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EMBEDDED SYSTEMS

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Keywords: mechatronics, education, embedded systems
Abstract: The paper deals with embedded systems, which are as inseparable part of mechatronic systems. The main task of them is to sense, monitoring and control of mechatronic products activities. Embedded systems can be realised via using of microcontroller, PLC, embedded PC or as combination of them. Embedded systems also can work in network as collaborative systems.

1 Introduction

Actually, several billions of microprocessors are made per year, but only few percent of them are used a brain of personal computer. Overwhelming majority of microprocessors becomes a part of embedded systems. Embedded systems are special computer systems, which are completely embedded into devices, which are controlled with them. Embedded systems as a basic part of everyday used products as car, printers, cameras, medical devices, gaming devices, washing machine, grass-cutting robots, vacuum cleaner robots, aeroplane, missile rockets, mobile phones, etc. (Figure 1).

Figure 1 Embedded systems using

Term “embedded systems” is used for:

- Combination of hardware and software for executing of specific tasks.
- Embedded systems is a system which fully or partially autonomously execute tasks depended on human intervention.
- Embedded system is designed for executing of several tasks via using of the most effective way.
- Embedded system is computer system for specific tasks.

Using of embedded systems is practically unlimited and new products with embedded systems are daily introduced in market. This fact still causes that the price of microprocessors, microcontrollers and FPGA chips, fall down. Developing of new product with implemented flexible embedded systems is much cheaper then developing of complicated control structure. Developing of control system via using of embedded system became very simple thing.

Standard personal computer is usable for more purposes (text processing, image processing, internet, email, listening of music, watching the video, playing game etc., but embedded system is used only for one purpose related to product. Striking impact of embedded systems is visible in automotive industry. One car includes several tenths of embedded systems used for various activities as battery management, blind spot detection, air suspension system, parking assistant and self parking system, security system, tire pressure monitoring system, seat control, window lift, emergency brake system, internal combustion motor control, engine cooling system, cruise control, cross-traffic alert system, lane change assistant, collision avoidance system, air condition etc [1-9].

Tasks of embedded systems is very frequently related to specific period and time keeping is marginal important for right functionality of whole product. Very good example of embedded system is autopilot in aeroplane, where embedded system has to react very fast during the fly. This is the reason, why real time response is expected from embedded systems.

Embedded systems are applied for controlling of processes and functions of products. It is necessary to obtain amount of information for this controlling and embedded system evaluate these information in running programme and make decision about next activities. Mechatronic product also can communicate with user and can make advice what user should make. This product with embedded system behaves as intelligent system and it is able automatically decide about its activities. Behaviour of this product is subjected to user, which has possibility to affect to its functions. Besides this, the product can has also other functions unknown for user as checking of product status, check of battery status, user security checking, damage protection, etc. Product should be designed also for unexpected situations caused by user or by others impacts. Key task of mechatronic product is to help to user with safely using of product. In addition, the product should eliminate bas steps of user, which can be dangerous for product or for user or their environment.

2 Embedded system design

Embedded system development is supported also with Matlab/Simulink package with "Embedded coder". Embedded system is also called as "Electronic Control Unit" – ECU or "production control unit. These units are designed with respecting of minimum production costs in serial production. ECU very often consists of system with lower CPU (Microprocessor) performance and low memory and often with fixed point math. Simulation model of controlling is completed in Matlab/Simulink and then "Generator of production code" is used for generating of C-code with quality of hand-written source code on the level of excellent programmers. It also enables the implementation of fix-point math routine and memory optimization for selected microcontroller. Generated C code needs only minor revision and then it is necessary for implementation into target microcontroller.

Figure 2 Design of embedded system

Initial stage of mechatronic product design can be supported through the using of model-based design. It could help to identify weak places and mistakes in product design. Overall design is then faster and more successful than before. For this reason the model of system is in the centre of product design process during the all stages of product life cycle as requirement definition, own product design, simulation and verification of design and testing of product and also recycling after end of product life. Model simulation results show the problems and it is possible to modify design in early stage of design. Simulation shows if future product will fulfil of customer requirements.

Fast product developing requires the model based design as device for effective product design through the using by:

- Common design environment for all members of team.
- Coupling of product design with customer requirements.
- Simultaneous integration of design testing for continuous identification of errors and repairing of errors.
- Debugging of the algorithm using the multi-domain simulation.
- Automatic generation of software code.
- Developing and repeated using of testing system.

- Automatic generating of documentation.
- Repeated using of design for distribution of system to more processors and hardware devices.

3 Model based design

Model-Based Design helps engineers achieve certification to safety standards by supporting requirements traceability, verification, and documentation (Figure 2). These capabilities span multiple design stages. For example, requirements linked to model are inserted as comments in generated code. Qualification kits, available for several verification tools, can reduce the amount of manual review needed.

It is also increasingly common for organizations to adopt Model-Based Design on large programs spanning multiple organizations. This allows system-level performance to be assessed and integration issues to be uncovered much earlier in the design process.

When detailed models from multiple organizations are combined, resulting models can contain hundreds of thousands of blocks. Modeling tools have evolved to meet these challenges with improved support for large-scale modeling, including support for composite models from other model files and support for signal buses.

When organizations adopt Model-Based Design, they improve product quality and reduce development time by 50% or more. It also causes that product will be cheaper and more competitive on market.

In generally, there are six steps to modeling any system:

- Defining the System.
- Identifying System Components.
- Modeling the System with Equations.
- Building the model.
- Running the Simulation.
- Validating the Simulation Results.

We perform the first three steps of this process outside of the software environment before we begin building our model. Mainly, these first three steps are important and many people make mistakes in these steps. Finally, when system is modeled through the equations, next building of the model is more or less routine operation. It is important to say that every model is not perfect and every time we have to neglect any points and simplify system description. Overall process requires the experiences. When we will try to make absolutely prefect model, very complicated model and slowly simulation will be as the result of them.

Defining of the system - the first step in modeling a dynamic system is to fully define the system. If we are modeling a large system that can be broken into parts, we should model each subcomponent on its own. Then, after building each component, we can integrate them into a complete model of the system.

Identifying System Components - the second step in the modeling process is to identify the system components. Three types of components define a system: parameters (system values that remain constant unless you change them), states (variables in the system that change over time), and signals (input and output values that change dynamically during a simulation).

Modeling the System with Equations - the third step in modeling a system is to formulate the mathematical equations that describe the system. For each subsystem, use the list of system components that we identified to describe the system mathematically. Model may include: algebraic equations, logical equations, differential equations, for continuous systems and difference equations, for discrete systems etc.

Building the Simulink Block Diagram - after we have defined the mathematical equations that describe each subsystem, we can begin building a block diagram of our model for example in MATLAB/Simulink. Build the block diagram for each of our subcomponents separately. After we have modeled each subcomponent, we can then integrate them into a complete model of the system.

Running the Simulation - after we build the Simulink block diagram, we can simulate the model and analyze the results. Simulink allows us to interactively define system inputs, simulate the model, and observe changes in behavior. This allows us to quickly evaluate your model.

Validating the Simulation Results - finally, we must validate that our model accurately represents the physical characteristics of the dynamic system. We can use the linearization and trimming tools available from the MATLAB command line, plus the many tools in MATLAB and its application toolboxes to analyze and validate our model.

4 Conclusion

Model-Based Design with MATLAB and Simulink is an efficient and cost-effective way to develop complex embedded systems in aerospace, automotive, communications, and other industries. It enables system- and component-level design and simulation, automatic code generation, and continuous test and verification [2].

Plant models provide another perspective on the system. Modelling the non-software parts of the system gives engineers another view into system behaviour. Engineers can often learn more about system dynamics through simulation than from the real system because simulation provides details on force, torque, current, and other values that are difficult or impossible to measure on the actual hardware.

Creating plant models requires engineering effort, but this effort is often overestimated, while the value provided by plant modelling is underestimated. When developing plant models, it is a best practice to start at a high level of abstraction and add details as needed. Choosing a level of abstraction that is just detailed enough to produce the needed results saves modelling effort as well as simulation time.

System behaviour is defined not only by the embedded control software, but also by the electronic and mechanical components, including the connected sensors and actuators. Early simulations in which the architecture is executed provide more insight when they are performed in a closed loop with plant or environment models. System-level optimization requires multi-domain simulations. It is impossible to optimize today's sophisticated systems by tuning one parameter at a time. To deliver maximum energy efficiency and highest performance at minimal material cost, engineers must optimize the system as a whole, and not just the embedded software [3-19].

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EXPERIMENTAL STAND FOR ACTUATOR TESTING

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Keywords: actuator, experimental stand, measurement, mechatronics
Abstract: The paper deals with experimental stand for testing of actuators. Shape memory alloy has been one of the possible tested actuators on this stand. Experimental results gave recommendation for design of the products with tested actuators. This stand is also able to test dynamic properties of actuators.

1 Introduction

Actuator is a device for conversion of any energy to mechanical work. The main aim is to use the actuator with minimum losses and minimum size and low price.

Mechatronics applications grooving up and there is a need for actuators as base part of mechatronic systems (fig. 1, fig. 2, fig. 3).
Also smaller miniature products need also smaller actuators. Conventional actuators are sometimes not successful for using in this area, because of low efficiency and overall costs.

Figure 1 Machine with electromagnetic actuator

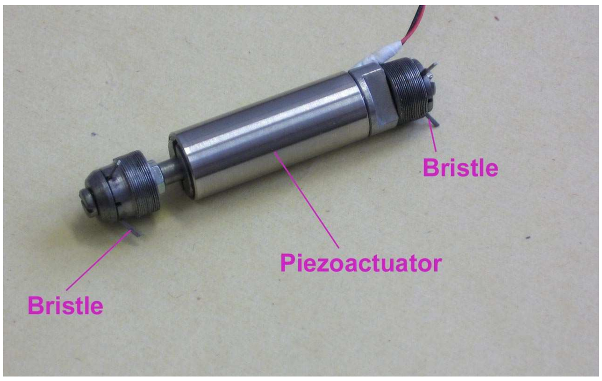

Figure 2 Machine with piezoelectric actuator

Conventional actuators is based on electromagnetic principle and on the base of theory, the efficiency in small dimensions (less than 10 mm) is lower than in bigger dimensions.


Figure 3 Machine with shape memory alloy actuator

This is the reason of using of unconventional actuators as shape memory alloys actuators, piezoelectric actuators, magnetostrictive alloy, electrostatic actuators etc. Piezoelectric actuators uses the piezoelectric phenomenon where the connected electric voltage is converted to stroke or displacement of piezoelectric material. Magnetostrictive materials need magnetic array for generation of material stroke. Magnetostrictive alloy and piezoelectric actuators have fast response time (several nanoseconds or microseconds). Obtained strokes for these actuators are low (only about 0.1 percent).

Shape memory alloy needs thermal activation for generation of displacement. Displacement is about 5 percent from dimension of shape memory alloy actuators. Main disadvantage of shape memory alloys is very slow reaction time (several seconds).

Shape memory alloy with acronym SMA is very interesting material activated with temperature change. It means that material has defined shape and after thermal heating, it is deformed, but after cooling, it returns to previous defined shape. This thermal activation is caused from internal structure transformation between martensite and austenite.

Shape memory alloy actuators are available in various forms as wire, roods, spring etc.

Shape memory alloy is available as two-way SMA, which provides pull and contract force, but with smaller displacement in comparing with one-way SMA, which provides only contract force and return to previous position

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has to be made with bias force from spring or additional force (mass gravity etc.) [1-5].

Shape memory alloy needs bias mechanism for ensuring of properly function (fig. 4). There are several ways of biasing as using of weight for generation of pull force, using of spring and antagonistic arrangement of two shape memory alloy actuators for alternate using as bias mechanism.

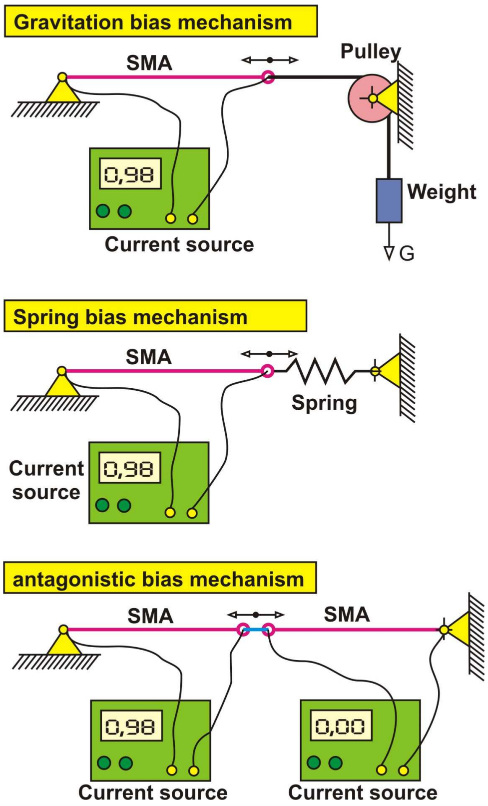

Figure 4 The SMA applying with bias force [1, 2]

There are more than twenty alloys of materials, which have shape memory effect. The most famous alloy is Nitinol, which is as alloy from Nickel and Titanium.

Thermal activation can be made with external heating and cooling system. The most frequently used is thermal activation with joule heating caused with electrical current through the material. Cooling is with passive heat exchange with surroundings or active cooling with any cooling systems.

Practical using of shape memory alloy meets with problem of attaching to mechanical parts. Actuator in wire form cannot be welded or soldering. There is a possibility of using of crimp technology of attaching to the end of actuator (fig. 6).

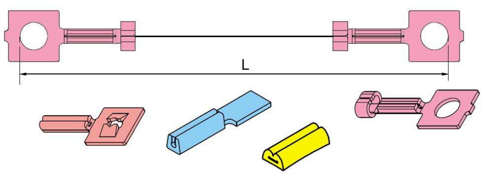

Figure 6 Crimping of the shape memory alloy actuators

Shape memory alloy can be activated using the heating caused by passing electrical current. Activation time depends on value of electrical current. Maximum value of electrical current is defined by actuator manufacturer. Activation time is also affected by way of shape memory alloy application (attaching to other parts, thermal isolation, air flow, surround temperature etc.).

Deactivation time is longer than activation, because there is only passive convection is used. But there is a forced ways of actuator cooling.

The shape memory alloy is frequently used in automotive industry, aeronautics, medicine, machinery etc.

2 Testing stand for experimental verification of shape memory alloy actuators

Activation and deactivation of wire shape memory alloy causes the change of this length - stroke. This active stroke allows to lift any weight or active force useful for any application. Useful force is decreased with required bias force or bias weight.

Experimental stand (fig. 7) has been developed for experimental testing of the shape memory alloy. Predefined bias weight is used for tested actuator. One end is fixed and connected to power supply. Second end is connected with tension rope to bias weight. Second end is also connected to power supply and control unit. Position of second movable end is measured as actuator stroke. Also additional weight can be added during the experiment. The aim is to obtain power characteristic of actuator. It means dependence of useful active force and stroke of actuator.

End position is sensed via using of permanent magnet and magnetically sensitive sensor.

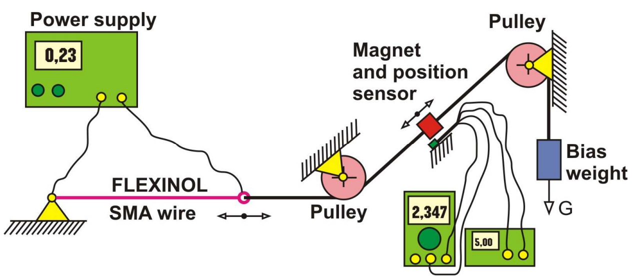

Figure 7 Experimental test stand for testing of shape memory alloy

Apparatus allows to slowly change of supply electrical current. Stroke of actuator has the significant hysteresis also occurs during the loading of actuator. This hysteresis can be as problem in control process.

Permanent magnet is used as reference point of movable end point of shape memory alloy actuator. Hall sensor has been used for sensing of the magnet position (fig. 8).

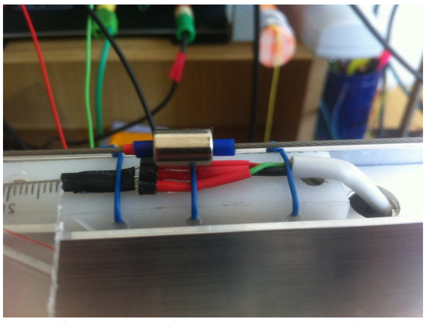

Figure 8 Hall effect sensor for measurement of position of shape memory alloy end

Calibration procedure shows dependence of output voltage on position of permanent magnet position (fig. 9). There is useful range for measurement between the values from 6 mm up to 20 mm.

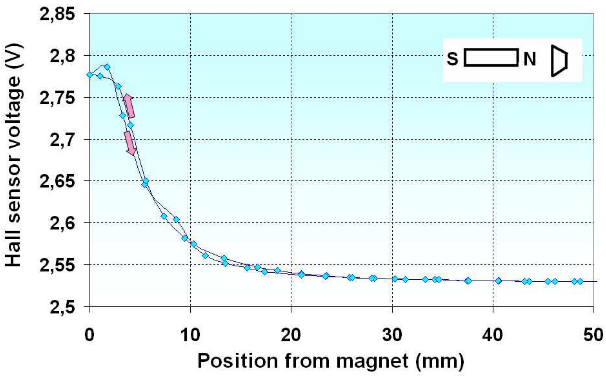

Figure 9 Hall effect sensor calibration characteristic

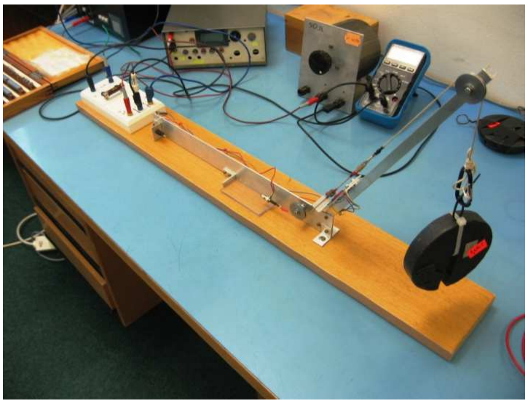

Figure 10 Experimental test stand for testing of shape memory alloy

Figure 10 shows experimental stand for testing of shape memory alloy actuators.

3 Conclusion

Shape memory alloy is actuator, which is as thin wire, and it is able to generate up to 5% stroke (from overall length) under the loading. Output mechanical work related to its dimensions is much bigger than from others conventional actuators. This type of actuator has also good corrosion resistance and biocompatibility. These actuators produces no noise, no dust and no electromagnetic array. All these properties give the great possibility for application in many various application [4-27].

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