure (kPa)	10	20	50	10	20	50	10	20	50	10	20	50
$\mathbf{t^r_{min}}$ **(°C)**	480	460	440	460	440	440	440	440	440	440	440	440

MINIMUM IGNITION TEMPERATURE OF DUST CLOUDS DEPENDING ON WEIGHT AND THE PRESSURE (SAMPLE C) Table 2

Weight (g)	0,1			0,2			0,3			0,5		
Pressure (kPa)	10	20	50	10	20	50	10	20	50	10	20	50
t^{r}_{min} (°C)	480	440	440	460	440	440	460	440	440	480	440	440

CONCLUSIONS

Forming dust from wood pellets during production, transport and use can create an explosive atmosphere. To develop preventive fire protection measures need to know ignition sources of ignition and established the dust clouds. Determination of ignition temperature of dust pellet is important to assess the fire hazard. Ignition temperature of the deposit dust significantly affects the thickness of the dust. It has been found that with an increase of thickness of dust layer ignition temperatures are reduced. The ignition temperature of dust clouds significantly affects moisture and particle size of the wood dust.

ACKNOWLEDGMENT

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REFERENCES

1. MALAŤÁK, J., VACULIK, P. 2008. *Biomass for energy production.* Praha: Powerprint s.r.o. ISBN 978-80-213-1810-6
2. BALOG, K., TUREKOVA, I. 2008. *Fire hazard of food dust*. Ostrava: SPBI Spektrum, 2008. ISSN: 1211-6920
3. OLLSON, M. Wood pellets as low-emitting residential biofuel. Göteborg: Sweden, (online) 2002. (cit. 2013-03-1) Available at: http://publications. lib.chalmers.se/ records/fulltext/5787.pdf
4. STN EN 50281-2-1 Electrical apparatus for use in the presence of combustible dust, Part 2-1: Test Methods. Methods for determining the minimum ignition temperatures of dust.
5. KASALOVÁ, I. 2009. The fire-technical characteristic assessment of food dust. Trnava, ISSN: 978-80-8096-080-3
6. BLOM, G. The Feasibility of a Wood Pellet Plant Using Alternate Sources of Wood Fibre. (online) 2009. (cit.2012-03-1) Available at: https://circle.ubc.ca/bitstream/handle/2429/16890/BlomGarrett_WOOD_493_Graduating_Essay_2008.pdf?sequence=1.

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2013 Special Number

MINIMUM IGNITION TEMPERATURE OF WOOD DUST LAYERS

Martin PASTIER, Ivana TUREKOVÁ, Zuzana TURŇOVÁ,
Jozef HARANGOZÓ

ABSTRACT

Fire characteristic (properties) are used to determine the fire risk and explosion hazard of materials. They are defined as numerical values which describe behavior in the process of burning. They can be determinate by standardized test methods. In this paper is described the most important fire technical characteristic of dust layer (minimum ignition temperature) and the results of standard laboratory method determination for wood dusts, aswell.

KEY WORDS

wood dusts, fire characteristic, minimum ignition temperature, dust layer

INTRODUCTION

Fires and dust explosions are one of the biggest threats in many industries where dust layers and/or clouds forms during technology processes, which are capable of ignition (1). Due to the wide application of wood and wood based materials is just wood dust one of the most common industrial dusts (2).

An accumulated combustible dust layer on some hot process equipment such as dryers or hot bearings can be ignited and result in fires when the hot surface temperature is sufficiently high. Hot surface ignition temperatures of dust layers refer the minimum surface temperatures which can ignite a certain thickness of dust layers. For layer thickness found that the thicker the layer is, the lower the ignition temperature is. As a dust layer thickness increases, the temperature gradient in the dust layer becomes smaller, which reduces the conduction rate consequently. This results in the local temperature increases, exothermic reaction, and ignition at lower temperature of hot plate. About the particle size, the more complete oxidation occurred in smaller particle until a certain critical size. If the particle size is much bigger, surface area and rated combustion are too small to overcome the rate of heat dissipation. The dust layer depth is the most important factor affecting the ignition temperature and particle size is not important and packing density affected the ignition temperatures of only thin layers (3).

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When a dust layer is positioned on a hot plate a heat transport occurs from the plate surface, through the layer up to its opposite surface where the heat energy is dissipated to the environment. The heat flux causes temperature rise in the layer and starts a chemical reaction in the dust that in turn leads to further increase of temperature inside the layer. The rate of the chemical reaction also depends on temperature. Therefore, if the temperature inside the layer reaches a certain critical value the rate of heat transfer to the surrounding air will be too low to compensate the rate of heat production in the chemical reaction. As a result an ignition of the dust layer occurs (4).

MATERIAL AND METHODS

Three samples of wood dust resulting from the manufacture of wood and wood based materials in wood workshop were tested. The samples consist of particles of different sizes resulting from the cutting of material. A sample of material particles are formed when cutting particleboard and fibreboard on the saw. Sample B was collected from the forming saw where the raw slabs from the poplar, spruce, alder and ash tree are processed. Sample C consists of particles that arise when cutting chipboard. Before setting a minimum ignition temperatures sieve analysis was performed. Size distribution of dust samples is shown in Figure 1.

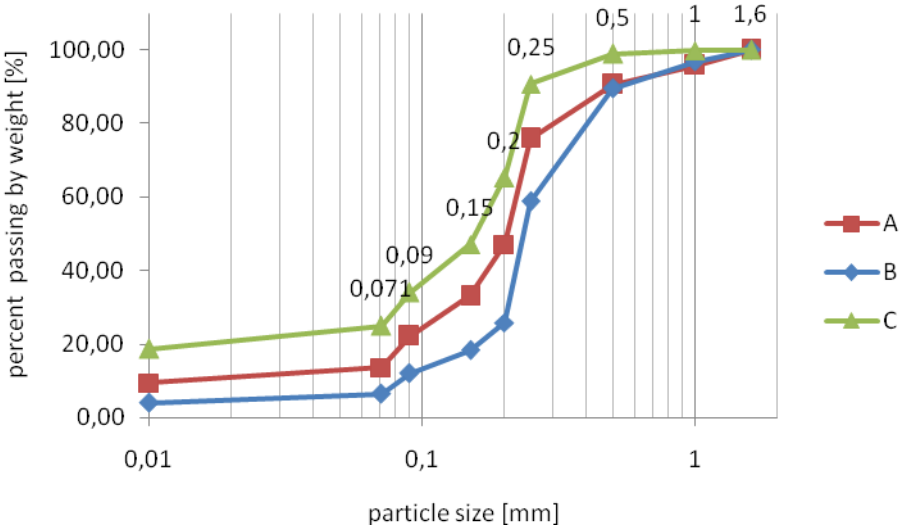

Fig. 1 *Size distribution of dust samples*

In all cases, the the dust consists of approximately 90% of particles finer than 0.5 mm. For determining the minimum ignition temperature of dust layers were all samles sieved through a sieve. The mesh size of the sieve was 0.5 mm. Particles larger than 0,5 mm were removed from the samples of dust.

The minimum ignition temperature was determined on an electrically plate 185 mm in diameter according to STN EN 50281-2-1: 2002 Electrical apparatus for use in the presence of combustible dust. Part 2-1: Test methods. Methods for determining the minimum ignition temperatures of dust. This standard define minimum temperature for ignition of a dust layer as a minimum temperature of a hot surface by which can arise an ignition of a dust layer with a setting thickness located on that hot surface.

According to STN EN 50281-2-1:2002 as an ignition of dust layer is considered the case when arises smouldering or creating of flames in the material or a measured temperature is

450°C or higher by a test or can be warmer in 250 K or in higher above the temperature is set for a hot surface. It characterise a dust according to its ability to ignite in the layer by a heat stress by a hot environment or with a contact with a hot surface (5).

RESULTS AND DISCUSSION

Test samples were dried and undried and tested in two heights layer for 5 mm and 12.5 mm. Samples were dried 12 hours at 103 °C. The measured humidity values are shown in Table 1.

THE MEASURED HUMIDITY VALUES OF DUST SAMPLES

Table 1

Sample	Humidity (weight %)
A	4,7
B	5
C	3,2

Behaviour of the sample during the measurement showed the fact that smouldering and flowingly ignition was visible mainly by edges of the circle. The sample was thermally forced by a metal circle and therefore has a better conductivity than an individual dust sample and the heat were spread more quickly. A dust layer forced to heat carbonated, after volume decreasing it was realized a separation of the sample from the circle edges. This enables an oxygen input into this zone and it was followed by a sample ignition. The behaviour of dust sample during the measurement is shown in Figure 2.

Fig. 2 *Carbonization of dust sample during the testing*

From the setting of minimum ignition temperatures of the tested dusts were defined minimum temperatures of hot surfaces, where is a probability of ignition of 5 mm dust layer. There were observed the conditions of initiation process of burning by a different dust layer thickness located on the warming surface. The behaviour of undried and dried samples of dust was also monitored. The aim was to set the influence of the thickness of the layer on the result value of the minimum ignition temperature. There were compared values of minimum ignition temperatures of the wooden dusts in the layers 5 mm and 12.5 mm. In Table 2 are shown the results from the measurement of minimum ignition temperature of organic dust layers.

RESULTS FROM TESTING OF MINIMUM IGNITION TEMPERATURE OF WOOD DUST LAYERS

Table 2

	Undried		Dried	
Layer	5 mm	12.5 mm	5 mm	12.5 mm
Sample	Minimum ignition temperature (°C)			
A	350	300	340	300
B	330	300	330	300
C	340	300	340	300

The highest minimum ignition temperature at 5 mm layer was determined for sample A in undried state. The lowest minimum ignition temperature was determined for the sample B in the dried and undried state. Figure 3 shows the course of temperatures of dried and undried sample B at 300 °C of heated surface and this temperature was determined as minimum ignition temperature.

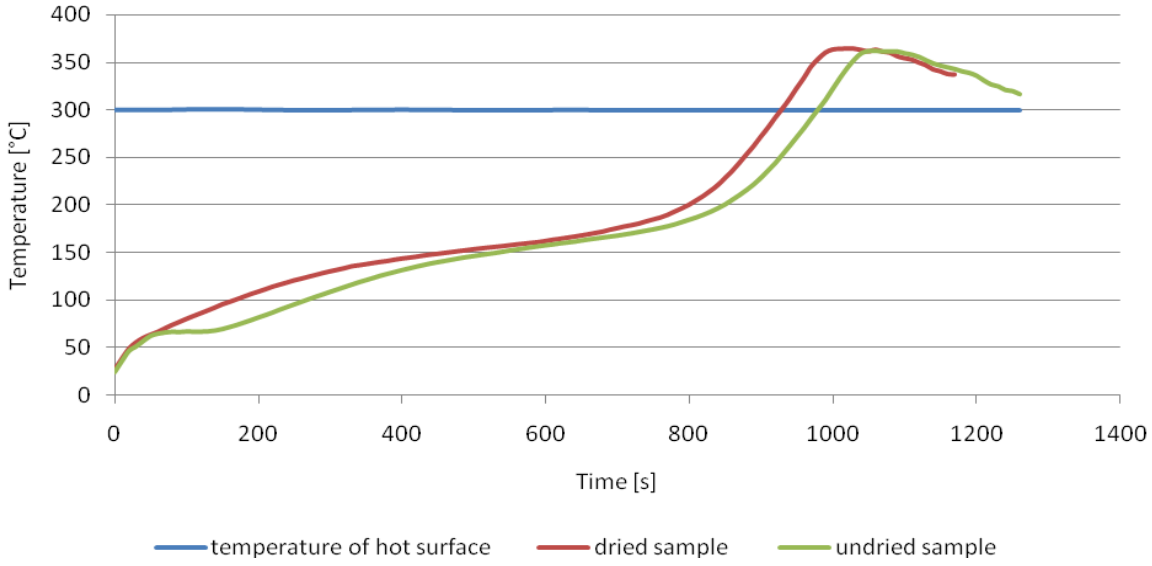

Fig. 3 *The course of temperatures of dried and undried sample B*

From the record of temperatures can be seen the difference between the initiations of dried and undried samples. The minimum ignition temperature was determined equally to 300 ºC. The only difference is the time required to initiation. The temperature increase of undried samples stopped at approximately 70 °C and after 1 minute the temperature increase continued. This holding is caused by evaporation of humidity from the sample. Similar course of temperature was recorded for samples A and C in both layers 5 and 12.5 mm.

CONCLUSION

Regulations concerning safety rules for usage of electric power equipment installed in conditions where flammable dusts are present require that the surface temperature of those machines should not exceed 2/3 of the minimum ignition temperature of the dust cloud, and as regards dusts that create a layer – the temperature on surfaces of various types of equipment has to be at least lower by 75 K than the minimum temperature of the dust layer.

Analysing the minimal ignition temperature on hot plate depends on the thickness of the dust layer. Whenever this temperature was measured for the 12.5 mm layer, minimum ignition temperature was average lower by 50 - 30 °C than the temperature for 5 mm layer of dust. Another important factor is the time to ignition, which depends on the humidity of dust. Humidity of dust samples to 5% prolong time ignition about a minute. Comparing results one can say that ignition temperatures of wood dusts sample differ only slightly from each. The maximum temperature of appliance and machinery in wood workshop should not be higher than 225 °C for the 12.5 mm dust layer. Analysis of minimum ignition temperatures depending on the humidity does not indicate significant changes in minimum ignition temperature, higher moisture content only delays the time to ignition.

The most frequent reason for the aerosol explosion is an initiation from the hot dust layer. From this reason it is important to know a minimum temperature for a dust layer ignition. The ignition of a dust layer is one of the important characteristics of the dust materials. Setting of the lowest temperature for ignition can define the danger grade of ignition of the dust layers.

ACKNOWLEDGMENT

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REFERENCES

1. POLKA, M., SALAMONOWICZ, Z., WOLINSKI, M., KUKFISZ, B. 2012, Experimental analysis of minimal ignition temperatures of a dust layer and clouds on a heated surface of selected flammable dusts. In: *Procedia Engineering*, 45, p. 414 – 423, ISSN: 1877-7058
2. BLAIR, A., S. 2007. Dust explosion incidents and regulations in the United States. In: *Loss Prevent. Process Ind*., 20, p. 523–529. ISSN: 0950-4230
3. ZALOSH, R., G. 2003. *Industrial Fire Protection Engineering*. Wiley, p. 132, ISBN: 978-0471496779
4. DYDUCH, Z., MAJCHER, B. 2006. Ignition of a dust layer by a constant heat flux-heat transport in the layer. *Journal of Loss Prevention in the Process Industries*, 19, p. 233–237. ISSN: 0950-4230
5. SLABÁ, I., TUREKOVÁ, I. 2012. *Smouldering and Flaming Combustion of Dust Layer on Hot Surface.* Dresden: Scientific Monographs, 88 p. ISBN 978-3-9808314-5-1

INDUSTRIAL MANAGEMENT AND QUALITY ENGINEERING

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USING COMPETENCY MODELS IN INDUSTRIAL ENTERPRISES

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ABSTRACT

The paper focuses on using competency models in industrial enterprises. This article deals with the theory of competencies, competency models and their utilization. Competency models are a key tool in human resource systems and practice. Managerial competencies enable employees to achieve results, thereby creating value. It follows that managerial competencies aligned with business objectives help foster an organization's success. Organizations must understand their core competency needs - the skills, knowledge, behaviors, and abilities that are necessary for people in key roles to deliver business results. The ability to identify the skills and competencies required for tomorrow's industry leaders is essential for companies that hope to remain competitive. Identifying appropriate competencies helps senior managers in selecting, developing, and coaching future leaders, as well as mapping career paths and planning management succession.

KEY WORDS

managerial competence, competency models and hypotheses

INTRODUCTION

Today managerial competencies play an important role in different types of organizations. The aim of enterprises is to constantly improve the performance of their employees. Competencies can detect the differences between mediocre and outstanding managers. The potential power of an organization is to possess excellent or above-average employees, through the elimination of average employees with continual education and the development of their personality (1). Although, there are many theoretical concepts, the introduction of a competency approach is not a simple process. To begin with it constitutes a change, aiming to improve performance across the organization.

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DEFINITION OF MANAGERIAL COMPETENCIES

The publication of D. C. McClelland's article instigated a large number of studies, concerned with the definition of a managerial competence. It also created many competency models. Among the different authors, however, there is still no consensus as to what managerial competence is and what constitutes managerial competence (2). At present there is no agreement in the understanding of this concept among the experts in the field of management competencies. The problem is the discrepancy in the explanation of what the competence entails and what not. Very often the concept of managerial competence is linked to a profession or to a work activity. Moreover, the meaning of the term itself refers to the power to take decisions and this entails responsibility for the consequences stemming from these decisions (3).

CH. Woodruff best defines this problem in his article 'What is meant by a competency' when he claims that the *managerial competence* is used as an umbrella under which everything fits, that may directly or indirectly relate to the job performance. He defines it as "a set of employee's qualities that must be used for the position and within these qualities the tasks arising from the position should be competently mastered". According to him the competent managers should simultaneously fulfil three basic conditions to accomplish their tasks. And these are:

- to possess the knowledge, skills and abilities, which are required for this position,
- to be motivated to perform this position and to be willing to spend the necessary energy,
- to have the ability to use these qualities in business environments (2).

The authors of this article argue that the ***managerial competence*** presupposes *an ability that effectively enhances the qualities of the manager and that results in an above-average performance on the part of the manager*.

COMPETENCY MODELS

A competency model is a descriptive tool that identifies the knowledge, skills, abilities, and behavior needed to perform effectively in an organization. Designed to help an organization meet its strategic objectives through building human-resources capability, competency modeling has been in existence since the 1970s, starting with the first models created by David McClelland (2).

Competency models focus on behavior rather than on personality traits, because personality traits are usually hard to measure accurately. Expressing desirable traits in behavioral terms is essential for a competency model to be useful as a human-resources tool, because the model must not only define the competencies necessary for effective performance but also indicate how to tell when a particular competency is being demonstrated. Most competency models express traits and characteristics in behavioral terms on the grounds that behavior is the observable manifestation of personality traits and characteristics. Competencies are deemed critical for inclusion in a model when they distinguish superior performers from poor performers.

Competency models are less specific than is the job analysis typically performed for specific positions, and models can encompass a whole family of jobs.

Using Competency Models

Competency models provide a common language for discussing capabilities and performance. The development of a competency model can help provide guidance for a host of different HR practices and ensure that those practices are consistent. Specifically, competency models can be used as a foundation from which to establish criteria for a broad array of HR systems. For instance, listed below are eight HR activities that can be guided or enhanced with the use of a well-developed competency model (4).

Recruitment and selection. Looking beyond skills to performance dimensions such as teamwork, competency models can help to establish what it takes to do well on the job. Armed with this information, companies can focus recruitment on finding the greatest number of prospective employees who have the right mix of competencies for the job in question. The content of appropriate selection instruments (e.g., structured interviews, role plays) can target the key competencies— and, hence, the whole package of needed skills and abilities. Beyond their usefulness in improving selection tools, competency models also provide candidates with a clear and realistic picture of expected behavior.

Training and development. Assessing gaps between existing employee skills and those identified by a competency model can be extremely useful in devising a long-term strategic plan for leadership training and development. Identification of the skills needed to perform effectively makes it easier to ensure that the design and delivery of training are aligned with the organization's objectives. When a competency model is used as the foundation for training objectives, individual leadership gaps can be assessed and a training plan devised to address deficiencies.

Performance appraisals. Performancemanagement systems can be enhanced by a competency model that provides a shared set of expectations regarding what is important and what will be monitored and measured. Competency models help managers to focus performance-appraisal discussions on critical aspects of behavior, thus providing a strategic tool for consistent and meaningful evaluation.

***Coaching, counseling, and mentoring*.** Competency models are often used as the basis for 360-degree feedback, in which a manager receives performance information from all relevant sources (including supervisor, subordinates, self, peers, and customers, if applicable). Coaches and advisers can use the information so gathered to guide the employee in designing a development plan and making critical skill improvements. The clarity and specificity of competency models enable coaches and mentors to reinforce desired behavior and performance-management systems to necessary competencies.

Reward systems. A tremendous percentage of an organization's operating expenses is devoted to employee compensation. To attract, retain, and motivate employees, reward systems must be equitable and linked to desired behavior. Competency models can be extremely useful for defining the behavior that will be rewarded.

Career development. For employees who aspire to reach the next level on a career path, a competency model serves as a map. Competency models make employees aware of the behavior and skills needed to advance and achieve success, allowing them to prepare accordingly.

Succession planning. Competency models can be used to identify possible successors for critical jobs by clarifying the requirements for the job and providing a method for assessing a particular candidate's readiness. Without a clear understanding of the competencies needed by future leaders, it is difficult for a company to measure its "bench strength"— that is, to determine whether the organization has people with those capabilities and, if it does, who they are.

Change management. Organizations can work toward an uncertain future by creating models that are based on competencies that may be necessary for future leaders, as well as competencies needed for current operations.
Competency models confer several advantages on a company. First, a competency model is useful for building an integrated framework for developing a company's human-resources system. Used consistently, such a model should lead to improved and consistent performance standards. More important, the model can be a critical guide during periods of instability and change. Moreover, making HR decisions on the basis of carefully developed competency models reduces legal challenges to those decisions. Finally, well-developed competency models enhance a company's ability to communicate with its employees regarding the behavior connected with success, thereby increasing the firm's ability to achieve its business objectives (4).

OBJECTIVE OF MY DISSERTATION THESIS

Based on the analysis conducted by questionnaire survey in the medium industrial enterprises in Slovakia and theoretical knowledge gained from literature in the area of managerial competencies and competency models, we set the main goal of the dissertation thesis. The main objective of the thesis is to propose a methodology applications competency models in terms of medium-sized industrial enterprises.

In order to achieve main goal the dissertation thesis is necessary to fulfill the partial goals, which are necessary starting to fulfill the main objective

Partial objective

- Make general overview of theoretical knowledge for the issue of managerial competencies and competency models in industrial enterprises, the thesis will contain definitions of several authors dealing with issues of managerial competencies, which different perceptions of this term can not unify its meaning and essence.
- Analyze the current state of creation and application of competency models in terms of medium-sized industrial enterprises in Slovakia using research methods and tools (questionnaire survey, interview, observation and comparison).
- Verify the proposed methodology in the practice of industrial enterprises. Verification will be realized on a sample of medium-sized industrial enterprises. For verification will be used the following methods: a questionnaire survey, observation, interview.

HYPOTHESES

Based on the theoretical knowledge I set in the dissertation thesis the following hypotheses:

1. More than 50% of medium-sized industrial enterprises has not created competency model.

2. More than 50% of medium-sized industrial enterprises which have not created competency models, they plan to prepare for the future.
3. Subsidiaries assume competency models from its parent companies.
4. If a medium-sized industrial enterprise has created competency model, the performance of the managers of the company is higher than the performance of managers working in a business where such have not created competency model.

CONCLUSION

As organizations increasingly focus on human assets as a competitive advantage, they expect higher levels of performance from their employees. We anticipate the use of managerial competencies and competency models in the future as a tool of strategic human resource.

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REFERENCES

1. TREBUŇA, P. 2011. *Riadenie ľudských zdrojov v priemyselnom inžinierstve*. Strojnícka fakulta TU v Košiciach. Košice: Typopress, 2011.
2. KUBEŠ, M., SPILLEROVÁ, D., KURNICKÝ, R. 2004. *Manažerské kompetence: Způsobilosti výjimečných manažerů*. 1. vyd. Praha: Grada Publishing, 184 s. ISBN 80-247-0698-9
3. HOGHOVÁ, K. 2009. Comprehensive Analysis of Organizational Culture – the Basic Condition of its Forming. In: *CO-MAT-TECH 2009, Industrial Engeneering, Management and Quality for 21st century*. Trnava: AlumniPress, p. 119-124. ISBN 978-80-8096-100-8
4. McLAGAN, P. 1996. Great Ideas Revisited: Competency Models, Training and Development, v50 n1 p60-65 Jan 1996.

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CHALLENGES OF MEASURING THE DIRECT EFFECTS OF E-BUSINESS IN SMEs

Igor PIHIR

ABSTRACT

Development of fast Internet and constant growth of new information and communication technology brought to expansion of interconnections between modern companies and their business partners through new kind of business integration so called electronic business (e-business). As the new kind of business connection paradigm has been implemented and started expansion, justification of its use came into the scientific focus. Significant direct and tangible effects of the e-business application have been found and proven in large companies, but in small and medium-sized enterprises (SMEs) these effects have still been the area of exploration. According to latest researches in this field this paper, as a part of dissertation proposal, deals with the issues in the existing methods for e-business direct effects measurement in business processes. This research shows lack of appropriate methods specifically oriented to SMEs. Dissertation proposal is focused on four main problems in measuring future effects of e-business implementation in business processes. The paper emphasizes these issues, whose solution will further lead to new methodology for measuring and assessing direct effects of e-business implementation in SMEs as part of business to business (B2B) communication and the exchange of structured electronic documents in business process cycle, from order to payment.

KEY WORDS

e-business, cost reduction, effects measurement, SME

INTRODUCTION

Implementation and usage of e-business as way of interconnection between business partners through modern information and communication technology (ICT) is on path of growth. Their effects in use are actual topic of many scientific and pragmatic research projects. Challenges of e-business development, growth and future implementation in companies across the world are in focus of strategies in many countries and political and economic associations. For example European Union marks e-business in its strategic initiatives, such as: *The Lisbon Strategy*, also known as the *Lisbon Agenda* (1), *eEurope - An Information Society for All* (2), and other strategic documents and programs such as *A Digital*

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Agenda for Europe 2010 (3) and now the *Europe 2020 strategy* (4). All these strategies have the same goal, expanding of e-business in broader use and bring its benefits into the market. Other countries like Croatia have also developed similar strategies (5) to support more rapid development and implementation of e-business. All these strategies have launched many projects and workshops about e-business like: *CEN Workshop Agreements* (CWA) (6), *European e-Business Lab* (EBL) (7), *Pan-European Public Procurement Online* (PEPPOL) (8) and in period from 2002-2010 *E-Business Watch* (9), whose goals were to make these strategies implemented and monitor their progress. But despite these efforts level of e-business penetration is still low, especially in process automation, which brings benefits from interchange of structural electronic documents and further integration of business processes. The most suitable and most frequent business document, an invoice, could be taken as referent point and its penetration in structural form is at average level below 10% in EU (10). To overcome this problem and to increase the penetration level, scientists and professionals in this field have been investigating main barriers for further implementation of e-business and results show that there are few problems. Generally, but especially for SMEs, there have been non-realistic benefit expectations and lack of knowledge how to make realistic cost-benefit analysis for themselves (11), (12), (13). The main identified benefits from e-business are divided into direct and indirect benefits and tangible and intangible benefits (13), (14), (15). Direct benefits are recognised as increase in efficiency of business processes and they are foundation for measurable analysis of effects in e-business (14), (16), (17), (18). Direct benefits are also tangible which means we can count them and measure them. Indirect benefits are also measurable but the effects from them could be perceived in longer time period which means we could not see them clearly right away. Intangible benefits are not of material kind, but rather qualitative in nature and therefore hard to measure. An example could be an increase in quality level or customer perception which could ultimately lead to growth of sale or similar effects. Methods for measurement of direct benefits of e-business implementation and identified problems in the measurement are focus of this research paper, with aim to identify directions of further research. This article is also a part of proposal for dissertation theme, which is already accepted at University of Zagreb.

MEASUREMENT OF E-BUSINESS EFFECTS

Effects and benefits of any kind are main variable in decision making for management in evaluation process of e-business projects. Sometimes the decision is made by larger business partner and small companies need to adapt to new conditions without objection. But even in that case management needs to know what will be the effect for the company itself and its processes.

Many authors (19), (20), (21) have investigated methods for measurement of business effects and they have used methods such as: *Cost Benefit Analysis* (CBA), *Return on Investments* (ROI), *Internal Rate of Return* (IRR) and *Net Present Value* (NVP). All these methods are well known and have been used in justification of e-business and IT projects, but still, main problem of these methods is the lack of data. Data for these methods are obtained mainly by estimates (19), (20), (21). Mollogon and Raisinghani (20) in their paper show a practical approach to cost benefit analysis of e-business implementation. This approach and methods can be used in further analysis of business processes but only after we have already obtained the data about the processes in which the effects would be visible. For calculation of real costs and benefits of process improvement, researchers Giaglis, Mylonopoulos and Doukidis (22) have proposed modelling of business processes and use of simulation methods to obtain data about cost and time in processes improved by investments in ICT or electronic

data interchange (EDI). The next problem was how to measure real process costs because the estimates are not realistic. As a solution for this problem Peacock and Tanniru (14) and some other authors (17), (16) see an application of accounting methods that are used for allocation of indirect costs. Best known method is *Activity Based Costing* (ABC) described in paper from Cooper and Kaplan (23). Peacock and Tanniru (14) propose this method for justification of IT investments. ABC method allocate, already incurred and jet known costs from accounting records to some *cost trigger* or so called *cost driver*. Recently there has been developed a new method as an improvement to ABC method, so called *Time Driven Activity Based Costing* (TDABC) (24). The new method was based on ABC but the driver or trigger for cost allocation was time spent by the resource on activities in the process. Application of TDABC method is well described on case study example of process improvement by Stouthuysena and authors (25). In measurement of e-business effects the ABC and TDABC methods were used by authors Voutilainen and Pento (17) in electronic invoice implementation and Perego and Salgaro (16) in measurement of cost reduction in *order-to-payment-cycle* or supply chain integration. Application of business process modelling and ABC methods lead to successful calculation of direct and tangible effects of e-business implementation (16), (17), (27). These papers and the study show cost and cost reduction effects in cases of full use of e-business or in cases of no use of e-business at all. There are also scenarios of full or half automation of the processes but the extent of documents interchange is not taken into account.

Problems in this approach, as in professional studies like (26), (27), are in fact that effect are shown as large and mainly in consideration of full electronic way of doing business. The processes in which the e-business is implemented are processes that are supported with new technology and the cost reduction is possible, but it is not possible to do business in fully automated or new way because the implementation of e-business is slow and not all of our business partners would do the business with us in new way instantly. The same studies like Billentis study from year 2011 (26) show that the time needed to excide the level of, for example 60% of electronically processed invoices, could be gained through six to eight years period. See Figure 1 (left). With new method of involvement of business partners this period is lowered to approximately three years and it mainly means to force business partners to e-business or to help them to implement it. See Figure 1. (right).

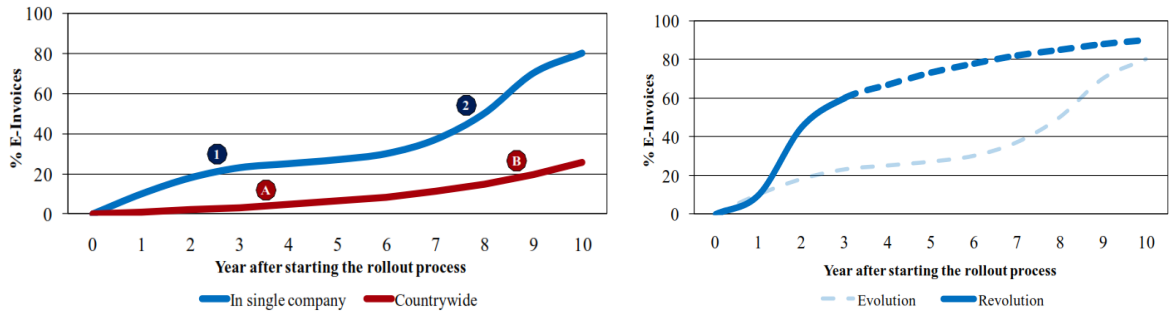

***Fig. 1** E-Invoicing penetration with traditional rollout methods (left) or with improved rollout methods (right)*

This study (26) shows us that penetration of e-business implementation is slow and not all business partners use it. This means that although we implement e-business in our process and we do business through that way with part of our business partners there is still large portion of business partners that do business with us at old fashion way through paper documentation. In perspective of SME the main thing is the parallel running of old and new business processes by which the company is able to reduce some of the costs. Problem is that the cost reduction will not be significant as promised by the studies, because some of cost reductions, mainly in

personnel, would not be possible due to normally small number of employees involved into the whole process in SMEs. Another problem is that in some cases the old process would be more expensive now then it was before, because the common cost would be divided onto smaller number of units (eg. smaller number of invoices was taken to the post office and overall cost of that activity remains the same).

MEASUREMENT OF E-BUSINESS EFFECT IN SMEs

SMEs are substantially different from large ones. The processes are in some way simpler but the logic is the same. What differentiates them substantially is the lower capital strength to make the change in there processes and small number of employees with knowledge that is needed for complex analysis. Harland and authors (11) made a longitudinal study in four years period to research differences between SMEs and large companies in implementation of e-business through supply chain. Authors found that the main barriers to implement the new way of doing business are lack of strategy for e-business implementation in supply chain, differentiation of companies in the supply chain by size (bargaining power and power of capital) and as third the lack of knowledge about the potential benefits from e-business implementation. Zheng and authors (12) state that SMEs have problems in identification and quantification of benefits of e-business, so they wait with process integration as an advanced form of e-business. Presence on Internet, web-page and e-mail usage is understood as simple form of doing e-business. MacGregor and Vrazalic (28) described full range of characteristics that differentiate the SMEs from large companies and represent them as special group of enterprises with main barriers to implement e-business in cost of implementation and project complexity. Cohen and Kalliroi (13) made a survey in Greece, were SMEs saw the cost reduction not as main goal of e-business implementation, but they perceive the direct and tangible costs of e-business as more significant than indirect and intangible ones. Cohen and Kalliroi (13) stated that large companies performed the analyses of the e-business implementation effects much more frequently than SMEs. Results are 3:1 in favour of large companies. This proves that there are really different groups of companies and that SMEs mainly or in much smaller manner have been doing analysis of e-business implementation effects before implementation. On the other hand, SMEs perceive direct costs and their decrease as important factor for e-business implementation, which leaves space for new methods for direct effects measurement especially tailored for SMEs. Chan, Chong and Zhou (29) in their research found twelve factors that influence the implementation of e-business and one of them was process efficiency.

Based on this we can assume that after the SMEs would conduct its own calculation of potential savings they could be more interested in the introduction of more advanced forms of e-business and integration with business partners. Furthermore, Volker (30) state that mutual identification of corresponding business processes lead to identification of activities which enable cost reduction and mutual benefits for both partners. The author also emphasizes significance of business processes modelling in standard notation or language such as *Unified Modeling Language* (UML), *Event-Driven-Process Chain* (EPC) or today standard in that area *Business Process Modeling and Notation* (BPMN).

Lyu, Huang and Li (31) state that the research made by Forester in 2006 on a sample of 540 SMEs in North America showed that the most significant impact that SMEs recognize was the increase in process efficiency by increase of employees' efficiency. The same authors (31) in their own empirical research on a sample of 200 SMEs in Taiwan, in 2010, made results in which 80% of SMEs reduced costs and increased the efficiency of the processes. Zheng and authors (12) state that there is a need for realistic business cases and examples that

show the real implementation effects of e-business in SMEs. For SMEs management they recommend identifying four important factors necessary for the decision on the introduction of e-business: a) to identify successful and realistic case studies with as much detail as possible, b) identify a set of data relevant for decision making, c) identify the SME business model, taking into account the conflicting objectives and d) find models for the cost-benefit analysis based on real examples.

RESEARCH PROBLEMS AND FURTHER WORK

In previous chapters literature review showed contemporary methods and approaches to measurement of e-business implementation effects. During the pilot research, on the real case study, process models were developed which employed contemporary measurement methods. Through this process some new research problems were found.

First problem lies in lack of knowledge and resources for process modelling in SMEs as a basis for analysis of possible effects. As a solution it is proposed to develop detailed models of generic business processes for SMEs on the basis of previous studies of generic process models made by author and developed in the projects (32), (33). Also, generic process reference models developed by the organization UN / CEFACT, NES (*Northern European cooperation on e-commerce and e-procurement*) and CEN (*European Committee for Standardization*) will be used as reference point. Process modelling in SMEs would not be made from scratch, but the generic model would be adjusted for specific company. In further research, according to the results of pilot research, several generic reference models will be used as reference and developed further in more detail needed for process simulation and cost calculation. Previous work (16), (17) has not shown the detailed level of process models from which SME could benefit in the implementation of measurement and analysis of the possible effects of e-business implementation.

Second problem is identified as lack in research methods used in most major papers and researches made by authors Perego and Salgaro (16) and Voutilainen and Pento (17). A measurement of activities duration in these studies was based only on time estimates of employees without measurement in practice. Authors of the paper (5) stated that they have measured time, but the data has actually been measured by employees themselves during performing these activities. Authors also made no detailed explanation of methodological procedure. Andersen and Kaplan (24) have stated that the application of TDABC methods is based on analysis of activities duration, which can be determined in three ways. The most precise measurement can be achieved by stopwatch method performed on the sample and the least precise method is estimate of time by employees themselves, which was applied in paper (4) and self-measurement as something in between was used in (5). This raises the question about the difference between the estimated and actual measured duration of activities and the accuracy of such calculations based only on an assessment of employees.

Third problem is a gradual introduction of e-business in the processes and parallel execution of processes supported by e-business and the processes that are run in old manner. This fact is not well described and taken into account in current studies and it is mainly ignored. Open question is how to improve the estimation and differentiation between the potential savings and realistically achievable savings in the context of parallel execution of existing and improved processes. The introduction of e-business is not a single sided project; the savings depend on the amount and dynamics of joint activities between business partners. Since previous studies suggest an increase in performance of the process and thereby induced savings in the work of employees as the most measurable direct effect of e-business, the

question is whether this kind of savings could be made in SMEs, with a relatively small number of employees in these processes. This problem is recognized by other authors exploring large companies (16), (17) and referred to by such use of free resources to other activities, but in the context of SMEs question is whether it would be really feasible and whether it would ultimately deliver savings.

Fourth problem partially lies on third problem and it is neglected in contemporary studies (16), (17). Previous research (16), (17) calculated savings and the effect of e-business implementation by neglecting the amount or scope of activities that will be improved. Analysis has been made on idealistic scenarios when all activities or business processes are improved. Also effects are calculated in cases where all documents are in electronic form and the process is automated or semi-automated. This is good calculation for possible maximum effects but that kind of effects would not be real or possible to achieve. Studies on the development of e-business rather suggest that the application of e-business is only in its infancy and only a small number of businesses in the EU use e-business and structured exchange of electronic documents. Its applications were estimated at 10-20% of transactions (26), (27). Further work would be oriented on benefits measurement and assessment in SMEs that do not yet have an e-business, so the question is how to estimate the potential scope of future e-business application with business partners and thus profitability of the overall assessment.

CONCLUSION

Based on previous research, it could be said that there is a need for new broader methodology especially developed for measurement of direct effects of e-business implementation in SMEs business processes. Even if SMEs often do not carry out cost-benefit analysis before or after e-business implementation, by the application of new methodology and generic business process models this would be possible. The new methodology would bring sufficient knowledge and SMEs would be able to use process models and conduct cost-benefit analysis to answer its own questions about feasibility of e-business implementation. Almost all contemporary studies suggest that the process improvement and cost savings motivate the introduction of e-business in SMEs, so the new methodology, with answers to previously mentioned issues in current research approaches would give SMEs a clearer picture of the effects and stimulate SMEs to implement e-business. Development of new methodology, which could provide more precise calculations and assessment of achievable savings by e-business implementation in SMEs, would be the subject of further research and dissertation of author.

The expected scientific and social contribution of this research would be a new methodology that would enable the prediction and measurement of the direct effects of possible e-business implementation in SMEs. Consequently author assumes greater utilization and faster implementation of e-business in SMEs.

REFERENCES

1. EC. Presidency Conclusions of the Lisbon European Council. European Council, Lisbon, 23.-24. 3. 2000.
2. EC. eEurope - An Information Society for All. COM (1999/687), European Commission, Bruxelles, 1999.
3. EC. i2010 - A European Information Society for growth and employment. COM (2005/229 Final), Bruxelles, 2005.

4. EC. Europe 2020 – A strategy for smart, sustainable and inclusive growth. COM (2010) 2020 final, Brussels, 2010.
5. VLADA RH. Electronic business development strategy in the Republic of Croatia 2007-2010. Zagreb, Croatia, 2007.
6. European Committee for Standardization (CEN). Electronic Business - CWA on electronic invoicing. http://www.cen.eu/cen/Sectors/Sectors/ISSS/CWAdownload/Pages/CWA%20eInvoicing.aspx, pristupano 30.03.2013.
7. European e-Business Lab (EBL). http://www.euebl.org/ebl/, pristupano 23.5.2012.
8. Pan-European Public Procurement Online (PEPPOL). http://www.peppol.eu/, pristupano 23.5.2012.
9. E-Business W@tch. ICT and e-Business for an Innovative and Sustainable Economy: 7th synthesis Report of the Sectoral e-Business Watch (2010). The European Commission 2010.
10. Eurostat, Enterprises sending and/or receiving e-invoices 2010. Eurostat 2011.
11. HARLAND, C.M. at all. 2007. Barriers to supply chain information integration: SMEs adrift of eLands. *Journal of Operational Management*, 25:1234-1254.
12. ZHENG, J. at all. 2004. Small firms and e-business: cautiousness, contingency and cost-benefit. *Journal of Purchasing & Supply Management*,10:27-39.
13. COHEN, S., KALLIRROI, G. 2006. e-Commerce Investments from an SME perspective: Cost, Benefits and Processes. *The Electronic Journal Information Systems Evaluation*, **9**(2): 45-46.
14. PEACOCK, E., TANNIRU., M. 2005. Activity-based justification of IT investments. *Information & Management*, 42:415-424.
15. VIDAS-BUBANJA, M., GRK, S., CVETKOVIĆ, N. 2010. Economic Aspects of Doing E-Business in Companies. *Megatrend revija*. **7**(2): 21-41.
16. PEREGO, A., SALGARO, A. 2010. Assessing the benefits of B2B trade cycle integration: a model in the home appliances industry. Benchmarking: *An International Journal*, **17**(4):616-631.
17. VOUTILAINEN, V., PENTO, T. 2003. Electronic invoice processing as a tool for cost reduction. *Frontiers of e-Business Research.*
18. VOLKER, H. 2008. Modeling Collaborative e-Business Processes in SME environments. *Journal of Information Science and Technology*, **5**(2):46-59.
19. LESJAK, D., VEHOVAR, V. 2005. Factors affecting evaluation of e-business projects. *Industrial Management & Data Systems*, **105**(4): 409-428.
20. MOGOLLON, M., RAISINGHANI, M. 2003. Measuring ROI in e-business: A practical approach. *Information Systems Management*. Spring.
21. ILOIU, M., ILOIU, S. 2008. Economic analysis of e-business investment projects. Annals of the University of Petrosani: *Economics*, **8**(1):267-272.
22. GIAGLIS, G.M., MYLONOPOULOS, N.A., DOUKIDIS, G.I. 1999. The ISSUE methodology for quantifying benefits from information systems. *Logistics Information Management*, **12**(1/2):50 – 62.
23. COOPER, R., KAPLAN R, S. 1992. Activity-Based Systems: Measuring the Costs of Resource Usage. *Accounting Horizons*.
24. KAPLAN, R.S., ANDERSON, S.R. 2007. Time-Driven Activity-Based Costing: A Simpler and More Powerful Path to Higher Profits. *Harvard Business School Press*.
25. STOUTHUYSEN, K at all. 2010. *Time-driven activity-based costing for a library acquisition process: A case study in a Belgian University*. Library Collections, Acquisitions, & Technical Services, 34:83-91.

26. KOCH, B. E-Invoicing / E-Billing in Europe and abroad. Billentis, 2011. http://www.ukeag.org.uk/media/155/e-invoicing_europe_etc_bilentis_report2011.pdf, pristupano (30.03.2013.)
27. Politecnico Di Milano. Joint collaboration: a powerful driver for Electronic Invoicing in Italy. Politecnico Di Milano School of Managment, 2009.
28. MacGREGOR, R.C., VRAZALIC, L. 2006. The Effects of Small Business Clusters in Prioritising Barriers to E-commerce Adoption in Regional SMEs. *Journal of New Business Ideas and Trends*, **4**(1):24-44.
29. CHAN, F.T.S., CHONG, A.Y.-L., ZHOU, L. 2012. An Empirical Investigation of Factors Affecting E-collaboration Diffusion in SMEs. *International Journal of Production Economics*, **138**(2), 329-344.
30. VOLKER, H. 2008. Modeling Collaborative e-Business Processes in SME environments. *Journal of Information Science and Technology*, 5(2):46-59.
31. LYU, J.-J., HUANG, Y.-C; Li, S-C. 2010. A Synthetic Assessment of E-business for SMEs' in Taiwan. *Contemporary Management Research*, 6(4):281-304.
32. BRUMEC, J. at all. Istraživanje generičkog procesnog modela tvrtke, identifikacija priključnih točaka za elektroničko poslovanje te tehničke i funkcionalne specifikacije e-Modula za njihovu implementaciju. Sveučilište u Zagrebu, Fakultet organizacije i informatike, Varaždin, 2009. Dostupno na http://edocument.foi.hr/dokumentacija/glavni-dokument, pristupano (30.03.2013.)
33. BRUMEC, J. at all. Usluge istraživanja i razvoja razmjene e-Računa u elektroničkoj trgovini. Sveučilište u Zagrebu, Fakultet organizacije i informatike, Varaždin, 2011. Dostupno na http://edocument.foi.hr/ , pristupano (30.03.2013.)

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PEOPLE AS A KEY RESOURCE OF COMPANY PERFORMANCE

Lenka PUCIKOVA, Paul WOOLLISCROFT, Milos CAMBAL

ABSTRACT

Recent years have seen a lot of new management approaches for improving organizational performance such as: total quality management, flat organizations, empowerment, continuous improvement, reengineering, kaizen, team building, and so on. Business leaders today are forced to focus even more on the profitability of their business. During the last several years, companies have initiated Performance Management (PM) systems to improve the quality of their management. In many companies they have succeeded, but in quite a few they have failed. This article presents the importance of Human Resources Management (HRM) and employees as a key factor on success of the company. Authors report that people in organization are a key resource of performance of company. The aim of the article is to analyze literature review and findings of researches with the purpose of completing the PhD theses of authors.

KEY WORDS

Performance Management, Human Resources Management, Performance Appraisal

INTRODUCTION

Armstrong's Handbook of Performance Management (1994/2006) noted that the aim of Performance Management is a means of getting better results from the organization, teams and individuals within an agreed framework of planned goals, objectives and standards. In fact, the PM cycle includes performance planning, assessment, coaching, development, recognition and compensation (Fig. 1).

Most experts agree that, when PM is implemented well, it can lead to important benefits for organizations. Based on Cascio (2006) study organizations with systematic PM systems are 51% more likely to outperform others regarding financial outcomes and 41% more likely to outperform others regarding additional outcomes including customer satisfaction, employee retention, and other important metrics. Another reason PM has become so popular is that it provides useful information needed for decision making in other HRM and development activities. For instance, consider the relationship between PM and training. Without doubt, PM provides information on developmental needs for employees. In the absence of a good PM system, it is not clear that organization will use their training resources efficiently.

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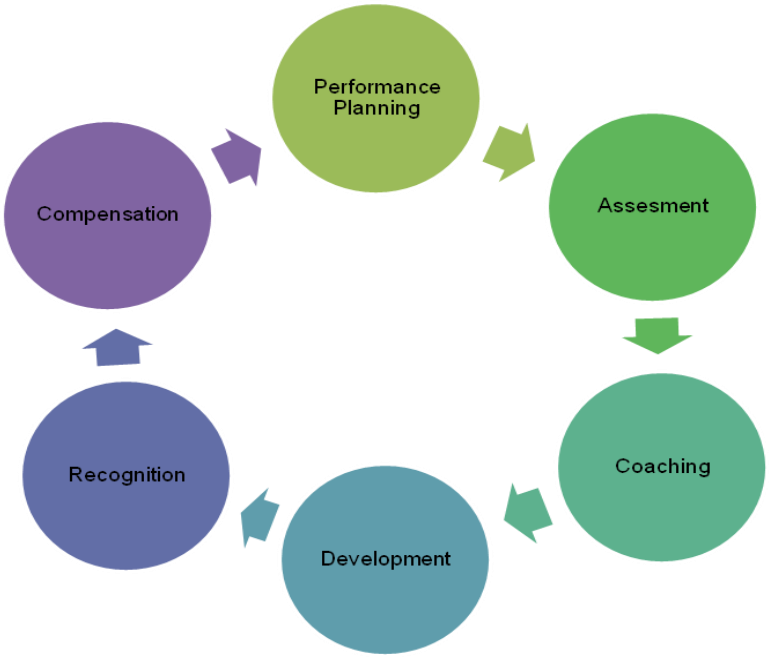

Fig. 1 *The Performance Management Cycle (Armstrong, 1994/2006)*

Without doubt, using a PM system is one of the best ways to drive performance, manage expectations and increase employee satisfaction within an organization. Certainly, to manage and improve employee`s performance, managers must explore the causes of performance problems, direct manager and employee attention to those causes, develop action plans and empower worker to find solutions, and use performance- focused communication. Surely, effective management of human resources can form the foundation of a high- performance work system (Krajcovicova et all, 2013). That means an organization in which technology, organizational structure, and people and processes all work together to give an organizational and advantage in the competitive environment. Hollenbeck and Wright (2011) argue that human resource management must ensure that the organization has the right kinds of people to meet the new challenges. Moreover maintaining a high performance work system may include development of training programs, recruitment of people with new skill sets, and establishment of rewards for such behaviors as teamwork, flexibility, and learning. In fact, the employees are an integral and indispensable part of running the business smoothly and efficiently. That's why, keeping in mind the crucial role of employees, a recent trend known as performance management has come into practice. In fact, using performance management can ensure that employees not only fulfill their responsibilities, but do so to the best of their abilities and up to company's expectations. Performance management allows the company to tap the full potential of staff. In short, it can be described as a comprehensive process starting from monitoring and developing the desired traits to rating their progress and rewarding them for their achievements. Lawer and McDermott (2003) made a point that it is very difficult to effectively manage human capital without a system measures performance. Therefore, an effective performance management system should be a key building bloc of every organization´s human capital management system.

FOCUSING ON PEOPLE RATHER THAN TECHNOLOGY

There is a common assumption that if companies perform well, they must have good managers at all levels of the organization. New researches confirm the notion that managers and management are more important that the industry sector in which company competes. Effective management has long been thought to make companies more efficient. However, it has always been assumed that good management increases productivity, this proposition has been proven in 2002 by McKinsey study of the manufacturing sector. To asses and measure the impact of management techniques, the researchers interviewed the director at 100 companies worldwide. Three management techniques had been thought to improve company`s performance: lean manufacturing, which minimizes waste; talent management, which attracts and retains high- caliber people; and performance management, which rewards employees who meet set goals. Moreover management must guide individual and collective action so that they harmonize with company`s overall strategy and values. Based on Vickers (2007) study a good PM system will require the right balance of technology, hard metrics and soft skills. It´s a critical challenge to meet, however, nowadays is the high performance the only long- term key success. In fact, PM is a process for establishing shared understanding about what is to be achieved and how it is to be achieved, and an approach to managing and developing people that improves individual, team and organizational performance. Moreover, PM focuses on future performance planning and improvement and personal development rather than on retrospective performance appraisal.

EMPOWERING EMPLOYEES

Based on Trend survey in 2011 within the Slovak companies more than 42% of employees are satisfied with their current job mainly because of the possibilities to educate which offer them a carrier grow. When management, as stated by Cagne (2002) takes steps to ensure that each person has the skills and resources necessary to accomplish his or her priorities, employees gain a new sense of empowerment. They know exactly what they have to do and surely have the resources to get the job done. In addition most experts agree that good PM require employees to prepare a self-assessment and reflect on their efforts over the reporting period.

Hay Group conducted the research in 2009 where they were focusing on comparison of companies where employees are highly engaged (through communication and leadership) and highly enabled (carefully selected for wed for well- designed job with adequate resources and training) with companies with low- engagement. This research found big performance differences. Based on the research the companies with high engagement and enablement have four and half greater growth than the companies with low engagement. Furthermore they have more than 54% higher customer satisfaction. Overall leadership, employee and organizational learning comprise organizational capability.

Besides, Armstrong (1994/2006) emphasize that employees are more productive when they believe management has the skill to lead them to success and to provide them with the knowledge and resources they need to meet requirements. Performance improvement is not achievable unless there are effective processes of continuous development of employees. More specifically PM is concerned with aligning individual objectives to organizational objectives and encouraging individuals to uphold corporate core values. Furthermore, providing opportunities for individuals to identify their own goals and develop their skills and competencies. Moreover, motivating people by providing them with recognition and the

opportunity to use and develop their skills and abilities. Thus, PM is essentially a developmental process that aims to improve the performance and potential of people through their own efforts and with the help of their managers and the organization.

LINKING INDIVIDUAL GOALS WITH BUSINESS GOALS

DeNisi and Pritchard (2006) conducted an expectancy- based motivational model for individual performance improvement (Fig. 2). They observed that the key for PM is to ensure that evaluation and outcomes are structured so that employees will focus their actions in the ways desired by the organization. In brief, the stronger the links between each element in the motivation process, the greater will be the motivation of employees to improve their performance.

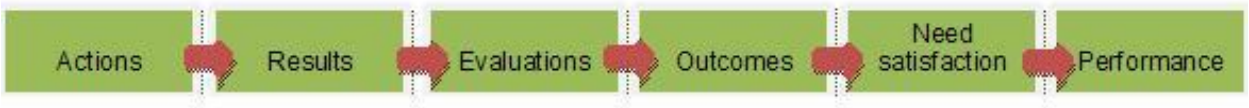

Fig. 2 *Expectancy- based motivational model for individual performance improvement (DeNisi, Pritchard 2006)*

An important aim of performance management is to support the achievement of the business strategy. Paladino (2011) noted that HRM integration is linking different aspects of human resource management, especially organizational development, human capital management, talent management, learning and development. It is focused on performance improvement in order to increase organizational, team and individual effectiveness. Aligning individual goals with the corporate goals makes everyone aware of what is critical to the company´s success. Furthermore it keeps people focused on the most important aspects of their jobs. In other words each employee should have a clear goals and the ability to accomplish those goals. Thus managers should determine whether employees have the necessary skills and other resources. Correspondingly, employees should participate in setting their own goals. Equally, they should feel that they are in control, in the sense that they have the skills, authority, and resources to accomplish those goals.

CONCLUSION

In order to reengineer organizations and improve technology, companies have tended to overlook their most valuable asset, their people. Measuring the contribution of people to the performance of an organization is not easy, but evidence of the link between organizational performance and people management rising. Surely, people want to have goals and to succeed in achieving their goals, and that kind of achievement can have a huge impact on revenues and profits of company. Regardless of the system used to manage performance, several elements must be in place to create the context for good performance. The system must be focused on the future, which is where the desired performance will occur. Besides, employees must be involved in regulating their own performance. As mentioned previously the purpose of the article is to complete PhD thesis of authors which needs further research of the impact of Performance Management to company performance.

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REFERENCES

1. ARMSTRONG, M. 1994/2006. *Handbook of Performance Management: an evidence-based guide to delivering high performance- 4th edition. Kogan page Limited: ISBN 978 0 7494 5392 3*
2. CASCIO, W.F. 2006. *Handbook of research in international human resources management.*
3. CAGNE, K. 2002. *Using Performance Management to Support an Organization´s Strategic Business Plan*. Employment Relations Today.
4. HOPKINS, B. 2009. *Cultural Differences and Improving Performance- How Values and Beliefs Influence Organizational Performance.*
5. HOLLENBECK, N., WRIGHT, G. 2011. *Fundaments of Human Resource Management.*
6. HAY GROUP SURVEY 2009. *Tough Decisions In a Downturn Don`t Have to Lead to Disengaged Employees*, http://www.haygroup.com
7. DORGAN, S., DOWDY, J. 2002. *H.ow Good Management Raises Productivity*. The McKinsey Quarterly.
8. DORGAN, S., DOWDY, J. 2006. *The link between management and productivity*. The McKinsey Quarterly.
9. DeNISI, A.S., PRITCHARD, R.D. 2006. *Performance Appraisal, Performance Management and Improving Individual Performance*. Management and Organization Review.
10. KRAJCOVICOVA, K., CAGANOVA, D., CAMBAL, M. 2013. *Competency models utilization in industrial enterprises*. In Advanced Materials Research.
11. PALADINO, B. 2011. *Innovative Corporate Performance Management: Five Key Principles to Accelerate Results.*
12. VICKERS, M., BALTHAZAR, C., 2007. *Finding the Keys to Performance Management.* Employment Relations Today.

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RISK MANAGEMENT AND THE EUROPEAN MARKET INFRASTRUCTURE REGULATION (EMIR)

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Prof. Dr. Dr. h. c. PETER JOEHNK[1, 2]

ABSTRACT

The European Market Infrastructure Regulation (EMIR) is a new act to controle the trade with OTC derivatives as a result of the financial crisis in 2007. The articel describes the main categories of these regulation and clarifies the question, whether these regulation is relevant for industrial companies or not.

KEY WORDS

Risk management, over the counter (OTC) market, derivative regulation, EMIR, Reporting, Clearing, central counterparty, collateral requirements

INTRODUCTION

The Bank for International Settelments published for the OTC derivative market transactions with a gross nominal value of 639 trillions US Dollar[1]. After a peak in 2008 statistics showed a drop in nominal values by a third and again an increase in 2011.[2] Experts leads back this development of a high market volatility, which increases the demand for hedging instruments. Despite the financial crisis, this market area was not regulated and non transparent. The new European Market Infrastructure Regulation (EMIR) shall regulate the OTC market and bring more transparency.

In a first step it will be investigated if this regulation can be relevant for industrial companies or whether it is only obligatory for financial traders. The result will be shown by the example of energy supply companies. In the following the main aspekts of this regulation will be explained in more detail.

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[1] BIS Quarterly Review December 2012
[2] See also: Kleist in IFC Bulletin No. 35 p. 45.

DERIVATIVE FINANCIAL INSTRUMENTS IN INDUSTRIAL COMPANIES

Derivative financial instruments - short derivatives - are instruments of finance management, which can be used for speculation, hedging or arbitrage. The speculation with financial derivatives has the objective to realise profits through expected price changes. Arbitrage means the utilization of unjustified price differences on a market – this is mainly an instrument of financial companies and is listed for completeness. A great significance for industrial companies has financial instruments for hedging of risks.[3]

Derivatives are characterised by the conclusion of a contract and performance of a contract differ timely, but the price is fixed at time of conclusion. They are products, which are derived from the value of other assets (underlying). Derivatives can be distinguished after their level of obligation in conditional and unconditional financial instruments. Another distinguishing feature is the risk profile. A symmetric risk profile is given, when chances of profit are same like risks of losses. Is the risk of losses limited of an option premium for purchasers and unlimited for vendors the risk profile is asymmetric.[4]

Another distinguishing feature is the trading place. Financial instruments can be traded on exchanges or over the counter (OTC). Exchange dealing is based on standardised contracts with margins. OTC derivatives are individual contracts without standardisation. Integral parts of the contract (currency, amount, term, interests) can be negotiated freely.

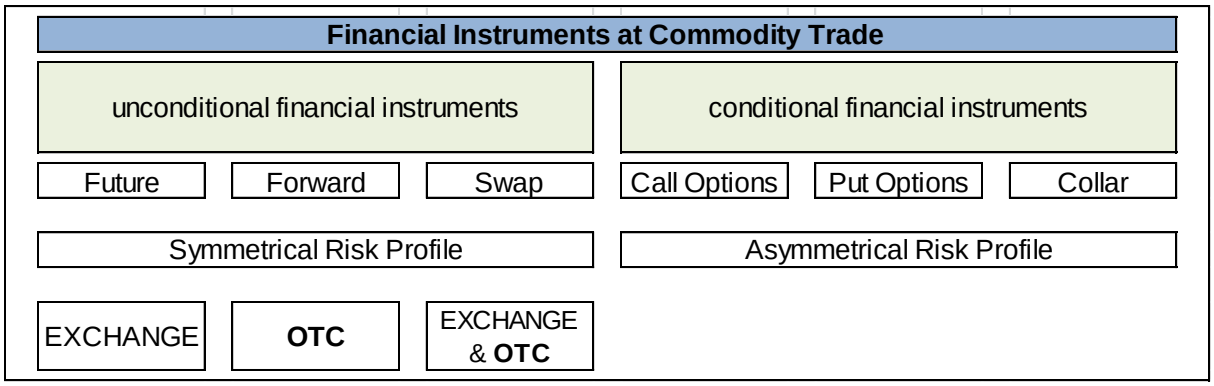

***Fig. 1** Financial Instruments at Commodity Trade*[5]

The energy market is characterized through his dependence on development of commodity prices for oil products, natural gases and black coal. The commodity prices are increased constantly in the past. These additional costs can be passed on customers or it has a direct impact of operating results. These can deteriorate the market position of a company or reduce customer satisfaction. It is necessary for the success of a company to dominate this risk situation for instance through an individual hedging strategy. The risk position can be secured, all or part of, through derivative financial instruments.[6]

In the sector of energy and commodity are Futures/Forward, Swaps and Options most traded products. Futures and Forwards are unconditional financial instruments, these means the obligation to take a specific amount of the asset on a certain date with a fixed price. The conditions of the contract are obligatory for both partners. Opportunities and Risks are

[3] See also: Zantow (2010) p. 364.
[4] See also: Prätsch, Schikorra, Ludewig (2010) p. 213.
[5] See also: Braun in Eller (2010) p. 186,
[6] See also:Braun in Eller (2010) p. 183 ff.

distributed symmetrically, because no payment of premium is due after conclusion of contract and the function of payment is linear. **Futures** can be traded at the exchange, because the conditions of the contract are standardised. A financial compensation is to pay at maturity. The current market value is compared to price at conclusion of contract. Differences are credited or debited to accounts of contractors. **Forwards** are individual contracts with a physical settlement.[7] **Swaps** are contracts with an exchange between a fix and a variable price. After a period the contracts will be evaluated. The difference between estimated value and predetermined Swap-Level is compensated financially. An **Option** is a right to buy or sell a special underlying asset for a fixed price. An underlying can be shares or products.

Approximately 95 % of all derivative financial instruments were contracted outside of approved exchanges.[8] The OTC market is non-transparent with a global nominal volume of 648 Trillion US-Dollar in 2011. The financial crisis has shown that the functionality of financial markets can be substantially disturbed by a non-transparent OTC derivate market. On this background, the G-20-Countries[9] have committed that all standardized OTC derivatives should be traded on exchanges or electronic trading platforms and cleared through a central counterparty until the end of 2012.[10]

This section has shown that OTC market is relevant also for energy companies. The next chapter will give an overview on the new EU regulation and the impact on energy companies.

REGULATION OF THE OTC DERIVATIVE MARKET

The declaration of G20 countries about the regulation of derivative markets is implemented in the United States of America by "Dodd-Frank-Act" and in the European Union by "European Market Infrastructure Regulation" (EMIR).

EMIR is entered into force on 16th August 2012. The regulation is not only legal for finance companies, but in principle for all participants of the OTC derivative market. The Regulation is directly applicable in the Member States and shall take effect without implementation into national legislation, other than EU directives. In national law only executive regulations are necessary, for instance for the definition of competent supervisory authority. The regulation requires anyone who has entered into a derivatives contract to report and risk manages their derivative positions. The aim of the regulation is to stabilize the market, to minimize systemic risks and economic risks, which result from default of a counterparty, and to design more transparency of the market.

EMIR contains four core areas, which must be observed by market participants. The market participants can be distinguished into two categories:

- Financial counterparties, which includes banks, insurances, investment firms and
- Non-financial counterparties, which covers any counterparty that is not classified as a financial counterparty

The obligation to report contract details to a trade repository as well as increasing requirements for risk management and management of collaterals is relevant for all market participants.

[7] See also: Braun in Eller (2010) p. 187f.
[8] See also: European Commission 2/2012,
[9] G20 major economies is a group finance ministers and central bank governors of 20 major economies – United States of America, Canada, Mexico, Brazil, South Africa, Argentina, China, Japan, South Korea, India, Indonesia, Russia, Turkey, European Union, Germany, France, United Kingdom, Italy, Saudi Arabia and Australia.
[10] See also: Sigmundt in BaFin Journal 01/2012 p. 12

Reporting (Art. 9 EMIR) All counterparties with outstanding derivative contracts have to report details of these contracts to an authorized trade repository. The report must include at least: involved counterparties, type of derivative, underlying, nominal value, maturity, terms of contract and settlement. Modifications or completions must be reported as well. The details are to be reported no later than one day after realisation. The scope of application includes derivative contracts completed before EMIR entered into force and are still outstanding as well as contracts, which concluded after. The notification can be executed by any of the parties or delegated of CCP. It is to ensure that the notification is not repeated. Problems and Risks should be identified early through this data collection.[11]

Risk management (Art. 11 EMIR) standards are increased, if derivatives are not traded on CCP. Market participants have to implement procedures and measures to reduce operational and default risks. Another requirement is the implementation of formal processes to exchange of central conditions and current market values. Furthermore escalation procedures are setting with regard to identification, documentation and monitoring of critical aspects, for instance Valuation of OTC derivatives. The Risk management has to be checked by auditors, if threshold (nominal value > 100 Mio. € or more than 100 OTC derivatives) are exceeded.

Collateral Management (Art. 11 EMIR) is relevant for companies, which complete derivative contracts without CCP. They have to implement a risk management, which is able to identify need for collateral timely and appropriate. This requirement is currently substantiated through Basel Committee[12].

Clearing (Art. 4 EMIR) is the obligation to transact qualified OTC derivative contracts through a central counterparty (CCP). So far, derivative contracts were concluded on the basis of individual agreements between parties. The inclusion of a CCP is designed to offset effects of one of counterparts. The market should be secured against insolvency of individual market participants. CCP´s require margins, which shall cover for instance the risk of change of prices until the settlement of the contract. All CCP´s deposit in a clearing fond. The objective is to secure the failure of another CCP.

Affected by the clearing obligation are financial counterparties. Non-financial counterparties are subject to the clearing obligation only if certain threshold in the closed OTC derivatives contracts is exceeded. After the ESMA[13] draft 1 trillion Euro notional amounts of credit derivatives and equity derivatives, as well as each of 3 trillion euros nominal value of interest rate derivatives, currency derivatives and commodity derivatives.

[11] See also: Sigmundt in BaFin 01/2012 p. 14.

[12] Basel Committee on Banking Supervision is a forum for regular cooperation on banking supervisory matters. Its objective is to enhance understanding of key supervisory issues and improve the quality of banking supervision worldwide. It seeks to do so by exchanging information on national supervisory issues, approaches and techniques, with a view to promoting common understanding. At times, the Committee uses this common understanding to develop guidelines and supervisory standards in areas where they are considered desirable. In this regard, the Committee is best known for its international standards on capital adequacy; the Core Principles for Effective Banking Supervision; and the Concordat on cross-border banking supervision. (See also: www.bis.org)

[13] European Securities and Markets Authority (ESMA) mission is to enhance the protection of investors and reinforce stable and well-functioning financial markets in the European Union. As an independent institution ESMA achieves this mission by building the single rule book for EU financial markets and ensuring its consistent application and supervision across the EU. ESMA contributes to the supervision of financial services firms with a pan-European reach, either through direct supervision or through the active co-ordination of national supervisory activity. (see also: www.esma.europa.eu)

Derivatives that were entered to hedge operational risks should be deducted when calculating the thresholds. Thus the clearing obligation is primarily of importance for large companies that use OTC derivatives for speculation and trading.[14]

CONCLUSION

The implementation of the EMIR requirements is necessary for all companies, which trade with OTC derivatives. Particularly for companies with larger derivatives it can lead to considerable expenses, which is intensified by the time. The topics clearing obligation, risk management, collateral management and reporting have to be analyzed. The intensity depends on business model and use of derivatives. A key point from the company's perspective is to develop an understanding of the interactions and influences on treasury and finance departments. A comprehensive analysis is necessary. The future will show, whether the rules are again just another bureaucratic bubble or whether desired effects occur actually.

REVIEWER'S NAME

Joehnk, Peter, Prof. Dr. Dr. h. c.

REFERENCES

1. ELLER, R., HEINRICH, M., PERROT, R., REIF, M. 2010. *Management von Rohstoffpreisrisiken – Strategien, Märkte, Produkte*. Gabler Verlag.
2. PRÄTSCH, J., SCHIKORRA, U. LUDEWIG, E. 2010. *Finanzmanagemen*t, *3. Auflage.* Springer Verlag.
3. ZANTOW, R., DINAUER, J. 2011. *Finanzwirtschaft des Unternehmens - Die Grundlagen des modernen Finanzmanagements, 3. Auflage*. Pearson Studium.
4. BaFin Journal 01/2012: Sigmundt, Dr., Christian EMIR: Neue Regeln für den Handel mit OTC-Derivaten
5. IFC Bulletin No. 35: Kleist, v., Karsten: The BIS framework for monitoring financial derivatives

[14] See also: Sigmundt in BaFin Journal 01/201 p. 12

RESEARCH PAPERS
FACULTY OF MATERIALS SCIENCE AND TECHNOLOGY IN TRNAVA
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A PROPOSED METHODOLOGY OF RESOLVING CONFLITS WITHIN MULTICULTURAL TEAMS IN INDUSTRIAL ENTERPRISES

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Krzysztof WITKOWSKI[3]

ABSTRACT

The main aim of the presented paper is to clarify the need of resolving conflicts within multicultural teams in industrial enterprises, increasing awesome of multiculturalism on Slovakia as necessary part of our life and to suggest the structure of the dissertation thesis. The author base the study on the assumption that extensively developed intercultural relationships lead to mutual understanding between people and consequently to less interpersonal conflicts.The paper is divided in two main chapters. The first one deals with the theoretical bases of given issue, to clarify the concept of multiculturalism. The emphasis is primarily on the issue of conflict resolution within multicultural teams in industrial enterprises. The second one consists of reasoning and continuity of the paper, brief characteristics, goals, hypotheses, theses and benefits valuation.

KEY WORDS

globalization, multicultural, conflit, team, multicultural team

INTRODUCTION

In the introduction, the authors explain the importance of increased attention and interest in the area of multiculturalism. Industrial enterprises nowadays are increasingly aware of this issue as they become more open to different cultures and they are confronted with intensive international migration and previously isolated societies become more pluralistic. As a result of these processes, individuals are more frequently in contact with members of different cultures. "Think globally, act locally" has become a slogan for our society. This way of thinking and acting was transferred to almost all areas of life (economic, political and educational) and it is applied in the context of schools, societies and enterprises as well. The ability to understand and accept cultural diversity is becoming essential in the ordinary working environment. Enterprises supporting the knowledge improvement of their own

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employees have understood that a friendly working environment leads to increased motivation, consequently reflected in their performance. The training focused on skills development in this area can help to reduce interpersonal misunderstandings, bring new ways of conflict resolution and harmony in the workplace and thereby also increase productivity. Furthermore, it teaches us to be tolerant towards others, their habits, culture and history. "Strangers" can be a source of experience for us and they can enrich our personal lives. Discussion of the issues surrounding multiculturalism and also the identification of sustainable key performance parameters within multicultural work environments can contribute to more effective conflict resolution in the workplace and promote awareness towards the tolerant coexistence and social cohesion.

According to systems theory can not fully understand anything in isolation, but everything must be seen as a dynamic and multi-layered system. Everything is in conjunction, the functioning of the system consists of many simultaneous and mutually dependent elements. The system is always more than the mere sum of its individual parts. If we accept this interpretation of the world, some traditional and sacred concepts soon lose their meaning. If everything is judged in terms of global, interconnected system, where is then the place for the "national culture", "the interest of the nation", "national history" and of course "nation-state"? "Global" and "local" converge together (Figure 1), (1).

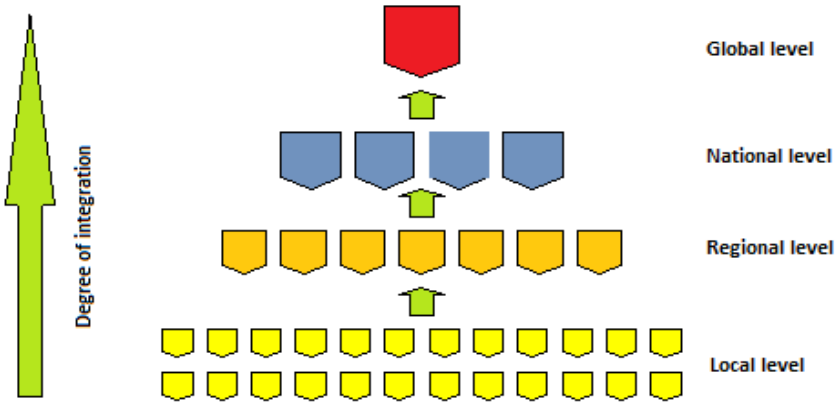

Fig. 1 *Integretion of society (Own elaboration)*

THEORETICAL BASIS OF THE CONFLICT, TEAM AND MULTICULTURALISM

Conflict is a meeting of two or more opposing views, trends, attitudes, interests and so on. The course of this dynamic process depends on the participants of the conflict, their temperament and processing. Research in the field of leadership and management has shown that conflict resolution requires 20 to 21% of the time management. Conflict situations are situations in which the efforts, plans, or the interests of two or more parties appear to be incompatible, inconsistent, contradictory. Conflicts arise at all levels mainly of the existence of different co-operating partners with their own objectives (2).

Conflict in a team is not necessarily seen as a negative phenomenon. Conflict can bring new ideas and new approaches for organizations how to solve problems. It can help detect problems and provide important opportunities for improving communication skills (3).

There is no single accepted definition of what is a conflict. Generally, the conflict is situation where at least two participants seek to obtain the same farm which is not enough or is indivisible. The topic of the paper is the proposal of methodology how to resolve conflict

effectively within multicultural teams in industrial enterprises. Below is Videnová´s definition of conflict: "*misunderstanding, disagreement, change, failure of two or more conflicting interests, values, goals emerging in all processes of the organization based on of cause of cooperation of various people who working in teams for accomplish the objectives of the team as well as the whole society with limited resources (human, financial, material and so on.). The emphasis is focus on sustainability and terms of constant changes as well.*"

Conflict as a three-dimensional parameter

In the paper, the conflict is perceived as three-dimensional parameter. It can help to approach the issue closer to reality. However, the authors will resolve conflicts that result from any changes or failures between two or more processes in the enterprises. For example, between work teams in production and logistic. Conflict "C" will be perceived as the function "f" and the three variables: entity "e" time "t" and also place "p". In practice, it can help to find out why, where (p), when (t) and by whom (e) the problem was occurred (4).

$$C = f(e, t, p)$$

The conflict will be perceived as a process that has varying degrees - phase (Figure 2). The individual stages of the conflict can be defined as the appearance of a conflict, disagreement, polarization, separation, destruction and frustration.

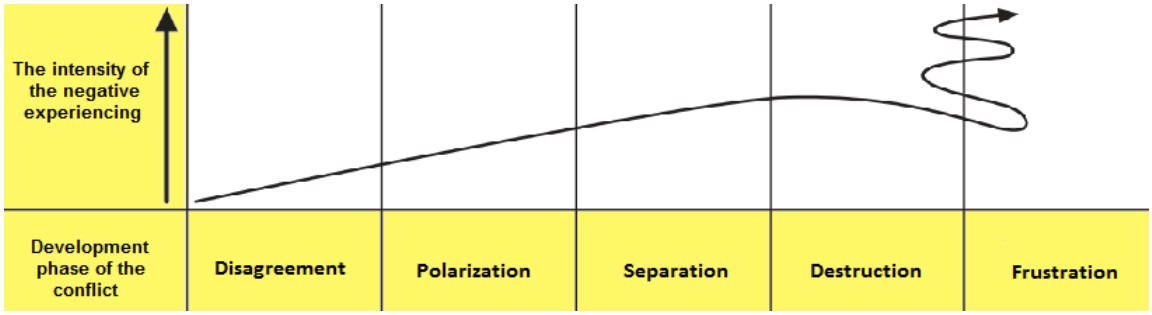

Fig. 2 *Development phase of the conflict (Own elaboration according (5))*

The authors focused mainly on describing aspects that give rise to misunderstandings in the workplace. Figure 3 shows the area of authors´s interest. The authors will examine the reasons of conflicts in multicultural teams in industrial enterprises and why conflicts are appearing. Then it will be explored in the following months through getting information from analysis, questionnaire and interview with experts in this area.

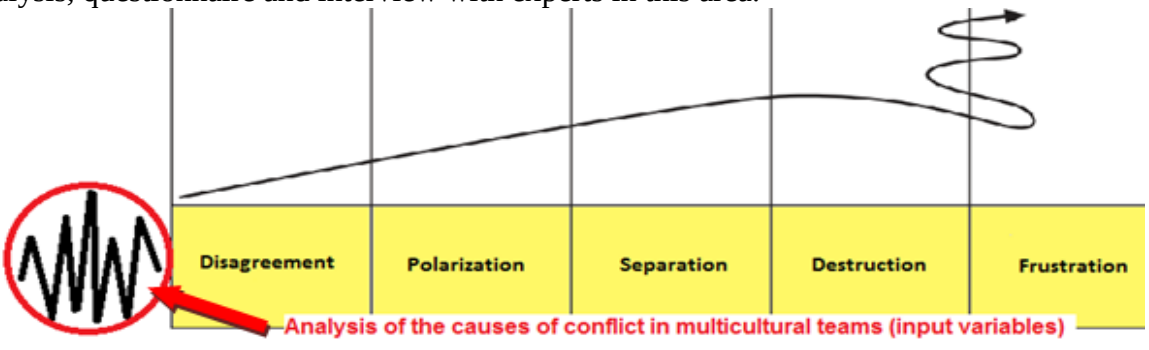

Fig. 3 *The main part of research (Videnová)*

The most common and easiest way of conflict resolution is no solution. Therefore, the simplest solution of conflicts is to prevent them. Prevent problems in the team is possible with good teamwork and good work of manager (6).

The basis of resolving of each conflict is an agreement. Figure shows the possible ways of resolving conflicts (agreement) by Thomas Kilmanna (7) and (8).

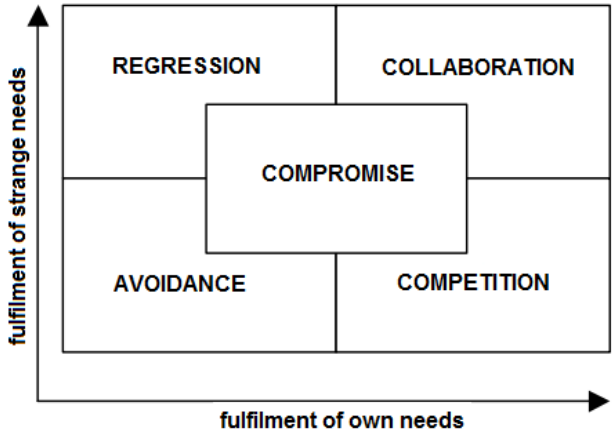

Fig. 4 *The basic strategy for resolving conflicts by Thomas Kilmanna (7)*

MULTICULTURAL TEAM AND ITS CHARACTERISTICS

The main difference between intercultural and multicultural management is defined below. According to the authors, this paper is necessary in order to define and know this concept and differences for understanding this issue:

- Intercultural management is the most dynamic term of these focusing on the interaction between cultures on an interpersonal level, for example researching how the member of one culture is adjusting and acting in another culture.
- Multicultural management research focuses on several (usually more than two) cultures living side by side and deals with basic psychological processes.

Takeuchi defines multicultural team as a group of individual members from different nationalities and cultures with different values and cultures who are working towards the common goal (9).
Videnová created and defined multicultural team as: „ *a group of people cooperating together to achieve the objectives of the group and thus the whole society, where at least two or more members of the group come from different nationalities, have different values and culture. Group of people of one country cooperating with a group of people in another country in order to achieve the objective will regard as multicultural team as well.*

Objectives of this paper are as follows:

The main goal of this paper is the analysis of theoretical knowledge in practical terms of multicultural teams industrial enterprises and create "A proposed methodology of resolving conflict within multicultural teams in industrial enterprises."

1. To achieve the main objective will be supported by the achievement of the the following objectives:

2. Based on the study of literature and other sources to analyze the theoretical background. To elaborate a comprehensive overview of the issues of conflict resolution, teams, multicultural teams, conflict management standards in different cultures.
3. To define and to specify the terms of conflict, a multicultural team and create own definition of these terms.
4. To define existing methods and techniques in conflict resolution. To define and analyze work in multicultural teams and to find relationship between them.
5. To define standards for resolving conflicts in different cultures (the three most common cultures cooperating with industry in Slovakia).
6. To analyze the current situation of conflict resolution and perception of multiculturalism through research in an environment of industrial enterprises.
7. To summarize and evaluate the outcomes obtained by the analysis of the current situation. To evaluate their relationship to the hypothesis and define the problems that occur in these areas.
8. To propose a methodology for resolving conflicts within multicultural teams in industrial enterprises.
9. To assess and evaluate outcomes and applicability of the proposed methodology in practice by the experts.
10. To evaluate the benefits from a theoretical and practical perspective.

In the paper, the authors defined the research presumptions and working hypothesis based on theoretical knowledge. In the future the authors intend to examine the following working hypotheses whose confirmation respectively rebuttal will be based on the results of the evaluation questionnaires and interviews with experts from this area.

Research presumptions:
RQ1: Presume that the majority of industrial enterprises don't have overworked method on resolve conflicts in multicultural teams.
RQ2: Presume that the majority of Slovak industrial enterprises to don´t deal with the issue of multiculturalism and multicultural teams.
RQ3: Presume that most enterprises perceive a conflict as a threat not as opportunity.
RQ4: Presume that is a growing number of multicultural teams in Slovakia.
Working hypothesis:
H1: If industrial enterprises will have overworked method to resolve conflicts in multicultural teams thus the overall time needed to resolve conflicts will be reducing.

CONCLUSION

Due of expanding globalization of the working market the more and more industrial enterprises are becoming open for employees from all corners of the world. This phenomenon is mainly due to the lack of skilled labor in local work markets and especially the nature of multinational companies. The authors of this paper focused on theoretical basis of conflict resolution within multicultural teams in industrial enterprises. Using of the literature the authors has summarized the theoretical knowledge of conflict resolution, team and multiculturalism. However, Videnová defined the notion of conflict and team for. The authors had set the main objective and sub-objectives, hypotheses and research presumptions and also pointed out the reasons why it is necessary to resolve this issue. The main objective of this work is to develop theoretical and analytical basis of the field for further processing.

ACKNOWLEDGMENT

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REFERENCES

1. HOFFMANOVÁ, V. 2003. *Úvod do problematiky globalizácie*. Prešov: Metodicko-pedagogické centrum. ISBN 80-804-5309-8
2. Konflikty: Tichomír Kotek, 2003 (cit. 2012-10-20). Dostupné na internete: http://web.tuke.sk/ksv/kotek/konflikt.pdf
3. Resolving Conflict in Work Teams: Townsley, Carole A., CSWT Reports. 2001 (cit. 2012-10-20). Dostupné na internete: http://www.rvarmstrong.com/.htm
4. Manažment konfliktov v tíme: Ondrej Žáry, 2006 (cit. 2012-1-9). Dostupné na internete: http://www2.fiit.stuba.sk/~bielik/courses/msi-slov/kniha/2006/groupa/essay/13.pdf
5. LEBEDA, P., 2011. *Konflikt – organická součást (ne)udržitelného růstu (na příkladu podnikání). Systémové konflikty*. s. 192 – 196.
6. LABÁTH, V. 1994. *Alternatívne riešenie konfliktov. Tréningový manuál*. Bratislava: PDCS ©, ISBN 80-968934-7-5
7. Highpoints From the Amplifying Your Effectiveness Conference: Starrett, E., 2003 (cit. 2012-1-9). Dostupné na internete: http://www.stsc.hill.af.mil/crosstal/Starrett.html
9. Negotiations and Resolving Conflicts: Wertheim, E., An Overview, 2003 (cit. 2012-1-9). Dostupné na internete: http://web.cba.neu.edu/~ewertheim/interper/negot3.htm
9. TAKEUCHI, R., DURIAU, V.J., 2000. *Internal and External fit of Multicultural teams within Multicultural Corporations*.

RESEARCH PAPERS
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THE STRATEGIC DEVELOPMENT OF MULTICULTURAL COMPETENCIES THROUGH A BALANCED SCORECARD APPROACH

Paul WOOLLISCROFT, Dagmar CAGANOVA, Milos CAMBAL, Jana MAKRAIOVA

ABSTRACT

The need to develop a clear understanding of multicultural competencies is essential to fully develop a strategic approach to human capital management (HCM). As Slovak workplaces become more diverse, culture and intercultural management has gained greater significance and the adoption of a strategic approach is now critical to the success and competitive advantage of the organisation. Moreover, it is necessary to address this field of management to ensure the high performance of organisations, especially those operating within a global setting. The focus of the research is on the identification of multicultural competencies in the context of Slovak industrial enterprises to measure and identify linkages between cultural aspects and the strategic business performance.

KEY WORDS

Globalisation, Multiculturality, Industrial Enterprises, Balanced Score Card, Human Capital Management, Performance

INTRODUCTION

The trend towards globalisation has resulted in an increased need to focus on the development of multicultural competencies for the effective management of organisations. This need has been accelerated in the context of Slovak enterprises due to recent accession to the EU and an influx of Foreign Direct Investment (FDI). As workplaces in Slovakia have become more diverse, multicultural management and intercultural management competencies have gained increased prominence.

The number of enterprises operating in increasingly competitive global market has resulted in the need to adapt the traditional role of Human Resource Management (HRM) and emphasise Strategic Human Capital Management (HCM), whereby employees are regarded as the most important asset of an organisation (1). This paper focuses on research conducted

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amongst employees in Slovak enterprises and the aim is to develop a clear understanding of the role of multicultural management competencies and the implementation of HCM practices. The initial findings represent the preliminary research and will inform the basis of further research to apply a methodical approach with the application of a balanced scorecard (2) to ensure multicultural competencies are linked with the overall business strategy and vision.

MULTICULTURAL PRACTICES IN THE SLOVAK REPUBLIC

The rapid globalisation of the Slovak economic system has led to large scale FDI with numerous MNC's including Peugeot-Citroen, Kia and Volkswagen opening subsidiaries in recent years. To harmonise management within both the Slovak subsidiary and the corporate entity it is necessary to understand and appreciate the role of culture at both a national and corporate level. As culture is applied to both nations and organisations a clear distinction between national and corporate culture is necessary. Schein (3) referred to organisational culture and corporate culture interchangeably and described it as being comprised of "the attitudes, experiences, beliefs and values of an organisation", whereas Deal and Kennedy (4) described culture as "a system of informal rules".

MULTICULTURAL MANAGEMENT COMPETENCY DEVELOPMENT

Several academics have identified a clear relationship between company performance and management competencies. The human capital of an enterprise refers to the people who work for the organisation and who ensure its continued success (5). Whilst the notion of human capital was originally proposed by Beer et al (6), it has become increasingly more popular in recent years, as organisations operating in globally competitive marketplaces and face increased pressure to strategise. Kanter and Dretler (7) argue that human capital should be measured in terms of management competencies, stating the role of effective communication and developing new routes of communication as of critical importance, whereas, McCall and Hollenbeck (8) and Kuhlmann and Stahl (9) emphasise the role of tolerance, openness and understanding cultural ambiguity. In an online questionnaire by Woolliscroft et al (10), 132 professionals in Slovakia were surveyed and a matrix of 20 key management competencies developed:

MATRIX OF 20 KEY MANAGEMENT COMPETENCIES Table 1

Communication	Openness of thinking	Language competency	Social competency	Culture consciousness
Ethics	Ability to manage diversity	Cultural empathy	Tolerance towards ambiguity	Honour and integrity
Ability to collaborate	Flexibility	Managing unpredictable situations	Professional excellence	General management skills
Life-long learning	Resourcefulness	Self-confidence	Critical thinking	Managing stereotypes

Woolliscroft at al (10)

STRATEGIC HUMAN CAPITAL MANAGEMENT

Armstrong (1) states that HRM requires *a strategic and coherent approach to the management of an organisation's most valued assets – the people'*. This argument is further

developed by Glisby and Holden (11) , who state that knowledge possessed by people within an organisation, or "tacit" knowledge, represents a genuine source of competitive advantage, however it is critical to translate the "tacit" to "explicit" knowledge, thus allowing it to be measured, and aligned to the overall strategic vision of the company. The process of developing a clear linkage between the activities (actions) of managers within their daily roles and the overall strategy and vision of the organisation is depicted in Figure 1. The hierarchy indicates an upward chain of interactions starting with the daily "actions" of individual managers, which are primarily assessed by individual KPIs. The individual managers KPIs are subsequently aligned with the CSFs (Critical Success Factors) of the organisation to ensure actions are linked with overall company success. Finally the CSFs are aligned with the organisational objectives, strategy and vision.

Fig. 1 *Hierarchy of Strategic Management Development: Mind tools (12)*

As a means of implementing the strategic management hierarchy into practice it is possible to develop and utilise a balanced scorecard approach as initially proposed by Kaplan and Norton (2). The methodology consists of the four strategic areas of financial, customers, growth and learning and the internal business processes. For each of the areas it is necessary for the organisation to outline their actions, KPIs, CSFs and objectives as shown in Figure 1. The adoption of a balanced scorecard approach enables a strategic perspective to be taken with regards to management competencies. Figure 2 (13) illustrates that the three fundamental pillars of creating long-term shareholder value are human capital, information capital and organisational capital, with these processes underlining the subsequent internal processes and customer centric activities.

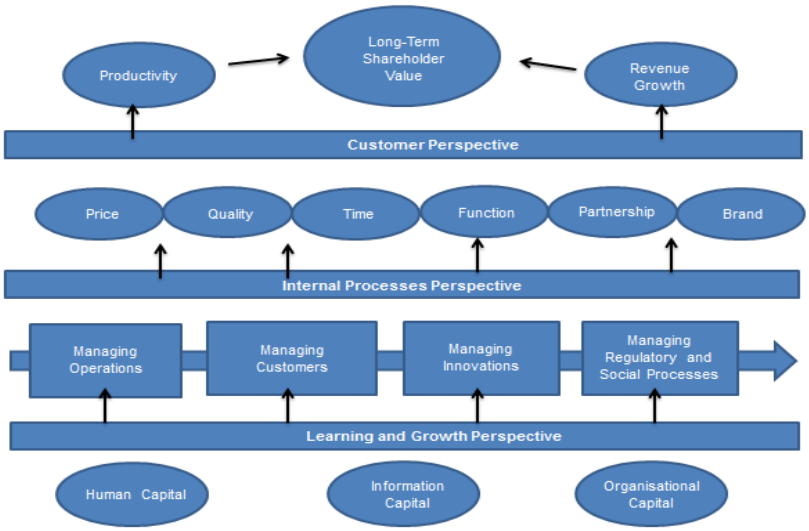

Fig. 2 *A systematic balanced scorecard approach: Marr (13)*

Figure 2 illustrates that the learning and growth perspective, representing the explicit and tacit knowledge of the organisation, is the foundation of shareholder value and without this information the subsequent internal process of managing operations, customers, innovations and process regulations and the attributes from a customer perspective would not be achievable. As a result, whilst the core pillars of learning and growth are not explicitly linked with productivity and revenue growth they underpin all the other activities and therefore should be given strategic importance within the organisation.

METHODOLOGY AND FINDINGS

The preliminary research study was conducted by means of a structured online administered questionnaire of 132 employees within industrial enterprises, research institutions and universities in Slovakia. The research was carried out during the autumn and winter of 2011. The questionnaire was designed specifically to measure responses relating to the importance of key managerial competencies initially identified by Woolliscroft et al (10). The study focused predominately upon the identification and ranking of management competencies. As a result the research to date was exploratory and is intended to represent a starting point for more in-depth research leading to the PhD thesis.

WEIGHTED AVERAGE SCORE INDICATING THE MOST IMPORTANT COMPETENCIES FOR SLOVAK MANAGERS

Table 2

Competency area	Weighted arithmetic average	Standard Deviation
Social competency	4.25	0.736436
Communicative competency	4.540323	0.573602
Tolerance towards ambiguity	4.145161	0.820047
Critical thinking	3.637097	0.81651
Culture empathy	4.169355	0.78001
Professional excellency	3.91129	1.047363
Language competency	4.306452	0.774362
Flexibility	4.129032	0.792787
Ability to collaborate with and lead individuals	4.112903	0.785038
Ability to manage diversity	4.177419	0.730095
Self-confidence/independence	3.717742	0.903046
General managerial skills	3.862903	0.864485
Openness towards other ways of thinking	4.314516	0.765874
Resourcefulness	3.790323	0.825737
Life-long learning	3.798387	0.999837
Culture consciousness (sensitivity. adaptability)	4.233871	0.708347
Ethics	4.193548	0.789829
Honour. truthfulness and integrity	4.104839	0.850223
Managing stereotypes	3.491935	0.954581
Managing unpredictable situations	3.951613	0.914532

5	very important
4	Important
3	neither important nor unimportant
2	less important
1	Unimportant

It is evident from the findings shown above that within Slovak enterprises the greatest emphasis is placed upon language, social and communication competency which all score as important. This reflects the limited usage of native languages when operating globally and the need to utilise additional languages when working in a multicultural environment. It should be highlighted that the majority of the above competencies can be regarded as important irrespective of the multicultural nature of the workplace. As a result a model of Multicultural Human Capital Management (MHCM) will be developed in order to identify those competencies which uniquely add value to the organisation through their multicultural nature. Furthermore, by drawing clear linkages between the multicultural competencies and the balanced scorecard elements of „learning and growth“, „internal processes“, „customer“ and „financial“ (13), the knowledge management process is valuable to ensure that the competencies develop strategic importance within the context of multicultural management.

CONCLUSIONS AND FURTHER RESEARCH

As a result of the findings to date, competencies can be identified which are of importance for Slovak enterprises. The overall objective of the research however, is to investigate more deeply and develop a structured framework of knowledge management which clearly links competencies of multicultural managers with the strategy and vision of the organisation. The next stage will form the main body of research for the PhD thesis and will comprise a large-scale online-administered survey of 250+ managers within industrial enterprises in Slovakia. This will not represent simply a follow-up study as the focus will be on industrial enterprises not including research institutions. The study will build upon the research to date and the objective will be to develop a model which enables tacit knowledge to be translated to explicit knowledge and to establish clear linkages to the overall strategy, ensuring tacit knowledge is measurable and the role elevated to strategic importance.

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REFERENCES

1. ARMSTRONG, M. 2006 *A Handbook of Human Resource Management*, 10th edition. London: Kogan Page Ltd. ISBN: 0-74-944105-4
2. KAPLAN, R and NORTON, D. 1996. *The balanced scorecard: Translating strategy into action*. Cambridge: Harvard Business School Press, USA.
3. MARR, B. 2010. What is a modern Balanced Scorecard? Management Case Study, The Advanced Performance Institute Available at: <http://www.ap-institute.com> (Accessed on 3rd march 2013).

4. SCHEIN, E. H. 1985. *Organizational Culture and Leadership*. San Francisco: Jossey-Bass. ISBN:0-87-589639-1
5. DEAL, T.E. AND KENNEDY, A.A. 2000 *Corporate Cultures*. New York: Perseus Books. ISBN: 0-73-820330-0. P91
6. FURNHAM, A., & GUNTER, B. 1993. Corporate culture: definition, diagnosis and change. In: *Cooper, C.L., Robertson, I.T. (Eds), International Review of Organizational Psychology*. West Sussex, John Wiley & Sons.
7. BEER, M., SPECTOR, B., LAWRENCE, P., QUINN MILLS., D. AND WALTON, R. 1984. *Managing Human Assets.* New York: The Free Press, ISBN: 0-02-902390-4
8. KANTER, R.M., AND DRETLER, T.D. 1998. Global strategy' and its impact on Local operations: Lessons from Gillette Singapore. *Academy of Management Executive*, **12**(4), pp. 60–68.
9. MCCALL, M.W AND HOLLENBECK, G.P. 2002. Developing global executives: The lessons of international experience. Boston: Harvard Business School Publishing. ISBN 1-57851-336-7
10. KUHLMANN, T. AND STAHL, G. 2001. Developing Global Business Leaders: Policies, Processes, and Innovations. Quorum Books. Westport. ISBN: 1-56720314-0
11. WOOLLISCROFT, P.S., CAGANOVA, D., CAMBAL, M. and SEFCIKOVA, M. 2012. A multicultural competencies approach to developing strategic human capital management within Slovak Enterprises. *Research papers, Faculty of Materials Science and Technology in Trnava, Slovak University of Technology in Bratislava*, Special Number.
12. GLISBY, M and HOLDEN, N.J. 2011. Mastering Tacit Corridors for Competitive Advantage. *Global Business and Organizational Excellence*.
13. MINDTOOLS. 2013. Performance Management and KPIs, Available at: <http://www.mindtools.com> (Accessed on 3rd March 2013).
14. MARR, B. 2010. What is a modern Balanced Scorecard? Management Case Study. The Advanced Performance Institute Available at: <http://www.ap-institute.com> (Accessed on 3rd march 2013).

MACHINE PRODUCTION TECHNOLOGIES

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2013 Special Number

THE EFFECT OF WAVEGUIDE SHAPES ON THE MODAL PROPERTIES AND AMPLIFICATION FACTORS

Lenka ČIČMANCOVÁ, Milan NAĎ

ABSTRACT

Improving of machining process is one of the most important requirements that are expected from the machining methods. In many machining processes, the positive effects of ultrasound are applied. The performance of these machining systems and quality of machining process depends on the correct design of the individual system elements, mainly waveguide. For the correct functioning of the system, the waveguide must have the required dynamic properties - natural frequencies and amplification factors. The waveguide modal properties (natural frequencies, mode shapes) are determined by the numerical simulations using finite element method (FEM) design procedures. The effect of different waveguide shapes (conical, exponential, catenoidal) and their dimensions on modal properties and amplification factors are presented in this paper.

KEY WORDS

ultrasonic waveguide, modal properties, amplification factor, finite element method

INTRODUCTION

Ultrasonic vibrations give considerable benefits for a variety of industrial applications. The remarkable advantages are achieved by the use of ultrasound in various machining processes. The different physical approaches of ultrasonic vibration energy applications can be presented in various machining processes. Two fundamental principles are used in ultrasonic machining processes, i.e. ultrasonic machining (USM) - ultrasonic transducer which is utilised indirectly to propel abrasive particles suspended in slurry at the work surface causing slow erosion and ultrasonic assisted machining (UAM) (1) - ultrasonic vibrations are transferred directly on the cutting tool and it can be applied to different machining technologies - turning, grinding, boring, milling and others. The repetitive high-frequency vibro-impact mode brings some unique properties and improvements into metal cutting process (1), (2), (3). The electromechanical transducer of ultrasonic machining systems acts as the source of mechanical oscillations. The electro-mechanical ultrasonic transducers generate the vibration with frequency $f_{res} \approx 20$ kHz and more. The amplitude of the resulting ultrasonic vibrations is

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inadequate for realization of the cutting process. To overcome this problem, a waveguide focusing device is fitted onto the end of the transducer. The waveguide transfers the longitudinal ultrasonic waves from the transducer to end of the toe with attached the cutting tool. The cutting performance of ultrasonic machining equipment depends on the correct design of the waveguide. It amplifies the input amplitude of vibrations so that at the output end the amplitude is sufficiently large to required machining process (3). Positive results in machining processes of hardly machinable materials, which usually could not be achieved by conventional machining processes are obtained by using UAM. The main benefits of ultrasound applications in machining (1), (2) are related to a reduction in cutting forces, improved machined surface quality, reduction wear and increasing life cycle of tool, etc.

The main aim is to present generally valid rules leading to the geometrical design of conical, exponential and catenoidal waveguide shape with required dynamical properties.

ULTRASONIC WAVEGUIDE DESIGN AND MATHEMATICAL MODEL

The main function of the waveguide is to amplify the amplitude of ultrasonic vibration of the tool cutting edge to the level required to the effective machining. The waveguide transfers the vibrational energy from the transducer towards to the tool interacting with workpiece. The manufacture and design of the waveguide require special attention because wrong manufactured waveguide will deteriorate performance of machining and can lead to the damage of the vibration system and cause considerable damage to the generator.

The most important aspect of the waveguide design is waveguide resonant frequency and the determination of the correct waveguide resonant wavelength. The required performance of a waveguide is assessed by an amplification factor (4):

$$\vartheta = |A_1/A_0|, \qquad \text{fundamental request:} \quad \vartheta > 1, \tag{1}$$

where A_0 - amplitude of input end of horn, A_1 - amplitude of output end of horn.

Waveguides are made of isotropic material (Young's modulus E, density ρ, Poisson's number μ). The equation of motion of longitudinally vibrating ultrasonic waveguide with variable circular cross-section can be expressed in following form

$$\frac{\partial^2 u}{\partial t^2} - \frac{c_p^2}{S(x)} \frac{\partial}{\partial x}\left[S(x) \frac{\partial u}{\partial x} \right] = q(x,t), \tag{2}$$

where $u(x,t)$ - longitudinal displacement of cross-section in x-direction, $c_p = \sqrt{E/\rho}$ - velocity of propagation of the longitudinal waves in x-direction, $S(x) = S_0 f(x)$ - circular cross-section, $f(x)$ - function defining the change of the cross-section in longitudinal direction.

The solution of equation of motion for free vibrating (i.e. $q(x,t) = 0$) has the form $u(x,t) = U(x)e^{i\omega_0 t}$ and after substitution dimensionless quantities (Tab. 1) into [2], we can write

$$\frac{1}{S(\xi)} \frac{d}{d\xi}\left(S(\xi) \frac{d\overline{U}(\xi)}{d\xi} \right) + \beta^2 \overline{U}(\xi) = 0 \tag{3}$$

where $\beta = \omega_0 l_0 / c_p$ - frequency parameter, ω_0 - natural angular frequency, l_0 - length of waveguide.

THE DIMENSIONLESS QUANTITIES Table 1

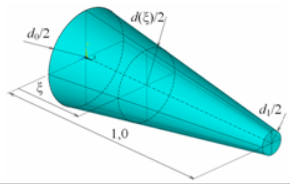
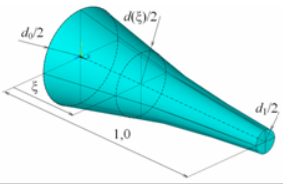
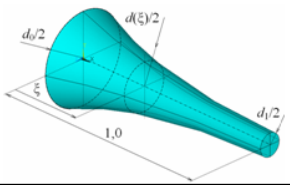
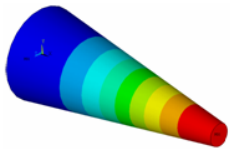
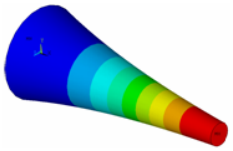
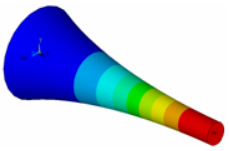
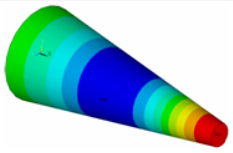
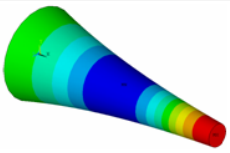
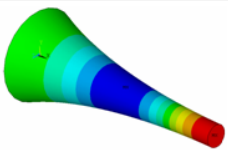
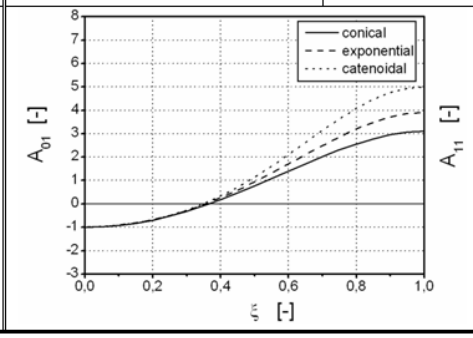
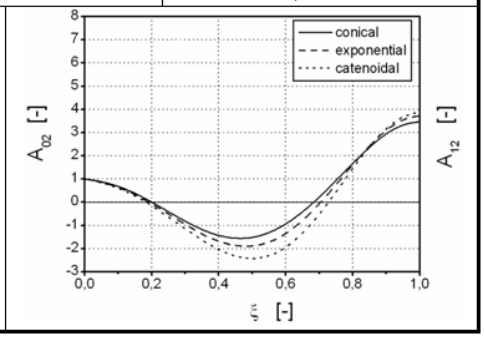
dimensionless coordinate	dimensionless longitudinal displacement	dimensionless ratio of diameter
$\xi = x/l_0 \quad \xi \in \langle 0;1 \rangle$	$\overline{U}(\xi) = U(\xi)/l_0$	$\psi = d_1/d_0 \quad \psi \in (0;1\rangle$

Generally, in machining processes only two vibrating mode shapes of waveguides are used, i.e. “half wave” shape and “wave” shape (Tab. 2). The most common shapes and their geometrical dimensionless parameters are shown in Tab. 2.

ANALYSIS AND RESULTS

The numerical simulation and determination of modal properties of considered waveguides shapes are carried out. The numerical analyses are performed for parameters defined in Tab. 2. The steel as a waveguide material is used to numerical simulation.

GEOMETRICAL PARAMETERS OF WAVEGUIDE SHAPES Table 2

	CONICAL	EXPONENTIAL	CATENOIDAL
Slenderness ratio δ: $\delta = \frac{d_0}{l_0}$; $(l_0 = 1{,}0)$			
Mode shapes: 1st „half wave"			
Mode shapes: 2nd „wave"			
Shape parameters	$d_0 = \delta$; $d(\xi) = d_0 f(\xi)$; $d_1 = \psi d_0$ $\Rightarrow$ $S(\xi) = S_0(f(\xi))^2$		
Shape function	$f(\xi) = 1 - \xi(1-\psi)$	$f(\xi) = \psi^{\xi}$	$f(\xi) = \frac{\cosh[\kappa(1-\xi)]}{\cosh(\kappa)}$ $\kappa = \ln\left(\frac{1+\sqrt{1-\psi^2}}{\psi}\right)$; $\psi \le 1{,}0$
Mode shapes: for dimensionless parameters: $\delta = 0{,}4$ and $\psi = 0{,}25$ A_{0k} - input amplitude A_{1k} - output amplitude			

The dimensionless resonant frequencies for different geometrical shapes of waveguides can be expressed as

$$\theta_k = \frac{f_{0,k}^{shaped}}{f_{0,k}^{cylidrical}}, \qquad \text{resp.} \qquad f_{0,k}^{shaped} = \theta_k f_{0,k}^{cylindrical} \qquad [4]$$

where $f_{0,k}^{shaped}$ - k^{th} natural frequency of shaped waveguide, $f_{0,k}^{cylindrical}$ - k^{th} natural frequency of cylindrical waveguide for corresponding slenderness ratio.

The dependencies of dimensionless frequencies θ_1, resp. θ_2 on the slenderness ratio δ for the various ψ parameters are shown in Fig. 1÷Fig. 3 and the dependencies of the amplification factor ϑ_1, resp. ϑ_2 on the ratio δ for various ψ are shown in Fig. 4÷Fig. 6.

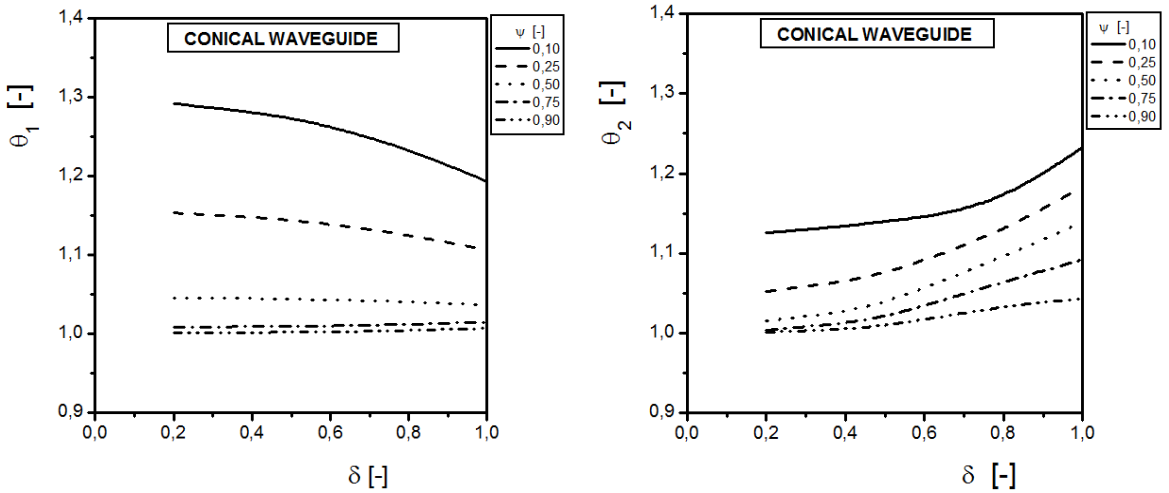


Fig. 1 *Dependency of θ_1, resp. θ_2 vs. slenderness ratio δ for conical waveguide shape*

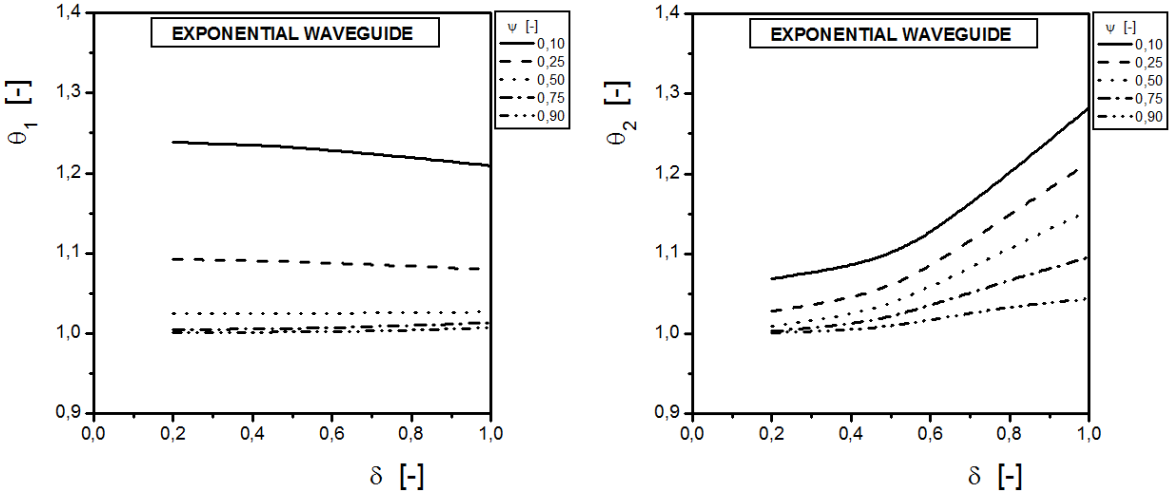


Fig. 2 *Dependency of θ_1, resp. θ_2 vs. slenderness ratio δ for exponential waveguide shape*

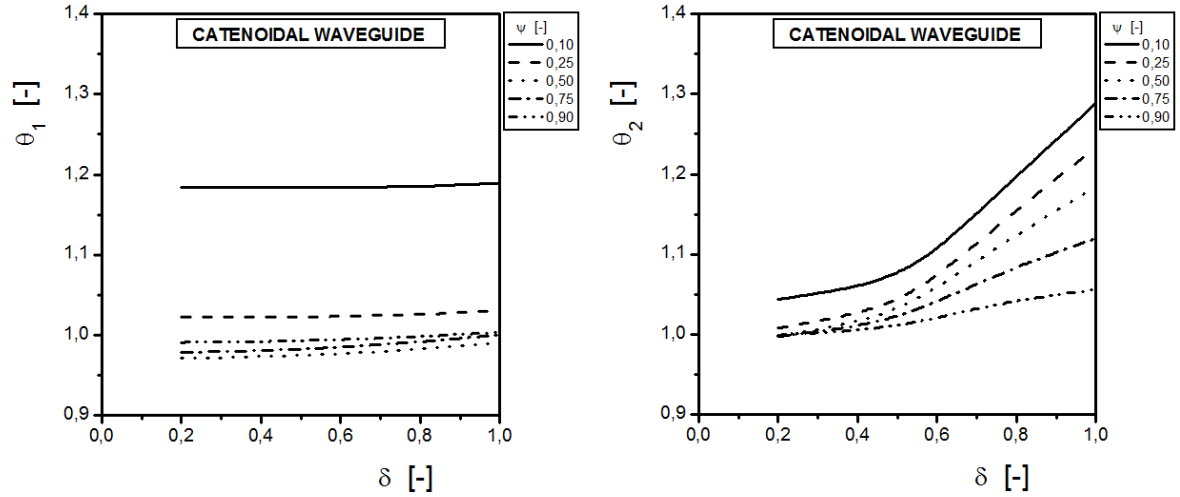


Fig. 3 *Dependency of θ_1, resp. θ_2 vs. slenderness ratio δ for catenoidal waveguide shape*

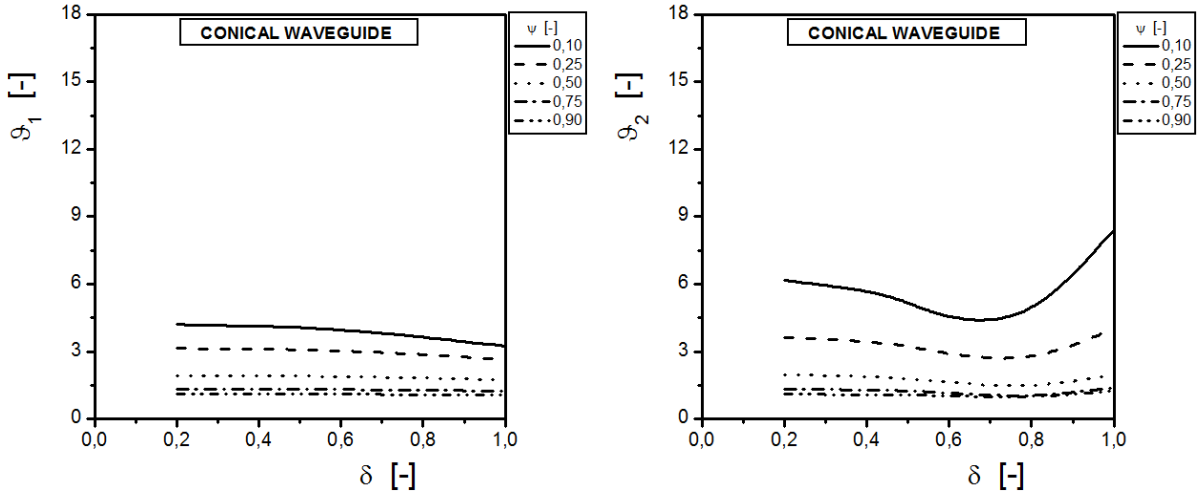


Fig. 4 *Dependency of ϑ_1, resp. ϑ_2 vs. slenderness ratio δ for conical waveguide shape*

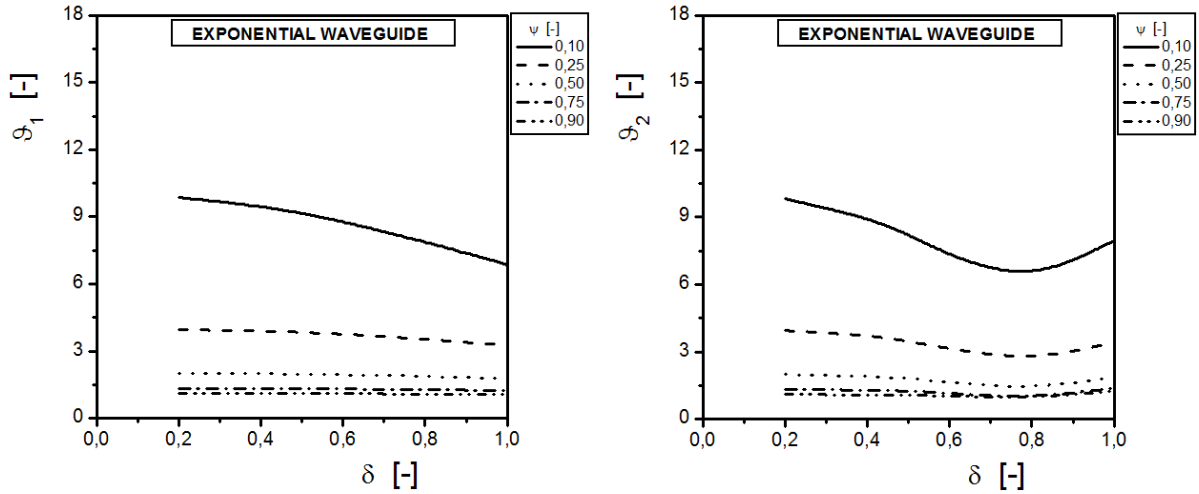


Fig. 5 *Dependency of ϑ_1, resp. ϑ_2 vs. slenderness ratio δ for exponential waveguide shape*

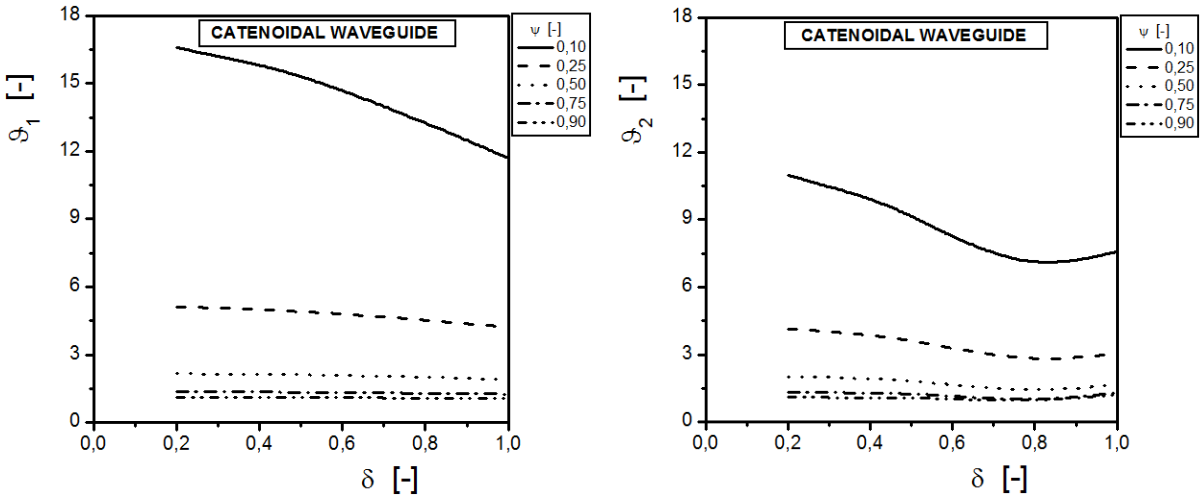


Fig. 6 *Dependency of ϑ_1, resp. ϑ_2 vs. slenderness ratio δ for catenoidal waveguide shape*

CONCLUSION

The effect of the waveguide geometrical shape for ultrasonic manufacturing technologies is analysed in this paper. The different geometrical waveguide shapes were considered. The effects such as a slenderness ratio δ and ratio of output to input diameter on natural frequencies and amplification factor had been analysed.

Using Eq. [4], the required value of resonant frequency is determined. The fundamental requirements to the application of these waveguides for ultrasonic machining technologies are that the resonance frequency has to be more than 20 kHz and amplification factor is greater than 1,0.

ACKNOWLEDGMENT

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REFERENCES

1. ASTASHEV, V.K., BABITSKY, V.I. 2007. *Ultrasonic processes and machines: Dynamics, control and applications*. New York: Springer Science+Business Media. ISBN 978-3-540-72060-7
2. BABITSKY, V.I., KALASHNIKOV, A.N., MEADOWS, A., WIJESUNDARA, A.A.H.P. 2003. Ultrasonically assisted turning of aviation materials. *Journal of Materials Processing Technology*, **132**(1-3), 157-167. ISSN 0924-0136
3. NAĎ, M., ČIČMANCOVÁ, L. 2012. The effect of the shape parameters on modal properties of ultrasonic horn design for ultrasonic assisted machining. In: *Proceedings of the 8th International Conference of DAAAM Baltic Industrial Engineering*: Tallinn, Estonia 19-21 April 2012. Tallinn: Tallinn University of Technology, 57-62. ISBN 978-9949-23-265-9
4. NAĎ, M., ČIČMANCOVÁ, L. 2013. Effect of shape parameters on the modal properties of stepped ultrasonic concentrator. *Applied Mechanics and Materials*, **309**, 43-49. ISBN 978-3-03785-636-9

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THE IMPACT OF ALIGNMENT CONDITION IN THE MEASURING PLAN BY USING THE SOFTWARE CALYPSO ON THE REPEATABILITY OF MEASURED VALUES

Zdenko GUNIŠ, Augustín GÖRÖG, Juraj VAGOVSKÝ

ABSTRACT

The main goal of this publication is to determine the impact of the alignment condition to the repeatability of measured values. In the experimental work were performed four series of measurements, each contains 25 individual measurements on a single component. The component was measured according to the rules for making the comparison of measured values for repeatability. This comparison of measurement results was made by using statistical methods. A given goal was completely fulfilled. Experimental work has shown a dominant impact of the alignment condition on the measured values.

KEY WORDS

CMM, repeatability, valueA, standard deviation

INTRODUCTION

In practice, it is necessary to evaluate the capability of the measuring device of process. Nowadays, many companies in the industry use the coordinate measuring machines for measuring of the geometrical characteristics. The question is, whether this device is or is not able to perform a repeated measurement without different measured values on the same component and with the same conditions. The evaluation of the measurement process plays a very important role especially because of bringing the variability to the manufacturing process. If the measurement is correct, and the made component is declared to be defective, then it has an economic consequences. Measuring plans for Coordinate Measuring Machines (CMM) are in present made by using of CAD software that is linked directly to the measuring device. The measuring plan must take steps that will eliminate the fluctuations in the measured values of the measuring plan. These steps will be described in the next section. However, despite of the great accuracy and universality of the gauge, we can't prevent the errors in measurement. An important factor in the evaluation process is evaluation of the measurement repeatability of measurement results. The standard defines repeatability as a closeness conformity between the results of measurements which were obtained in the same

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object, carried out under the conditions of repeatability; these are the same measurement procedure, using the same measuring equipment, measurement with the same operator, the same measurement place and conditions of environment during measuring and short time intervals between measurements. Repeatability is possible to quantify by the characteristics of the precision results. Precision is the closeness of agreement between independent results, which were conducted under the specified conditions, in another words we can say under the conditions of repeatability. Thus the repeatability of results relates to the precision of the measured values around the average value. It may be expressed, for example by standard deviation. Accuracy is the tightness of the conformity between the results of measuring the same quantity, carried out under the same conditions towards the accepted reference value, that is towards the true value.

THE DEFINITION OF THE PROBLEM

The creation of measuring plan is submitted to a sequence of steps. First, we have to know what we want to measure, which measuring devices we use, what elements we use to define the coordinate system components. They're so called reference elements, which should be produced on the components with maximum accuracy. These elements are also used in focusing and aligning of components. Nowadays, the measurement is executed by using CAD model, which carries the reference (nominal) values, or dimensional shape characteristics. This CAD model includes these elements (planes, cylinders, cones etc.) which have a perfect shape and size and the creation of the measuring plan comprises basically from the first step in establishing nominal values of measured characteristics. For the creation of coordinate system are used bases contained in the drawing documentation, according which is the component focusing on the desk CMM. If we create a coordinate system from the elements which are contained in the CAD model, then is this coordinate system considered as a reference for measuring plan. On these surfaces will be the component focused also in real measurement. If we want to measure a component on the desktop, first we need to measure the component manually, it means that each elements have to be scanned by minimum number of points to define the substitute geometry. Subsequently the software calculates in its internal algorithm a shifting and tilting of the actual coordinate system towards the reference system and it starts a CNC mode. The scanning is in CNC. Here begins a certain issue. Component is scanned but aligning within it contains some error defined as valueA. This means that the actual coordinate system is shifted and tilted towards the nominal about some specific amount. Does this valueA an impact on the further course of measurements and affects the measured values? How do we can eliminate this error in the measurement process to cause the minimal impact on the test result? In a present day exists a PCM condition, that is inserted into the measuring plan, and that can repeats the alignment until the valueA isn't minimized. This means, that the measurement does not start in CNC mode while this value is less or equal to the maximum permissible value in the condition of alignment. Nowadays is this condition used only in certain cases or not, because it extends the time of measurement. The usage is limited mainly because of the ignorance of the impact of this condition on the result of measurement, repeatability of measured values and capability of measurement process. Therefore, the goal of the experimental work was to determine the impact of the conditions on the repeatability of the measured values and clearly confirm or deny its impact (TŮMOVÁ 2009, ISO/WD 15725-1).

CONDITIONS OF MEASUREMENT

For the realization of the experimental work was chosen the coordinate measuring machine DURAMAX (ZEISS), which uses contacting scanning head VAST XXT TL-3. Measured component was proposed on the base of the shape demands, then we can measure various geometrical characteristics of it. For the creation of a measuring plan has served to us a measuring and evaluation software CALYPSO 5.4, where measuring plan was created. For the simplification of programming was used CAD model of components in a STL format. To create a coordinate system of component were used bases, that are included in the drawing documentation. The component was measured on these surfaces and in measuring plan was gradually changed the condition of aligning. The measurement parameters were set (the tracks of scanning points, stride length, movement speed of touch probe). To determine the impact of the alignment condition for the repeatability of measured values was suggested the following procedure. The first series of measurements was performed without entering the alignment condition. The component was clamped to the preparation and measurement took a place of defined characteristics. In a second series of measurements was into the measuring plan entered the condition as baseSystem(). valueA≤0.5. In the third series of measurement, this condition was defined as baseSystem ().valueA≤0.05 and in the fourth was used the baseSystem().valueA≤0005. The characteristics that were evaluated are valid according to STN EN ISO 1101:2006 – Geometrical Product Specifications GPS. These characteristics were set according to tolerance of drawing documentation. To evaluate the repeatability of the measured values was necessary to release and re-clamped component from the preparation. The component was measured in each series 25 times. Repeatability was evaluated graphically and numerically (median, standard deviation, precision of measured values).

MEASURED VALUES AND THEIR EVALUATION

The measurement was kept to the laboratory terms. The temperature of environment was 20 °C this means that the maximum permissible error of the machine in the range of temperature 18-22 °C is the MPEE = (2.4 + L/300) mm.

From the drawing documentation were chosen the characteristics, which served for comparison of the alignment impact on the repeatability of measured values. The first measurement was made without the condition of alignment, subsequently, after the first series of 25 measurements was into the CNC program gradually inserted the condition of alignment valueA<0.5, valueA<0.05 and valueA<0.005. The course of measured values can be seen in the following figures. For the comparison were chosen some characteristics. Course of the measured values for the measurement of distance is in Fig. 1, here can be clearly seen more stable values by using the alignment conditions in comparison with the measurements where this condition wasn't used. The total difference can be seen in the standard deviation in Fig. 2.

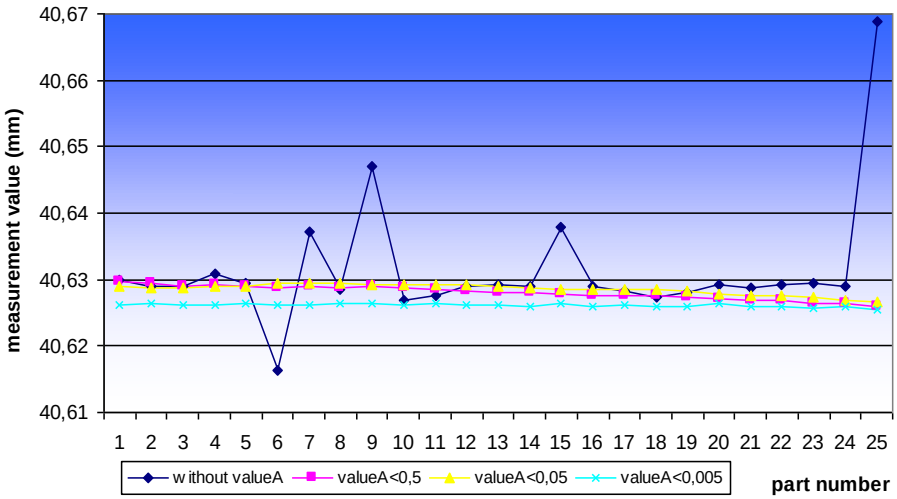

Fig. 1 *The course of measured values for DIS_40,63mm*

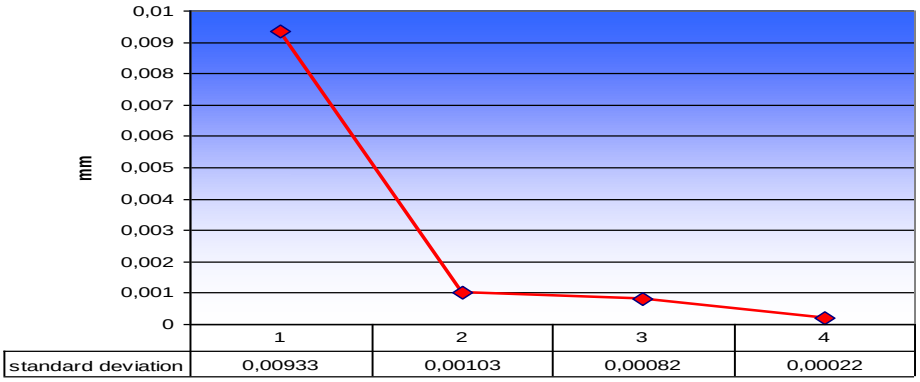

Fig. 2 Standard deviation of measured values for DIS_40,63

The next from the measured characteristics was the axial runout. Here we can see a noticeable difference between the measured values with using the alignment condition and without the alignment condition. The course of the measured values is shown in Fig. 3 and the resultant standard deviation is shown in Fig. 4.

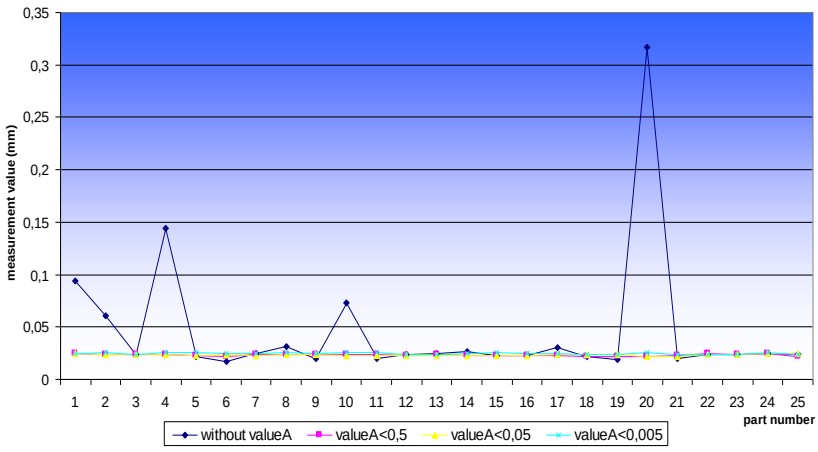

Fig. 3 *The course of measured values axial runout*

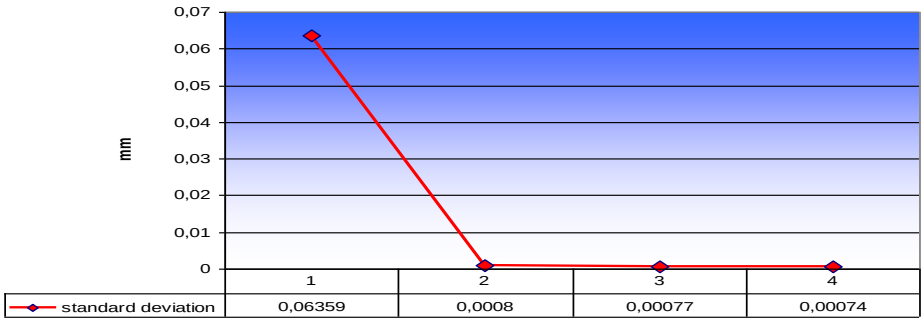

Fig. 4 *Standard deviation of measured values for the axial runout*

Significant difference between the measured values was especially shown in characteristics that are difficult to measure. It was a complex component shapes, and some characteristics were evaluated from the elements, because they could not be measured as a whole. Such elements have also been used when evaluating the parallelity, and its results are shown in Fig. 5. The standard deviation had a downward trend with applying the flatness conditions (Fig. 6).

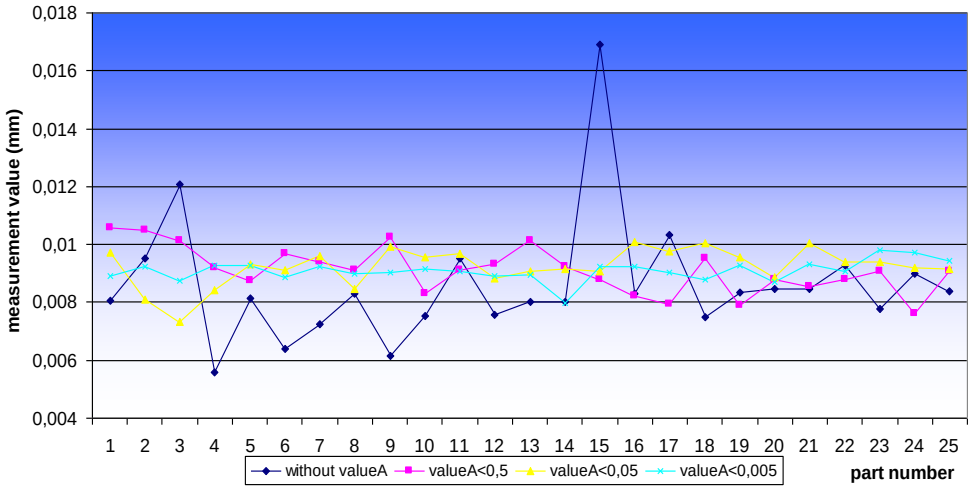

Fig. 5 *The course of measured values when measuring parallelism*

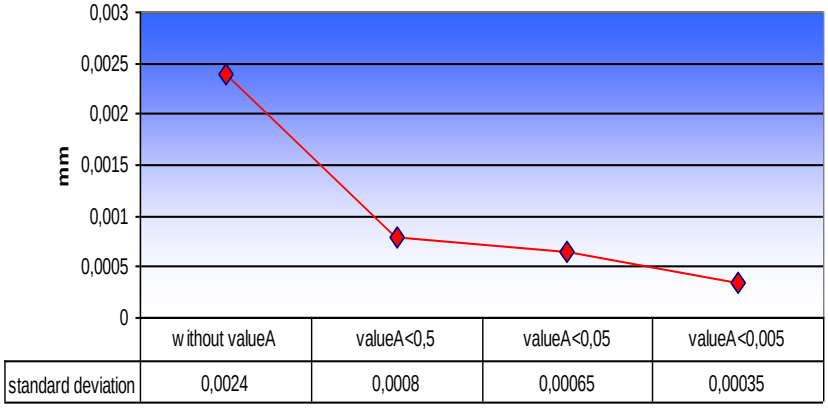

Fig. 6 *Standard deviation of measured values for parallelism*

CONCLUSION

It is often impossible to clamp a complex shape components into the products, where is guaranteed the repeatability with high accuracy. Therefore the experimental work was conducted to assess the impact of alignment condition on the repeatability of measured values. With decreasing of the valueA was the standard deviation of the measured values varied significantly what can be seen in these figures. The measurement results clearly demonstrate the impact of alignment conditions on the repeatability of the measured values, which has important and essential meaning in practice. The scores very clearly demonstrate, that if we want to measure in serial measurements, where it is not possible to use the preparation with guaranteed repeatability of clamping, it is necessary to insert the alignment condition into the measuring plan. The value into which the part is aligning (valueA) should be specified according to the smallest defined tolerances in the drawing documentation. This issue requires a big consideration, because the coordinate measuring technique is widely used in practice. To further determination of the impact on the measured values will be necessary to apply the obtained knowledge on the component, which can be regarded as a standard. It is necessary mainly from the reason of the determination the impact of this condition on the accuracy of measured values.

ACKNOWLEDGMENT

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REFERENCES

1. TŮMOVÁ, O., 2009. *Metrologie a hodnocení procesů*. Praha: BEN – technická literatura. ISBN 978-80-7300-249-1
2. ISO/WD 15725-1 – Accuracy (trueness and precision) of measurement methods and results
3. STN EN ISO 1101:2006 - GPS

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2013 Special Number

CRYOGENIC ROTARY ULTRASONIC MACHINING OF TITANIUM ALLOYS

Marcel KURUC, Martin SAHÚL, Marek ZVONČAN,
Jozef PETERKA, Ľubomír ČAPLOVIČ

ABSTRACT

Titanium alloys are utilized especially in applications that require a good combination of high strength, low mass and good corrosion resistance in aggressive environments. However, mechanical properties prejudge titanium alloys to hard machinability. Machining of titanium alloys is usually accompanied by cooling with liquids or gasses. One of the most effective cooling approaches is cooling by liquid nitrogen. Liquid nitrogen decreases temperature of tool, but also increases strength, hardness and brittleness of workpiece. One of the most suitable machining methods to machine hard and brittle materials is ultrasonic machining. In this article, rotary ultrasonic machining of titanium alloys under cryogenic conditions is analyzed.

KEY WORDS

Cryogenic machining, Rotary ultrasonic machining, Titanium alloys, Liquid nitrogen

INTRODUCTION

Commercial production of titanium began in the 1950s (Singh and Khamba, 2006). It has become an important material especially in spacecraft and aircraft, where it is primary applied to production of jet engines and airframe components. These components demand high geometric accuracy and low roughness of surface. Machining of titanium alloys is accompanied by high tool wear and low tool life. Worn tool cannot reach neither required accuracy, nor roughness. Rotary ultrasonic machining is able cost-effective machining hard machinable materials with relative high material removal rate and it also reaches high precision and low roughness. It makes rotary ultrasonic machining suitable for machining of titanium alloys, especially under cryogenic condition.

MATERIALS AND METHODS

Titanium has the highest strength-to-weight ratio of any metal. Therefore, titanium and its alloys have high utility in manufacturing sector. Also, titanium has excellent corrosion

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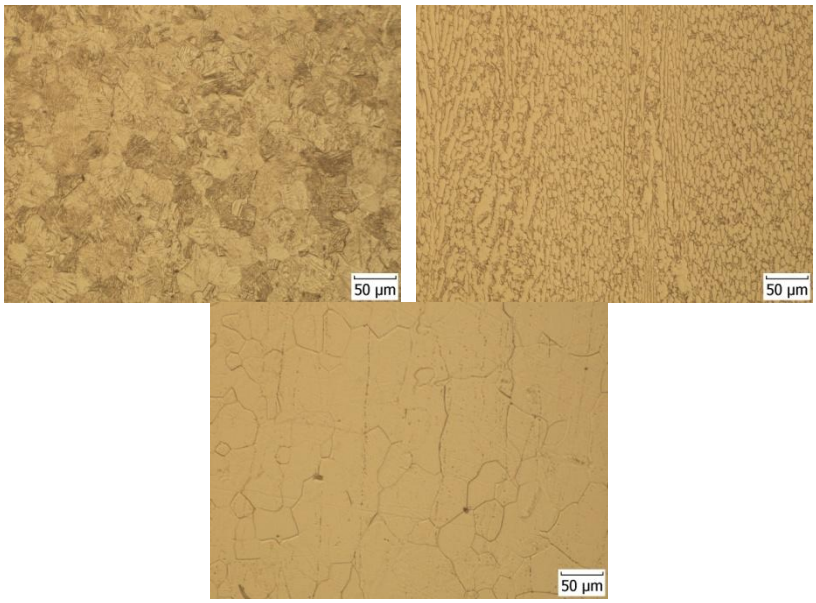
resistance. However, their properties prejudge titanium alloys to hard-machinability. They can reach value of yield strength up to 1400 MPa (Boyer, 1996; Peters and Leyens, 2009). Therefore, high cutting forces are required for machining of titanium. Higher cutting forces generate more process heat. Titanium alloys have poor thermal conductivity and it causes high temperature at the tool, because generated heat cannot be fast enough to be lead away by chips and it remains in tool-workpiece interface. This effect decreases tool life and increase tool wear.

Pure titanium has two allotropic modifications. Alpha-titanium is present up to 882 °C and it is characterized by hexagonal close-packet (HPC) lattice. Over this temperature, up to melting point (1668 °C), beta-titanium is present, which is characterized by body centered cubic (BCC) lattice (Hong et al., 2001). However, we can affect resultant structure of titanium alloys at room temperature by adding alloying elements. Consequently, three structure types can be obtained at room temperature: alpha structure, alpha + beta structure, and beta structure. Beta-titanium alloys are characterized by higher mechanical properties and they can be heat-treatable. In comparison to other titanium alloys, beta-titanium alloys offer higher tensile strength due to deeper hardenability, increased fatigue strength and better forming properties (Machai and Biermann, 2011). In this article, the investigation of titanium alloy resultant phase to suitability to rotary ultrasonic machining under cryogenic condition is planned. There will be investigation of its influence to cutting forces, too. Representative of alpha-titanium alloys is Titanium Gr. 2. Alpha+beta-titanium alloys representative is Titanium Gr. 5. Finally, Titanium Gr. 19 is representative of beta-titanium alloys. Chosen titanium alloys and their chemical composition are recorded in Table 1. Chemical composition has been reached by EDX analysis.

CHEMICAL COMPOSITION AND PRESENT PHASES IN INVESTIGATED TITANIUM ALLOYS Table 1

Material	Chemical composition [wt. %]						Phase
	Ti	Al	V	Cr	Zr	Mo	
Titanium Grade 2	100	-	-	-	-	-	α
Titanium Grade 5	89,96	5,81	4,23	-	-	-	α + β
Titanium Grade 19	73,12	3,39	8,08	5,98	4,62	4,80	β

Resultant microstructure is shown in Figure 1. To reach these microstructures, samples have been grinded by emery with granularity 600, then by emery with granularity 1200. After grinding, the polishing follows. To polishing the solutions that contain diamond abrasive are needed. Size of diamond particles are 9 μm, 6 μm, 3 μm and finally 1 μm. To highlight microstructure etching by Kalling´s etchant containing 10 ml of water, 3 ml of HNO_3 and 1,5 ml of HF for 5 to 10 seconds has been used. Microstructure has been observed by light microscope.



a) b) c)

Fig. 1 *Microstructure of titanium alloys: a) Grade 2, b) Grade 5, c) Grade 19*

To machine hard and brittle materials, one of the most suitable machining processes is unconventional method called Ultrasonic machining (USM). USM is a mechanical material removal process based on ultrasonic vibration of an abrasive particles carried in coolant. Application of USM brings many advantages. Workpiece is neither thermally nor chemically affected, and machined surface has low roughness (Thoe et al., 1998). Coolant in process circulates between a tool and the workpiece and it is primary used for removing of chips and for carrying of abrasive particles, not for cooling of the tool.

Rotary ultrasonic machining (RUM) is a hybrid machining process, which combines advantages of USM and diamond grinding. It achieves higher material removal rate than can be obtained by either diamond grinding or USM (Hu, 2002). In addition, it can reach higher precision and lower roughness compared to USM. RUM is cost-effective machining technology available for milling hard and brittle materials, like glass and ceramics. Even during machining such hard-machinable materials, it can reach superior surface finish, improved accuracy of holes, capability to drill deep holes, etc. In contrast with USM, RUM utilizes rotating tool with diamond abrasive bonded on active part of tool. There the coolant is also used, but in this case coolant does not carry abrasive particles. Primary application of coolant is also for removing of chips. Machining strategies of RUM are common plunging, and also face milling, as shown in Figure 2.

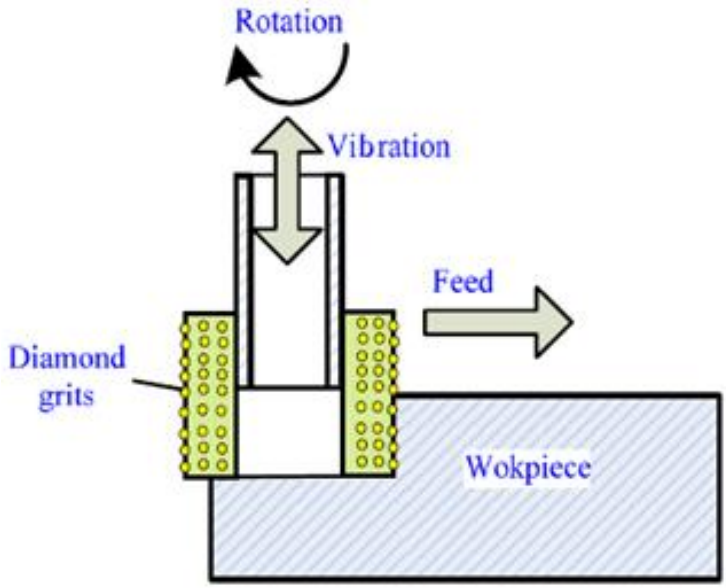


Fig. 2 *Illustration of rotary ultrasonic machining during side milling (Gong et al., 2010)*

ANTICIPATED RESULTS

A lot of researches based on increasing of tool life are focused on liquid nitrogen. For example, Yildiz and Nalbant (2008) ascribe the liquid nitrogen cooling approach the biggest impact on increased tool life, on improved surface roughness and on temperature control among all cooling strategies. Hong et al. (2001) applied small focused micro-jets of liquid nitrogen towards the tool tip, which cause increasing tool life in machining of Ti-6Al-4V up to five times. Umbrello et al. (2012) compared cryogenic cooling approach and dry machining, and they find out that turning with cryogenic cooling can reach as low roughness as grinding.

Application of liquid nitrogen is focused on the cooling effect, because temperature of liquefaction of nitrogen is – 196 °C (77 K). Lubrication effect of liquid nitrogen is insignificant. When any material is exposed to cryogenic temperatures, its mechanical properties will change. Its hardness and strength will be increased and material becomes more brittle. Especially materials with cubic lattice are susceptible to embrittlement. That also affects cutting forces. Therefore, mechanical properties of material under cryogenic conditions are important to know, especially impact strength is relevant. Velocity of heating of frozen material on atmosphere is another important attribute. Based on these facts, simulation of heating the sample for impact bending test has been investigated. Simulation has been created by ANSYS software. As shown in Figure 3, titanium sample reaches room temperature after few minutes after exposing surroundings. The highest amount of temperature has been absorbed at the beginning of heating. Development of temperature in first 150 seconds is shown in this figure. Uniform temperature of sample has been – 196 °C, temperature of surrounding has been + 20 °C. In this figure longitudinal sectioned sample is shown. Therefore, temperatures in the middle of the sample can be observed.

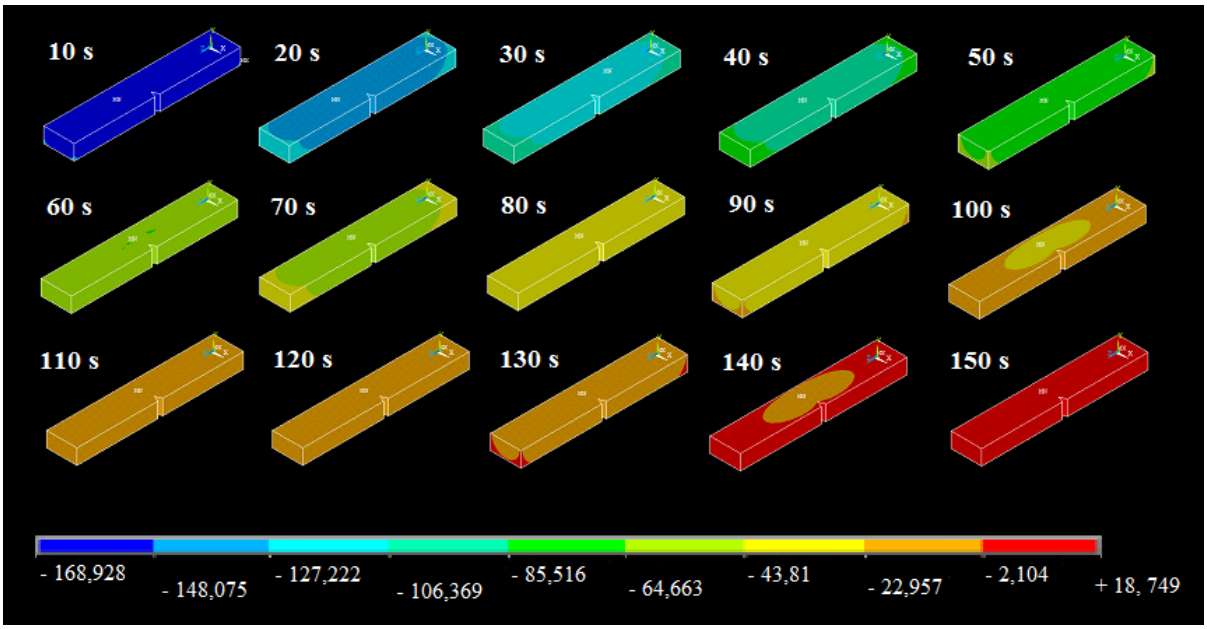


Fig. 3 *Development of temperature in time for frozen titanium sample*

Detail about development of specific temperatures in hottest and coldest places of frozen titanium sample in five minutes are shown in Table 2. Information in this table is based on simulation that was mentioned above. Temperature arises fast at the beginning. But with increasing of temperature of sample, velocity of heating is decreasing. Difference between surface temperature and core temperature is decreasing with exposing time and rising temperature. It is because heat drain is rising with rising of difference between temperature of sample and temperature of surrounds.

DEPENDENCE OF TEMPERATURE ON TIME DURING HEATING OF TITANIUM SAMPLE

Table 2

Time [s]	***10***	***20***	***30***	***40***	***50***	***60***	***70***	***80***	***90***	***100***
$\mathbf{T_{min}}$ [°C]	-169	-142	-118	-97	-80	-65	-52	-41	-32	-24
$\mathbf{T_{max}}$ [°C]	-145	-116	-94	-76	-61	-48	-37	-29	-21	-15

Time [s]	***110***	***120***	***130***	***140***	***150***	***160***	***170***	***180***	***190***	***200***
$\mathbf{T_{min}}$ [°C]	-17	-12	-7	-3	+1	+4	+6	+8	+10	+12
$\mathbf{T_{max}}$ [°C]	-9	-5	-1	+2	+5	+7	+9	+11	+12	+13

Time [s]	***210***	***220***	***230***	***240***	***250***	***260***	***270***	***280***	***290***	***300***
$\mathbf{T_{min}}$ [°C]	+13	+14	+15	+16	+16	+17	+17	+18	+18	+18
$\mathbf{T_{max}}$ [°C]	+14	+15	+16	+17	+17	+18	+18	+18	+19	+19

Figure 4 shows graph of dependence that was mentioned above in Table 2. Size of used sample for impact bending test is normalized: 10x10x55 mm. This sample has notch in the middle. Notch could be V or U shaped, and in this case, it is V shaped. Angle of notch is 45 ° and its depth is 2 mm (Tanaka and Bar, 1980). Surface of the sample has higher temperature than core of sample. Therefore, the highest temperature is on edges, and the lowest temperature is in the middle of the sample.

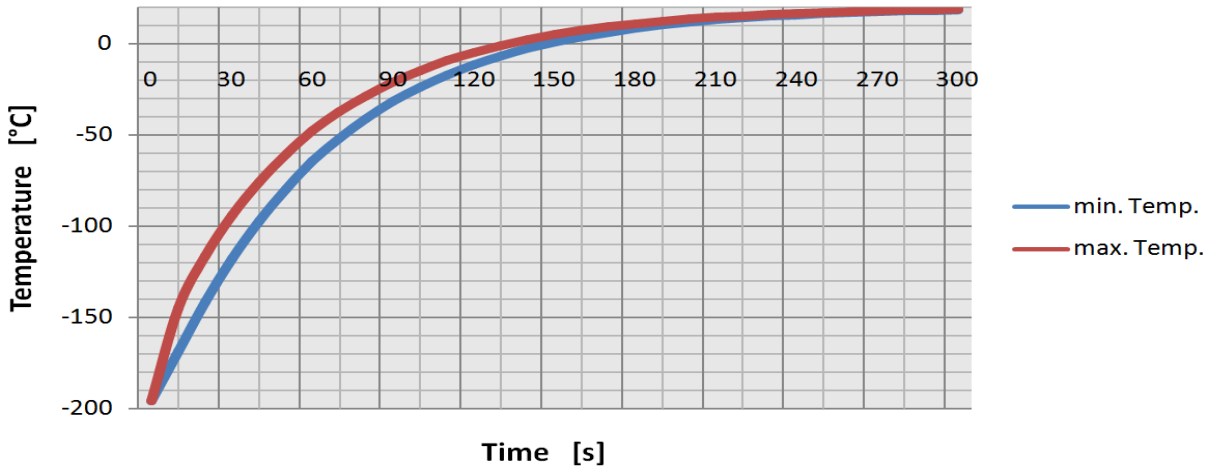


Fig. 4 *Graph of development of temperature in surface and core of titanium sample in five minutes*

CONCLUSION

It is commonly known that the machining of titanium alloys is performed at slow cutting speeds and it is accompanied by rapid tool wear. One of the most significant methods to increase tool life is utilizing of coolants. Cryogenic cooling has the biggest impact on increasing of tool life from all cooling approaches (Yildiz and Nalbant, 2008). Cryogenic cooling is utilized even in ultra-precision machining (Kakinuma et al., 2012).

Use of rotary ultrasonic machining is another way how to machine hard-machinable materials and to reach high quality of the machined surface. RUM is especially suitable for hard and brittle materials. Therefore, cryogenic cooling could enhance machining process.

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REFERENCES

1. SINGH, R., KHAMBA, J. S. 2006. Ultrasonic machining of titanium and its alloys: A review. *Journal of Materials Processing Technology*, 125-135.
2. BOYER, R. R. 1996. An overview on the use of titanium in aerospace industry. *Materials Science and Engineering* A 213 (1), 103-114.
3. PETERS, M., LEYENS, C. 2009. Titan und Titanlegierungen. *Wiley VCH*, Weinheim.
4. HONG, S. Y., MARKUS, I., JEONG, W. 2001. New cooling approach and tool life improvement in cryogenic machining of titanium alloy Ti-6Al-4V. *International Journal of Machine Tools & Manufacture* 41, 2245-2260.
5. MACHAI, C., BIERMANN, D. 2011. Machining of β-titanium-alloy Ti-10V-2Fe-3Al under cryogenic conditions: Cooling with carbon dioxide snow. *Journal of Materials Processing Technology* 211, 1175-1183.
6. THOE, T. B., ASPINWALL, D. K., WISE, M. L. H. 1998. Review on ultrasonic machining. *Tools Manufact*., **38**(4), pp. 239-255.

7. GONG, H., FANG, F. Z., HU, X. T. 2010. Kinematic view of tool life in rotary ultrasonic side milling of hard and brittle materials. *International Journal of Machine Tools & Manufacture*, 50, 303-307.
8. HU, P., ZHANG, J. M., PEI, Z. J., TREADWELL, C. 2002. Modeling of material removal rate in rotary ultrasonic machining: designed experiments. *Journal of Materials Processing Technology*, 129, 339-344.
9. YILDIZ, Y., NALBANT, M. 2008. A review of cryogenic cooling in machining processes. *International Journal of Machine Tools and Manufacture*, **48**(9), 947–964.
10. TANAKA, K., BAR, H. 1980. Impact bending test on steel at low temperatures. *The Japan society of mechanical engineers*, **23**(185), 1736-1744.
11. KOBRIN, P. A., SEMIATIN, S. L. 2001. Determination of interface heat-transfer coefficients for permanent-mold casting of Ti-6Al-4V. *Metallurgical and materials transactions B*, **32**B, 685-695.
12. UMBRELLO, D., MICARI, F., JAWAHIR, I. S. 2012. The effects of cryogenic cooling on surface integrity in hard machining: A comparison with dry machining. *CIRP Annals – Manufacturing Technology 61*, 103-106.
13. KAKINUMA, Y., KIDANI, S., AOYAMA, T. 2012. Ultra-precision cryogenic machining of viscoelastic polymers. *CIRP Annals – Manufacturing Technology, 61*, 79-82.

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THE EFFECT OF INNER REINFORCING CORES ON NATURAL FREQUENCIES OF THE LATHE TOOL BODY

Ladislav ROLNÍK, Milan NAĎ

ABSTRACT

The contribution is mainly focused on research and development of structural modification of machine tools, lathes in particular. The main aim of the modification is to change the modal properties (mode shapes, natural frequencies) of the lathe tool. The main objective of the contribution will be to formulate, mathematical analyse and evaluate the proposed methods and procedures for structural modifications of the tool, represented by beam body. A modification of modal properties by insertion of beam cores into beam body is studied in this paper. In this paper, the effect of material properties and geometrical parameters of reinforcing cores on natural frequencies of beam body is presented. The implementation will bring benefit on machine productivity, decreasing the machine tool wear and in many cases it will lead to better conditions in the cutting process.

KEY WORDS

lathe tool, modal properties, Euler-Bernoulli beam theory, vibration, reinforcement

INTRODUCTION

During the technological process, the various excitation effects affect the machine tools, for example lathe tools, drills, boring bars, etc. Cutting speeds, cutting forces, chip-making manner, the stiffness of MTW (machine-tool-workpiece) system are predominant effects affecting the dynamics of MTW system and also influencing the machining process (roughness of the machined surface, tool wear, tool or workpiece damage, noise generated by the machining process, etc.).

Therefore this paper is mainly focused on the analysis and modification of dynamic properties of the beam body. Dynamic properties are mainly represented by the modal properties (mode shapes, natural frequencies) that depend on the geometrical parameters and material properties of beam structure. An Euler-Bernoulli beam theory (1) is used as a simple model to illustrate the structural dynamic properties of a tool body in this paper. The Euler-Bernoulli beam model assumes that the deflection of the centerline is small and only transverse. While this theory assumes the presence of a transversal shear force, it neglects any

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shear deformation and the rotary inertia is also neglected. In the case of improper modal properties, the required modal properties of beam can be obtained by appropriate structural modifications of the beam body. In this paper, the modification of dynamic properties of beam is based on changes of material properties and geometrical parameters of beam cores.

THEORETICAL FORMULATION

The modal properties of beam with uniform double axes symmetric cross section are analysed. The beam cross section consists of a basic profile and reinforcements with longitudinally uniform cross section, which are embedded into beam body (Fig.1).

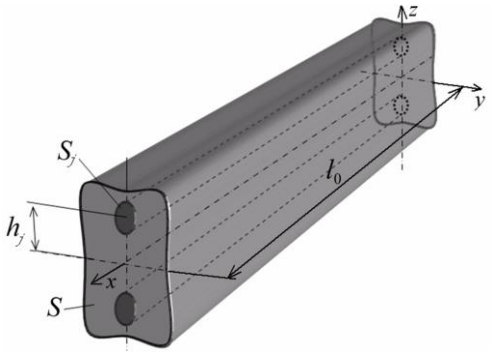

Fig. 1 *General model of beam structural element with reinforcing cores*

Mathematical model of beam body without reinforcing cores

The equation of motion for the free bending vibration of homogeneous Euler-Bernoulli beam with constant cross-section and without reinforcements (1) is in the form

$$EJ\frac{\partial^4 w(x,t)}{\partial x^4}+\rho S\frac{\partial^2 w(x,t)}{\partial t^2}=0\,, \qquad [1]$$

where S is the cross section area, EJ is the beam bending stiffness, J is the quadratic moment of the beam cross section, w is the beam deflection, ρ is the density and E is the Young´s modulus of beam material.

The equation [1] has supposed solution in the form $w(x,t)=W(x)T(t)$ and after introducing dimensionless parameters

• dimensionless deflection of beam $\overline{W}(\bar{x})=W(x)/l_0\,,$ [2]

• dimensionless coordinate $\bar{x}=x/l_0\,,$ for $\bar{x}\in\langle 0.0;1.0\rangle\,,$ [3]

is transformed into ordinary differential equation of the fourth order

$$\overline{W}^{IV}(\bar{x})-\beta^4\overline{W}(\bar{x})=0\,. \qquad [4]$$

The solution of equation (4) has the form

$$\overline{W}(\bar{x})=A\sin\beta\bar{x}+B\cos\beta\bar{x}+C\sinh\beta\bar{x}+D\cosh\beta\bar{x}, \qquad [5]$$

where A, B, C, D are integration constants and β is the frequency parameter.

Generally, the boundary conditions for cantilever beam [3] are expressed by

$$\overline{W}(0)=\overline{W}'(0)=\overline{W}''(1)=\overline{W}'''(1)=0\,. \qquad [6]$$

Then, the natural angular frequency for the geometric parameters and material properties of the homogeneous beam can be expressed in the form

$$\omega_i=\left(\frac{\beta_i}{l_0}\right)^2\sqrt{\frac{EJ}{\rho S}}\,, \qquad [7]$$

where β_i is the frequency parameter determined from frequency equation (Tab.1).

Mathematical model of beam body with reinforcing cores

Next, we consider the beam body with uniform cross section of basic beam profile having inserted reinforcing cores with uniform circular cross section. The "reinforcing" core is not correct term. Reinforcing effect occurs only when the core structural parameters raise the stiffness properties of the basic beam. In formulating the mathematical model of the beam structure modified by reinforcing core, the following assumptions are considered:

- reinforcing cores are symmetrical with respect to both axes *y*, *z*,
- beam cross section of the is perpendicular to the neutral axis *x*,
- isotropic and homogeneous material properties of structural parts of the beam,
- beam cross section before and during deformation is assumed as planar,
- perfect adhesion is supposed at the interface of structural parts of the beam.

The equation of motion for free bending vibration of the modified beam has the form

$$EJ(1+\Delta_{EJ})\frac{\partial^4 w(x,t)}{\partial x^4}+\rho S(1+\Delta_{\rho S})\frac{\partial^2 w(x,t)}{\partial t^2}=0 \qquad [8]$$

where Δ_{EJ} and $\Delta_{\rho S}$ are dimensionless modification parameters.

The dimensionless parameters Δ_{EJ}, $\Delta_{\rho S}$ defining changes in structural parameters are:

- dimensionless mass modification $\Delta_{\rho S}=\sum_j(\delta_{\rho,j}-1)\delta_{S,j}\,,$ [9]
- dimensionless stiffness modification

$$\Delta_{EJ}=\sum_j(\delta_{E,j}-1)\delta_{J,j}=\sum_j(\delta_{E,j}-1)\delta_{S,j}\delta_{\xi,j}\,, \qquad [10]$$

- dimensionless density $\delta_{\rho,j}=\rho_j/\rho\,,$ [11]
- dimensionless Young's modulus $\delta_{E,j}=E_j/E\,,$ [12]
- dimensionless cross-section $\delta_{S,j}=S_j/S\,,$ [13]
- dimensionless quadratic moment $\delta_{J,j}=J_j/J\,,$ [14]
- dimensionless radius of gyration $\delta_{\xi,j}=(\xi_j^2+h_j^2)/\xi^2$, where $\xi^2=J/S$ [15]

where ρ_j - j^{th} core density, S_j - j^{th} core cross section area, J_j - j^{th} core quadratic moment of cross section, E_j - j^{th} core Young's modulus, and h_j - position of the j^{th} core (Fig.1).

By using solution $w(x,t) = W(x)T(t)$ and the relations [2], [3] in equation [8], the equation (4) is valid and frequency parameter β of modified beam structure is expressed by

$$\beta_i = \sqrt[4]{\omega_{m,i}^2 l_0^4 \frac{\rho S(1+\Delta_{\rho S})}{EJ(1+\Delta_{EJ})}}, \qquad [16]$$

where $\omega_{m,i}$ i^{th} natural angular frequency of modified beam structure. It can be defined by

$$\omega_{m,i} = \omega_i f_m(\Delta_{\rho S}, \Delta_{EJ}), \qquad [17]$$

where $f_m(\Delta_{\rho S}, \Delta_{EJ}) = \sqrt{\frac{1+\Delta_{EJ}}{1+\Delta_{\rho S}}}$ - modification function. [18]

The modification function $f_m(\Delta_{\rho S}, \Delta_{EJ})$ represents the structural changes within beam caused by changes in core structural parameters (density, core diameter and position of the both reinforcements to the neutral axis of the beam structure).

FREQUENCY EQUATIONS AND THEIR ROOTS FOR DIFFERENT BEAM BOUNDARY CONDITIONS Table 1

Case	Boundary conditions		Frequency equation	Roots		
	$\xi = 0$	$\xi = 1$		β_1	β_2	β_n
1	F	F	$\cosh(\beta)\cos(\beta) = 1$	4.73	7.85	$\frac{2n+1}{2}\pi$
2	SS	SS	$\sin(\beta) = 0$	π	2π	$n\pi$
3	C	C	$\cosh(\beta)\cos(\beta) = 1$	4.73	7.85	$\frac{2n+1}{2}\pi$
4	C	SS	$\tanh(\beta) = \tan(\beta)$	3.93	7.07	$\frac{4n+1}{4}\pi$
5	C	F	$\cosh(\beta)\cos(\beta) = -1$	1.88	4.69	$\frac{2n-1}{2}\pi$
6	F	SS	$\tanh(\beta) = \tan(\beta)$	3.93	7.07	$\frac{4n+1}{4}\pi$
F – free; SS – simply supported; C – clamped						

Modal properties (natural frequencies, mode shapes) of the beam structural element depend on the beam attachments to the foundation. The frequency equations and their roots for different boundary conditions are expressed in (Tab.1).

ANALYSIS AND RESULTS

The influence of changes in structural parameters of reinforcing cores on the modification function f_m is expressed by the dependency on mass modification $\Delta_{\rho S}$ or stiffness modification Δ_{EJ}. The dependencies of the function f_m on mass modification $\Delta_{\rho S}$, for stiffness modification parameters Δ_{EJ} are shown in Fig.2.

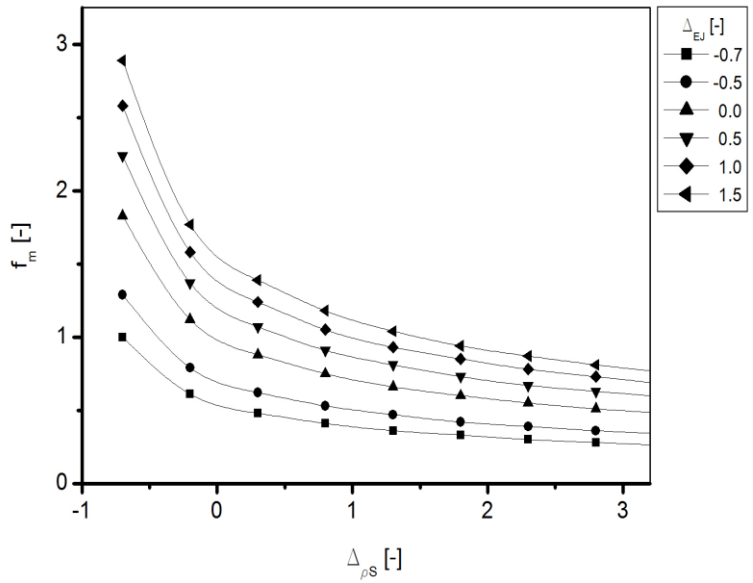

Fig. 2 *The dependency of f_m on $\Delta_{\rho S}$ for different flexural rigidity modification Δ_{EJ}*

The influence of stiffness modification Δ_{EJ} on the modification function f_m, for mass modification parameters $\Delta_{\rho S}$, is shown in Fig. 3. As it follows from the assessment of the above mentioned dependencies, the growth of the mass modification value $\Delta_{\rho S}$ causes the decrease of modification function and if the value of stiffness modification Δ_{EJ} is increasing, the modification function has an upward trend.

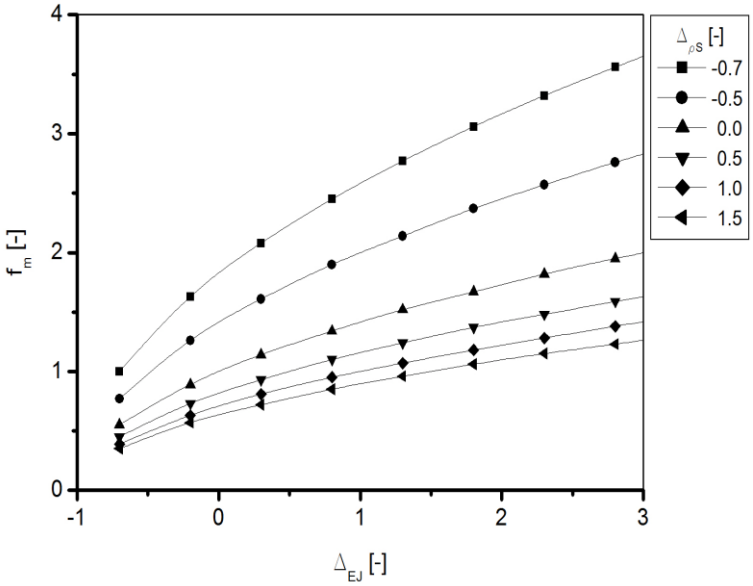

Fig. 3 *The dependency of f_m on Δ_{EJ} for different mass modification $\Delta_{\rho S}$*

Determination the cores geometrical parameters and material properties to achieve required value of the modification function, resp. required natural frequency:

For this purpose, two identical cores situated symmetrically to planes *xy* and *zy* are considered. To define the geometrical parameters value of the modification function f_m is selected (Fig. 4 - dashed line). The required cross section area of the both cores ($S_1 = S_2$) and their position to the neutral axis of the beam structure ($h_1 = h_2$) are determined by using a

corresponding curves (for selected value $\Delta_{EJ(k)}$) to determination of dimensionless modification parameter $\Delta_{\rho S}$. The dimensionless mass modification $\Delta_{\rho S}$ with dimensionless stiffness modification $\Delta_{EJ(k)}$ for the defined parameters δ_E and δ_ρ ($E_1 = E_2$; $\rho_1 = \rho_2$) can be expressed (Fig. 4a) by following schema

$$f_m(\Delta_{EJ}, \Delta_{\rho S}) : \Delta_{EJ(k)} \rightarrow \Delta_{\rho S}, \qquad [19]$$

The dimensionless cross section area δ_S can be expressed from following expression

$$\delta_{S,1} = \frac{\Delta_{\rho S}}{n(\delta_{\rho,1} - 1)}, \quad \text{for given purpose} \Rightarrow n = 2. \qquad [20]$$

Then, the cross section of the both cores can be determined from [13]. The position of the both cores to the neutral axis of the modified beam structure ($h_1 = h_2$) is obtained from the following relation

$$h_1 = \sqrt{\delta_{\xi,1}\xi^2 - \xi_1^2}, \quad \text{where} \quad \delta_{\xi,1} = \frac{\Delta_{EJ(k)}}{n(\delta_{E,1} - 1)\delta_{S,1}}, \quad \text{for given purpose} \Rightarrow n = 2. \qquad [21]$$

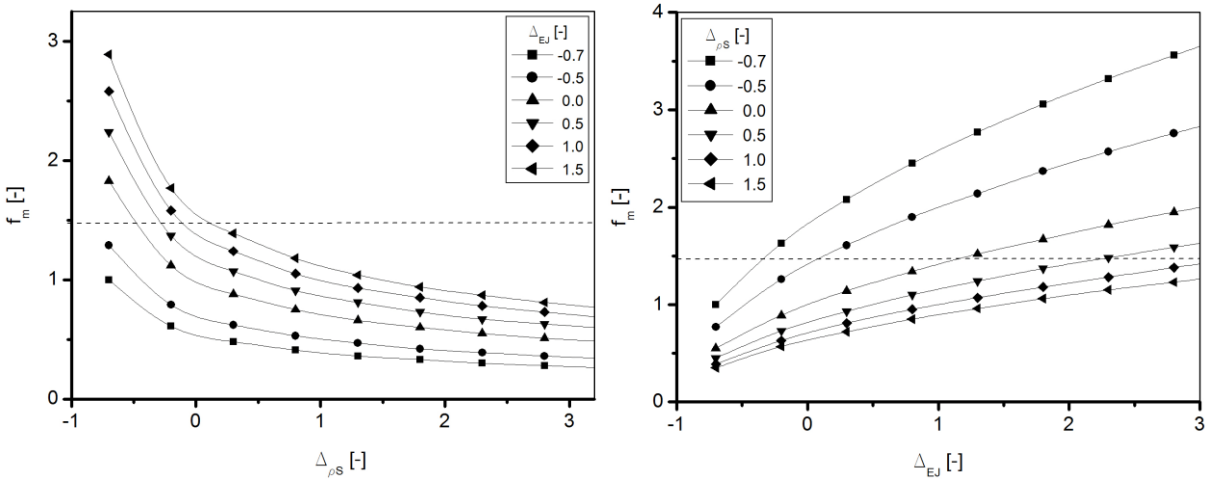

Fig. 4 *Determination of core parameters*

The similar approach can be used to define the material properties of the reinforcing cores ($E_1 = E_2$; $\rho_1 = \rho_2$) for given geometrical parameters.

CONCLUSION

The modal properties analysis of beam structures modified by cores is presented in this paper. The main aim of analyses was to determine the dependency of the beam natural frequencies on material properties and geometrical parameters of reinforcing cores. The natural angular frequency of modified beam structure can be determined by multiplying of natural angular frequency unmodified beam structure and modifying function,

$$\omega_{m,i} = f_m(\Delta_{\rho S}, \Delta_{EJ})\omega_i, \qquad \text{for } i = 1, 2, ..., \infty, \qquad [23]$$

The modifying function $f_m(\Delta_{\rho S}, \Delta_{EJ})$ considering all the relevant structural changes of beam body and cores parameters is derived. For the defined dimensionless mass and stiffness modification, the function $f_m(\Delta_{\rho S}, \Delta_{EJ})$ has the same value for all natural angular frequencies. This manner of the beam structural modification offers very effective tool to modification of dynamical properties or dynamical tuning for similar beam structures.

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REFERENCES

1. MAGRAB, E.B. 2012. *Vibrations of Elastic Systems.* London: Springer, pp. 83-165.
2. CLOUGH, W.R., et al. 2003. *Dynamics of Structures*. Berkley, Computers & Structures, Inc., 754 p.
3. NÁNÁSI, T. 2007. Boundary conditions and vibration of slender beams. In: *Proc. of the Inter. Conference - Engineering Mechanics 2007*. Prague, pp.1-8.
4. THORBY, D. 2008. *Dynamics and Vibration in Practice - An Engineering Handbook*. Oxford: Elsevier Ltd., 650 p.

RESEARCH PAPERS
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DEVELOPMENT OF SURFACE ROUGHNESS IN HARD TURNING OF 100CR6 USING MIXED CERAMIC CUTTING TOOL WITH WIPER GEOMETRY AND CONVENTIONAL GEOMETRY

Michaela SAMARDŽIOVÁ[1], Miroslav NESLUŠAN[2]

ABSTRACT

Hard turning has been applied in machining since the early 1980s. There is an effort to substitute finish grinding by hard machining, because of machining by cutting tool with defined geometry. For machining of hardened steels (up to 45 HRC) are used two different cutting materials. PCBN are used the most for discontinuous machining of hardened steel (up to 63 HRC) and mixed ceramic tools, which are used in the experiment. This paper reports a development of surface roughness parameters when using wiper tool geometry of mixed ceramic tool and conventional geometry of mixed ceramic tool in hard turning. Roughness parameters (Ra, Rz, Rsk, Rku, RSm, Rdq) are measured when changing the feed, depth of cut and cutting speed are constant.

KEY WORDS

hard turning, mixed ceramic tool, tool geometry, surface roughness parameters

INTRODUCTION

Hard machining (hard turning) is a lathe machining process of hardened steels with hardness higher than 45 HRC. Machining hardened materials, mainly steels, is one of the leading removal methods of producing parts in such manufacturing branches as automotive, bearing, hydraulic and die and mold making sectors. This technology has also some disadvantages in comparison to grinding operations, f. e. production of the white layer, surface roughness, dimensional accuracy (1).

Surface integrity is very important to solve when taking into consideration workpiece functional properties. Surface quality is recognizing by the surface roughness, which plays an important role in many areas and it is a factor of great importance in the evaluation of machining accuracy (2). Low surface roughness means high surface finish.

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Very important steps for successful implementation of hard turning are selection of suitable cutting parameters for a given cutting tool, workpiece material and machine tool (3).

Many experiments achieved that the wiper geometry has a significant effect on the surface integrity and it can help to improve surface quality. The main difference between conventional geometry and wiper geometry is in the shape of the minor cutting edge (Figure 1). The aim of this article is to investigate the effect of the wiper mixed ceramic insert on the surface roughness in finishing by hard turning of hardened steel (100Cr6).

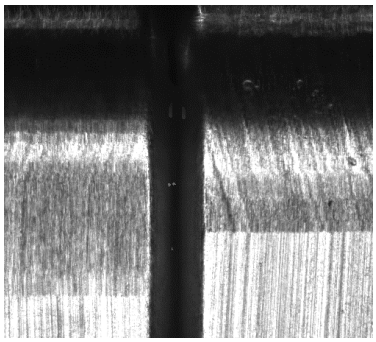

Fig. 1 *Comparison of the shape of the minor cutting edge, left – wiper, right – conventional geometry*

EXPERIMENTAL INVESTIGATIONS

Cutting conditions

Workpiece material used for this experimental study was hardened steel 100Cr6 with Rockwell´s hardness 62±1 HRC. This workpiece was turned using mixed ceramic tool with radius 0,8 mm and coated by TiN by Sandvik Coromant company. Hard turning (Fig. 2) was performed using cutting speed 100 m/min. Depth of cut was constant with value 0,25 mm. Feed was changing from 0,05 until 0,5mm for conventional geometry and for wiper geometry too. Used values are shown in the table 1. These cutting conditions are recommended from the producer, first two values and last two values of the feed rate are critical values, the aim was to find out, how are these two insert geometries behaving in the cutting process.

FEED RATE´S VALUES USED IN THE EXPERIMENT

Table 1

Nr.	1	2	3	4	5	6	7
Feed f (mm)	0,05	0,08	0,1	0,2	0,3	0,4	0,5

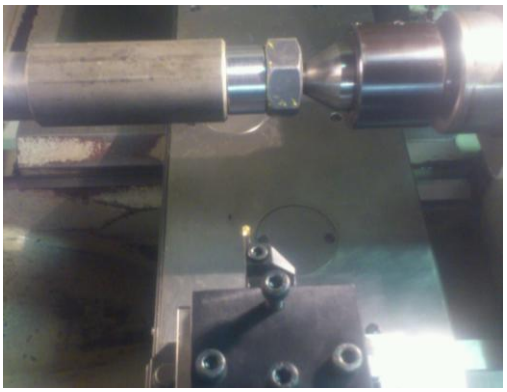

Fig. 2 *Hard turning*

The experimental part is performed on the workpiece (Fig. 3), which is turned using wiper insert geometry (1/2 of the workpiece) and conventional insert geometry (1/2 of the workpiece) with cutting speed 100 m/min, depth of cut 0,25 mm and all the feeds from the table 1. For hard turning was used lathe SUI 500.

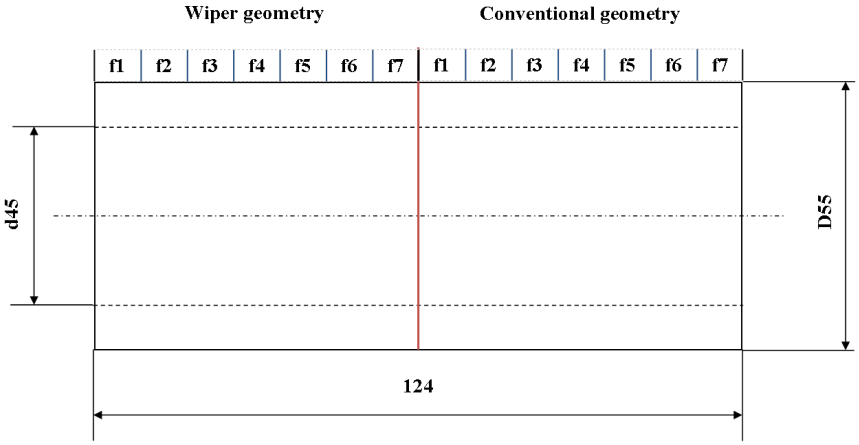

Fig. 3 *Workpiece and experimental plan, d – internal diameter, D – external diameter*

Measurements of surface roughness

Different surface roughness parameters were measured for three times, average values were used for the evaluation. Measurement of the surface roughness parameters was performed on Surfcom 1900SD3 from Carl Zeiss company.

EXPERIMENTAL RESULTS

Roughness profile was recorded for every part of the workpiece when feed was changed.

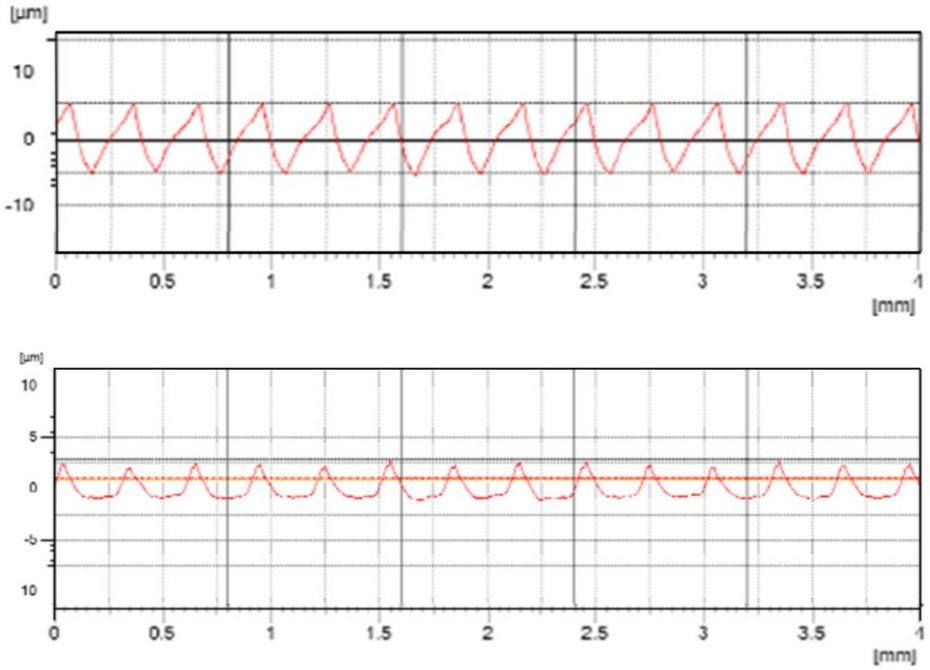

Fig. 4 *Roughness profile, v_c = 100 m.min^{-1}, a_p = 0,25 mm, f = 0,3 mm, upper – conventional geometry, lower – wiper geometry*

In the figure 4 are examples of the profiles, which have different amplitude when using the same cutting conditions for both geometries. Using of wiper geometry helps to obtain better surface.

Roughness parameters Ra, Rz, Rsk, Rku, RSm, Rdq were measured for both used insert geometries. Values for conventional geometry are shown in the figures 5 and 6.

There is an evident difference between measured roughness values when comparing roughness obtained using conventional geometry with values obtained using wiper geometry except parameter RSm (The Mean width of profile elements). These values are almost the same for both geometries.

Typical for wiper geometry is longer minor cutting edge, which width determines range of feed´s values, when surface roughness is not changing. It can be summarized when using the same cutting parameters for hard turning that it is possible to achieved more than two times lower values of roughness parameters Ra and Rz with wiper than conventional geometry when using the same cutting conditions (Figure 5).

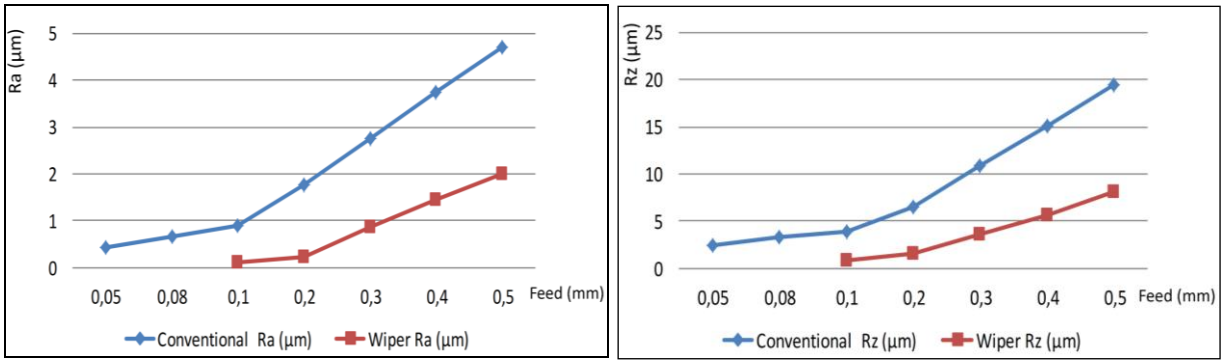

Fig. 5 *Graphs of the surface roughness parameters Ra and Rz*

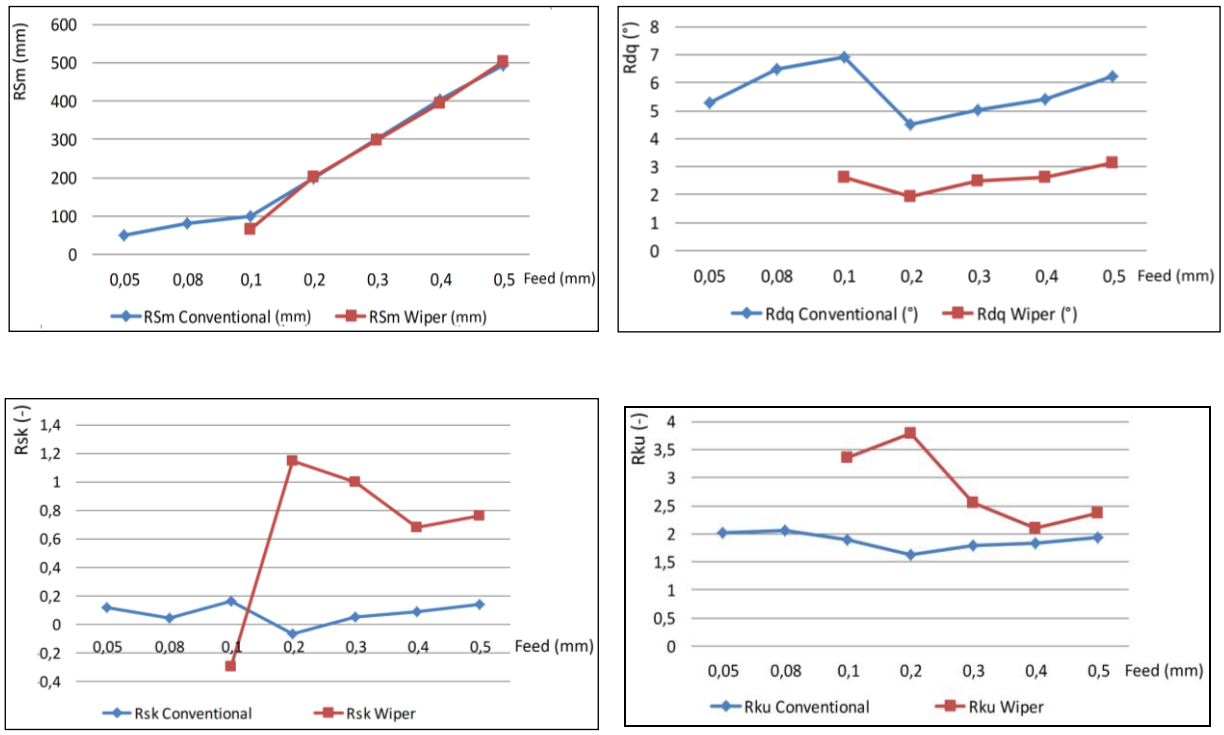

Fig. 6 *Graphs of the surface roughness parameters RSm, Rsk, Rku, Rdq*

Other roughness parameters (Fig. 6) have different character than parameters in the Fig. 5. RSm has very similar values for both geometries. Rsk talks about skewness (asymmetry) of the roughness profile. Conventional geometry is giving more symmetric workpiece profile. On the other hand profile has more valleys, when using wiper geometry, because of its longer minor cutting edge, which is removing peaks.

Rku (kurtosis of the roughness profile) parameter achieved higher values for wiper geometry than conventional. Root mean square slope of the roughness profile Rdq has lower values for wiper insert geometry in comparison to conventional geometry. The reason is again shape of the minor cutting edge, which eliminates peaks from the profile, and the slope is not so steep.

CONCLUSION

There are many different factors influencing surface accuracy and quality, one of them id feed, which is dealing with in this article.

According to this experiment it is possible to sum that insert geometry very influence surface quality, especially surface roughness parameters. There is an opportunity to use wiper geometry (which is different from the conventional geometry in the shape of the minor cutting edge), when needed better surface quality, but it is necessary to take into consideration higher cutting force components when dealing with energy consumption of the process.

Profile figures show us, how exactly is quality of the surface changing depending on feed.

Evaluation and the measurement of cutting tool components and cutting tool wear for conventional and wiper geometry will be aim of the other experimental work of these authors.

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REFERENCES

1. GRZESIK, W. 2012. Functional properties of hardened steel parts generated by turning and ball burnishing operations. In: *Advances in manufacturing science and technology*, **36**(4).
2. PALANIKUMAR, K., KARUNAMOORTHY, L., KRATHIKEYAN, R. 2006. Assesment of factors influancing surface roughness on the machining of glass – reinforced polymer composites. *Journal of Materials and Design*, 27, 862-871.
3. SHAW, M. C. 1984. *Metal cutting principles*. Oxford university press, Oxford, NY.
4. AOUICI, H., YALLESE, M. A., CHAOUI, K., MABROUKI, T., RIGAL, J.F. 2012. Analysis of surface roughness and cutting force components in hard turning with CBN tool: Prediction model and cutting conditions optimization. In: *Measurement, Elsevier*, p. 344-353.

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