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MEASUREMENT OF DUST MASS CONCENTRATION

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Keywords: dust mass concentration, measurement, calibration, uncertainty
Abstract: The paper deals with measurement of dust mass concentration in working environment. Because of variability of the quantity, also uncertainty balance is needed. There are several methods for measurement of dust mass concentration. Gravimetric methods is frequently used for this purpose, but also this method is used as reference methods for calibration of others methods of measurement.

1 Introduction

Dust mass concentration is a quantity measured in working environment and also in country environment. The dust mass concentration in country environment is increased in last years. It is related to pollutants producet by factories, cars, coal heating and other human activities.

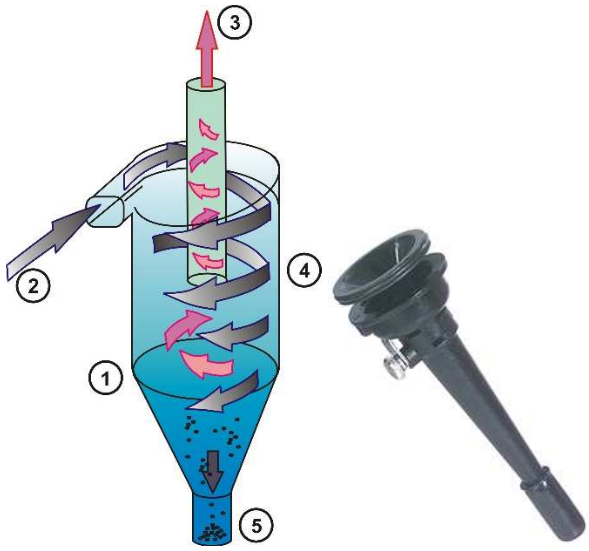
Working environment is mainly sensed inside buildings. There are defined linits for the values of dust muss concentration for working environment.

Pollutant emmision is very strictly monitored parameter of air quality.

Dust is very dangerous for human helathy and life. From hygienic viewpoint, the dust is defined as small particles of solid state materials, which are dispersed in environment air otherwise which are sedimentary on various objects. These particles come from the various technological operations (metallurgical technological operations, combustion of various substances, ore-working industry, threadmills, cement industry, cereals cleaning, processing of dry vegetal materials, wood processing etc.).

For practical purposes it is possible to divide dust particles into these categories – dimensional fractions: respirable and non-respirable dust fraction. The main goal of this dividing is to imitate the dust separation of the human breathing. So, respirable fraction is the part of dust particles, which is possible to respirable inside the human breathing ways.

Respirable dust transducer would by a sensitive only to respirable dust fraction. This requirement is achieved in practise with using of pre-separator. The most used pre-separator is so-called cyclone, which uses the mechanical way of the dust separation. A cyclone (fig. 1) is a size-selective device used to separate respirable and non-respirable-sized particles from the air. The name „cyclone“ is coming from their principle, which is based on high velocity airflow rotating inside cyclone and separating the particles with high aerodynamics diameter. The small particles pass thorough the cyclone and they are collected on filter material [1-17].



1 – cyclone separator, 2 – dusty air inlet, 3 – respirable dust air outlet, 4 – airflow path, 5 – non-respirable dust fraction
Figure 1 separation of non-respirable dust fraction [18]

Dust laden gas enters the chamber from a tangential direction at the outer wall of the device, forming a vortex as it swirls within the chamber. The larger articulates, because of their greater inertia, move outward and are forced against the chamber wall. Slowed by friction with the wall surface, they then slide down the wall into a conical dust hopper at the bottom of the cyclone. The

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cleaned air together with respirable dust fraction swirls upward in a narrower spiral through an inner cylinder and emerges from an outlet at the top. Accumulated non-respirable particulate dust is deposited into a hopper, dust bin or screw conveyor at the base of the collector.

The cyclone is made from electrostatic conductive material (aluminium or conductive plastic), which is needed for elimination of electrostatic phenomena which occurs in nylon cyclone.

There is also a different way how to separate dust. For optical measurement method it is possible via "non-mechanical way". One of the possible ways is based on suitable wavelength of light radiation and scatter angle. Another possible non-mechanical way is based on suitable signal processing from light scattering sensor [1-17].

The main goal of this paper is to show the possibility of change of the mechanical pre-separators with suppressing of the dust transducer sensitivity to non-respirable dust fraction based on signal processing for light scattering dust transducer. This way represents one of the possible approaches to the problem solving, which is oriented to replacement of the mechanical parts with electronics or signal processing for obtaining of the overall properties improvement of the function, which has been provided via mechanical part.

2 Gravimetric method for dust mass concentration measurement in working air environment

The gravimetric method principle (fig. 2) lies on fact, that dust sample from air is captured on suitable type of the filter.

Weight difference of the filter before and after sampling and airflow velocity is basic information for dust mass concentration Mc identification. It can be obtained from equation (1):

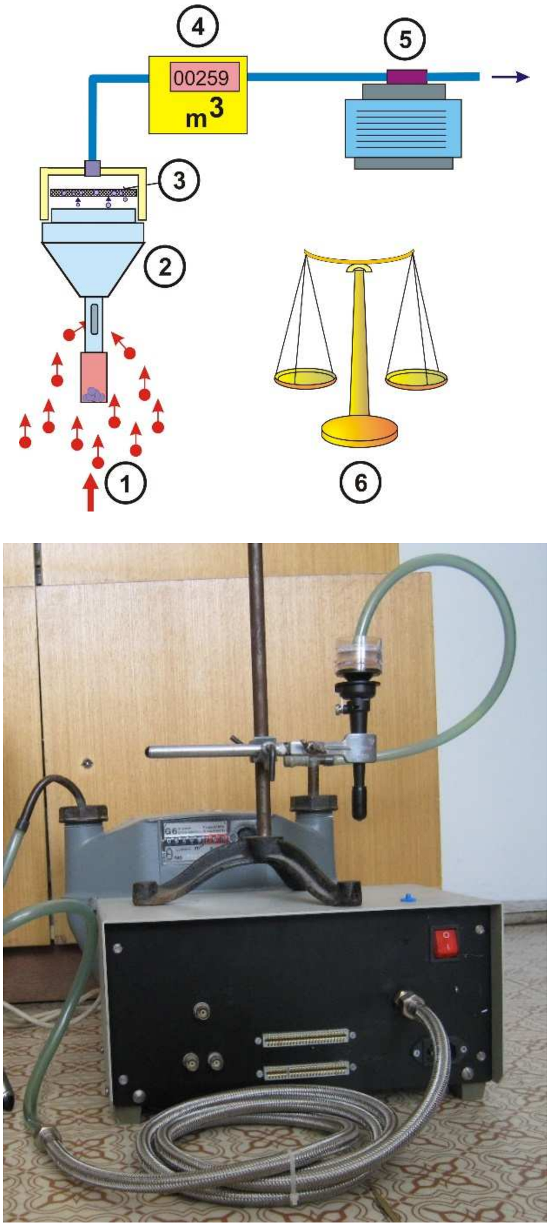
$$M_C = \frac{m_{before} - m_{after}}{Q_V} \quad (1)$$

where: m_{before}, m_{after} – are filter weights before and after sampling,

Q_V – volume airflow velocity,

The main advantage of the gravimetric method is simplicity and comparable results independent on used measuring devices. So, the gravimetric method has been accepted as reference method for dust mass concentration measurement [19].

Filter is made from cellulose, glass fibre, teflon, MCE – mixed cellulose ester, PVC, silver etc. Measurement range with this method is 0.1-2000mg/m3 (it depends on device producer) [19].



1 – dusty air, 2 – cyclone, 3 – filter, 4 –volume flowmeter, 5 – high-volume pump, 6 – analytic scales

Figure 2 Principle of dust mass concentration measurement with gravimetric method [19]

3 Uncertainty of measurement of dust mass concentration

Standard uncertainty of measurement of dust mass concentration can be described as (2):

$$u_{Mc} = \sqrt{\left(\frac{\partial M_C}{\partial m_{after}}\right)^2 \cdot u^2_{mafter} + \left(\frac{\partial M_C}{\partial m_{before}}\right)^2 \cdot u^2_{mbefore} + \left(\frac{\partial M_C}{\partial Q_V}\right)^2 \cdot u^2_{Qv}} \quad (2)$$

where: m_{before}, m_{after} – are filter weights before and after sampling; Q_V – volume of sampled polluted air; umafter, umbefore – are standard uncertainty of measurement of filter weight before and after sampling; u_{Qv} – is standard

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uncertainty of measurement of volume of sampled polluted air.

Partial sensitivities can be derived as follow (3):

$$\frac{\partial M_C}{\partial m_{after}} = \frac{1}{Q_V}; \frac{\partial M_C}{\partial m_{before}} = -\frac{1}{Q_V};$$
$$\frac{\partial M_C}{\partial Q_V} = -\frac{1}{Q_V^2}\left(m_{after} - m_{before}\right). \quad (3)$$

After substitution of partial sensitivities into equation 2 (4):

$$u_{Mc} = \sqrt{\left(\frac{1}{Q_V}\right)^2 \cdot u_{mbefore}^2 + \left(-\frac{1}{Q_V}\right)^2 \cdot u_{mafter}^2 + \left(-\frac{1}{Q_V} \cdot \left(m_{after} - m_{before}\right)\right)^2 \cdot u_{Q_V}^2} \quad (4)$$

Uncertainty of both weight measurements are equal $u_{mbefore}=u_{mafter}=u_m$, so it is possible write equation for standard uncertainty of dust mass concentration (5):

$$u_{Mc} = \frac{1}{Q_V}\sqrt{2 \cdot u_m^2 + \left(m_{after} - m_{before}\right)^2 \cdot u_{Q_V}^2}. \quad (5)$$

Standard uncertainty um and u_{Qv} should be as combined standard uncertainties which consist of standard uncertainty obtained via using of method A and via using of method B. Conditions are not fulfilled for obtaining of standard uncertainty obtained via using of method A. Consequently, standard uncertainty um and u_{Qv} are equal directly to standard uncertainties obtained via using of method B (it means from datasheet supplied by producer).

4 Calibration of dust mass concentration measurement devices

Standard VDI2206 deals with calibration of dust monitors. Calibration based on this standard assigns the values of dust mass concentration to the measured values of output quantity from dust monitor (e.g. intensity of scattered light). The most frequently used methods is comparative measurements directly on explored place exposed to dust emmision.

Practical realistaion of calibration depends on many factors as working conditions, optical and physical properties of dust, condition of sampling of air contamined with dust. All these factors should be respected also during the calibration process. Because of these reasons, calibration requires large attention. All condition during calibration has to be noted for later analysis. The mentioned standard recommends the minimally 15 comparative measurement for reliably execution of calibration process. Time of one measurement should be less then 30 minutes.

5 Conclusion

Final standard uncertainty depends on calibration process. Also previous experiences show signification of calibration process. Dust mass measurement is very specific type of measurement, because of their variability. This variability is caused by production process, which is as source of dust pollutant emissions etc. Consequently, calibration process has to be executed directly on measured place and it is necessary to repeat it very frequently (mainly in case of changed production conditions). This paper also shows that calibration is very significant for determination of uncertainty of measurement and shows the way how it is possible to minimize the uncertainty of measurement [6-39].

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DIDACTIC MODELS OF MANIPULATORS

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Keywords: mechatronics, experimental model, control unit, didactic

Abstract: The paper deals with experimental model designed for educational purposes. These educational models support the creativity and innovation thinking of students. Both designed models are as compact model, but they enables completely rebuilding by students also students can add new units for extending of possibilities of these model.

1 Introduction

Mechatronics is interdisciplinary field which integrates mechanics, electronics and intelligent control. Mechatronic product is developed with aim to obtain improved properties or totally new functions are added. There are two ways for mechatronic product developing. First way is to improve already existing products, which have been before in mechanical form or electromechanical form. Second way is to develop completely new products, which have not been before.

Developing of mechatronic, products require synergy integration of knowledge from various areas as mechanics, electronics, control system, pneumatics, hydraulics, optics, thermomechanics, precision engineering, etc. Developing of successful mechatronic products needs optimal combination of all related areas.

Educational activities in mechatronic need practical experimental models of mechatronic products. Students can make any experiments and generate innovation ideas for improving of mechatronic products [2-10].

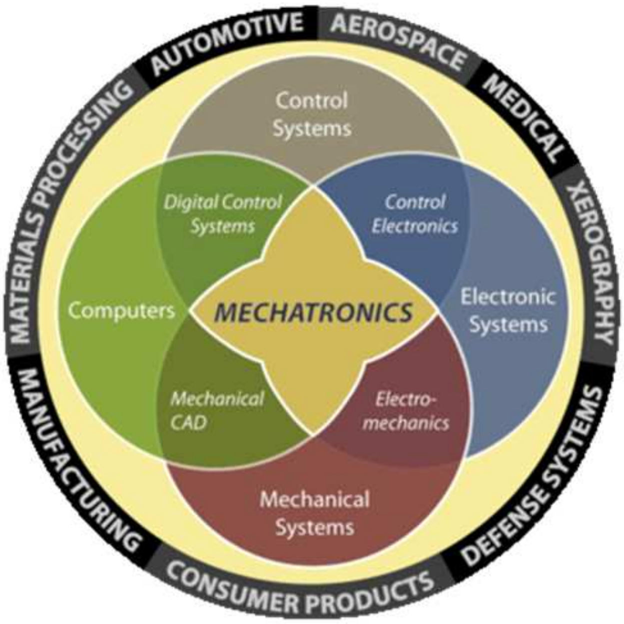

Figure 1 Mechatronics definition and application areas [1]

The main aim of this paper is present designed didactic models suitable for educational in mechatronics.

2 Joint manipulator

The aim was to develop manipulator, which will be useful for experiments, but also allows to modify and change the solution, add new functions and include innovations. Joint manipulator has 4 degree of freedom. Base of the manipulator can rotate to full rotation (360°). Every joint actuator allows to rotate in range ±90°. All construction of manipulator is designed as fully demountable and it is possible to build new modified model with new parameters. The variability of design was the first important aim. There is a bigger place for creativity of student. Also students can design totally new parts and subsystems for adding of new functionality to manipulator. The manipulator is controlled by the using of microcontroller, which is as small control unit for control of all actuators integrated in manipulator.

Figure 2 3D model of the manipulator

Position servomechanisms have been used as actuator in every joint of manipulator. These servomechanisms are simple and compact units, which can be controlled through the pulse width modulated signal from microcontroller. Printed circuit board is designed as user friendly solution

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with protection against the wrong connection of any devices to board. The boards also allows variability of electrical connection and students can make modification or also can include the new innovative ideas.

3D model of manipulator has been developed for making the simulations of manipulator movements. These simulations give results from movement and it is necessary to know about the possibility of movement conflict between the parts of the manipulator.

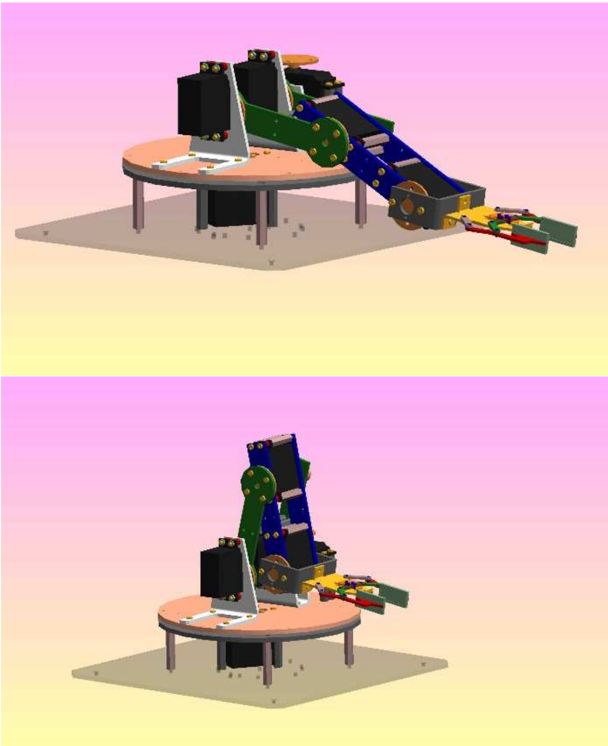

Figure 3 Kinematic simulations

Manipulator includes end-effector uses kinematic mechanism parallelogram for handling with any object. End-effector is able to hold cuboidal objects with maximum dimension 35 mm. It is designed as plane mechanism with parallel contact planes. Motion of the end-effector is realized via using of position servomechanism. Contact planes also includes tactile switch for recognition of object holding.

3 Cartesian manipulator

Next designed manipulator has cartesian kinematics (fig. 5) with independent movements in X, Y and Z axis. All axis is actuated with servomechanisms with belt transmission systems as transformation units for change of rotation motion to linear motion. These belt system have to be preloaded and suitable preloading mechanism should be placed in the manipulator (fig. 6).

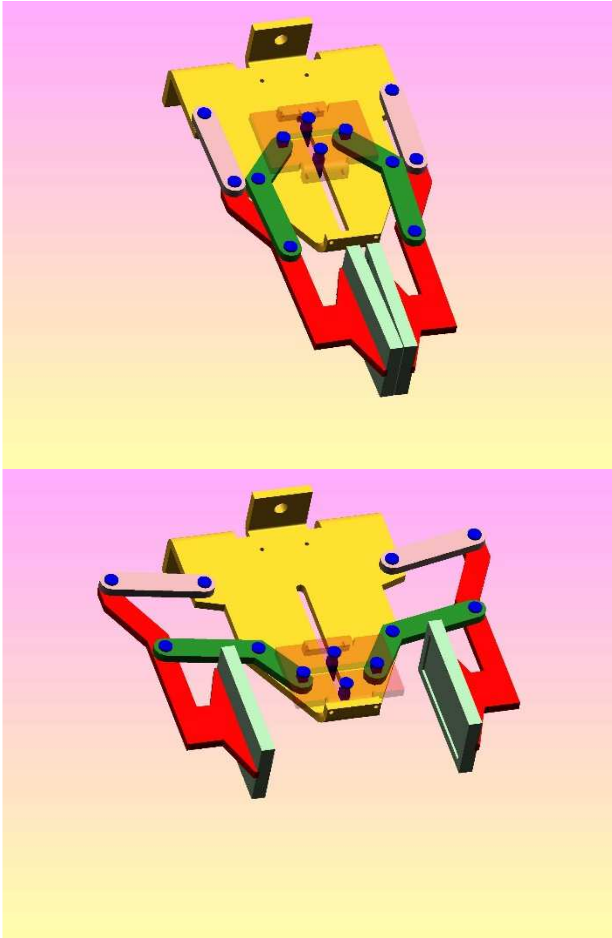

Figure 4 Design and simulation of end-effector

Unique design of this cartesian manipulator lies on principle that it is built on two beams. All movements are sensed with resistive position sensor. Information about all position are acquired into control unit for feedback controlling. Workplace of this manipulator is defined as cuboid. System enables to execute simultaneous movements in all axes.

4 Didactic aims

During the educational process it is important for students to absorb the theoretical knowledge earned during the lectures and then to realize it practically in the laboratories. The level of the presented absorption of the knowledge depends, to a great extent, on realized cognitive methods and utilized didactic tools. The proposed didactic model is supporting the applied educational approach by solving the defined problem situation. This approach, first of all, applies the problem interpretation-method and heuristic and the research methods. The problem solving philosophy of the education is based on the fact that during the problem task solving and the same by the model situation problem solving processes the students are acquiring the experience from their creative activity and

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they are creatively mastering their knowledge and the ways of their activity.

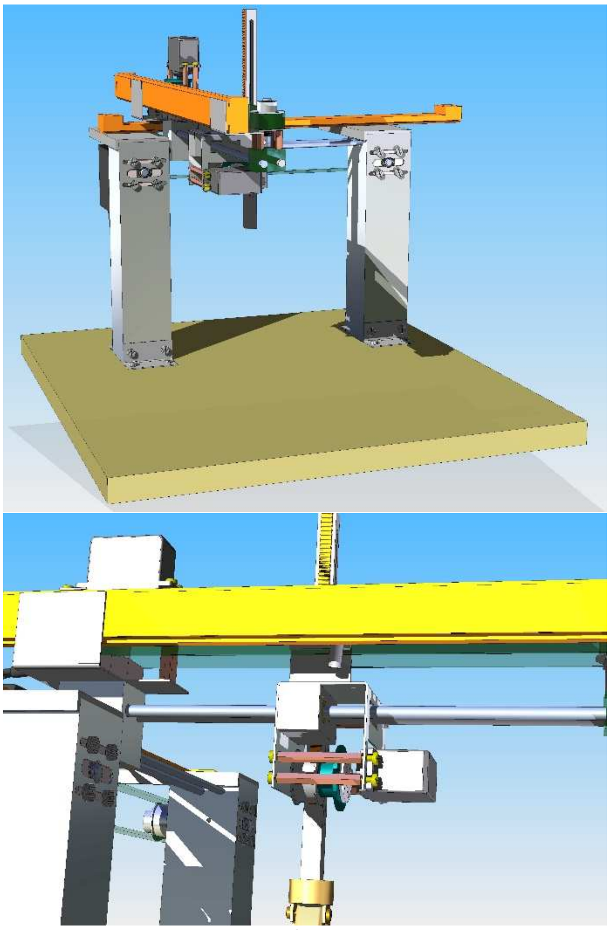

Figure 5 Design of cartesian manipulator

The students are joining the problem searching and problem solving processes through the activities of the teacher. This way the students are learning how to earn the new knowledge independently, they are applying their earlier acquired knowledge, and along with it they are personally experienced from their creative activities. The practical realization of the task and the personal involvement in problem solving are imitating the teamwork and the individuals may be aware of their importance within it. This approach is also of psychological and social natures both for the individual person and for the realization team.

The creative thinking rises during the problem solving situation when the student collides with an obstruction, some difficulty in his activity, some conflict if he impacts something unknown and uneasy and surprising and incomprehensible, whereas he does not know the way of overcoming the problem or the obstruction and he cannot solve it on the basis of his actual knowledge. In other words, the mechatronics is not only about the lectures and it has to pass to the students´ hands. So that the hands may act, they are directed by the brain. The brain has to think what directive to get out and what activities will be performed by the hands. If something is coming to the student’s hands really, it means the integral chain of consideration and researching and the individual study and consultations among the team members and with the pedagogue who is both the guardian and the anchorman of the entire project. In this manner, the students are learning the philosophy of the mechatronics approach to the project of the products. Their, both the thinking and the creativity, are getting a new dimensions enabling the student’s capability to get under better control the problem situations solving in the practice. Moreover, these manner-trained graduates markedly increase the probability of their practice. The same they may to fortify the competitiveness of their employers.

The design of the architecture of the model is modular and thus enabling an operative alteration of both the hardware and the software configurations.

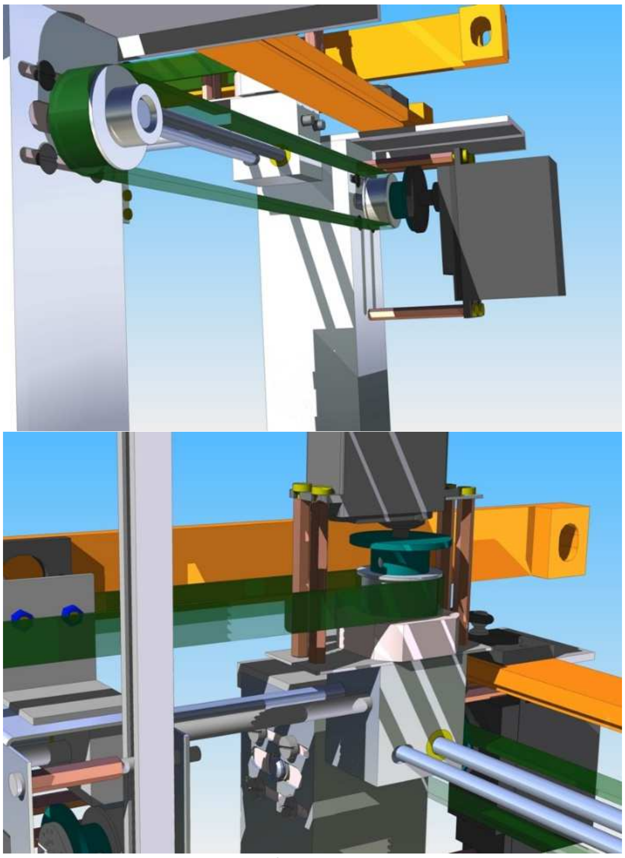

Figure 6 Drives for cartesian manipulator

5 Conclusion

Practical experiences can be obtained only when students will make a training on practical real models. Mentioned models have been built as compact systems, but it enables to modify any segments and units and students also can include any innovations into model. All works can be managed as team work and everything is made for properties improvements. [4-30].

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