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Editorial

The ***Journal of Production Engineering*** *dates back to 1984, when the first issue of the* ***Proceedings of the Institute of Production Engineering*** *was published in order to present its accomplishments. In 1994, after a decade of successful publication, the Proceedings changed the name into Production Engineering, with a basic idea of becoming a Yugoslav journal which publishes original scientific papers in this area.*

After 17 years, the journal now has a fresh and modern design, and has embraced some novel areas of interest, one of them being the environment protection.

In 2009 year, our Journal finally acquires its present title - ***Journal of Production Engineering****. To meet the Ministry requirements for becoming an international journal, a new international editorial board was formed of renowned domestic and foreign scientists, refereeing is now international, while the papers are published exclusively in English. The Journal is distributed to a large number of recipients home and abroad, and is also open to foreign authors. In this way we wanted to heighten the quality of papers and at the same time alleviate the lack of reputable international and domestic journals in this area.*

Editor in Chief

Professor Pavel Kovač, PhD,

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Review Paper

Kovač, P., Mankova I., Gostimirović, M., Sekulić, M., Savković, B.

A REVIEW OF MACHINING MONITORING SYSTEMS

Received: 21 January 2011 / Accepted: 07 May 2011

Abstract: *This paper follows a recent update of the literature on machining monitoring systems. The paper reviews the past contributions in these areas and provides an up-to-date comprehensive survey of methodology overview, sensor technologies, signal processing, decision making strategies for process monitoring and integrated workpiece quality evaluation. Tool wear measuring technique using vision system as well. Application examples including sensor systems are reported. Future challenges and trends in sensor based machining operation monitoring are presented.*

Key words**:** *monitoring systems, machining operations*

1. INTRODUCTION

Manufacturing enterprises currently have to cope with growing demands for increased product quality, greater product variability, shorter product life-cycles, reduced cost, and global competition [1, 2, 3]. A key issue for an unattended and automated machining system is the development of reliable and robust monitoring systems.

Machining problems, such as cutter breakage, excessive wear, chatter and collision, impede production consistency and quality.

The complex interactions between machines, tools, workpieces, fluids, measurement systems, material, humans and the environment in cutting operations requires that sensors be employed to insure efficient production and protect workers and the environment.

Loss due to disturbance could be prevented, or at least limited, using an in-process tool condition monitoring (TCM) system. An accurate and reliable TCM system could increase savings between 10% and 40% [4].

Now there are additional requirements for increased flexibility. Specifically, sensor systems must be able to be interfaced with open system architecture controllers for machines and systems must be designed to accommodate needs of so called “reconfigurable” systems

The typical machining process monitoring system operates according to the following rationale. In the cutting region there are several process variables, such as cutting forces, vibrations, acoustic emission, noise, temperature, surface finish, etc., that are influenced by the cutting tool state and the material removal process conditions. The variables that is prospectively effective for machining process monitoring can be measured by the application of appropriate physical sensors. Signals detected by these sensors are subjected to analogue and digital signal conditioning and processing with the aim to generate functional signal features correlated (at least potentially) with tool state and/ or process conditions

The measuring techniques for the monitoring of machining systems have traditionally been categorized into two approaches: direct and indirect.

In the direct approach the actual quantity of the variable, e.g. tool wear, is measured. Examples of direct measurement in this case are the use of cameras for visual inspection, radioactive isotopes, laser beams, and electrical resistance. Many direct methods can only be used as laboratory techniques. This is largely due to the practical limitations caused by access problems during machining, illumination and the use of cutting fluid. However, direct measurement has a high degree of accuracy [5].

Through indirect measurement approaches, auxiliary quantities can be measured. The actual quantity is subsequently deduced via empirically determined correlations. Indirect methods are less accurate than direct ones but are also less complex and more suitable for practical applications. In contrast to the traditional detection of tool conditions, the approach is that machining processes are being continuously monitored via sensing devices to quantify the process performance or provide information for process optimization.

A tool condition monitoring system can therefore be viewed [6] as serving the following purposes:

1. advanced fault detection system for cutting and machine tool,
2. check and safeguard machining process stability,
3. means by which machining tolerance is maintained on the workpiece to acceptable limits by providing a compensatory mechanism for tool wear offsets, and
4. machine tool damage avoidance system.

2. METHODOLOGY OVERVIEW

According to the literature, a generic methodology for developing an intelligent monitoring system for machining is composed of six key issues:

1. Sensors: The cutting process can be characterized by a variety of physical quantities. Appropriate sensors such as dynamometers, AE sensors, accelerometers, current/ power sensors, etc., transform a physical

quantity into the corresponding electrical signals. It is important to take into account the reliability of each sensor, the cost, its intrusive nature, and its application in order to select the most appropriate sensor system for a given monitoring purpose. Frequency of sensor usage related to machine monitoring systems is presented in [7]

2. Signal processing: Signal processing can be more or less complex, consisting in amplifying and filtering (with analogical low-pass, band-pass, or high-pass filters) the signals. Sample frequency limitations of acquisition boards must be taken into account to avoid aliasing. In addition, digital signal processing through digital filters and signal segmentation operations has to be considered to be able to acquire the part of the signal which is of interest.

3. Feature generation: The sensor signal has to be transformed into features that could describe the signal adequately. Many different features from the time domain, frequency domain and wavelet domain can be used for this purpose.

4. Feature selection/extraction: In order to develop robust and reliable models for monitoring, it is necessary to use the most meaningful features which best describe the machining process. Feature selection and feature extraction are two methods which allow the most useful sensory features to be defined.

5. Process knowledge model

(a) Design of experiments: Experimental runs in machining for modeling purposes are both economically costly and time-consuming, so an effective design of experiments is to enable monitoring systems to be applied in industry.

(b) AI technique: Monitoring systems require reliable models which are able to learn complex non-linear relationships between process performance variables and process variables in machining. An adequate selection of the AI technique is crucial to develop reliable machining models. This selection depends mainly on the number of experimental samples, the stochastic nature of the process, the desired model accuracy, and the explicit or implicit nature of the model.

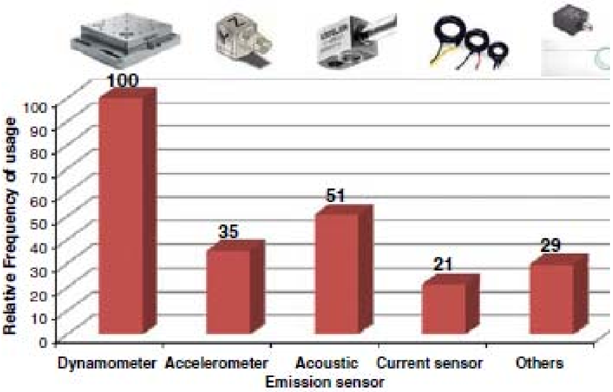


Fig .1 Frequency of sensor usage related to machine monitoring systems [7]

3. MOTOR POWER AND CURRENT MEASUREMENT TECHNOLOGY

When using an indirect sensor system based on motor current or power, it is crucial that the relationship between input current/power and output force/torque is linear and understood.

The signal features [6]:

1 the amount of spindle power required for material removal may be a very small part of total power

2 the spindle motor power is proportional to the resultant cutting force, the least wear sensitive parameter;

3 temperature rises inherent in electrical motors influence power consumption;

4 drive motors are highly dependent on the axis lubrication state, transverse rate and axis condition.

4. FORCE AND TORQUE MEASUREMENT TECHNOLOGY

Force and torque sensors generally employ sensing elements that convert the applied force or torsional load into deformation of an elastic element. The two main sensor types used are piezoelectric based and strain based sensors Direct force measurement using piezoelectric sensors is possible when the force transducer is mounted in line with the force path. In cases where more measurement flexibility is required, multi-component force transducers have been developed and are used extensively in lab based applications Strain gauge force transducers, consisting of a structure that deforms under a force, offer reasonably high frequency response and long-term stability. The total cutting force could be obtained by the summation of the static and dynamic forces.

Experimental setup with 3 component dynamometer acoustic emission sensor and 3 –component accelerometer for machining process monitoring is in Fig 2 [8].

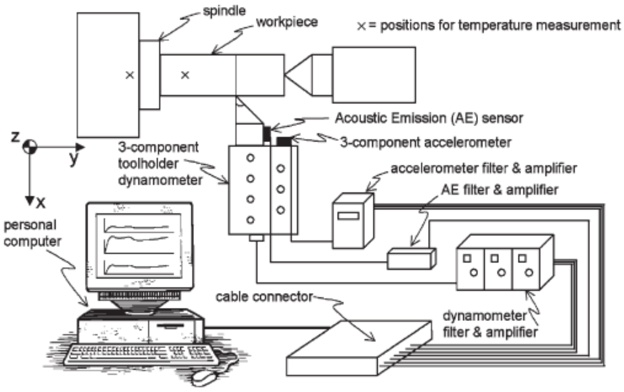


Fig. 2 Monitoring setup [8]

5. ACOUSTIC EMISSION MEASURING TECHNOLOGY AND SENSORS

Piezoelectric sensor technology is particularly suitable for measuring acoustic emission (AE) in machining process monitoring. With very wide sensor dynamic bandwidth from 100 to 900 kHz, AE can detect most of the phenomena in machining, though significant data acquisition and signal processing is required [6] (Fig. 3)

The capacitance principle can also be used for detecting AE, as the capacitance of two parallel plates changes with the distance between plates. The accuracy of this AE detection method is higher than many other techniques and capacitance based AE sensors are used for calibrating other AE sensors. However, capacitance type displacement sensors for AE are very sensitive to sensor position and surface mounting.

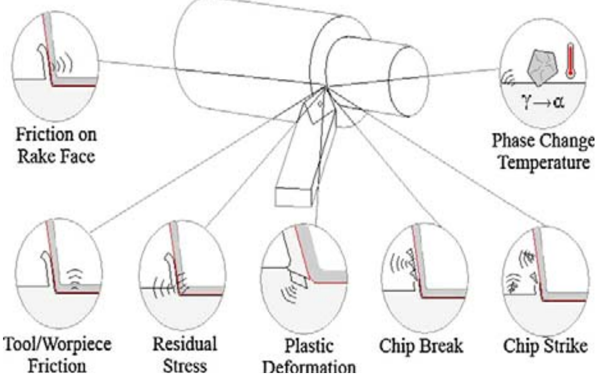


Fig. 3 Sources of AE in machining [6].

During metal cutting the workpiece undergoes considerable plastic deformation as the tool pushes through it. Within the deformation zones (dislocation movements) strain energy is released as the bonds between the metal atoms are disturbed. This released energy is commonly referred to as acoustic emission. Other sources of AE include phase transformations, friction mechanisms (tool-workpiece contact) and crack formation or extension fracture

6. VIBRATION

A large variety of sensing principles are used for sensing vibration. However, piezoelectric transduction is the most common type in vibration sensing of machining operations. Vibrations that occur during metal cutting can be divided into two groups:

(i) dependant and
(ii) independent of the cutting process

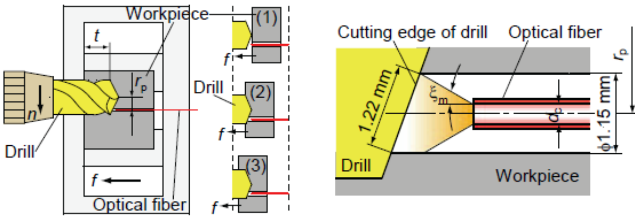
As in many applications using machine vision, object illumination notably impacts the process and for industrial applications can lead to process unreliability [9].

7. THE CUTTING TEMPERATURE

The resultant high temperatures around the cutting tool edges has a direct controlling influence on the rate and mode of cutting tool wear, the friction between chip and cutting tool, and also that between the cutting tool and the newly formed surface. As the temperature distribution is not uniform, knowing the exact amount of heat transferred via the tool is not straight forward.

For practical applications such as on-line TCM, remote thermocouple sensing appear to be the only worthy way to measure the workpiece-tool temperature but a direct measurement of the tooltip or rake face temperature distribution cannot be obtained. Past attempts at measuring the cutting edge temperature have proven exceptionally difficult due to lack of direct access to the cutting zone [10].

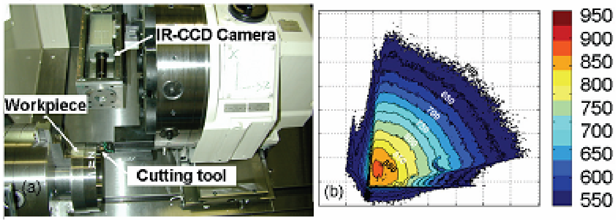
The cutting temperature is measured using a two-color pyrometer with an optical fiber. The fundamental structure is indicated in Figure 4 and the detail of temperature measurement condition is in Figure 4. In Figure 4(a), which is the top view of the cutting point, the optical fiber is inserted into the fine hole in the workpiece and is fixed to the bed of the lathe at the point where the distance between the cutting edge of drill and the incidence face of the fiber is 1mm. The distance of 1 mm is maintained constantly while the drilling is performed. The feed rate is given by the movement of the workpiece, but the optical fiber has no contact with the workpiece and is at a state of geostationary.



(a) Optical fiber setting (b) Detail of temperature measurement

Fig, 4 Arangement of optical fiber in drilling process and target area of temperature measurement [11]

A typical IR-CCD, described in [12], is shown in Figure 5 (a). It consists of a near infrared (NIR), high resolution (4.5 m), silicon-based, CCD camera with an observation area of 3.5 mm by 2.5 mm. Temperature measurements are restricted to the range of 500ºC to 1000ºC and are made with no coolant. A calculation of the uncertainty, which considers only a black body calibration source and assumes an emissivity higher than 0.5 for the tool insert, shows the maximum error to be less than 5%. The temperature distribution map for machining stainless steel at 220 m/min, [12], is given in Figure 5 (b)



Fig, 5 (a) IR-CCD measurement arrangement [12]. showing the (b) temperature maps (ºC) for machining SS2541 machined with an S6 insert at a cutting speed of 200 m/min and a feed of 0.15 mm.

A data acquisition system records the timing of the thermal and visible spectrum images, along with analog data such as cutting forces [13].

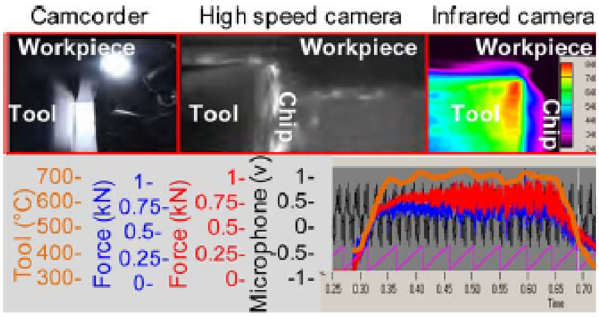


Fig. 6 Output parameters from dual spectrum equipment after orthogonal tests [13]

True temperature at any given location in the tool and corresponding cutting forces are played back in a synchronized manner. Fig. 6 shows an example of (i) a standard camcorder image, (ii) the visible spectrum image captured at 30,000 frames per second and 33 ms integration time, yielding 256 -128 pixel size, and (iii) the spectral radiance maps acquired at 300 frames per second and 19 ms integration time, from 3.8 mm to 5.1 mm in wavelength with 160 -120 pixel size.

8. INTEGRATED WORKPIECE QUALITY EVALUATIONS

Finally, was looked at the ability to integrate evaluation of the workpiece quality into cutting performance. This remains an elusive goal due to many challenges. The first challenge is defining workpiece quality quantitatively over the range of processes and parts manufactured (for example, subsurface damage in machining, or surface roughness).

Second, measuring or somehow assessing the quality elements of the workpiece as part of the production environment (for example, surface roughness that is dependent on so many independent variables in the process such as tool condition). Finally, it is not clear how to incorporate this information in some way into the machine and process control scheme.

The closest system relating to workpiece quality evaluation is the “workpiece monitoring” bar which, is hardly seen in practice in industry. But, this important piece is needed for much of the advancements in cutting performance reviewed above (open architecture adaptive control and reconfigurable systems, for example). This is one area where modeling is not easily applied. The challenge is integration of independent, reliable and capable sub-systems with the goal of assessing the product quality.

9. TOOL WEAR MEASURING TECHNIQUE USING VISION SYSTEM

The presented system [14] is characterized by its measurement flexibility, high spatial resolution and good accuracy. The system consists of a light source to illuminate the tool, CCD camera, laser diode (used in conjunction with profile deepness assessment) with linear projector, grabber for capturing the picture, and a PC.

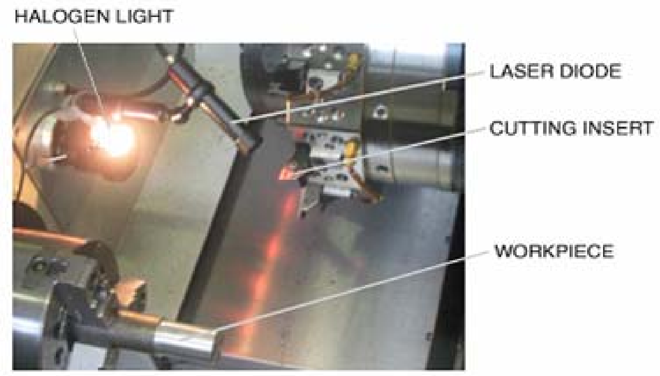


Fig. 7 Measurement set mounted on a machine tool

The technique is specially characterized by its determination of profile deepness with the help of projected laser raster lines on a tool surface. So it has advantage comparing with other techniques, which can measure only 2D profiles. With the technique presented in this paper a 3D image of relief surface can be obtained without having need to employ a very complicated measuring system.

For on-line tool wear monitoring using geometric descriptors from digital images LDA (linear discriminant analysis) shows that three out of the nine descriptors provide the 98.63% of the necessary information to carry out the classification, which are eccentricity, extent and solidity [15]. The result obtained using a finite mixture model approach shows the presence of three clusters using these descriptors, which correspond with low, medium and high wear level. A monitoring approach is performed using the tool wear evolution for each insert along machining and the discriminant analysis. This evolution represents the probability of belonging to each one of the wear classes (low, medium and high). The estimate of the wear level allows to replace the tool when the wear level is located at the end of the M class (medium), preventing that the tool enters into the H class (high) Fig 8.

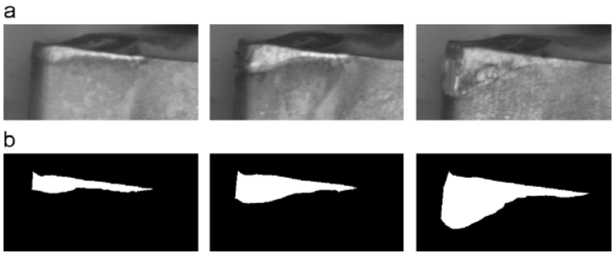


Fig 8 (a) First image in series shoving three wear levels: (b) segmented images with the worn region in white [15]

10. MONITORING OF CRATER WEAR IN TURNING USING ULTRASONIC TECHNIQUE

The ultrasonic probe of 10MHz having 10mm diameteris used to transmit/receive (T/Rprobe) the ultrasonic signal in to the uncoated carbide insert (CTC2135). The tool-transducer configuration as shown in Fig. 9, is favorable to measure the crater wear.

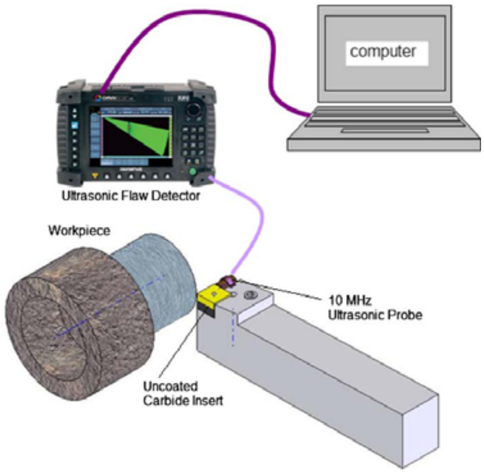


Fig. 9 Online setupforcraterwearmonitoring [16]

The ultrasonic waves transmitted through the insert are reflected back from the side flank. The maximum energy is received in this condition because, the surface of the side flank acts as a flat reflector

The total amount of reflected ultrasonic energy decreases with gradual wear due to scattering of ultrasound waves. The increase in crater depth increases the scattering and this energy loss can be correlated with crater depth.

11. DECISION MAKING SUPPORT SYSTEMS

In monitoring and control activities in modern manufacturing systems, the computing methods employed intelligent sensors and sensorial systems. A number of schemes, techniques and paradigms have been used to develop decision making support systems functional on machining process conditions based on sensor signals data features. The most frequently employed for the purpose of sensor monitoring in machining, including neural networks, fuzzy logic, genetic algorithms and hybrid systems able to synergically combine the capabilities of the various cognitive methods

10.1. Neural network

An artificial neural network (NN) is a computational model of the human brain that assumes that computation is distributed over several simple interconnected processing elements, called neurons or nodes, which operate in parallel. A NN provides a mapping through which points in the input space are associated with corresponding points in an output space on the basis of designated attribute values, of which class membership can be one. NN can capture domain knowledge from examples, do not archive knowledge in an explicit form such as rules or databases, can readily handle both continuous and discrete data, and have a good generalisation capability Knowledge is built into a NN by training. Some NN can be trained by feeding them with typical input patterns and expected output patterns. The error between actual and expected outputs issued to modify the weight of the connections between neurons. This method is known as supervised training.

10.2. Fuzzy logic

Fuzzy logic is a logical system, which is an extension of multivalve logic. But in a wider sense, FL is almost synonymous with the theory of fuzzy set. A fuzzy set is a set without a crisp, clearly defined boundary. It can contain elements with only a partial degree of membership. A fuzzy set defines a mapping between elements in the input space (some times referred to as the universe of discourse) and values in the interval [0, 1]. A membership function is a curve that defines how each point in the input space is mapped to a membership value (degree of membership or truth degree) between 0 and 1. The membership function can be any arbitrary curve, the shape of which can be defined as a function suitable from the point of view of simplicity, convenience, speed and efficiency.

10.3. Other methods (genetic algorithms, hybrid systems, etc.)

Genetic algorithms (GA) belong to a branch of computer science called "natural computation" where programmers, inspired by phenomena in the biological world, create models of these systems on a computer. This technique can solve complex problems by imitating Darwinian theories of evolution on a computer. The first step in the use of a GA is building a computer model to represent a given problem. Interacting variables in the problem are first combined and encoded into a series of binary strings (rows of ones and zeros) to form numerical "chromosomes". The computer randomly generates an entire "population" of these chromosomes and ranks them based on a "fitness function” which determines how well they solve the problem. Those strings which are deemed the "fittest” are allowed to "survive" and "reproduce" with other chromosome strings, through genetic operators such as "crossover" and ‘‘mutation", to create "offspring" chromosomes [6, 17]

Figure 10 shows the AI approaches applied in machining monitoring systems according to the references found in the research platform *ISI*-Web of knowledge from 2002 to 2007.

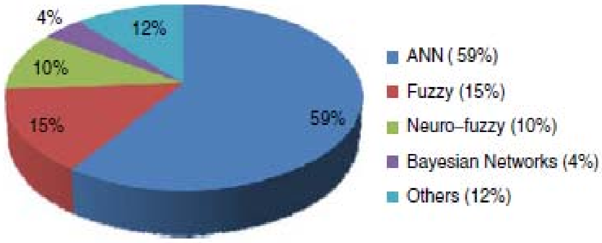


Fig. 10 Frequency of usage AI approaches applied in machining monitoring systems according to the references found in the research platform *ISI-Web of knowledge* from 2002 to 2007

12. INTELLIGENT SENSOR MONITORING

Intelligent sensor monitoring systems including, abilities for self-calibration and self diagnostics, signal conditioning, and decision making. Recommended measures [6]:

1 more applied research in intelligent sensor monitoring applications to manufacturing,
2 development of high performance equipment,
3 efforts towards standardisation,
4 promotion with industry,
5 robust pattern recognition paradigms; and
6 training and formation of skilled operators in intelligent sensor monitoring.

13. CONCLUSIONS

Many machining monitoring systems based on in process models have been developed in the past for optimising, predicting or controlling machining processes. All research works present different methodologies without showing clear guidelines or key issues for the development of intelligent machining systems.

The paper has reviewed: (1) methodology for monitoring overview (2) the different sensor systems applied to the monitoring of machining processes, (3) tool wear measuring technique, (4) decision making support systems, (5) the DoE required to model a machining operation with minimum experimental data and (6) the main characteristics of several AI techniques to facilitate their application/selection.

Cutting forces (static and dynamic), AE and vibration (acceleration) are considered the most widely applicable parameters. Advances and increased sophistication in instrumentation technology employed for measuring these parameters make them viable, practical, cost effective, robust, and easy to mount and have the quick response time needed to indicate changes for on-line monitoring of machining process.

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Original Scientific Paper

Maňková, I., Kovac, P., Kundrak, J., Beňo, J.

FINITE ELEMENT ANALYSIS OF HARDENED STEEL CUTTING

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Abstract: *Hard machining, as attractive replacement for many rough and finish grinding operation, generates high cutting forces and temperature that enhance tool wear when act together. Therefore, the tool geometry and machining parameters have to be carefully optimized for a given material. Because of high cost and time consuming experimental work up-to-date advanced software for modeling and simulation brings quick and adequate solution. The aim of this contribution is to study the influence of cutting parameters on accompanying phenomena when hard turning process with mixed oxide ceramic inserts. Hardened steel with hardness of HRC 55 has been employed in modeling and trials. In order to better understand dynamics of cutting hardened steel, investigation has been performed making use finite element simulation in two dimension, and experimental analysis of cutting force. The potentiality of the model as well as the experimental results are compared and discussed.*

Key words: *Hard turning, cutting force, temperature, Advant Edge modelling.*

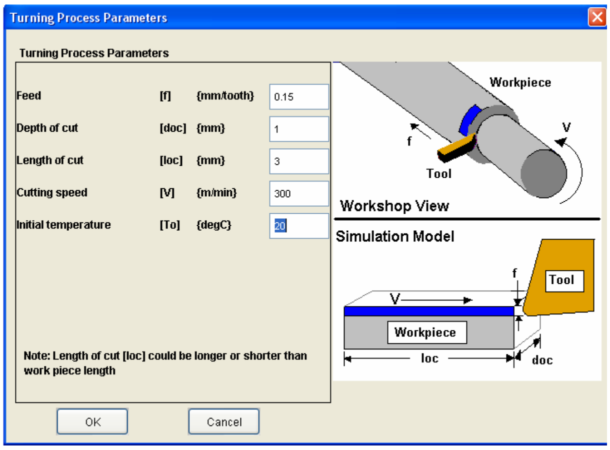
1. INTRODUCTION

Hard turning is a complex process with chip formation occurring at tool nose radius and relative small feed and depth of cut. Most research on hard turning in the literature is limited to experimental work, while practical theoretical models including FEA (finite element analysis) of this promising machining process are scarce, due to the inherent complexity of a hard turning process. In order to improve the fundamental understanding of hard turning and process optimization for producing favourable surface integrity, theoretical modelling of a hard turning process has economic as well as scientific importance [1, 2]. The finite element method seems to be the right tool to predict cutting performance including chip flow and morphology, cutting forces, and complex residual stress and cutting temperature fields which are often beyond the capability of current measurement methods. A 2D FEA modelling of temperature and forces in orthogonal cutting of hardened steel was reported more times [3, 4, 5, 6]. Nowadays variety of applicable FEM modelling software is available. The choice of finite element software for machining analysis is an important factor in determining the quality and scope of analysis that can be performed.

One of this software ThirdWave System's AdvantEdge is a machining specific FEM package. It has pre-programmed modules for both 2D and 3D machining operations including turning and milling. AdvantEdge also comes with a workpiece modeller as well as a material property library.

As AdvantEdge has been explicitly written with machining operations in mind, its solvers have been optimized specifically for metal-cutting processes. Also, the software has a very user friendly interface with simple input screens to supply the tool and workpiece geometries as well as the process parameters. AdvantEdge has a built-in editor for simple tool and workpiece geometries and allows for the import of more complex geometries. AdvantEdge also has a very extensive material library with models of many engineering metals and alloys, including several aerospace alloys [4]. Specifying new materials is relatively simple and the user has the capability to enter the properties of the material using different models. The program also uses adaptive meshing to handle increase the accuracy of the solution in the areas of high deformation and allows a reasonable degree of flexibility in the meshing controls [7, 8, 9].

On the other hand AdvantEdge does not give the user much flexibility in configuring the controls of the solver. While this may be preferable in some cases, this means that the user is restricted to the preset controls of the software. If a quick, easy to setup machining simulation is needed, then the preferable software packages would be AdvantEdge. This package allows quick setup of simulations and has built in modules to specify material properties, tool and workpiece geometries and process parameters, Fig 2.



Turning Process Parameters

Turning Process Parameters

Feed	[f]	{mm/tooth}	0.15
Depth of cut	[doc]	{mm}	1
Length of cut	[loc]	{mm}	3
Cutting speed	[V]	{m/min}	300
Initial temperature	[To]	{degC}	20

Note: Length of cut [loc] could be longer or shorter than work piece length

Fig. 2 Example of one of the input set up window

In this study a general practical 2D model has been applied to analyze hard turning steel with of HRC 55 using mixed oxide ceramic cutting tool. The goal of this study is to investigate the influence of cutting parameters on the accompanying phenomena of hard turning process – cutting force and temperature. Experimental evidence and simulation results are compared.

2. HARD TURNING – DEFINITION OF INPUT PARAMETERS FOR MODELLING

Machining conditions in hard turning are different from conventional turning. Depth of cut, feed rate, and cutting tool nose radius are typical finishing conditions in hard turning. Because of the low depth of cut and the large cutting tool nose radius, chip formation usually takes place in the nose radius or on the chamfer of a cutting tool. Thrust force appears to be the largest force component, while the feed force component is the smallest one using a worn tool. By increasing the tool flank wear, a significant rise of the thrust force component can be observed. Considering a very small contact area on the tool-chip interface, extremely high stresses and temperatures develop on the area. A numerical simulation may provide a powerful tool to analyze the contact mechanics on the tool/chip and tool/workpiece interfaces [1].

Cutting temperature is of fundamentals importance in hard turning. Cutting temperature may cause thermal damage and even white layer when machining hardened steels. The influence of cutting temperature on the surface integrity may be more important than the tool life. However, the fact that temperature is most difficult to measure explains the numbers of different methods used over the years [2].

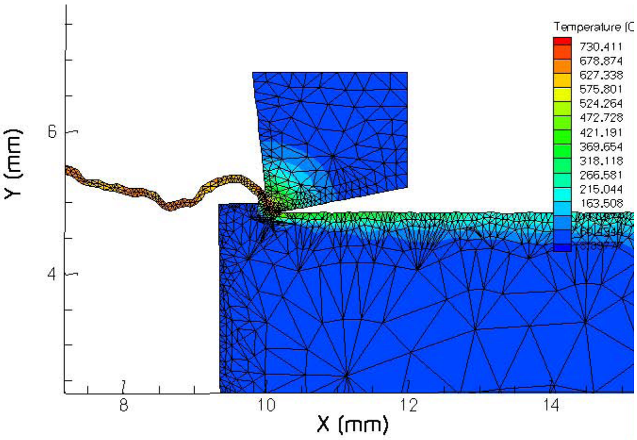


Fig. 3 Example of graphical output from temperature simulation [11].

In this study a 2-dimensional version of software AdvantEdge has been used for simulation. The finite element model is composed of workpiece and a tool. Workpiece is defined as a deformable body while the tool is considered as a rigid. A user defined geometry and cutting edge radius parameterizes the cutting tool. The tool penetrates through the workpiece at constant speed and constant feed rate. Material properties are essential inputs for any FEM simulation and other analytical modelling of a machining process.

The applied software employs well-known Johnson-Cook material model to describe material behaviour. Friction on the tool-chip interface is a major input determining the dependent variables such as chip morphology, cutting forces, residual stresses, and temperatures. Therefore, an accurate determination of the friction condition is of considerable importance for finite element analysis of metal cutting. Friction conditions at the tool/chip interaction was modelled by using an average friction coefficient only determined by Coulomb's friction law as a value of 0,5. It limits application of the model and reduces FEA model efficiency significantly [2, 10].

A Lagrangian finite element-based machining model is applied in the simulation of cutting force components and temperature in two-dimensional turning of hardened steel. The cutting force Fc force in X direction (F_X) and transverse force in Y direction (F_Y) on the tool are displayed as functions of time. In simulation with AdvantEdge, there is no separation criteria defined since chip formation is assumed to be due to plastic flow; therefore the chip is formed by continuously re-meshing the workpiece. Adaptive re-meshing of the model is used to avoid extreme element distortions due to the strong deformations. It re-meshes the workpiece periodically to refine large elements, re-mesh distorted elements, and coarsen small elements. Heat transfer to the tool is allowed, Fig.3, but heat transfer by radiation, convection or conduction was considered as negligible. The model is discredited by triangular elements and uses maximum 12000 elements, depending on the chip configuration [11]. The length of cut was set to 5 mm. The simulation was conducted with coolant off and initial temperature was fixed at 20°C. The simulation was conducted in rapid mode.

3. EXPERIMENTAL CONDITIONS AND MODEL VALIDATION

For simulation, workpiece material AISI 1045 hardened at hardnes 55 HRC have been employed. Turning process was conducted with mixed oxide ceramics insert D310 (70% Al_2O_3+30% TiC) with a SN geometry, nose radius $r_\varepsilon = 0{,}8$ mm, and chamfered edge 0,2 x 20°, $\gamma = -6°$, $\alpha = 6$. Set of cutting conditions are follows: cutting speed v_c = 90, 120, and 150, 240 and 350 m/min, feed rate: f = 0,047, 0,1, 0,15 and 0,2 mm, depth of cut: a_p = 0,5 mm.

In this study, external longitudinal turning of hardened steel of hardness 55HRC had been employed for measurement of cutting force components F_c, F_f, F_p by triaxial dynamometer. The difference between the simulated values and the experimental ones did not exceed 10% [11]. These differences could be caused by different way of cutting 2D in simulation and 3D in measurement. 2D simulation is unable to make punctual estimation of thermo mechanical stress induced on the material/tool interface therefore modeled and simulated outputs from software has only informative character [8]. Comparisons of measured and simulated data are illustrated graphically in Fig. 4.

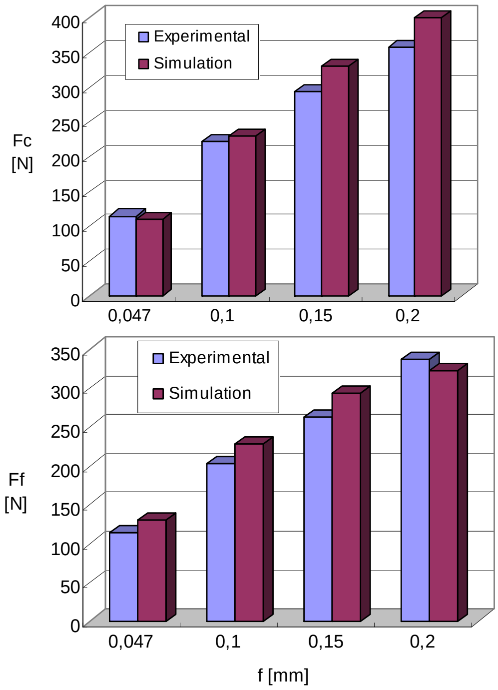


Fig. 4 Comparison of experimental and simulated cutting force values F_C, Ff, for v_c = 120 m/min, workpiece hardness 55 HRc

Figure 4 illustrates the cutting force behaviour in function of the feed rate, while the other parameters remain constant. It is interesting to note the linearity of the cutting force within the feed rate range considered. Simulation results have been processed graphically. AdvantEdge software shows simulation results in different way such as a table or graph or color area, Fig.5.

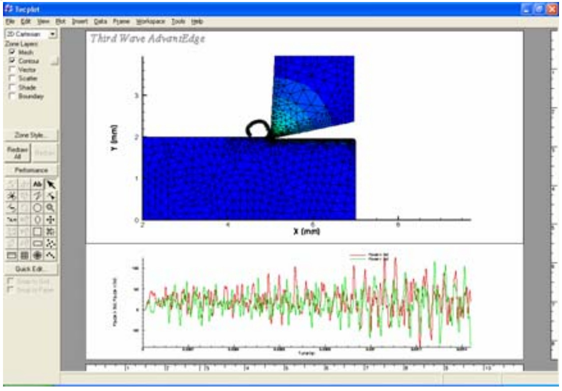


Fig. 5 Example of graphical output from cutting force simulation

4. SIMULATION RESULTS AND DISCUSION

Effect of cutting parameters and material hardness on cutting forces

Ceramic cutting tools have an advantage in the machining of hard work piece materials at high speed. The variation of main cutting force with cutting speed has been modelled. It can be noted that the cutting forces of the ceramic cutting tool slightly decreases with cutting speed, Fig 6. The decrease of cutting force with respect to cutting speed when using mixed alumina ceramic cutting tool shows that this type of ceramic cutting tool can machine the work piece material with high speed and at low cutting forces. The lower cutting forces result in a lower distortion of work piece, which improves the surface finish while machining with the ceramic cutting tools and particularly by using mixed oxide ceramic cutting tools.

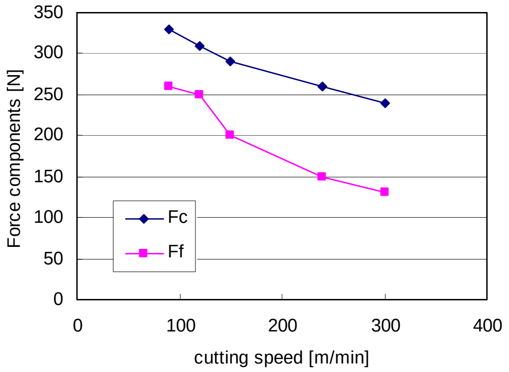


Fig. 6 Numerical results of cutting force component for different cutting speed, HRC 55, ap=0,5mm,f= 0,15mm

Effect of cutting parameters on chip deformation

Besides the cutting and transverse force it is possible to extract from the proposed model predictions for values that it would be very work-intensive or even impossible to obtain otherwise. Examples for such cases are: plastic strain rate, chip deformation, von Misses stresses, and temperature distribution and heat rate.

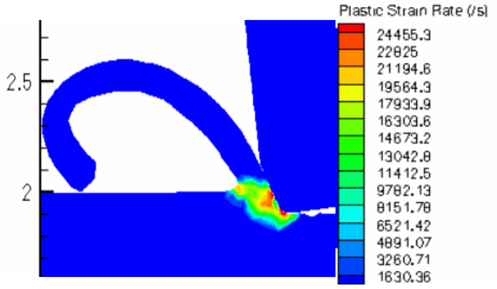


Fig. 7 Example of graphical output from plastic strain rate HRC55

In Fig.7 plastic strain rate in shear zone for cutting speed 120 m/min, is shown. This figure demonstrates the model at a step analysis, for length of cut l = 1,2 mm, where cutting is well into the steady-state region.

Effect of cutting parameters on cutting temperature and heat flow

The knowledge of maximum temperature and of the distribution of the temperature field in the rake face of the tool is of great interest because of high temperature in ceramics tool are connected to wear mechanics that reduces the tool life. With the simulated results provided by model it is possible to minimize unwanted effects and to choose suitable cutting condition in order to optimise the process [8].

Considering of low thermal activity of ceramics it is assumed that the temperature distribution on the rake face of the cutting tool is mainly determined by sources of plastic deformation of the metal on the shear plane and by the friction on the tool-chip interface. Depth of cut a_p = 0,5 mm and feed per revolution f = 0,15 mm were fixed. Simulation results are processed in figure 8. Graphs show variation of temperature for three values of cutting speed. Figure 9 represents the temperature distribution on rake face of cutting inserts. Rake face temperature is growing with increasing of cutting speed.

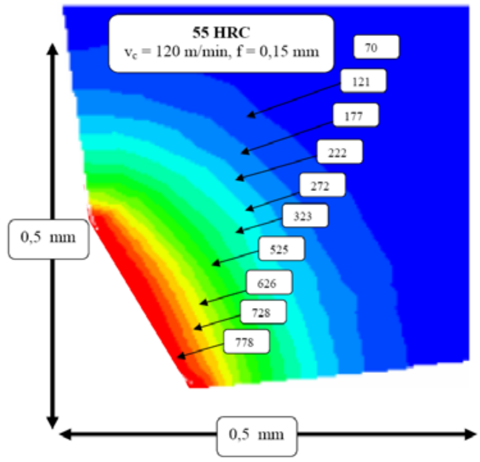


Fig. 8 Temperature distribution on tool rake face

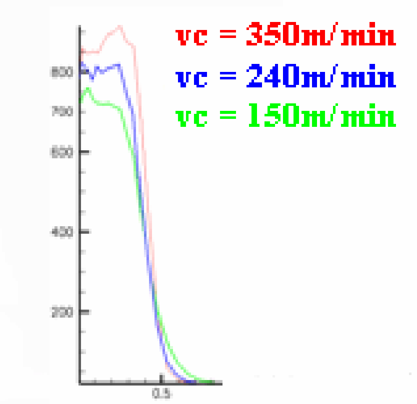


Fig. 9 Temperature vs distance along the tool rake face for 55HRC material hardnes

5. CONCLUSION

Summarizing the results reported above it can be concluded that hard turning has many advantages in comparison to other processes in machining of hardened steels. The finite element methods have been extensively used for modelling machining operations. This method is also used in the present paper and the software AdvantEdge is employed. Simulation of 2D orthogonal cutting model is provided. The modelled results for cutting and transverse force components have been compared with experimentally achieved values. However, other results such as temperature distribution, chip thickness and chip deformation as well as plastic strain rate had been only predicted; because of measuring these data is more time consuming and very work intensive.

From the analysis provided in this contribution can be concluded that the proposed model fits quite well and is suitable for practical application mainly in industry. Therefore FEM simulation software provide very important role in research work because of a minimum amount of experimental work is needed and produce reliable results, allowing for industrial use of optimal production.

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Original Scientific Paper

Beňo, J., Ižol, P.

BASIC RESEARCH ON TOOL EDGE FRACTURE WHEN NECK – DOWN TURNING MILD CARBON STEEL

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Abstract: *Tool edge fracture is very undesired phenomenon appearing in many metal cutting operations and its nature seems to be of hardly predictable. In contrast to the tool wear, neither tool fracture appearances nor fracture mechanisms have been studied extensively for having random features and final consequences. Paper discusses and introduces combination of classic studies with modelling of stress distribution, while procuring causes of tool edge fractures are introduced. Based on known approaches to the contact phenomena, three types of stress in tool wedge have been modelled which account for inception of fracture mechanisms. Moreover, outer appearances of tool fracture are discussed when neck-down turning mild carbon steel. Four basic outer appearances of tool edge damage are introduced.*

Key words: *neck-down turning, simulation, tool loading, principal stress*

1. INTRODUCTION

Metal cutting tools are subject of scientific research which is motivated by increasing of quality and productivity of machining as well as by utilisation of tool performance. If tool performance is being discussed in scientific sources, one expresses such quantity indirectly, either as tool edge wear or as acceptable cutting speed. Thus, tool wear phenomena as wear progress and its outer appearances are comprehensively introduced in scientific sources and monographs devoted to the principles of machining as [1], [2], [3], etc.

Wear phenomena account excellent predictability due to application of advanced tribological approaches based on temperature effects on tool wedge including mechanics of contact and wear. On the other hand, there are hardly predictable phenomena associated with tool edge damage and that are fracture of tool, chipping on tool edge and huge plastic deformation of tool wedge shape. If anything from three phenomena mentioned appears, needs for tool change are the effects. Workpiece deterioration and time losses when producing any batch of engineering components are the further effects, too.

Tool edge fracture seems to be any subclass of tool damage as such, therefore, it cannot be studied as any isolated phenomenon for having been penetrated through scientific fields as:

a) metallurgy and heat treatment
b) deposition technology of tool coating
c) fractography as explanation of any fracture surface
d) thermal softening as irreversible plastic deformation of tool wedge due to temperature rise when cutting
e) fracture mechanics
f) mechanical testing of tool materials as hardness, compression test, notch toughness, etc.
g) fracture toughness K_{IC} and transverse rupture strength, (TRS)
h) tool damage theory, tool reliability prediction
i) tool material testing in continuous/interrupted cutting, and so on.

Factors of tool edge damage mentioned above can be classed comprehensively according to the Figure 1. In order to apply any approach in the study of tool damage, properties of tool material must be known and that are the quantities introduced in the Table 1. Data from Table 1 indicate clearly that brittle fracture of tool edge is subject to K_{IC} while dividing line lies within K_{IC} 8 ÷ 10,8 $Nm^{3/2}$ and that are sintered carbides as tool material commonly used in machinery.

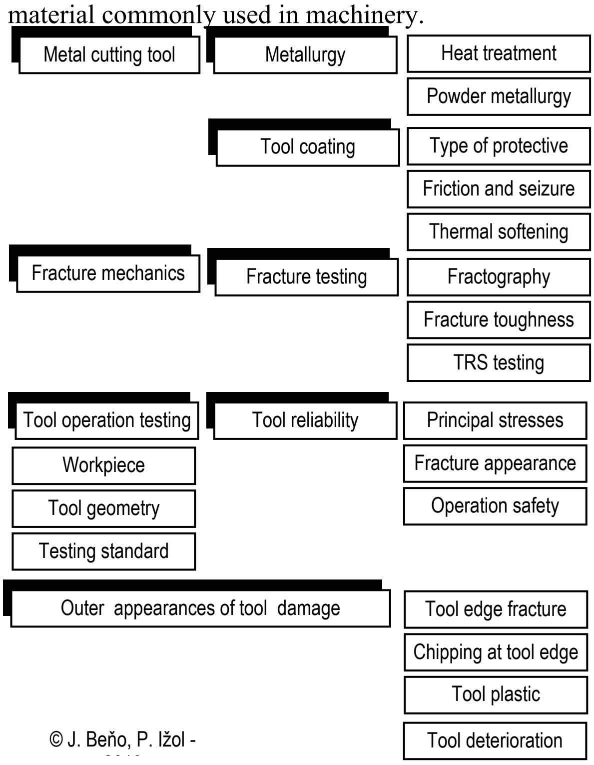

Fig. 1 Main fields of science associated with tool edge damage and tool fracture – based on data from [1]

2. SHORT REVIEW OF TOOL FRACTURE CRITERIA

There are three main reasons which account for any tool edge damage. Not surprisingly, machining operation is the first reason and that may be inaccuracies of workpiece being set into motion or small rigidity in tool clamping. The second reasons follows chiefly from defects in heat treatment of High Speed Steel (HSS) for appearing of tool body fracture. The third reason is the cutting as such, i.e. metal removal whereas tool edge damage appears either as irreversible change in shape of tool wedge arising out of plastic deformation or as brittle fracture at tool wedge. Furthermore, cutting is accompanied with chipping at tool edge including thermal cracks at tool rake because of surface fatigue.

Tool material	K_{Ic} [$N.m^{3/2}$]	TRS [$N.mm^{-2}$]
Aluminum ceramics Al_2O_3	2,33	690
Ceramics Al_2O_3 + TiC	3,31	860
SiAlON	5,0	750
Cubic boron nitride	6,3	570
Polycrytaline diamond	3,7	1100
Sintered carbide	8 ÷ 10,8	1100 ÷ 2100
High speed steel	-	2800

Table 1 Fracture toughness K_{ic} and Transverse rupture strength TRS for common tool materials

Trent [2] pointed out that deformation of tool edge depends on combination of speed v_c and feed per rev f while the latter causes edge deformation when being greater than f = 0,4 mm. Weber [3] introduced so called safety factor $k_{pl} = 1,2 \div 3$, consisting of hardness of tool material, chip and cut surface. If $k_{pl} > 1$, no plastic deformation occurs whereas $k_{pl} < 1$ refers to mean temperature θ_m responding to thermal softening of tool edge. Tlusty [4] showed that maximum tensile stress from chip - tool contact is of the account brittle fracture to appear suddenly. In other words, maximum tensile stress inflicts tool damage in synergy with shear stress. According to Uehara [5] tool damage is activated by mean temperature θ_m. Thus, chipping at tool edge sustains an evidence of fatigue in tool material, a phenomenon that appears because of cyclic loading of tool edge. Microcracks activated by thermal effects are always perpendicular to tool edge while any thermal crack may come by length app 1 μm. Such crack, however, seems to be far smaller that that of classic fracture mechanics. According to [6], crack length is of consequence of quantities listed in Table 1 as:

$$\ell_{cr} = \frac{2}{\pi}\left(\frac{K_{Ic}}{TRS}\right)$$

and that means $\ell_{cr} \approx 50$ μm in case of sintered carbides.

Brief summary of chosen published results shows the mechanisms of chipping and fracture at tool edge are governed by chip tool contact and stress resulting from contact loading (principal stress as minimum/maximum as well as shear stress). The former depends on cutting conditions and the latter results from cutting force. Thus, experimental programme consists of combination of measurement (forces, chip – tool contact, chip ratio) and FEM modelling of stress distribution in the tool wedge. FEM models have been reviewed with outer appearance of fracture of tool edge when neck–down turning.

3. EXPERIMENTAL AND FEM MODELLING

Basic research has been carried out when neck-down turning mild steel 12050.1 (AISI 1045). Forces as tangential F_c and normal F_{cn} were measured using dynamometer Kistler 9265A1. Force response has been transmitted into μM4 BMC converter and PC. The NextView software was used and force response was filtered within 2 seconds signals. Chip – tool contact ℓ_c has been measured by Eschenbach 3351 microscope. Tool bar with diameter 200 mm has been cut by necking tool as "parting" operation , cutting speed was hold v_c = 100 m/min while feed per rev was used f ≥ 0,245 mm till chipping and tool edge fracture appear. Cutting tool STN 223731 HW P 20 (25x10x150 mm) with relief angle $\alpha_n = 8°$, zero rake $\gamma_n = 0$ and active edge length ℓ = 6 mm was used without coolants. FEM in Cosmos/M software was applied when modelling stress distribution in tool wedge while such factors as tool material properties, tool geometry, chip – tool contact and tool body design have been considered. Static features of forces were used for having simplified modelling procedure. Stress distributions are concerned with such speed per rev, which precedes any damage by chipping, tool edge deformation and brittle fracture [7].

4. RESULTS ON TOOL EDGE DAMAGE

Basic knowledge associated with damage of tool edge seems to be distribution of stress on tool rake. Zorev solution [8], often recounted in books and papers, is the most popular approach in modelling of stress distribution at tool rake as shown in Figure 2.

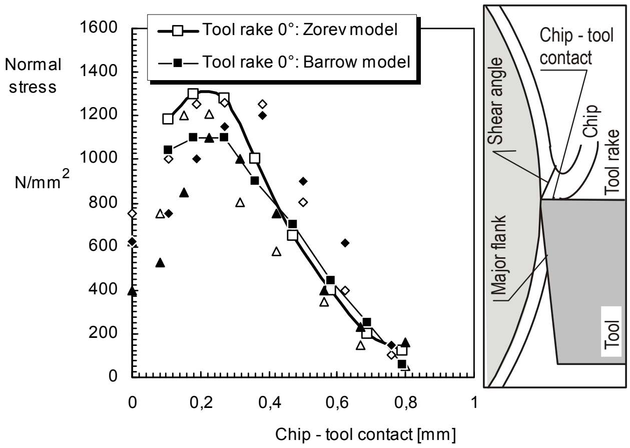

Fig. 2 Distribution of normal stress due to chip – tool contact: neck – down turning, feed per rev: f = 0, 245 mm, speed: v_c = 100 m/min, workpiece: steel 12050, without cooling

Another solution by Barrow [9] assumes uniform distribution of normal stress within sticking contact. Former and latter, however, give similar results of normal stress distribution as shown in Figure 2. One must note such distribution does not bring about any damage but foregone conclusion – namely, peak of any stress distribution must receive any maximum and then triggering any mechanism of tool body damage.

It is commonly known that sudden fracture at tool edge is the cause of dynamic change in cutting force progress. Cutting force increases for a moment and then decreases from its peak for having been lost real area of contact at tool rake. Then, tool edge failure must be looked for in the stresses that occur in tool wedge, i.e. principal and shear stress, as well.

According to the mechanics, principal stress is such component which acts at right angles to a surface occurring at a point at which the shearing stress is equal to zero. Such definition can be used in that case only while tool removes chip safely – i.e. without edge chipping and fracture damaging. Thus, stress distribution discussed below is associated with the safe operation when neck-down turning, i.e. feed per rev is not greater than f > 0,245 mm. Having been used force data and true chip – tool contact length, either producing stress distribution at tool rake, principal stress in tool wedge appears in two divergent form shown in Figure 3 and 4.

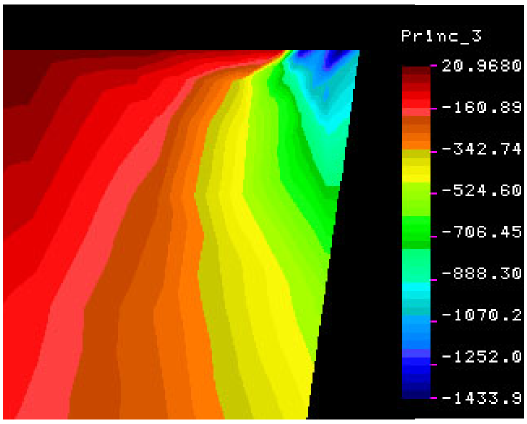

Fig. 3 Minimum principal stress based on tool loading by Zorev model - zero tool rake, data from Fig. 2

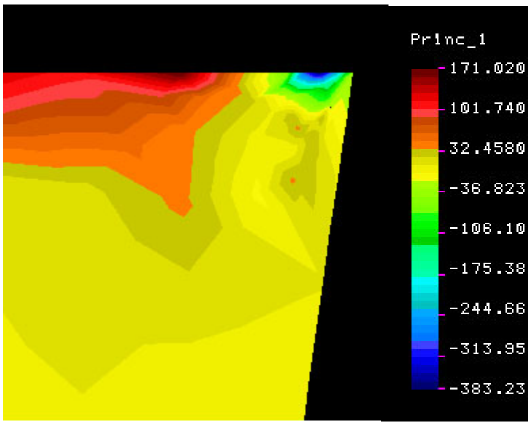

Fig. 4 Maximum principal stress based on tool loading by Zorev model : zero rake, data from Fig. 2

Minimum principal stress is localised within the sticking contact between chip and tool rake. It seems to be a factor that brings about the so called chipping phenomenon for load application between small part of either tool surface, i.e. tool rake and flank. According to the Figure 5, chipping is barely a phenomenon having any uniformity. Because of applied loading, tool edge does not loss its sharpness completely but gradually and that often maintains a part of original tool edge.

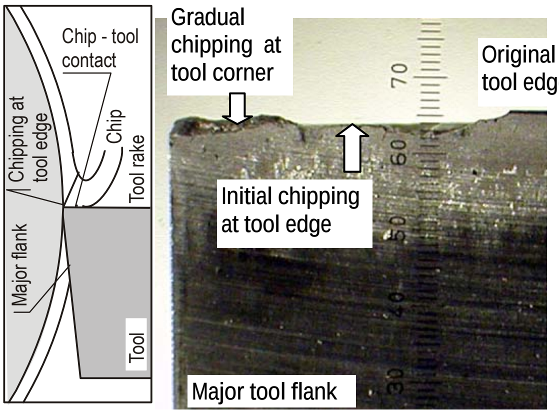

Fig. 5 Two types of tool edge damage by chipping – initial and gradual loses of major tool edge - variability of loss of tool edge sharpness: experimental data in text, feed f = 0,262 mm

Real tool performance loss rises from synergy of stresses applied in tool wedge for their amplifying due to feed per rev. If feed per rev is grater than f = 0,265 mm, principal stress is greater than that of Figure 4, data app 250 N/mm^2 may produce plastic deformation of minor tool edge. Because of machining by neck down turning, minor tool edge undergoes loading by shear stress. Having been modelled shear stress at the half of tool edge in Figure 6, a case valid for safely operation, one must note very interesting stress distribution at tool rake.

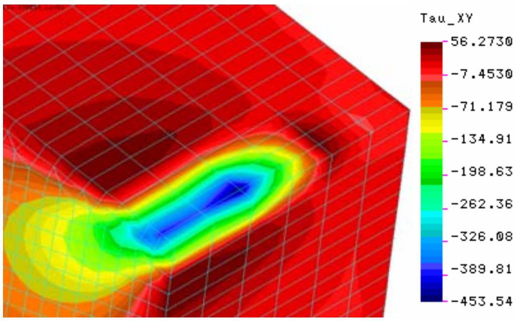

Fig. 6 Distribution of shear stress at tool rake based on loading of the half of tool edge

Firstly, minimum shear appears directly at chip – tool contact while location of shear stress is being equal app to –450 N/mm^2 and coincides with a location of maximum normal stress in Figure 2. If cutting conditions are associated with chipping, a consequence may be seen in Figure 5 and that is gradual chipping at tool corner. If feed is equal app f ≈ 0,28 mm and more, tool edge may wear progressively, however, tool corner as a location between major and minor tool edge undergoes quasi plastic deformation. Based on our observations, quasi plastic deformation prevails at minor tool edge for very poor heat transfer between tool and new surface. Evidence of such conclusion can be made from Figure 7 showing a rest of a chip joined tool relief by welding. But fracture a tool relief precedes such welding of chip rests for drawing off tool wedge toughness through heat accumulation.

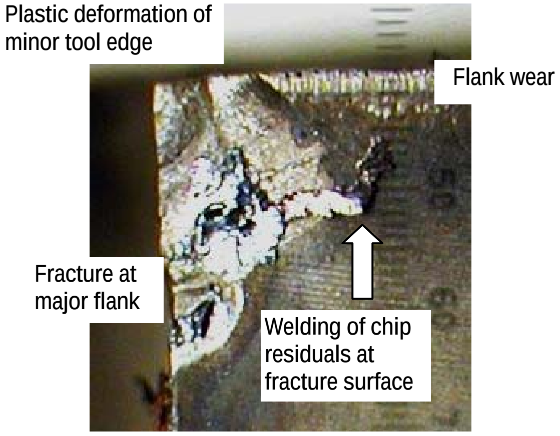

Fig. 7 Outer appearance of tool fracture accompanied with plastic deformation at minor tool edge, f = 0,28 mm

The last fracture appearance is shown in Figure 8 and it conveys fracture activated by thermal effect. Such type of tool damage can be derived from Figure 6, however, a bit in different manner. Maximum valued of shear stress are spread at tool rake in form of regular wave – like distribution as shown in Figure 6. If chipping at tool edge gains a shape of pits, which are usually greater than 20 ÷ 30 μm, cleavage fracture at tool rake seems to be as quasi planar removal of sintered carbide. Thus leaflet – like form of fracture is assumed due to variability of shear stress and chip – tool contact temperature, as well.

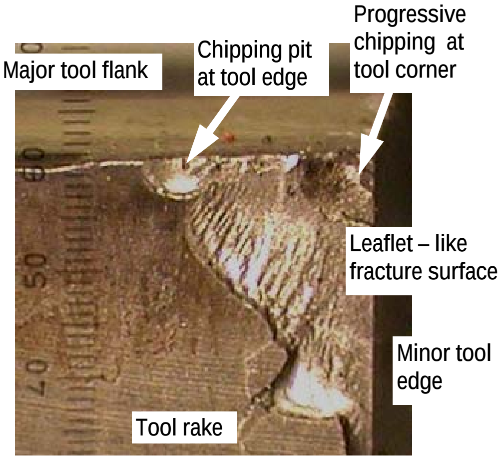

Fig. 8 Fracture surface at tool flank arising from chipping pits at tool edge, feed per rev f = 0,302 mm

5. CONCLUSION

Tool edge fracture is always an undesired phenomenon in any metal cutting operation. Proper knowledge on tool fracture criteria as well as elimination of initial stages of tool fracture prevent subsequent total deterioration of tool in whole.

Neck – down turning is an opposite of the orthogonal cutting, therefore, it seems to be most appropriate way in investigation of tool edge fracture phenomena. Not only does major tool edge undergo stress loading but also minor cutting edge is engaged in removal, too. Based on such experimental approach, initial and gradual chipping have been identified due to overrun of safe limit of feed. Plastic deformation between both tool edges was identified as a reason which brings about fracture at tool flank. Finally, distribution of shear stress and maximum principal stress lead to the synergy of chipping pits with fracture propagation and that means chiefly fracture surface at tool flank.

Tool fracture accompanies metal cutting practice in the long term, nature of tool edge damage remains of incomplete understanding. Though a simple operation of metal cutting and common sintered carbeide has been used, an attempt has been made in paper to classify and account for the basic outer appearances of tool fracture. Comprehensive studies of such phenomena, however, can contribute to the elimination of tool damage in other operations which apply advanced tool inserts and new tool materials, as well.

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ANALITICAL AND EXPERIMENTAL STUDY OF CUTTING FORCE COMPONENTS IN FACE MILLING

Received: 23 October 2010 / Accepted: 17 March 2011

Abstract: *This paper presents experimentally obtained cutting force components patterns for one revolution during face milling. Measurement of cutting force and results presentation are done by data acquisition system set by authors. The virtual instrument used for measuring the cutting force during face milling was set by use of graphical programming software. Results of experiments are presented in graphical forms and mathematical model for cutting forces components are determined. Influence of cutting speed, feed and depth of cut on the cutting force orthogonal components are analyzed.*

Key words: *Milling, Cutting forces, Data acquisition, Virtual instrumentation.*

1. INTRODUCTION

Cutting force and their moments have significant importance in engineering technology and general in the theory of material machining technology. They represent the basic categories of cutting mechanics.

It is commonly known that during the metal cutting process, the tool geometry changes as a result of tool wear and that these changes can have undesirable effects on process performance. The most significant variation from sharp tool operation is an increase in cutting forces, which can lead to variations in process stability, part accuracy and part surface finish.

Researches in the field of metal processing technology, chip removal, in most of his works, were focused on machinability of material. Machinability of material defining features of tool life, cutting forces, surface quality, cutting temperature and chip form. Knowing these features, as well as important technological characteristics of the material, it is important to both the classical and the design of technology for automated cutting process. In accordance with that is to create a database of machinability and optimization of cutting parameters.

The importance of knowledge of cutting force, as one of the most important machinability functions is large, which is why this issue is constantly attracted the attention of researchers in this field. Knowing the value of cutting force provides to: determine the energy balance of machine tools, perform the calculation and dimensioning kinematics elements of machine tools, perform the calculation and dimensioning of cutting tools and auxiliary equipment, perform optimization of machining processes (based on calculation of optimal values of the elements of the regime and equations whose description of the cutting force), adaptive control machining systems and others. Cutting forces in milling are intensively studied both analytically and experimentally [1]. In Figure 1 are shown the orthogonal cutting forces in face milling process.

Face milling process particularity like multi tooth that simultaneously cutting with difference in chip cross section of one tooth, influenced development of variety of models for cutting force calculation. Variation in chip cross section gives difference in intensity of cutting forces and thermal load of single tooth.

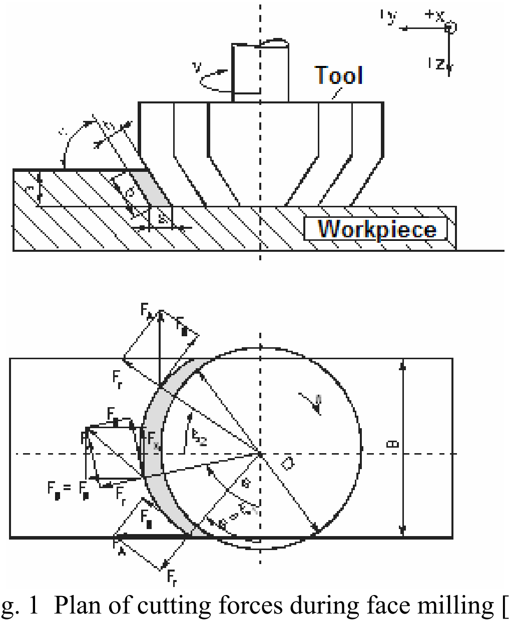

Fig. 1 Plan of cutting forces during face milling [2]

Force F_a changes in direction and intensity during a tooth cutting, so its components F_x and F_y are different intensity according the angle change from 0°÷180. The position $\varphi = \xi_1$ component $F_x = 0$, and the F_a has the feed motion direction, and $F_a = F_p$, where F_p is feed force. If the direction of F_a is perpendicular to the feed then $F_y = 0$ ($\varphi = \pi/2 + \xi_2$). If components F_x and F_y are known it can be calculated on the basis of their force F_a .

Two other components that may decompound the force F_a are the forces in tangential and radial direction. These are the main cutting force F_g and the (passive) penetration cutting force F_r.

If are considered two positions of milling teeth in cut, so the first position is for φ<π/2, in the second is for φ>π/2. The equations that connect these forces are:

Position I:

$$F_x = -F_g \cdot \sin\varphi + F_r \cdot \cos\varphi \qquad (1)$$

$$F_y = F_g \cdot \cos\varphi + F_r \cdot \sin\varphi \qquad (2)$$

$$F_z = F_a \qquad (3)$$

Solving the system of equations (1) (2) and (3) gives:

$$F_g = -F_x \cdot \sin\varphi + F_y \cdot \cos\varphi \qquad (4)$$

$$F_r = F_x \cdot \cos\varphi + F_y \cdot \sin\varphi \qquad (5)$$

$$F_a = F_z \qquad (6)$$

Feed force in the direction of feed motion F_p at any time is equal to the force F_y, respectively:

$$F_p = F_g \cdot \cos\varphi + F_r \cdot \sin\varphi = F_y \qquad (7)$$

Position II:

$$F_x = -F_g \cdot \cos\left(\varphi - \frac{\pi}{2}\right) - F_r \cdot \sin\left(\varphi - \frac{\pi}{2}\right) \qquad (8)$$

$$F_y = -F_g \cdot \sin\left(\varphi - \frac{\pi}{2}\right) + F_r \cdot \cos\left(\varphi - \frac{\pi}{2}\right) \qquad (9)$$

$$F_z = F_a \qquad (10)$$

Taking into account the addition formula:

$$\sin\left(\varphi - \frac{\pi}{2}\right) = \sin\varphi \cdot \cos\frac{\pi}{2} - \cos\varphi \cdot \sin\frac{\pi}{2} = -\cos\varphi \qquad (11)$$

$$\cos\left(\varphi - \frac{\pi}{2}\right) = \cos\varphi \cdot \cos\frac{\pi}{2} + \sin\varphi \cdot \sin\frac{\pi}{2} = \sin\varphi \qquad (12)$$

equations (8) (9) and (10) are reduced to equations (4) (5) and (6), whose solution has already been shown.

2. EXPERIMENTAL INVESTIGATION

In this work, using the developed system for monitoring, acquisition and measurement of cutting forces in milling process, by use of virtual instrumentation (VI) was performed measurements of milling forces. The aim of the task was to make the analysis of the influence of machining elements on the value of cutting force components. Calculation of the measured cutting force components; main cutting force, the force of penetration and force feed motion in time domain duration for a tool revolution will be made as well.

Additionally was performed a comparison of relationships between the main cutting force for two different steel (Č 1530 and Č 4732) at the same machining conditions.

3. ACQUISITION SYSTEM FOR THE FORCE DURING FACE MILLING

3.1. Characteristics of acquisition system

Measuring acquisition system must meet the following requirements [3, 4, and 5]:

- High efficiency and accuracy of results;
- Involvement of existing laboratory resources and their compatibility;
- Rational use of time and laboratory resources, with very little consumption of workpiece materials, cutting tools and time;
- To be suitable for serial testing in a large number of materials for the formation of computer databases on machinability material cutting;
- Good portability and compatibility;
- To enable the display of results and monitoring processes in real time;
- And finally, to enable the acquisition, storage and processing of data.

Figure 2 shows the measuring acquisition system scheme for the cutting force during face milling.

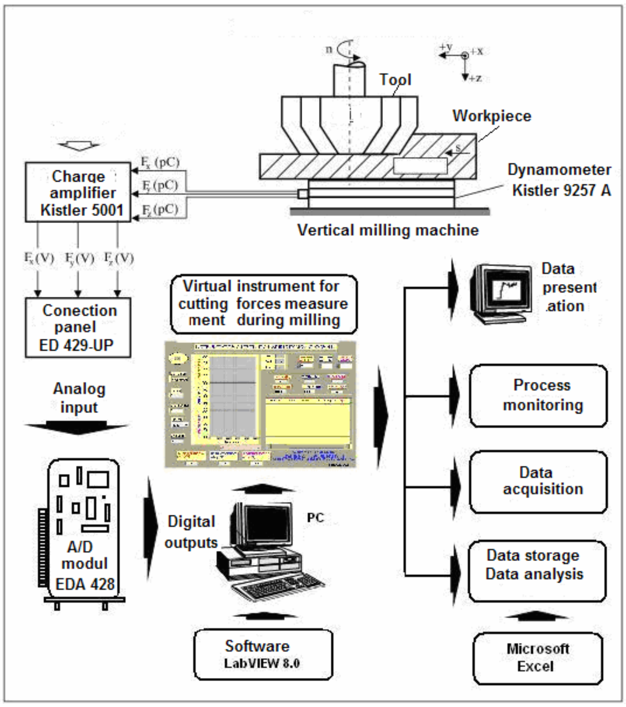

Fig. 2 Model for measuring acquisition system for measuring the cutting force in face milling [3]

From Figure 2 we can see that the system consists of the following components:

- Machine Tool (vertical milling machines - FAS-GVK-3)
- Tools (milling head with interchangeable cutting plates)
- Sensor measurement system (three component piezoelectric dynamometer - "Kistler"-9257A)
- amplifier measurement system (capacitate-amplifier "Kistler" - CA 500)
- Dial-up panel for connecting the module with the actual acquisition process (ED429-UP)
- Acquisition Module - A / D converter - ED428
- Computer System

- Program (software) support system
- VI for acquisition, display in real time, storing and processing data

3.2. Virtual instrument

Virtual instrument (VI) used for measuring the force in face milling was developed using graphical programming software Lab VIEW 8.0. VI is designed to allow easy reading voltage with dynamometer, which correspond to the forces of cutting during face milling F_x, F_y and F_z, view, change the values in the form of diagrams and tables, and display the maximal values of in a single measurement.

VI contains of three components:

- The front panel (front panel) - serves as a graphical user interface
- Block diagram (block diagram) - contains graphic VI source code, which defines its functionality.
- Connector and icon (icon and connector panel) - identifies the VI so that it can be used in another VI. VI in another VI is called SubVI and corresponds to subroutine in text-oriented programming languages.

4. ANALIZE AND DISCUSION

Using the system shown (Fig. 2) measurements were performed and acquisitions orthogonal cutting force components during milling.

During the experimental study measured were the orthogonal cutting forces F_x, F_y, F_z, and based on them were obtained through the computational processing components F_g, F_r, F_p and F_a according equations (1) to (10). Figure 3 shows the change of cutting force during face milling with milling cutter diameter D = 125 [mm], and with one tooth (insert of hard metal) [6]. Experimental testing was provided with new and worn cutting insert. Workpiece material was a steel Č1530 and Č 4732. The graph on Fig 3 presents the cutting forces measurements versus tooth position for the following cutting regimes: v=177 [m/min] a=1,5 [mm], s_z=0,223 [mm/t].

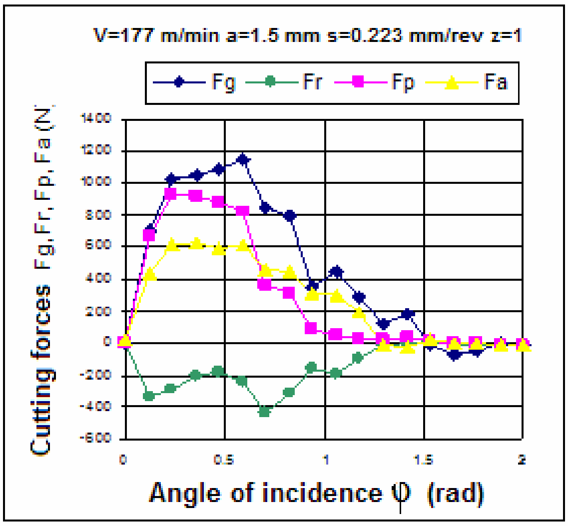

Fig. 3 Change cutting forces components versus the position angle for new cutting tool

In the second experiment (Figure 4.) machining is performed with the same cutting regime and the same workpiece material, but this time was used worn cutting insert. Flank wear land was 0.4 [mm], but there was concentrated tool wear at the corner of the insert tip with the maximal amount of 2 [mm].

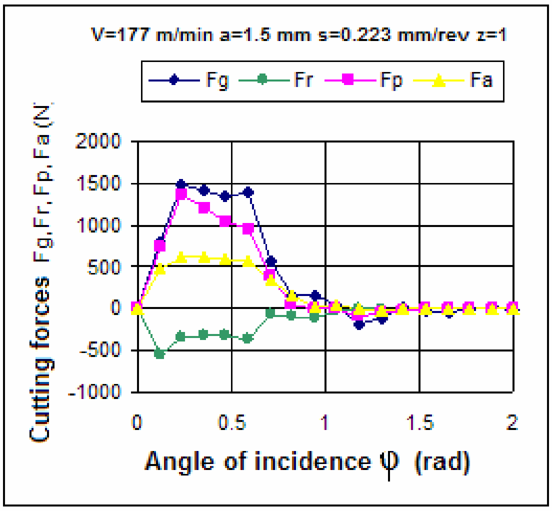

Fig. 4 Change cutting forces components versus the position angle for the worn cutting tool

Analyze of diagrams in Figure 3 and 4, shows that the machining with worn cutting insert increases the value of cutting force in relation to the case when the cutting was done with new insert.

In further processing of results was examined dependence on changes in the orthogonal cutting force constant depth a = 1 [mm] and the cutting speed v = 2.32 [m/s], and different feed s_z in interval of (0,178 [mm/t], 0,223 [mm/t], 0,280 [mm/z]) (Figure 5). Also was varied depth, with constant cutting speed and feed (Figure 6). In this case the value of cutting depth a_1=1[mm], a_2=1,5 [mm] and a_3=2,25[mm]. The value of cutting speed for this case was constant v = 2,32 [m/s], and feed s_z=0,178 [mm/t].

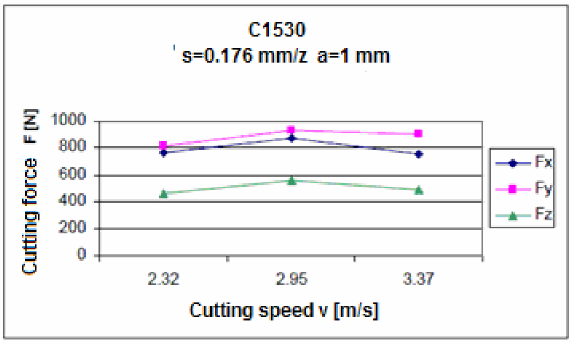

Fig. 5 Change orthogonal cutting force for constant cutting depth and feed, and different speeds with worn cutting tool

The analysis of the diagram in Figure 6, shows that with increasing values of feed and depth of cut the cutting force increase. Change of cutting speed has no great influence on the change of cutting force The largest increase in cutting force is according the variation of depth of cut (Figure 7).

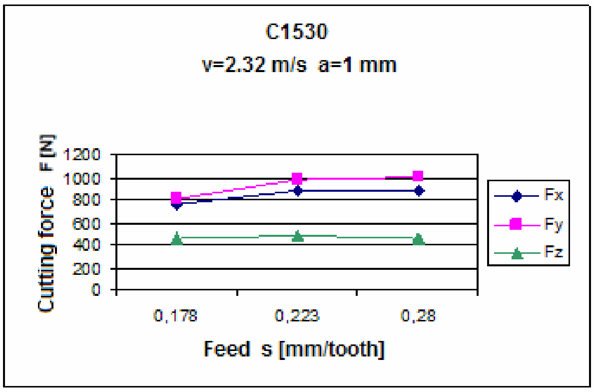

Fig. 6 Change of orthogonal cutting force components for constant cutting depth and cutting speed, and different feeds with worn cutting tool

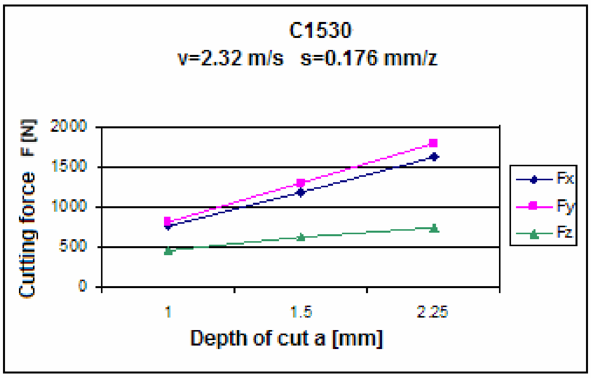

Fig. 7 Change of orthogonal cutting force components for constant cutting speed and feed and for different depths of cut with worn cutting tool

At the end analyzed were relationships for the major cutting force for Č 1530 and Č 4732 for the same machining conditions (Fig. 8)

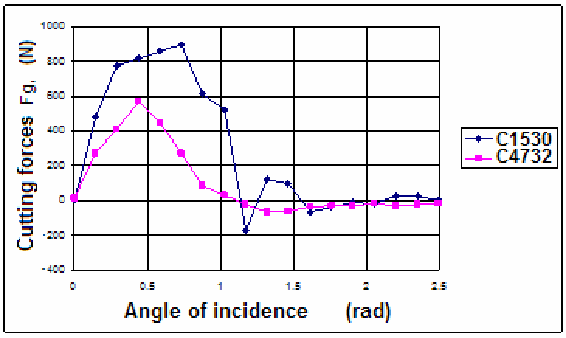

Fig. 8 Cutting forces for different machined materials (Č 1530 and Č 4732) and same cutting conditions

From Figure 8 can be seen that the steels with lower sulfur content (Č 1530) is difficult to machining (more major powers) versus the steel with higher sulfur content (Č 4732). This can be explained by the fact that the increased content of sulfur allows the creation of a larger number of MnS particles, which can easier plastically deform during the cutting process, unlike the tiles in perlite cementite that break. The presence of MnS particles reduces the length of contact on the rake face of tools. Shorter length of contact with cutting tool results in thinner chips and smaller cutting force components [1].

5. CONCLUSION

Investigation of cutting forces is a key part in the development of cutting technology itself. They are one of the main criteria for evaluating machinability of material and as such attract the attention of many researchers in this field. Exact knowledge of the characteristics and values of cutting force in the face milling is needed to study the dynamics of cutting process in interaction with the dynamics behavior of the machine tools structure.

According suggested equations determined were the main cutting force F_g and the (passive) penetration cutting force F_r versus tooth position for a revolution.

The experimental results analyze shows influence of cutting regime on cutting force .

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Original Scientific Paper

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VARIABLE CLAMPING FORCE CONTROL FOR AN INTELIGENT FIXTURING

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Abstract: *An Intelligent Fixturing System (IFS) is currently being developed to hold a family of thin-walled workpieces for machining operations. This is a cost-effective system which uses off-line optimisation of the clamps location and on-line adjustment of clamping forces. As adaptive clamping forces appropriate to the dynamic machining environment are employed, the IFS offers higher quality of machined parts and greater robustness to disturbances. This system incorporates a fixturing system, fixture stability model, force monitoring module, clamping force optimization algorithm and clamping control system. Using off-line simulations and on-line experimental tests, the performance of the proposed IFS is evaluated and verified.*

Key words: *intelligent fixturing, clamping control, stability*

1. INTRODUCTION

Flexible fixturing has a strong potential to reduce capital-investment costs by as much as 30% per machining system [1]. In standard production the classical fixtures are controlled and monitored by operators. In Intelligent Fixturing System (IFS), fixtures must work automatically, without operator intervention and cooperate with other devices of production system. The main elements of the IFS include a vision system, a universal clamping system, a part location system, and a micropositioner that positions the fixture so that the workpiece is precisely aligned with the machine tool's axes. The process begins when a part is loaded on a pallet and moves to a vision station. The vision station identifies the part and communicates part details to the appropriate stations that will be required to process it. A manipulator removes the part from the vision station and inserts it in a flexible workholding fixture. No effort is made to precisely locate the part in the fixture. After the part is secured, the entire fixture is transported to a station that locates the spatial position of the part. Accordingly, the part location data is communicated to a device called a Part Micropositioner, which adjusts the fixture to bring the part into the desired position [2]. Finally, the adjusted fixture is transferred via conveyor to a machining cell.

Intelligent clamping fixtures besides the base functions provide also some “intelligent” functions: control of clamping forces/torques acting on workpiece, monitoring of clamping operations and elements of fixtures [1], readjustment of locators and change of clamping elements [3]. The aim of force control is to decrease the workpiece deformation and workpiece surface damage. Typically, once a workpiece is being fixed in the fixturing system, the clamping forces applied to the workpiece are not changed during the entire machining. The application of clamping forces has been largely experience-based. Improper or inadequate fixturing process could result in elastic/plastic deformation, and static/elastic displacement that can significantly affect the final part accuracy. On the other hand, insufficient clamping may permit the part to slip or detach from the locator during the machining process, causing the fixturing system to lose its effectiveness. Especially in cases of machining of thin-walled and large-size aerospace components and other precision components, deformation and distortion can be minimised by optimising the location and magnitude of clamping forces. At some positions along the tool path, small forces may be adequate, but large forces may be required at others. Hence, our attention is focused on the force distribution. In an ideal intelligent fixturing system, both the location and magnitude of clamping forces have to be controlled in real time depending upon the geometry of the workpiece and cutting forces. The major disadvantages of an intelligent fixturing system where both location and magnitude of clamping force are controllable are very high cost and limited accessibility to the workpiece [4]. Another more cost-effective approach is to use off-line optimisation of the location of the clamps and on-line optimisation of clamping force magnitude. An ttempt was made to design an Intelligent Fixturing System (IFS) such that the fixture elements can be manipulated to provide dynamic clamping forces during the entire machining and fixturing process. For the proposed IFS in this paper, the clamping forces are adaptively adjusted to optimal values according to the cutter position and the cutting forces during machining with the objective of minimizing workpiece distortion while ensuring that it is adequately secured. In proposed system, a machine tool equipped with a CNC controller is considered. Three components of cutting forces in end-milling are calculated using the force prediction model developed by [5]. The clamping force optimisation algorithm calculates the optimal values of clamping forces considering the cutter location, the three cutting force components and the results of fixture stability model. These values are provided for a hydraulic clamping system. The values of clamping force thus calculated are reference values for the force control loop. To develop the efficient optimization control algorithm is essential to realize the real-time control of this intelligent fixturing system. The optimization algorithms were reported since 1980s [6]. However, these models are to complex and computationally lengthy; hence, are not suitable for real time control. In this paper, an effective algorithm and approach have been established for the on-line control of an intelligent fixturing system.

The proposed IFS is characterized by on-line monitoring, dynamic clamping forces, and real-time fixturing process control. At the conceptual design stage, electro-pneumatic, electro-hydraulic and electro-mechanical clamping devices have been compared in terms of force range, response time, working environment, size and cost. Finally electro-hydraulic controlled clamping elements are selected.

2. CLOSED-LOOP IFS

Based upon the above-mentioned facts, an intelligent fixturing system is developed (Figure 1). It adjusts the clamping forces adaptively as the position and the magnitude of the cutting forces vary during machining to achieve the minimum deformation of the workpiece. Proposed system is able to perform the following operations: monitor the clamping forces, monitor the machining forces and adjust the clamping forces according to the change in geometry of the workpiece. All the above operations have been designed into the presented fixturing system. To ensure that the controller has a sufficiently short response time, the models should be as simple as possible, and yet effective. Adjustment of the clamping forces during machining requires the control system to be responsive to the change in workpiece dimensions. This can be achieved by using a closed loop control using the parameter identification of adaptive control theory. The application of adaptive control theory in this research led to an intelligent clamping system. The framework of the system is shown in Figure 1. The structure consists of the modular fixturing system, fixturing stability model, clamping optimization algorithm, clamping control system, force monitoring module and communications with CNC machine tool.

At the beginning of the machining, reaction forces are measured through the sensors embedded in locators. This is a cylindrical locator assembly with built-in ring type force sensor (Kistler). The data are sent via force monitoring module to the fixture stability model.

The fixture stability model is used to monitor the fixturing stability during the entire machining operation. It is based on static equilibrium analysis. The model is aimed at analysing the configuration of the fixture, confirming or rejecting it, if all the set condition is not fulfilled. A stable fixturing system must hold a workpiece firmly in place during machining. Once instability appears, the module sends a command to the hydraulic system to increase the corresponding clamping force. This process is repeated until the completion of the machining process. Positive reaction forces at the locators ensure that the workpiece maintains contact with all the locators from the beginning of the cut to the end. A negative reaction force at the locator indicates that the workpiece is no longer in contact with the corresponding locators and the fixturing system is considered unstable. This stability criterion has been used by many other researchers [7,8]. The three components of cutting forces in end-milling are predicted using the cutting force model developed by [6]. Many cutting force models have been developed in the past for milling, drilling and other machining processes [9]. In the intelligent fixture system, cutting forces are predicted according to neural network model [6]. Neural networks simplify the determination of the cutting forces. The clamping force optimisation algorithm determines the optimal clamping force values considering the cutter location, the three cutting force components and results of the fixture stability model.

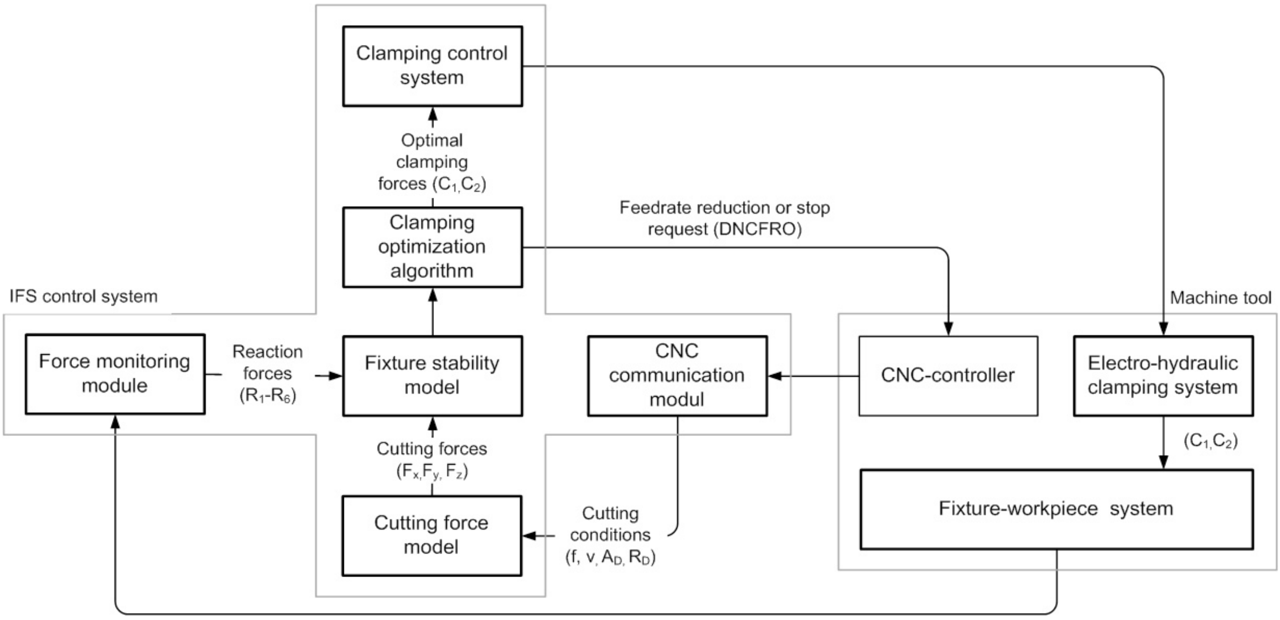

Fig. 1 Model based control scheme of closed-loop IFS

The clamping forces should ideally be just sufficient to constrain and locate the workpiece without causing damage to the workpiece. If the clamping forces are too large, the machined workpiece may warp when released from the fixture. The objective of the optimization algorithm is to minimize all the controllable and reaction forces. This is expressed as the minimization of the sum of the squares of the clamping and reaction forces. Based on the force analysis and rigidity and stability constraints, the algorithm determines the optimal clamping force for every cutter position. The used algorithm [10] is useful for designing fixtures since it can routinely determine the optimum sizes, direction and application points of clamping and reaction forces for different cases of clamping. The predicted optimal clamping forces are then applied in real-time using an electro-hydraulic clamping system. This system is designed to vary clamping forces on the workpiece during the machining process. Soft PLC controls a hydraulic system to apply the required clamping forces as the cutter moves to different locations on the workpiece. The clamping forces are proportional to pressure in hydraulic cylinder. This means, that the clamping forces can be monitored by pressure monitoring in cylinder.

2.1 Integration of the IFS with the machine tool

The machine tool can send commands to the fixturing system, and the fixturing system can send requests and information to the machine tool for certain tasks, such as stopping the machining process, decreasing feedrate. Data communication is achieved through the DNC2 interface (Fagor). The fixturing system communicates with the machining centre and adjusts its clamping accordingly. At the beginning of the machining process, the workpiece is clamped with an optimal clamping force. Once the machining process begins, the fixturing system monitors the clamping forces. Once the forces exceed predetermined thresholds, a feedrate reduction request or stop request is sent to the machine tool from the fixturing system.

3. EXPERIMENTAL SET-UP

To demonstrate the effectiveness of the proposed Intelligent Fixturing System, machining experiments are carried out on a thin-wall workpiece. The control scheme and set-up of the proposed fixturing system is shown on Figure 2.

On a Heller Bea 02 machine tool with Fagor CNC controller it is necessary to make the slot shown in Figure 2. Tool path if marked with arrow from point 1 to point 2). The milling cutter of 16 mm diameter with two cutting inserts (R-216-16 03 M-M) with the following cutting conditions: cutting speed (v=30m/min), feedrate (f_z=0.02mm/tooth), cutting depth (a=2.7 mm) is used for the experiment. The workpiece material is the steel Ck-45. The components of the cutting forces (X, Y, and Z directions) with cutting parameters defined above are calculated on the basis of reaction forces (R1 to R6) measured from the sensors. Piezoelectric sensors are built into six locators to measure reaction forces during machining.

4. RESULTS

The measured reaction forces are shown in Figure 3. It can be seen that the reaction force R1 at some tool position is almost zero, which means that the workpiece in not in equilibrium. This indicates that the fixturing system is not stable under this set of constant clamping forces (C1=300N C2=250N). The clamping forces must be increased until all the reaction forces become positive. Two hydraulic clamping cylinders are employed to clamp the prismatic workpiece. The fluid pressure in each hydraulic cylinder is measured by a pressure gauge.

The optimal clamping forces are shown in Figure 4. The corresponding positive reaction forces are given in Figure 5 that shows the workpiece will not detach from the six locators.

The results show that the clamping forces can be very small by applying varied clamping forces during machining in comparison with fixed clamping scheme. Tests with the prototype show that the fastest response time which can be achieved equals to 200 msec for a force step of 10 N.

The designed and tested system can deliver a maximum of 2500 N clamping force. A force resolution of +- 1 N has been achieved.

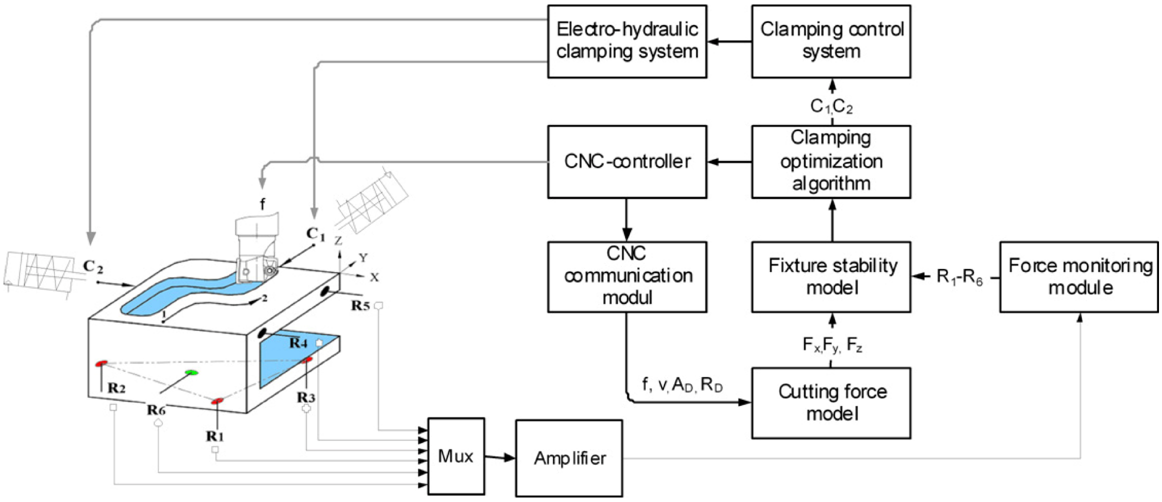

Fig. 2 Architecture of closed-loop IFS

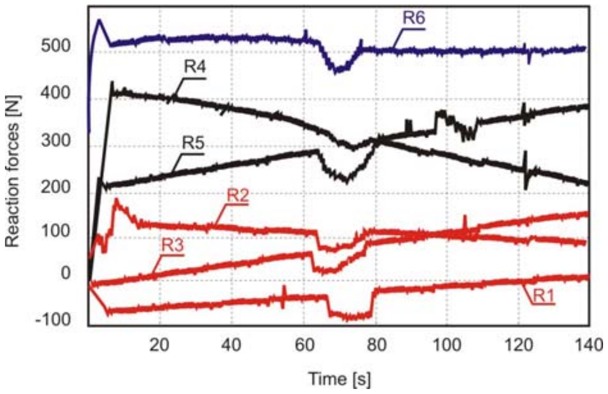

Fig. 3 Measured reaction forces on locators

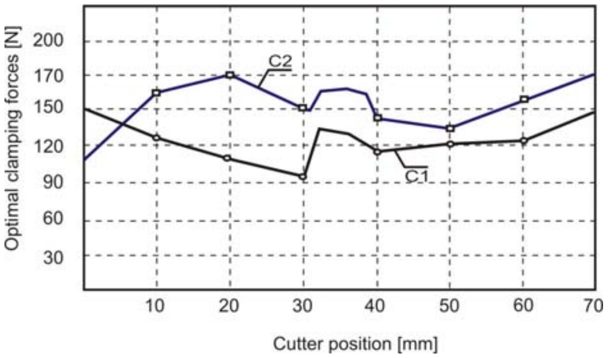

Fig. 4 On-line determined optimal clamping forces

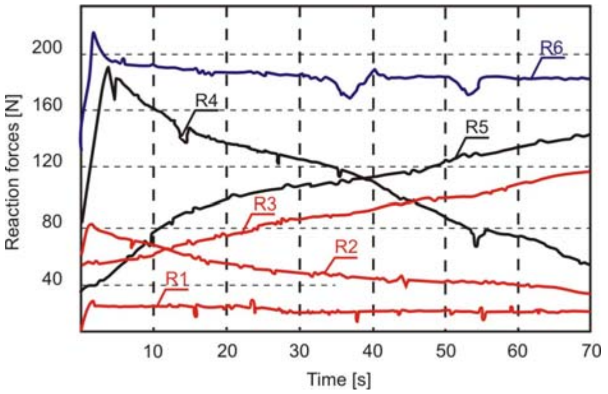

Fig. 5 Reaction forces corresponding with the optimal clamping forces

This error can easily be improved. It is determined by the resolution of the A/D conversion of the force signal, the noise in the force feedback (not filtered) and backlash movements of the actuator.

5. CONCLUSION

This paper presents the development of an intelligent fixturing system. Variable clamping force control is implemented in the IFS.

The main task of IFS is to adaptively adjust the clamping forces to achieve minimum deformation of the workpiece according to the cutter position and the cutting forces.The developed system is a solution for force controlled clamping with large force range, good resolution and fast response. The accuracy of the workpiece is improved due to adaptive control of clamping forces and the robustness of the systems to disturbances is also greater. The approach also uses an optimization algorithm to determine optimal clamping forces based on the static equilibrium analysis of the fixture system.

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Original Scientific Paper

Deticek, E., Zuperl, U.

POSITION CONTROL OF HYDRAULIC DRIVES IN MACHINE TOOLS BY FUZZY SELF-LEARNING CONTROLLER

Received: 18 March 2009 / Accepted: 15 September 2009

Abstract: *Fluid power actuators are characterized by their high-power density and excellent dynamic response. They are ideally suited to many high dynamic applications in modern machine tools. However, the disadvantages of hydraulic systems such as nonlinear dynamic behaviour due to friction, fluid compressibility need to be overcome. This is successfully obtainable only by implementation of modern digital control systems designed on the basis of modern control theory. The proposed new control strategy uses a combination of a fuzzy logic controller designed as a self-learning fuzzy system and conventional control approaches.*

Key words: *machine tools, fuzzy control, position, hydraulic drive.*

1. INTRODUCTION

In modern mechanical systems such as computer controlled machine tools, metal-forming machines, and injection moulding plastic machines, assembly and transport devices, material testing devices, etc., the demand of rapid speed operating movements to increase productivity comes to the foreground. To obtain this rapid movement, hydraulic drives controlled by resistance in impressed pressure network very often are used. Besides the excellent dynamics, the main advantage of such systems is the parallel use of multiple drives fed by one pressure net combined with energy recycling into the hydraulic accumulators. In particular, the hydraulic cylinders should be stressed at this point due to their ability of direct transformation of hydraulic energy into linear movements and forces. It is quite normal nowadays for cylinders to be equipped with electronically controlled proportional and servo-valves, as well as with position transducers and force sensors, creating together closed control loops. To fullfil another demand of the above mentioned machines, namely the accurate and precise position and force control, appropriate control strategies are needed. This paper presents a new hybrid-fuzzy control strategy for position control of electro-hydraulic linear drive. An adaptability is obtained by fuzzy logic controller designed as a self-learning system [1], while the reference tracking and position accuracy are improved by conventional control measures such as an inverse model fore-filter and switching integrator. The algorithm is experimentally investigated and implemented on the hydraulic device [2] for testing mechanical constructions-load simulator.

2. MATHEMATICAL DESCRIPTION OF ELECTRO-HYDRAULIC LINEAR DRIVE DYNAMICS

The electro-hydraulic linear drive under consideration is depicted in Figure 1. It consists of a double-road hydraulic cylinder with load mass and the electro-hydraulic servo-valve.

Without of detailed explanation of well known differential equations and by using linearization in particular operating point as well as Laplace

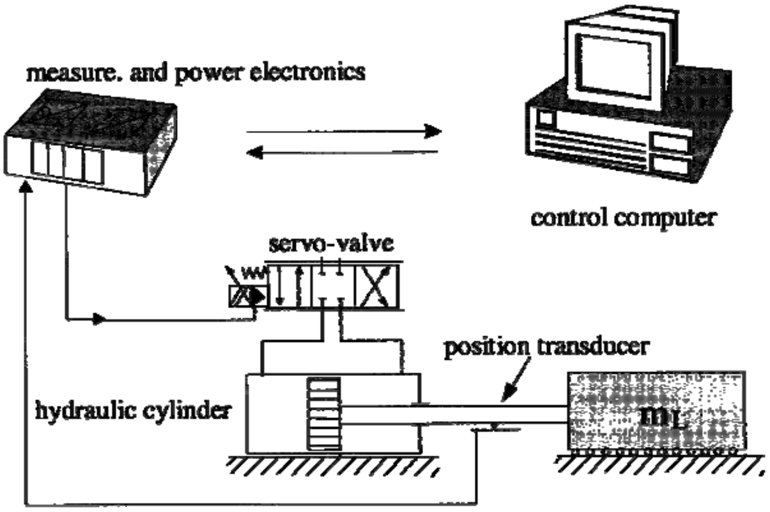

Fig. 1 Electro-hydraulic testing device of machine tool

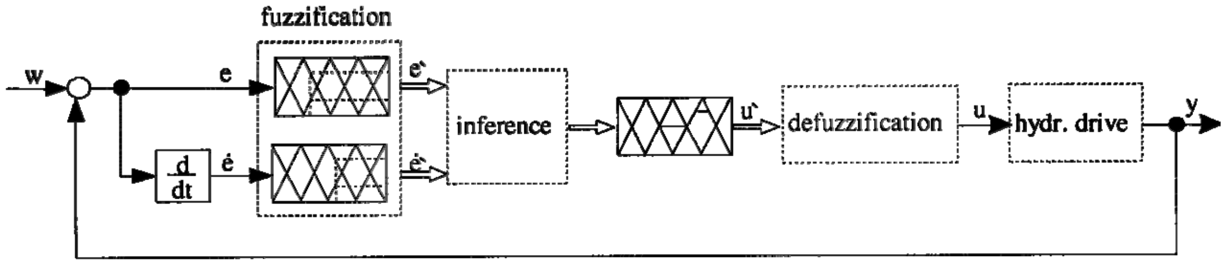

Fig. 2 Structure of fuzzy PD- controller

transformation the following transfer function can be obtained:

$$G(s) = \frac{Vs_{op}\omega^2{}_{op}}{s(s^2 + 2D_{op}\omega_{op}s + \omega_{op}^2)} \qquad (1)$$

3. FUZZY PD-CONTROLLER FOR POSITION CONTROL OF ELECTRO-HYDRAULIC LINEAR DRIVE COMPONENT

The starting point for development of more intelligent fuzzy controller (self-learning system) was, in the first step, the design of a fuzzy controller similar to the conventional PD-type controller. However, the clear goal of designing a fuzzy controller for position control of electro-hydraulic linear drive was not only to make an equivalent of a known controller, but to design a controller to be able to cope with nonlinearities and parameter changes of the hydraulic system in order to achieve fast responses without overshooting and small steady state errors. However, the first step was in the direction of fuzzy realization of a PD-controller. Namely, coming out from engineering experience with classical controllers is for position control of hydraulic drives only P or PD-type appropriate. This is due to stability reasons. In addition, the differential part of the controller, if it is used, must be set very carefully to prevent noise sensibility. The fuzzy PD-controller in this case is a fuzzy system with two input variables and one output variable. These variables are the control error e, the error derivative e. , and the servo-valve input voltage u, respectively. The rules that connect the variables are collected together into the rule base. The fuzzy controller structure is shown in Figure 2. All three variables are treated as linguistic variables and described with 13 linguistic terms. These terms are denoted with abbreviations: NVB (-6) -negative very big, NB (-5) -negative big, NQB (-4) –negative quite big, NM (-3) -negative medium, NS (-2) -negative small, NVS (-1)-negative very small, ZO (0) zero, PVS (1) -positive very small, PS (2)-positive small, PM (3) -positive medium, PQB (4) -positive quite big, PB (5) -positive big, PVB (6) -positive very big. The integers in brackets are used for numerical computation. Each linguistic term is represented by the fuzzy set with triangular membership function. This means that the variables *e*, *_e*, and *u*, interpreted now as fuzzy variables, are described with 13 mutually overlapping fuzzy sets, which cover the whole real range of the variables. The ranges or universes of discourse are scaled into the interval [1, ¡1], using scaling factors *Ke K_e*, and *Ku*, respectively . As a defuzzifcation strategy the center of area has been used [1, 3]. The rules have been selected using engineering judgment and experiences. For example, one of the possible rules has the form: *IFe ˆPS AND _e ˆNB THEN uˆNQB*. It can be explained as follows: if the error signal is small, the drive is near the desired position where it should be stopped. Simultaneously, the error derivative, which is negative big, shows that the drive approaches the desired position very fast. The conclusion is that the output of the controller (servo-valve input voltage) has to be significantly negative to produce a breaking effect and to prevent overshooting [4]. The necessary rules, in such a way derived, to replace linguistic terms due to the algorithm realization.

4. A FUZZY SELF-LEARNING POSITION CONTROL

The theory of fuzzy control seems to be a suitable tool for both modeling and control of complex,

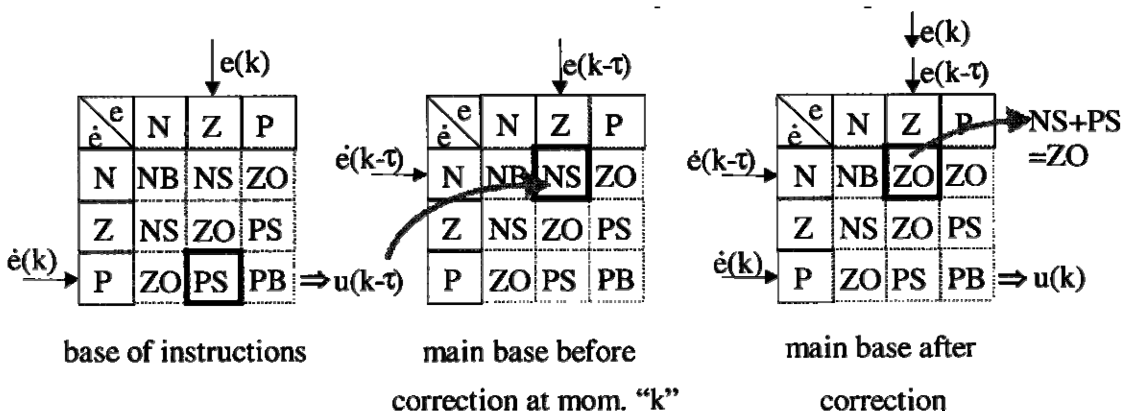

Fig. 3 Self-learning and self-organizing mechanism.

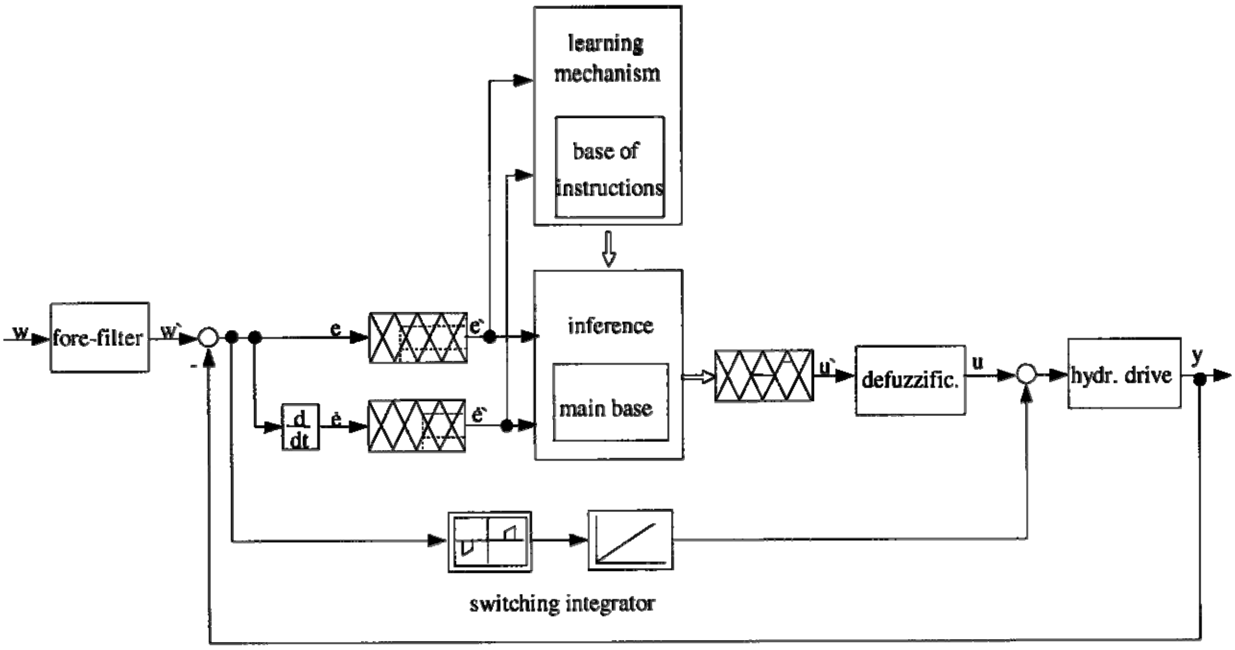

Fig. 4 The structure of hybrid fuzzy controller.

nonlinear systems. However, the primitive form of fuzzy control sometimes fails in dealing with these complex systems, mainly because it lacks enough adaptability. Several researchers have been devoted to developing fuzzy controller with more intelligence [5, 6, 7]. Unfortunately, most of them are difficult for real-time implementation. As pointed out earlier, the sampling intervals of few milliseconds are usual in digital control of drive applications.

This limitation must be taken into account in the case of designing a fuzzy controller, too.

The controller represented in this article (Figure 4) is not an adaptive system in the classical sense, but is a self-learning fuzzy system based on a so-called reinforcement learning procedure [4]. It tries to emulate human decision-making behavior, namely, the ability to create the rules and modify them according to experiences.

The system has the hierarchical structure of two rule bases. The first one is the general rule base of the fuzzy controller, as shown in the previous section.

The second one performance matrix) is constructed by ``meta''-rules and exhibits an ability to create and modify the main rule base according to desired overall performance of the system. In other words, the rules are modified on the way, in that they force the controlled drive in achieving the control errors as small as possible.

The procedure first checks the quality of control action by the comparison of present values of **e** and **e**˙ with expected values from the performance matrix. Simultaneously, the linguistic terms in the performance matrix show how the rules in the main rule base must be changed.

The question is which rule must be changed, if one knows that the present **e** and _**e**˙ mainly caused by a past control action.

The solution is determination of the time constant t, which shows that the state of the controlled drive at the *n*th discrete moment in the present, is mainly the consequence of the control action activated at the (*n*-t)th discrete moment in the past.

The determination of the t could be done on the basis of heuristic knowledge of the dynamic behavior of the controlled process.

The self-learning controller must, therefore, contain a memory buffer to save past information's, as well as a mechanism for changing rules. Through this mechanism, the creation of new rules is also possible, if they do not exist yet. So the controller possesses an ability for self-organization too.

Suppose the above learning process is convergent, then the main rule base becomes constant after a certain number of experiments, or in a certain amount of time that the controlled drive is in operation.

The main rule base stays constant as long as the system dynamic does not change.

If the variations of system parameters become significant, a new adaptation is necessary. The mechanisms of self-learning and self-organizing are explained comprehensively in Figure 3.

For the sake of simplicity, the control variables are described with three linguistic terms only.

5. EXPERIMENTAL RESULTS

The research equipment and electro-hydraulic linear drive under investigation are presented in Figure 1.

The testing device consists of the following main parts [8, 9, 10]: hydraulic cylinder (40/28 mm, h=200 mm), load mass (m=70-300 kg), servo-valve (MOOG-D-769-233) , incremental position transducer (ISKRA TGM 111-08-resolution 0.005 mm), and control computer (GESPAC-8420, CPU-68020, A/D, and D/A-16-bit). The experimental results, shown in Figure 5, prove that the self-learning controller enables a successful control of electro-hydraulic drive without any a priori knowledge of the system dynamic, not only

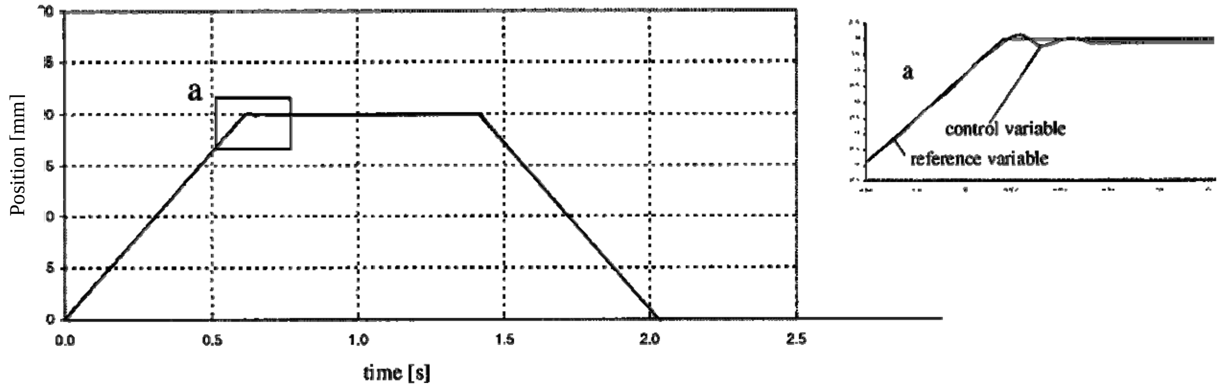

Fig. 5 Time response of electro-hydraulic drive controlled by hybrid fuzzy controller

during the operation, but also in the first start conditions [11]. It is also able to cope with nonlinearities and parameter changes, so it possesses a certain level of adaptability as well.

However, it is very difficult to predict the convergence of the learning process and, therefore, to predict the stability of the whole system in the design phase [12, 13, 14].

6. CONCLUSION

In this article are represented some results of investigations of possibilities to apply the fuzzy logic for control electro-hydraulic drive. Besides the PD-type fuzzy controller with constant rule base, self-learning fuzzy algorithm has also been developed.

The latter represents an attempt to introduce more intelligence into the hydraulic drive position control system.

The quality of control is improved by conventional control measures such as digital fore-filter and switching integrator, creating together a hybrid-fuzzy control structure. The essential advantage of a hybrid-fuzzy control structure lies in the fact that there is no need for presetting initial parameters. Furthermore there is no need for any previous knowledge about the operating regime and geometric parameters of the hydraulic drive. Although there are some very promising experimental results, it is early to exclaim the usefulness for industrial practice. This is because of the many degrees of freedom in designing a fuzzy system. The difficulties also occur in the prediction of a self-learning process convergence and overall stability of the system.

More attention will be paid to solving this problem in the future.

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Original Scientific Paper

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MACROSCOPIC MODELLING AND FEA OF TENSILE DEFORMED TWO-PHASE METAL-MATRIX MATERIALS

Received: 01 March 2010 / Accepted: 15 January 2011

Abstract: *Microscopic phenomena of the tensile deformation of the multi-phase metal-matrix materials, and of the matrix material flow in situ are very difficult to be traced.*

The solution of that problem is presented by macroscopic models enlarged for few orders of magnitude in comparison to the microstructure of real engineering materials. These models are suitable for the experimental as for the finite element analysis.

The mechanical properties of single model components are relatively very well comparable to those of the true multi-phase metal-matrix materials.

Key words: *multi-phase metal-matrix material, tensile deformation, modelling, testing*

1. INTRODUCTION

Important progress has been made in recent years in the scientific field of micro and macromechanical modelling of elastic and plastic deformation of multi-phase materials [1-3].

Phenomena of deformation and destruction of multi-phase metal-matrix materials are two of the most interesting problems in the scientific field of material science [4,5]. These two problems are very important because of the mechanical and applicable properties of the two-phase metal - matrix materials, such as their behaviour among the processes and treatments with different types of the mechanical engineering technologies [6]. With the tools of material science and physical metallurgy it is impossible to detect the processes in material on the macroscopic level [7]. That was the main reason that we tried to describe the processes in multi-phase metal - matrix materials among the plastic deformation due to the tensile loading with macroscopic models, destructive and non-destructive material testing methods, and numerical modelling (Fig. 1).

The constituents which presented metal matrix and secondary-phase particles (inclusions) are enlarged for few orders of magnitude in comparison to the real multi-phase metal-matrix materials. With the adequately combination of materials, geometries and arrangement of the constituents in the model, with corresponding non-destructive testing methods which enable observation of the model after the separate stages of deformation, with microhardness measurements, and the finite element analysis (FEA), the picture about sequences of the process at the tensile loading of multi-phase metal-matrix materials has been obtained [8].

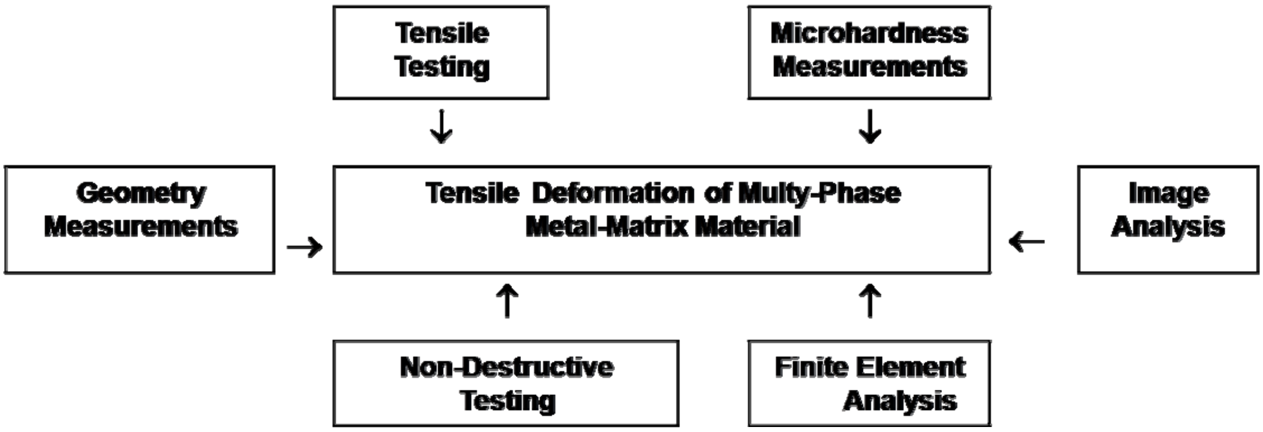


Fig. 1 Investigation concept

2. EXPERIMENTAL WORK

For the transformation and enlargement of the phenomena in the microstructure into the macroscopic world the macroscopic models considering tensile deformation have been done.

The models were composed of the metal tube and cylindrical inserts. In this types of models the matrix were simulated with the wall of the tube, and cylindrical inserts represented secondary-phase inclusions. This model enables direct observation of the matrix (tube) deformation; especially in zones directly at the inserts [9]. Tubes were made of ductile metals and alloys (copper, aluminium and their alloys), which were adequately heat treated (with annealing and quenching). Inserts were made of much more rigid materials (low-carbon and tool steels) [10].

Fig. 2 Universal static-dynamic testing machine INSTRON 1255.

The tensile tests have been done on the universal static-dynamic testing machine INSTRON 1255 (Fig. 2). The composed macroscopic models have been loaded up to the maximal tensile load at the tensile test. Before and after deformation with the tensile test, the macroscopic models have been investigated by X-ray diffraction, and by γ and neutron radiography (Fig. 3).

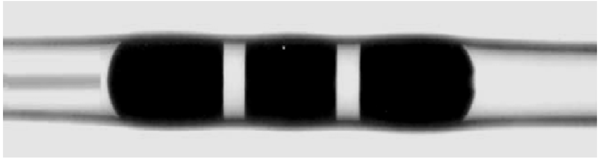
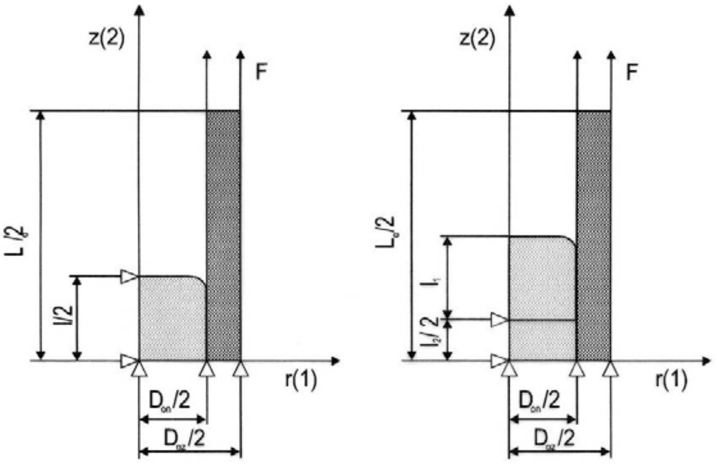


Fig. 3 Tensile deformed tubes made by copper. Loading of tubes is up to the maximal tensile load. Separation of the assembled inserts; deformation of the tube wall. Neutron radiography.

3. FINITE ELEMENT ANALYSIS

Numerical modelling of the tensile loading process of the macroscopic models of two-phase metal matrix materials have been done with finite element method (FEM), by ABAQUS software [11].

Input data for the finite element analysis (FEA) includes informations about: initial geometry of the system, mechanical properties of the individual constituents, initial, boundary and interface conditions and loads [12,13]. At the model description is also very important data the definition of the contact properties (friction) between matrix and secondary-phases inclusions. The axial symmetry of the tensile deformed systems matrix - inclusion (uniform or composed) has been considered.



Model	Matrix	Inclusion	L_0 (mm)	D_{0z} (mm)	D_{0n} (mm)	$l(l_1)$ (mm)	l_2 (mm)	ΔL (mm)
I	Cu	Steel	160.0	10.0	8.0	26.6		40.0
II	Cu	Steel	160.0	10.0	8.0	11.8	9.1	20.0

Fig. 4 Model - Initial geometry parameters of the experimental models I (left) and II (right) used in the finite element analysis.

The initial geometry parameters of the experimentally achieved macroscopic models have been used for description of the initial geometry in FEA. The initial parameters of the model I are the initial parameters of the experimental achieved model of the system matrix (tube) - uniform cylindrical inclusion, and the model II represents the experimental achieved model of the system matrix - composed cylindrical inclusion. All experimental models, used for FEA, have been composed in the way that the inserts have been put directly in the middle part of the matrix. Because of double symmetry of the chosen macroscopic models, owing to the tensile and radial axis it was possible in FEA to use only one quarter of the experimentally simulated macroscopic model (Fig 4).

Mechanical properties of the testing materials have been used on the base of the unaxial tensile tests or have been assumed on the base of the data from the professional literature [14]. For the matrix of the numerical simulated models, the copper tubes have been chosen. The value of the Young's modulus of the copper matrix is 119.0 GPa, and the Poisson's ratio is equal 0.343. True stress - true strain curve of the matrix (copper tube) was described by Holomon's expression:

$$\sigma = K \cdot \varepsilon^n \qquad (1)$$

where:
- σ is true stress,
- K is stress constant,
- ε is true strain, and
- n is strain-hardening exponent.

The value of the stress constant is 320 MPa, and the strain hardening coefficient is equal 0.54.

Matrices of the numerical simulated models have been modelled with the finite elements type CAX4, interfaces with type IRS21A, and the inclusions were simulated as a perfect rigid bodies [15].

Friction coefficient on the inclusion - matrix interface was assumed as an constant value (μ = 0.1) [16]. With the different model parameters (geometry, mechanical properties of the components, initial, boundary and interface conditions and loads) the numerical simulations have been done repeatedly. On this place only Von Mises equivalent stress in the matrix of the basic experimentally simulated models I and II is present (Fig. 3).

The Von Mises equivalent stress is defined with the principal stresses as follows:

$$\sigma_M = \frac{\sqrt{2}}{2} \cdot \sqrt{(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2} \qquad (2)$$

with:
- σ_1 as radial stress,
- σ_2 as axial stress,
- σ_3 as tangential stress, and
- σ_M as Von Mises equivalent stress.

In Figures 5 and 6 is present Von Mises equivalent stress distribution in matrices of the model I at 25 % deformation, and at the model II at 12.5 % deformation.

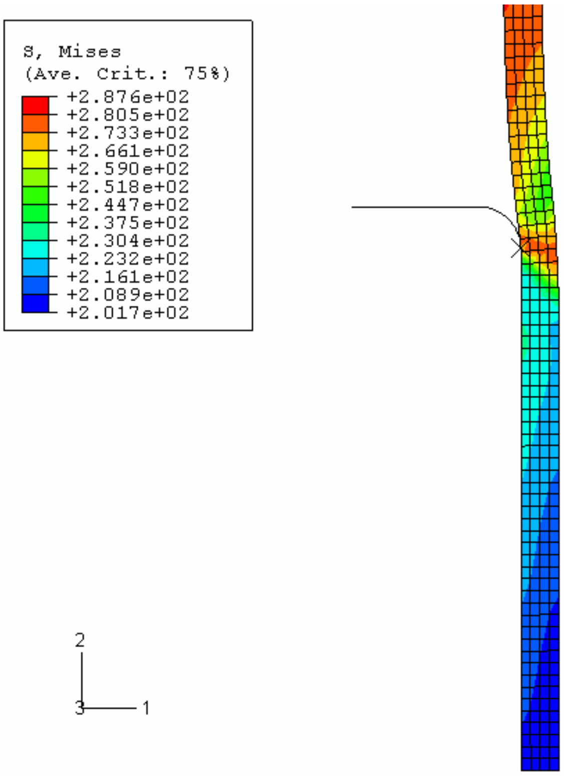


Fig. 5 Von Mises equivalent stress [MISES (MPa)] in the matrix of the model I at 25.0 % deformation

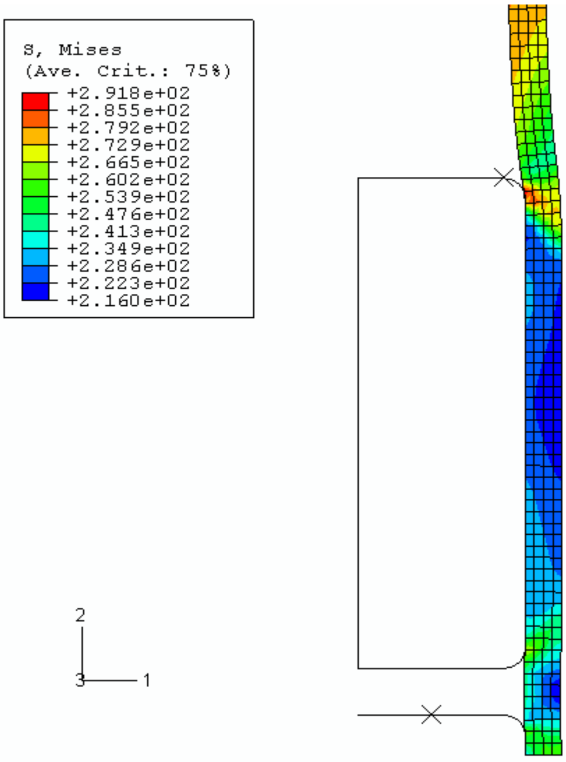


Fig. 6 Von Mises (MISES (MPa)) equivalent stress in the matrix of the tensile deformed model II at 12.5 % deformation.

4. CONCLUSIONS

The aim of our study is the designing of a corresponding macroscopic model of the multi-phase metal - matrix material useful for the tensile deformation tests, which should be suitable for both: experimental and numerical simulation and analysis. The basic aim of the connected experimental - numerical analysis is in the observation of the matrix material flow, and in the description of the stress - strain state in the matrix.

The changes of the geometrical parameters of the tensile deformed macroscopic models have been observed in situ with the transmission of macroscopic models with the X-rays, γ-rays and neutrons. For computational modelling the FEA and the ABAQUS software have been employed. The outcome of the FEA explains the results of the experimental investigations.

This investigation shows that it is possible to observe the phenomenon of elastic and plastic deformation of multi-phase metal-matrix materials on the macroscopic models composed of elements, which have properties very similar to the constituents of the real materials. The composed models should be in praxis useful for the tensile loaded multi-phase metal-matrix materials and composites.

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Original Scientific Paper

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AUTOMATED DESIGN OF ASSEMBLY SYSTEM WITH COMPUTER AIDED SYSTEM HELP

Received: 11 January 2009 / Accepted: 25 March 2009

Abstract: *The paper deal about automated assembly manufacturing cell design. First part is about Methods and techniques used for assembly systems design. Next part describes specific CAD systems used for design process of our assembly cell. With help of this CAD toll we have design geometric disposition of all system elements by CATIA and also parts of control system by FluidSim. Whole design problematic was completed by process simulation model created in Witness environment.*

Key words: *Cell, design process, simulating model, computer aided design*

1. INTRODUCTION

New manufacturing culture is changing the demands to the projecting works and look to the assembly research. The development of design methods and techniques of assembly processes and system is very important and necessary. Systematic approach is needed by design of assembly processes and systems. Also others aspects are influencing to the design process. Aspects such as knowledge from other research disciplines, professional creativity, tactical and strategic decision and so on. All these aspects are coming from changing technical, technological, economical and social conditions.

2. METHODS AND TECHNIQUES USED FOR ASSEMBLY SYSTEMS DESIGN

Negative aspect of design process is, that analytic and synthetic culture is not developed on good level. In generating process of assembly processes and systems are usually creating old solutions. In these days there are many methods and techniques, which can be used for solving of problems related to the designing process. These methods allow optimalizing and innovating also the assembly problems.

From verification view was our positive experiences reached in these areas:

Area	Used instrument
Graphic design	CATIA
Design and simulation of automate control system	FluidSim
Manufacturing system simulation	Witness

Aspects as high quality, short innovation cycle and other projects attributes can be attained very hard without automation projecting what means without any application of informatics and software technologies. Introduces computer aided instruments were used by design process of automated assembly cell.

3. ANALYTICAL PRINCIPLE OF MODEL DESIGN AND SIMULATION OF ASSEMBLY CELL PRODUCT BASE

The philosophy of product base design can be realized by help of synthesis process. This way can be the philosophy developed through these ways:

- variants creation based to the:
  - building elements selection
  - building elements combination
  - selection of massive variant

- valuate accessability of solution following to the:
  - accessability range identification
  - simulating of functional activity
  - parametrical accessability decision

During the interpretation model solution process there is needed to fulfil basic conditions such as:

- to have output characteristics of element base
- to have building elements with known technical parameters
- to have technical and economical conditions of solution and realization
- to have knowledge base gull of similar solutions
- use for solution some computer aided system

By the designing process we outcome from element base of manufactured product. In assembly cell there will be assembled pneumatic linear, single acting actuators which are showed at the figure number 1.

The product consists of 5 parts. His structural piece list is showed at the figure number 2.

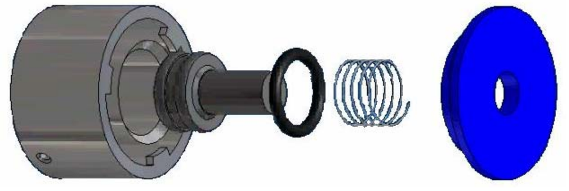


Fig. 1 The part assembled in assembly cell

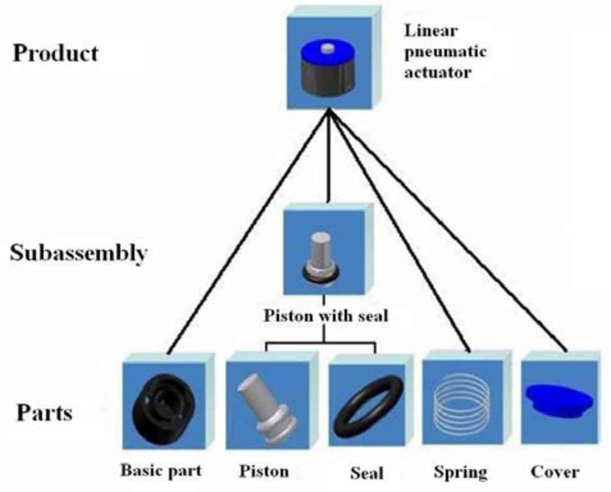


Fig. 2 Assembled product piece list

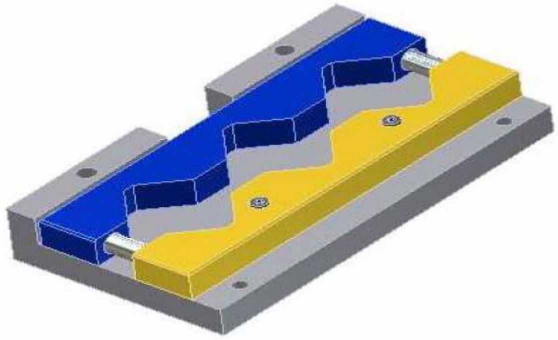
Other one request to the assembly cell was its building only from linear pneumatic driven actuators. . Single actuators were following to the specification chosen from firm FESTO offer. All chosen actuators were modelled in CATIA design environment.

Same way was also modelled all buffers, one buffer for each building part of whole assembled product. Base design criteria were to use gravitational power for part movement in to the buffer. This design will provide less actuator solution. Main advantage of this kind of solution is its simplicity. For cylinder clamping was designed pneumatic driven fixture. All CATIA 3D model are showed at the figure number 3.

a.) gravitational cylinder buffer

b.) gravitational cover buffer

c.) gravitational piston buffer



d.) clamping fixture

Fig. 3 Assembly cell devices – 3D models

Whole disposition solution of assembly cell, were modelled and was also simulated. The simulation helps to eliminate possible disadvantages and negatives in the design process. This way the design problems were not influencing, and was not taking to the verification process. The simulation model of whole device is showed at the figure number 4.

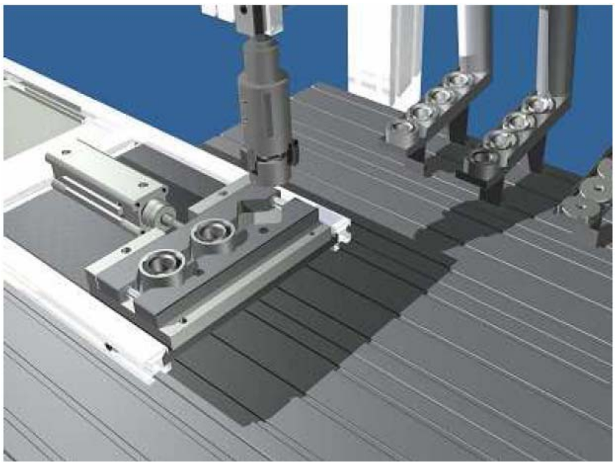


Fig. 4 Simulating model of assembly cell

4. SIMULATING MODEL CREATION OF ASSEMBLY CELL CONTROL SYSTEM

Next step of assembly cell design is to specify sensors which can be used, and which will insure back coupling in whole assembly process. Sensors and its problematic is an inseparable part of automated devices control system.

The software called FluidSim was used for creation and simulation of designed control system for assembly cell. This software allows to create some control scheme, which can be also simulated. Creation of control system scheme can be realized only after movement specification. (Fig. number 5.)

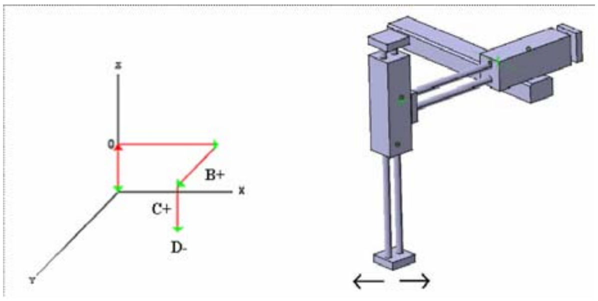


Fig. 5 Device movement analysis

Movement specification includes analyze of all device movements. Analyzed movements are then showed in diagram, which shows all movements in time steps. (Fig. number 6)

Outgoing to the device step diagram three control system alternatives were created. First alternative of control system used only pneumatic elements. Next alternative uses for creating of control system pneumatic components combined with tact blocks. Last one control system alternative combine pneumatic elements with electrical devices and creates simple pneumo-electric control system. Schemes of all three alternatives are showed at the figures number 7,8,9.

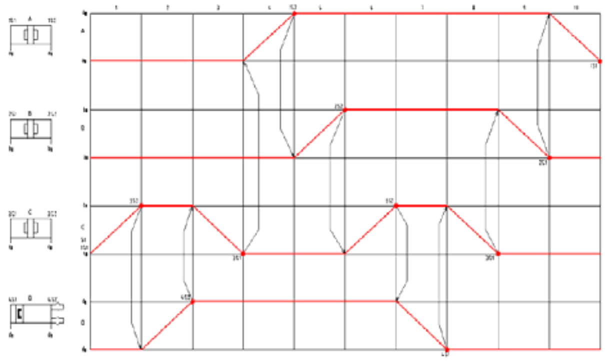


Fig. 6 Device step diagram

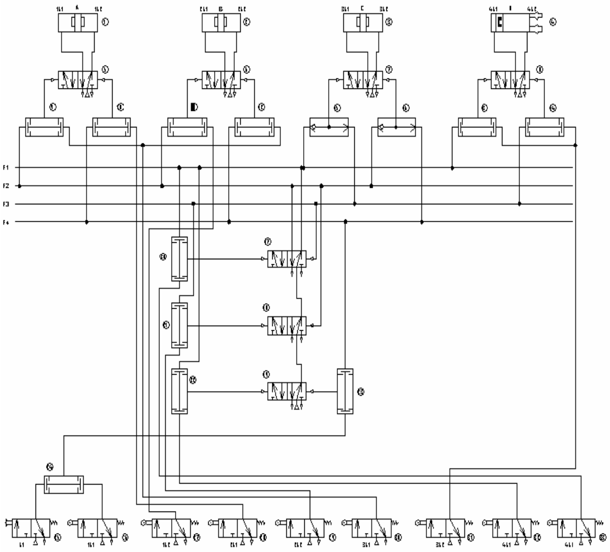


Fig. 7 Pneumatic control system – using of phases

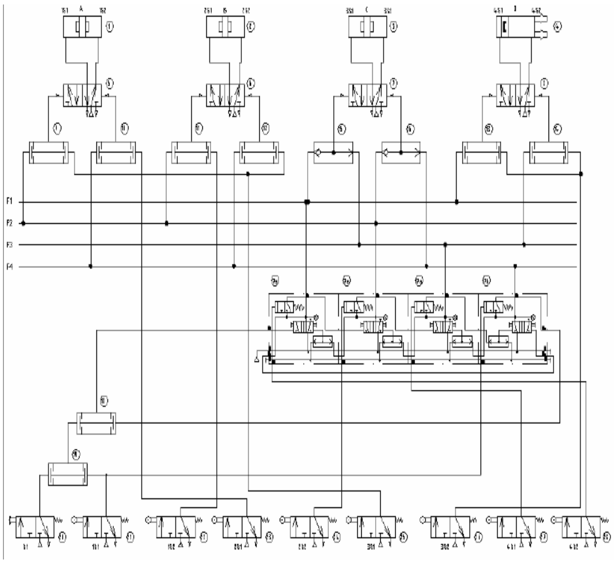


Fig. 8 Pneumatic control system – using of tact blocks

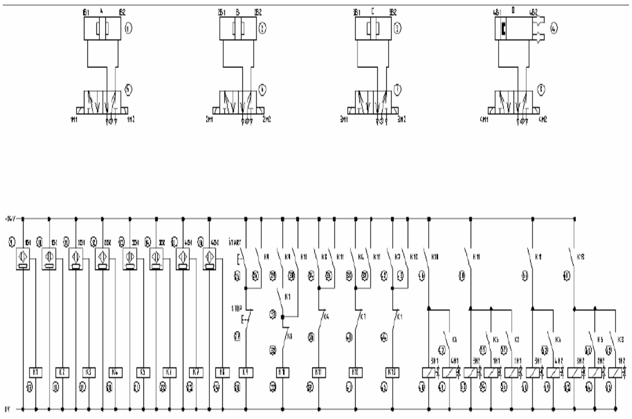


Fig. 9 Electro pneumatic control system

5. SIMULATING MODEL CREATION OF ASSEMBLY PROCESS IN TO THE ASSEMBLY CELL

Simulation can be defined as creation process of model. Model of real system which includes experiments realizations which are realized for better understanding of studied system. The system is studied for advice of various system activity variants. Simulating model is and dynamic model. In this model exists various events. This events are realized in the same order as in modelled system. Simulating methods are getting data with solving of data transformation.

This data was taken from simulating model observation. The observation activity is usually part of whole simulating model. Simulating model then gives outcomes data following to the information which are coming from time changes during the model running time. Running time is completely separated from real time in which are running the calculations.

This time separation permit to catch simulating events. Work with simulating time, design questions and model stay changes are important aspects of dynamic properties of modelled systems recording. Assembly process simulation model of our assembly cell is showed at the figure number 10.

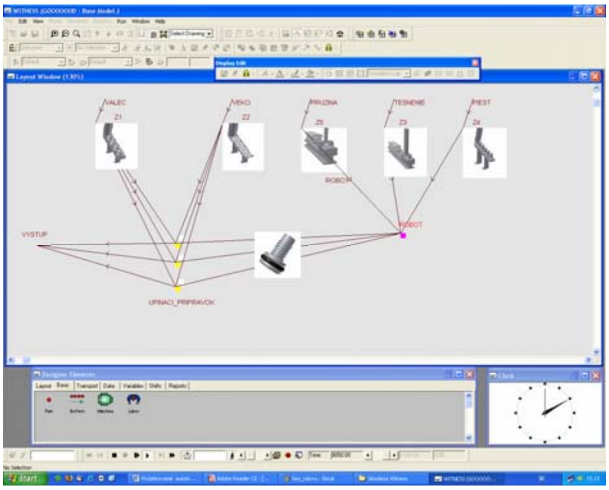


Fig. 10 Process simulating model

6. CONCLUSION

Research and realization of 3D models used for automated engineering systems, is important part of assembly systems design. Program modules of modern graphical CA system are working with high information database support, which includes elementary 3D objects used for design process of more complex models of assembly systems. Using of these types of CA systems is very important and its also short the designing time and allows possible disadvantages and mistakes and its elimination in the designing process, what save the time and also the money.

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Original Scientific Paper

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METAL SPUN AND DEEP DRAWN PART'S SURFACE LAYERS PROPERTIES EVALUATION

Received: 27 April 2010 / Accepted: 30 December 2010

Abstract: *Contribution states the experimental analysis of surface layers properties of thin-walled hollow sheet metal parts, manufactured by forming processes – deep drawing and metal spinning. It brings the results of the part's surface layer microhardness measurement after conventional metal spinning and deep drawing operation and the comparation of the strain-hardening effects of these processes.*

Key words: *surface layer, strain-hardening, metal spinning, microhardness*

1. INTRODUCTION

Every technological method, which takes part in production of final component, brings in the component specific properties that influence its exploitation, i.e. it takes effect on its utility properties. Generated superior parameters of surface layer significantly influence for example wear resistance, fatigue strength, corrosion resistance etc. These are important aspects, especially for parts that are under dynamic stress or exposed to difficult operative conditions.

Typical parts exposed to such conditions are containers and pressure tanks, e.g. compressed gases. Their most important construction elements are the shaped heads (bottoms of the tanks). These are classified as rotary parts, which are for the aspect of shape defined as hollow steel metal components. Heads are components of pressure tank that are manufactured out of boiler-irons, structural steels, aluminum and copper alloys, clad steels and reinforced plastic with carbon fibers [1].

Most applied method of heads manufacturing is deep drawing. However, from the economic aspects and quality indicators, the process of metal spinning is better alternative. After application of this technology a typical stress-strain states are generated in material and qualitative properties in surface layers [2, 3, 4], which have subsequently effect on the safety index of pressure tanks. Consequential facilities of surface layers determine, among other things, also material strain-hardening. Experimental analysis and comparation of above mentioned processes, from the surface layer strain-hardening, is the objective of this paper.

2. EXPERIMENT

For production of hollow sheet metal part, witch dimensions parameters are shown in Fig. 1 and listed in Table 1, was used thin steel sheet made out of material EN 10025-94 (ISO 630-80). Chosen basic mechanical properties and facilities defining material plasticity are listed in Table 2. The blanks with diameter D_0 = 180 mm were formed by deep drawing and metal spinning processes (Fig.1). Forming was performed by a company Sandrik 1895, spol. s.r.o., Hodruša-Hámre, at technological conditions listed in Table 3.

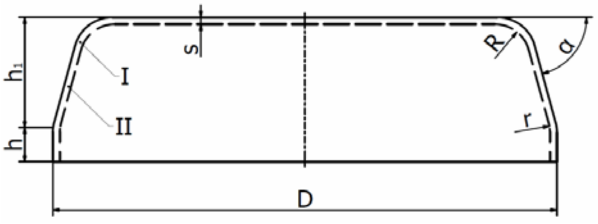

Fig. 1 Hollow sheet metal part shape and dimensions
I – bottom-wall of part, II – wall of part

D (mm)	h (mm)	h_1 (mm)	r	R	α (°)	s (mm)
140	**30**	**90**	**10**	**10**	**75**	**1**

Table 1. Part dimensions

R_m (MPa)	$R_{p0,2}$ (MPa)	$R_{p0,2}/R_m$	A_5 (%)	r_s	Δr	n	A_{sh}
340	**235**	**0.69**	**26**	**1.174**	**0.34**	**0.28**	**27.38**

Table 2. Values of chosen mechanical properties and properties defining material plasticity EN 10025-94

Process of deep drawing			***Process of metal spinning***		
Blank-holder force F_P (kN)	***Forming force*** F_T (kN)	***Forming velocity*** v (m.s^{-1})	***Feed ratio*** f (mm)	***Mandrel rotational speed*** n (min^{-1})	***Maximum circumferential velocity*** v (m.min^{-1})
20.11	**192.31**	**0.25**	**0.80**	**890**	**390.60**

Table 3. Technological parameters of deep drawing and metal spinning processes

Presented experimental observation and evaluation of surface layers properties is aimed at evaluation of material strain-hardening utilizing method of micro-hardness measuring according to Vickers, method HV 0.025, under STN 42 0375, measured on INDETA Met 1100 device. The measurement was carried out in direction from part's surface to its depth on positions, that are from aspect of hollow sheet parts production, defined as critical (Fig. 1), i.e. inter-stage spots of head to wall (I) and conic wall (II). For math formulation of material strain-hardening values was the measuring carried out five times, also on the base material (BM), whereby the measurement was applied in directions 0° and 90° refer to the rolling direction of the sheet. Measured and calculated values for base material are listed in Table 4.

Graphic evaluation of microhardness values of sample's surface layer, made by metal spinning, in positions I and II, under consideration of material rolling direction, is showed in Fig. 2. Graphic evaluation of microhardness values of sample's surface layer, made by deep drawing, in positions I and II, under consideration of material rolling direction, is showed in Fig. 3.

Surface distance (μm)	***5***	***10***	***15***	***20***	***25***	***Mean average***
$HV_{BM/0}$	**101.9**	**101.8**	**100.2**	**99.3**	**98.9**	**101**
$HV_{BM/90}$	**101.7**	**99.4**	**99.2**	**98.6**	**98**	**101.14**

Table 4. Microhardness values of surface layer – base material (BM)

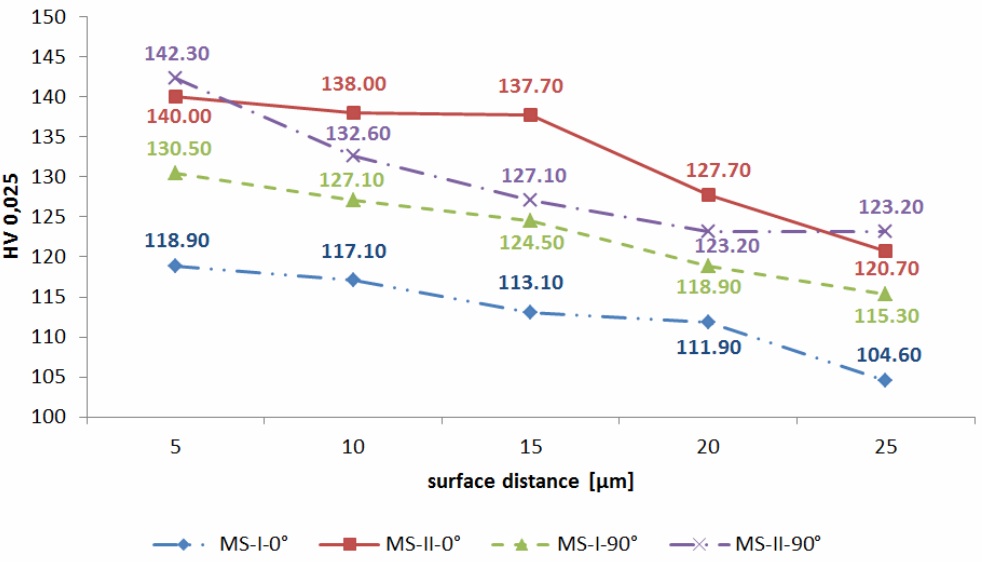

Fig. 2 Progress of microhardness values in surface layer of MS sample in position I and II, in direction 0° and 90° refer to the rolling direction

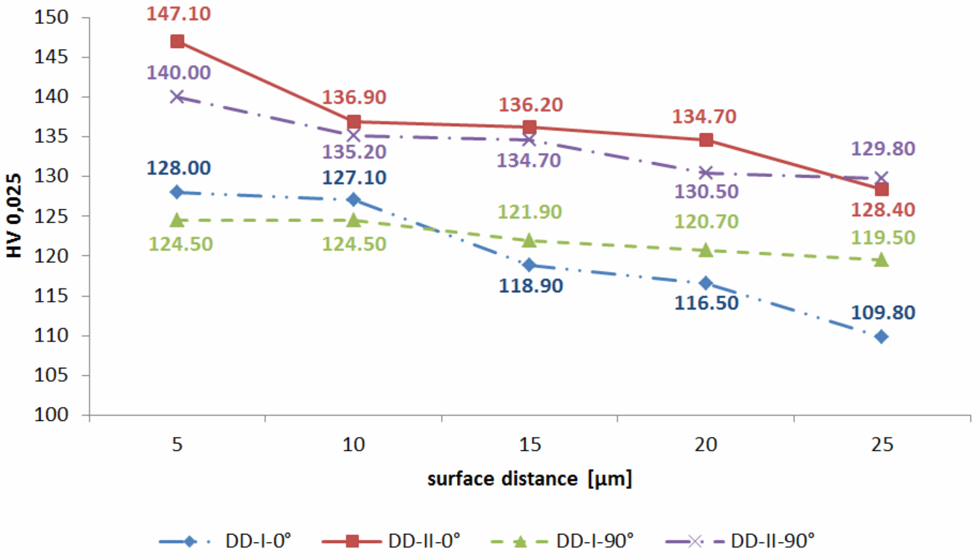

Fig. 3 Progress of microhardness values in surface layer of DD sample in position I and II, in direction 0° and 90° refer to the rolling direction

Consequently "relative material straining" (RMS) was interpreted on MS and DD samples considering BM, whereby the material rolling direction of the sheet was also regarded. Every sample was evaluated twice. The first calculation was aimed at comparison of base material with the inter-stage of head to wall. The second calculation was aimed at comparison of base material with the conic wall. Median calculation example of MS material, in position I, in direction 90° refer to the rolling direction ($RMS_{MS/I/90}$), states formula (1) and example of MS material, in position II, in the direction 90° with respect to the rolling direction of material ($RMS_{MS/II/90}$), states formula (2). Calculations of RMS for maximum values of microhardness, for those same directions and positions, are showed in formulas (3) and (4).

Presented procedure evaluates values of PMS for all microhardness values, measured in direction of material rolling. Equal computation was applied for the direction of 90° refer to the rolling direction. Saturation and comparison of single RMS values of DD and MS samples are showed in Fig. 4 and 5.

$$RMS_{MS/I/90} = \frac{HV_{MS/I/90} - HV_{BM/90}}{HV_{BM/90}} 100 = \frac{123.26 - 101.14}{101.14} 100 = 21.87\ \% \qquad (1)$$

$$RMS_{MS/II/90} = \frac{HV_{MS/II/90} - HV_{BM/90}}{HV_{BM/90}} 100 = \frac{128.92 - 101.14}{101.14} 100 = 27.47\ \% \qquad (2)$$

$$RMS_{MS/I/90\max} = \frac{HV_{MS/I/90\max} - HV_{BM/90}}{HV_{BM/90}} 100 = \frac{130.5 - 101.14}{101.14} 100 = 29.03\ \% \qquad (3)$$

$$RMS_{MS/II/90\max} = \frac{HV_{MS/II/90\max} - HV_{BM/90}}{HV_{BM/90}} 100 = \frac{142.3 - 101.14}{101.14} 100 = 40.7\ \% \qquad (4)$$

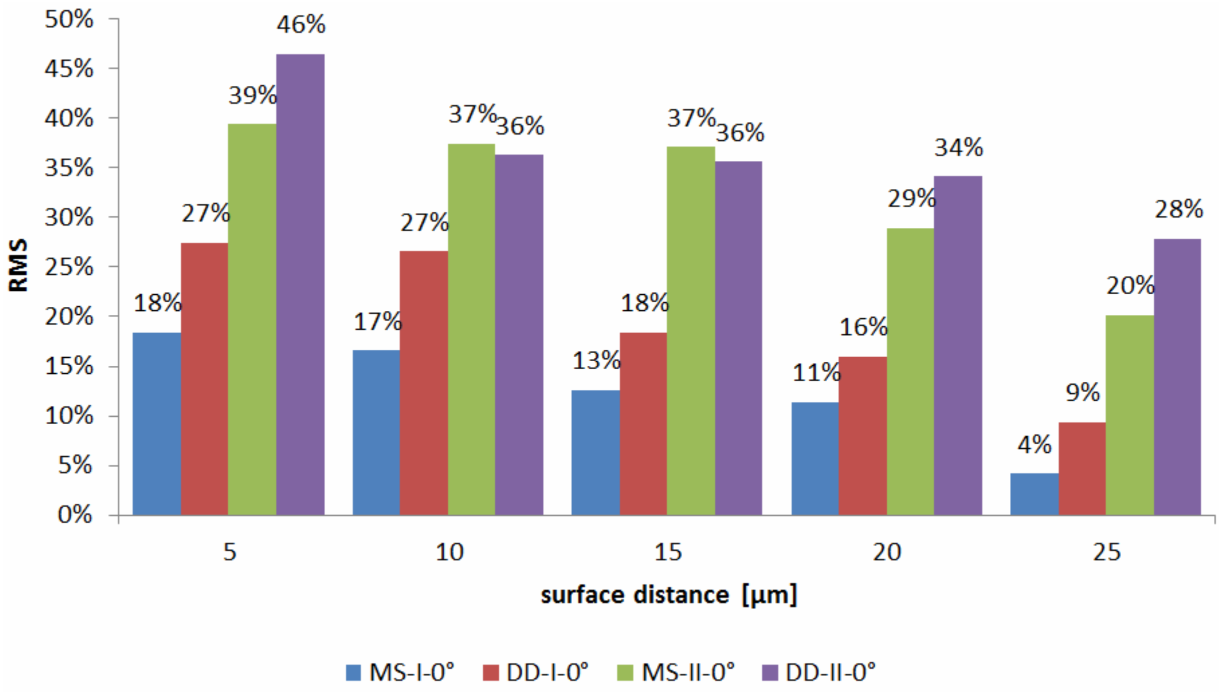

Fig. 4 Comparison of RMS values of DD and MS samples in positions I and II

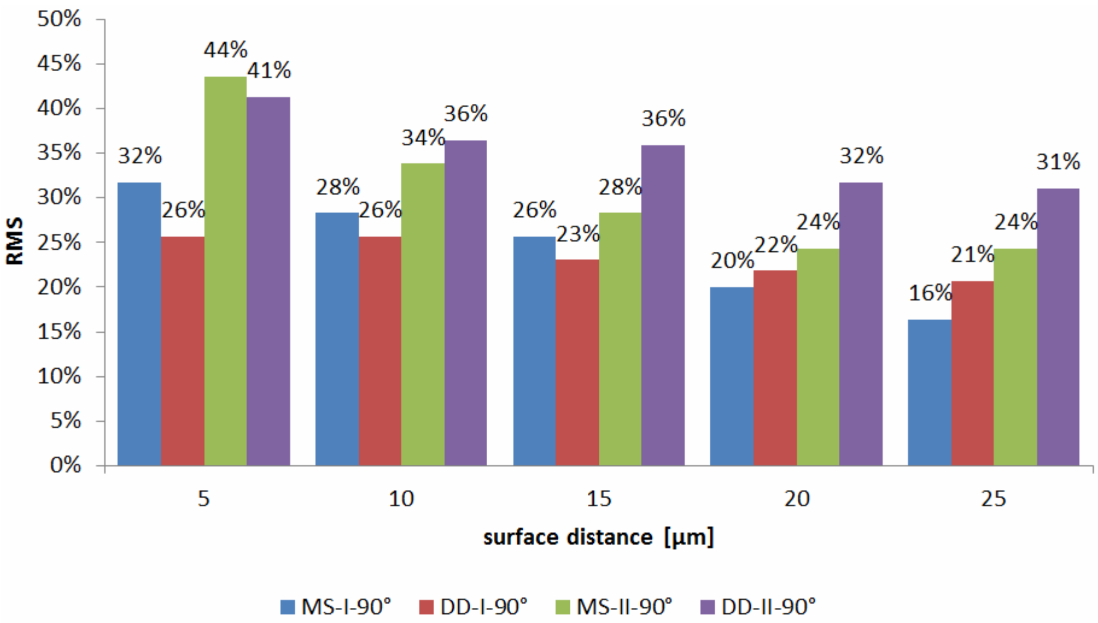

Fig. 5. Comparison of RMS values of DD and MS samples in positions I and II

3. CONCLUSIONS

From published results follow that the maximum values of RMS in both directions of material rolling is on DD sample, whereby its average value in position I-0 is 35.31%, in I-90 it's 32.73%, in II-0 the average RMS value is 18.87% and in II-90 it's 20.43%. The average RMS value of MS sample in positions I-0 is 12%, in I-90 it's 21.87%, in II-0 the average RMS value is 31.51% and in II-90 it's 27.47%.

Based on observation of strain-hardening values and their average RMS surface layers values of deep drawing and metal spinning samples it is possible to state that the different stress-strain conditions, parallel in material, generated different values of material strain-hardening. In the DD sample were higher values of mechanical hardening. Higher values of RMS for metal spun parts are possible to achieve by calibration, or by modification of technological parameters, i.e. choosing higher frequencies of mandrel speed, or higher feed ratio of spinning tool.

Besides propitious values of material strain-hardening on surface layers, typical stress-strain condition of material after spinning, effects also wear intensity positively, increases corrosion resistance and also some other values of mechanical properties and properties defining formability of materials, e.g. increases fracture limit, which is important aspect in process of exploitation.

Further we can state, that the final important properties of surface layers are influenced by initial direction of material rolling, since the values of RMS after spinning are almost equal to those made by deep drawing in direction 90° refer to the sheet metal rolling direction. However difference between the directions of material rolling values is higher, therefore we can predict, in theoretical line, places of potential failure in components exploitation process.

Following the carried out experimental measurement and its evaluation it is possible to state, that the metal spinning is more suitable for producing components with favorable manner of surface strain-hardening as technology of deep drawing,. The character of material deformation in the process of metal spinning determines other part's facilities, which are more convenient from the utilization point of view.

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Original Scientific Paper

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DISASSEMBLY PROCESS QUALITY IMPROVED WITH RFID TECHNOLOGY

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Abstract: *Focus of this research is how the availability of lifecycle information associated with products affects the performance of end-of-life disassembly processes. Also, intention is to study the impact of (none) availability of product information, and general understanding of information (none) availability on decision making efficiency, and make a suggestion how this problems could be salved.*

Key words: *disassembly, recycling, selection scenario.*

1. INTRODUCTION

Recycling is suggested to be a supporting process to the sustainable development and an instrument to overcome a pollution and depletion of natural recourses problems [1]. Recycling is a term that is mostly related to recycling of product and material. Product recycling implies reuse of already used, repaired products, individual components (parts/subassemblies) with the same, or some other purpose. Reuse of some components (part/subassembly) gives an advantage to recycling in a sense of avoiding or lessening thorough energy and emission into the environment, which originate from production and consumption during material prefabrication. Reuse could be defined as secondary usage of product or (mostly) parts-subassemblies, in new one, repaired or serviced products. Material recycling is related to the product recycling through process reconditioning of basic material for production new one or some other products. However, before recycling electric, electronic equipment and different products that contain dangerous components and materials - products that succumb to Waste Electrical and Electronic Equipment (WEEE) and Restriction of Hazardous Substances (RoHS) directives, needs to be disassembled. Disassembly has imposed itself as a necessary step at final dispose of products that are at the end-of-life.

Disassembly process could be defined as a product separating process of its ingredients or subassemblies, including analysis of a product condition and selection of separated components. Disassembly is always a group of operations, accomplished by using adequate tools and fixtures, in technological systems [8]. Disassembly and recycling cannot be regarded separately. Developments in the disassembly field have considerable importance for recycling processes and vice versa. All products admission in disassembly systems today have one common problem - lack of any information needed for their disassembly. This paper will represent current situation in already mentioned field and how disassembly influences the product quality. In addition, will be represented research results and conclusions, which have outcome of work in the laboratory conditions.

2. DISASSEMBLY SYSTEM INFORMATION

There are a many research centers for disassembly problems. The only purpose of some of these centers is disassembly process research and exploring all the possibilities for development of robotized and automated systems. This type of systems has no commercial purpose [3].

There are systems, which are established for the purpose of dealing with the problems of waste accumulation (e.g. PC monitors, air conditioners, refrigerators, etc.). The financial effect of those systems is in question. Another type of disassembly system is designed with the purpose of achieving great financial effects. In addition, they have research purpose. Information gathered from these systems is very important for the further analysis, and they are embedded in new developed products.

All these systems and feedback information gathered from them have great importance for defining basic problems, which arise during planning and disassembly process phase.

2.1 Problems during disassembly process planning

Based on information gathered in already mentioned systems, disassembly process research is done in several ways that can be classified in three categories:

- optimal disassembly sequence,
- disassembly process planning,
- using mathematical model for financial and ecological disassembly process characteristics optimization.

All the researches have the same purpose, which is to profile the ways of efficient and effective disassembly process performing in technical-technological and economical sense. Product redesign, based on gathered information from disassembly system and automated and robotized disassembly process, is the best way of achieving established goals. Frequently noticed problems in work and research processes are: lack of information about product, uncertainty in quantity planning, resource availability, location, different types of products, disassembly level, uncertainty in product condition, etc.

Researches of designing disassembly process and disassembly systems for several product types (electric motor, PC monitor, etc.) practiced in laboratory conditions have confirmed already mentioned observation. A specially formed research field deals with the lack of information for the disassembly process and selection of disassembled components. Further more, a suggestion was given about dealing with the problem of data acquisition and design of conditions for overcoming mentioned problems.

3. END OF LIFE STRATEGIES AND COMPONENT SELECTION

A starting point of designing disassembly system process is end of life strategies for products. Strategies for products at the end of a life cycle represent methods, which are used to conduct the general direction of products, and only suggestions are given for the management of a product at the end of a life. Studies related with the strategies of the products end of a life are numerous. The most accepted, and in its character, the most comprehensive classification of the products end of a life cycle is [7]:

- re-use of used products (1);
- reconstruction of used products (2);
- usage of already used products for spare parts (3);
- recycling with disassembly (4);
- recycling without disassembly (5);
- dumping of the used products (6).

The choice of strategies for reconstruction of used products (2), usage of already used products for spare parts (3) and recycling with disassembly (4) indicates the need for designing the disassembly system. After choosing the proper strategy for a given product and a sequential execution of certain procedures of disassembly, it is necessary to accomplish a selection of the disassembled components (parts/subsystems). In essence, we distinguish the next possibilities for the selection of components after the process of disassembly [5]:

- dangerous components – materials (H (hazard));
- material recycling (R);
- reusable (P);
- finishing (D);
- incinerate (I (incineration));
- waste disposal (W (waste)).

3.1 Component selection scenario

In the disassembly, the operation procedure is accomplished according to an adequate technological procedure, which is designated for every work place in particular. The procedure implies, in the most general case, the following (Fig. 1.) [6]:

- accomplishing operation with the help of appropriate tools and fixtures;
- analysis of the state and the diagnosis of the disassembled components (part/subsystem);
- selection of the disassembled components (part/subsystem) according to previously accomplished analysis of the condition and the diagnosis.

Initial problems in designing and working processes of disassembly systems are in a component selection phase. It is a result of a lack of information about products, and different product condition arrived in disassembly system. That is the reason for expansion of product design documentation with another document - scenario for component selection (Table 1).

Scenario for component selection is important document not only in designing disassembly system process, but later when system is functioning. It enables dynamic correction of variant component selection (parts/subassemblies). There are many possible selection alternatives for some components (Table 1. and Fig. 1.). The reason is that products arrive in disassembly system in different conditions.

Possible strategies for product:										
Part	**Modul**	**Pcs**	**Disassembly level**	**.......**	**Possible variants of selection after disassembly**					
					H hazard	**R recycle**	**$P_{1/2}$ reuse**	**D remanuf.**	**I inciner.**	**W waste**
				...						
				...						

Table 1. Component selection scenario

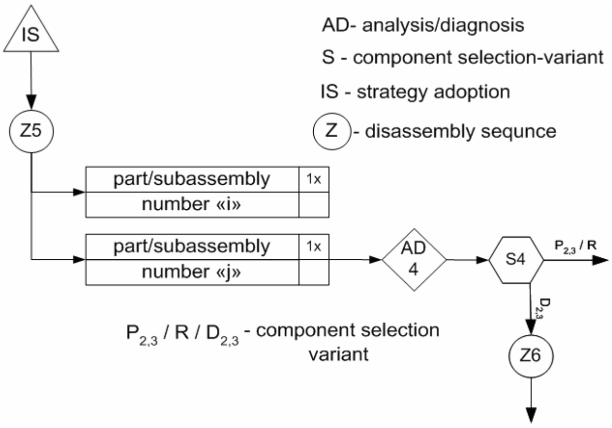


Fig. 1 Disassembly sequence procedure

3.2 Data acquisition system supported by RFID technologies

Data acquisition for disassembly process and system design is a very slow and complicated process. Information gathered and processed are frequently unreliable with lot of uncertainties. Obtaining acceptable quality level of a product processing at the end of it′s life depends on quality of gathered product information [2]. Problems with products identification and making recovery decisions, insufficient material composition information available to recycler, inaccurate estimation of residual life and value of components, leads to inefficient manual disassembly.There is a need for establishing design/disassembly data sharing system with the purpose of enabling clear, precise, and complete product information in real-time to all authorized users.

Radio frequency identification (RFID) technology uses radio waves to automatically identify physical objects (either living beings or inanimate items). Therefore, the range of objects identifiable using RFID includes virtually everything on this planet (and beyond). Thus, RFID is an example of automatic identification (Auto-ID) technology by which a physical object can be identified automatically [9]. Other examples of Auto-ID include bar code, biometric (for example, using fingerprint and retina scan), voice identification, and optical character recognition (OCR) systems.

3.3 RFID System

An RFID system is an integrated collection of components that implement an RFID solution. An RFID system consists of the following components (in singular form) from an end-to-end perspective:

- Tag. This is a mandatory component of any RFID system.
- Reader. This is a mandatory component, too.
- Reader antenna. This is another mandatory component. Some current readers available today have built-in antennas.
- Controller. This is a mandatory component. However, most of the new-generation readers have this component built in to them.
- Sensor, actuator, and annunciator. These optional components are needed for external input and output of the system.
- Host and software system. Theoretically, an RFID system can function independently without this component. Practically, an RFID system is close to worthless without this component.
- Communication infrastructure. This mandatory component is a collection of both wired and wireless network and serial connection infrastructure needed to connect the previously listed components together to effectively communicate with each other.

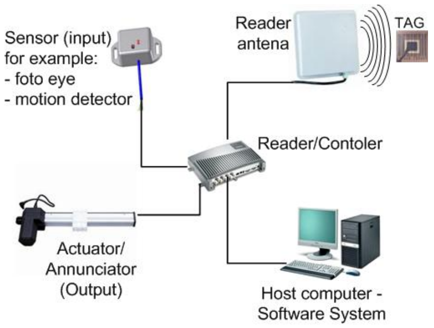
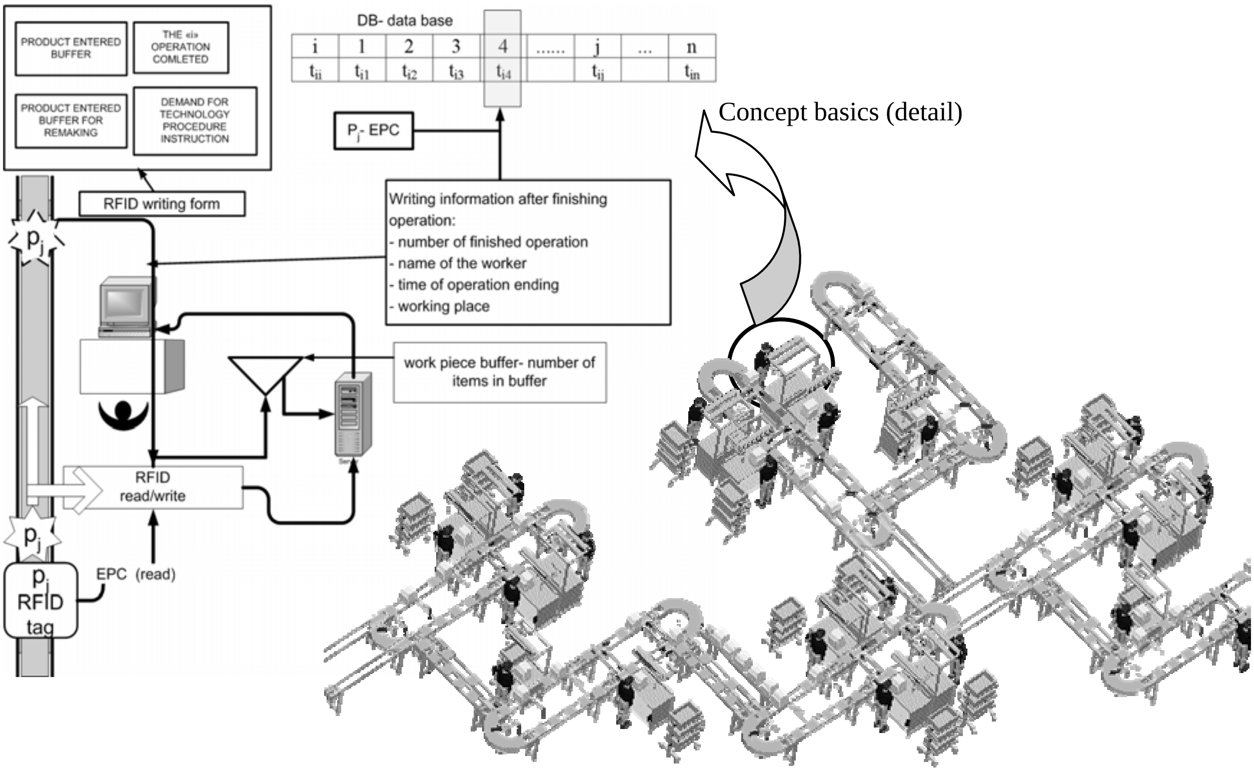


Fig. 2. An RFID system with example components [4]

Fig. 2. shows an instantiation of this schematic with example components. RFID technology implemented in disassembly system enables upgrading of information distribution about product at specific working places (e.g. description of partial working (disassembly) operations), process real-time control, supervision of free workers at individual working places, tracking accomplishment of individual operations, etc.



i	1	2	3	4	......	j	...	n
t_{ii}	t_{i1}	t_{i2}	t_{i3}	t_{i4}		t_{ij}		t_{in}

Writing information after finishing operation:
- number of finished operation
- name of the worker
- time of operation ending
- working place

Fig. 3 RFID technology application concept

Application of RFID technology can be accomplished in the following way (Fig. 3.). After product arrival in the disassembly system, it is necessary to put a transponder (tag) on the base part of the product which corresponds to the class and type of the product, for which the strategy has been chosen, with its EPC. After that, the product is being put on the disassembly line. In the work stations (where disassembly or remaking operations can be executed, according to chosen strategy (reconstruction of used products, or other strategy)), worker takes the product and RFID tag reader reads an EPC. Then, worker press's appropriate option button - RFID writing form "Demand for technology procedure instruction" and uploads set of instructions from the data base for the technological procedure of disassembly, in the form of a visual presentation on the monitor in front of the worker. Instructions are in a step by step form. After finishing the operation ("i" operation, i is the number of current operation) worker presses "The "i" operation completed" button and information like: number of finished operation, name of the worker, time of operation ending and working place are being written to RFID tag (at Fig. 3. these information are written to Database and operation 4 - t_{i4}). If there is a large amount of product on disassembly line the worker places product in a work piece buffer, and confirms that by pressing appropriate option button - RFID writing form, "Product entered buffer". If the product is arrived to the work station for remaking worker press's "Product entered buffer for remaking", and uploads set of instructons.

RFID tags can also be placed on workers clothes so it would be possible do detect specific position of every worker in system and his/she’s momentary operation. If the worker is free with the previous task on one working place, information is send to system control station. From this point another (new) task can be given to the worker.

Using RFID technology as an integral part of a system will allow real-time access to the product information from any point in the supply chain. In addition, this technology enables product information to be stored by various users in their networks through the whole products lifecycle, but allow access to the information only to authorized users. Information is dynamic, but also linked to the static information stored by the manufacturers through the Internet.

4. CONCLUSION

Products arriving to disassembly centers are made more then one decade before (according to the strategies 2-reconstruction of used products, 3-usage of already used products for spare parts and 4-recycling with disassembly). They all have common basic problem, which is lack of any information about them. During the disassembly sequence and system design, it is necessary to choose product disassembly strategies and establish a component selection scenario. This is very complicated and slow process. During the disassembly process, it is necessary to dynamically correct selection of the strategy for every individual product. Afterwards, it is necessary to make a component selection according with the chosen strategy and previously prepared documentation. A scenario for component selection and selection procedure needs to be integral part of product documentation during the product development phase.

In the future, a product quality will depend on product and documentation design, especially in the field of disassembly.

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Original Scientific Paper

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USE MULTICRITERIAL EVALUATION TO ASSESS THE COMPETITIVENESS OF PRODUCTS

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Abstract: *This article deals with the multicriterial evaluation of products. Each company is trying to be competitive in the market with their products. The European Commission applies the concept of competitiveness at different levels, from business (micro) plane to sectoral, regional and national (macro) level. At the macroeconomic level, competitiveness is determined rather than sustained growth in living standards. Sectoral level competitiveness refers to the situation (power) in the industry of the country, respectively region of the industry in other countries and regions. The company is competitive in producing goods or services with higher quality and lower cost than domestic and international competition. Competitive product is the result of all processes that precede the sales process. Dominating role they play in creating a new product. Accelerating the pace of scientific and technological progress requires that the rate of formation of a new product is continuously accelerated. Companies can be evaluated on their economic performance and also their products can be evaluated through various exact methods. This article deals with the method of the multicriterial evaluation. This paper presents a case study evaluation of the chosen product. In case study, fourteen gearboxes and their eleven parameters were compared by using MS Excel.*

Key words: *product, competitiveness, method multicriterial evaluation*

1. INTRODUCTION

Competitiveness can be defined at different levels:

- at company level,
- at industry level,
- at national level.

Competitiveness at industry level is the company's ability to be successful in this sector.

Competitiveness at national level, is the company's ability to be successful in international markets.

The company is competitive if it can produce products and services of the highest quality and at lower costs than its domestic and international competition. Competitive business advantage is the ability to consistently and profitably deliver products and services that customers are willing to buy at the expense of other competitors. [3]

The product is the main element of successful business strategy. Difficulty of commercial rating success of products depends on several factors, respectively, of the level of news, as well as the terms of their development, production and sales ratings. There are different approaches and methods. The most common use the different modifications of the scoring. They usually differ in the number and in the manner of evaluation criteria for the classification scheme as well as matching points. This paper deals with the multicriterial evaluation method.

2. EVALUATION OF PRODUCT COMPETITIVENESS

For each company is important to know their market position. There are variety of methods to determine whether a company is successful in the market or can not enforce. The choice of methods depends mainly on the scope and extent of intercompany comparison. Methods can be divided into: [10]

- comparative-analytical methods – for these methods are typical indicators that are expressed in words, e.g. quality products training of staff,
- mathematical-statistical methods – require numerical indicators.

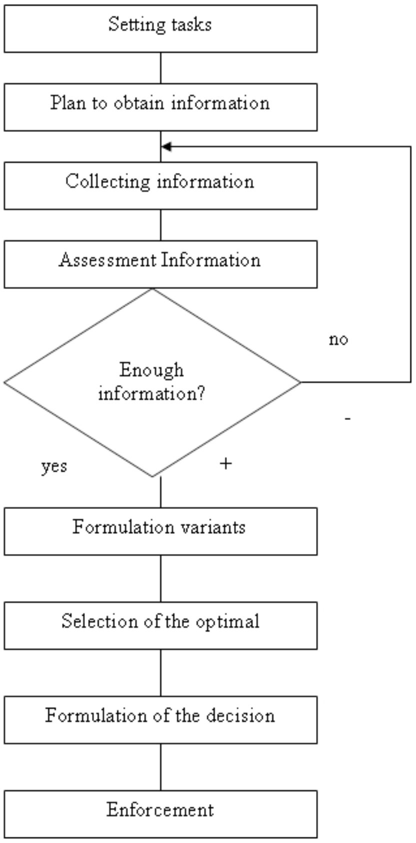

Fig.1 Decision making process

The statistical methods include the method of multicriterial evaluation. The most common approaches to multicriterial evaluation may include: [8]

- evaluation by calculating the surface/volume of the body in a geometric space,
- evaluation parameters of assessed entities.

In practice and in economic decision-making processes at all, we often face the problem of how to evaluate objects, which are characterized by different parameters (such as weight, size, consumption, power consumption, design, etc...) and therefore they have different dimensions, for example: kg, m, 1 / s, kW, points. Basic formal method of a decision making process can be shown in Figure 1.

2.1. Multicriterial evaluation method

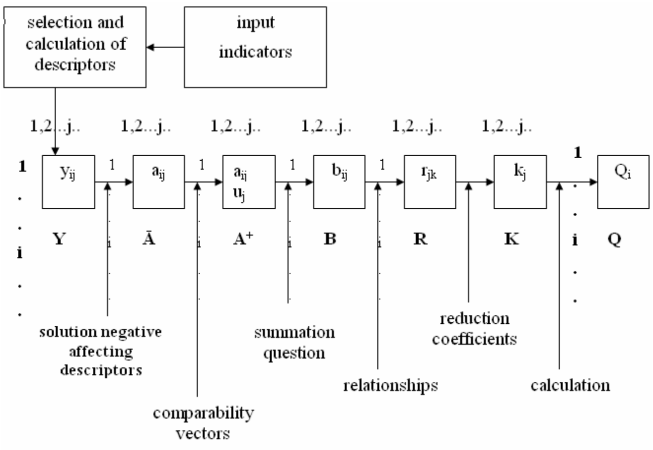

Fig.2 Multicriterial evaluation method

$Y = (y_{ij})$ matrix of variables

$\bar{A} = (a_{ij})$ matrix adjusted indicators

A^+ = extended matrix A of artificial vector

$R = (r_{ij})$ correlation matrix

$K = (k_j)$ line vector reduction coefficients

$Q = (Q_i)$ the resulting value

For applications of this method is advanced in terms of the following steps:

- Selection of subjects to be compared – i
- Selection of indicators that characterize the body – j
- Determination character indicators–indicators that have a negative impact on the subject are multiplied–1

The result is a matrix $A = (a_{ij})$. Comparability of vectors is the principle that the matrix *A* is added one more line, based on that creates an artificial vector $U = (u_j)$. Formed matrix is marked as A^+.

- Establishment of the starting matrix
- Determine the standard deviation and artificial vector average

Relationship for the standard deviation has the form:

$$s = \sqrt{\frac{\sum\left(a_{ij} - \overline{a_i}\right)^2}{n}}$$

Matrix elements B are obtained by transforming the matrix elements A of the relationship:

$$b_{ij} = \frac{a_{ij} - u_j}{s_j} \tag{2}$$

Matrix elements $B = (b_{ij})$ are measurable dimensionless numbers, which can be summarized. The standard deviation also serves as the instrument descriptors.

- Relations between the indicators, using the correlation matrix r_{ij}, whereby the correlation matrix

Relationship for the correlation matrix has the form:

$$r_{ij} = \frac{\sum_i \left(a_{ij} - \overline{a_j}\right)\left(a_{il} - \overline{a_l}\right)}{\sqrt{\sum_i \left(a_{ij} - \overline{a_j}\right)^2 \sum_i \left(a_{il} - \overline{a_l}\right)}} \tag{3}$$

Reducing constant:

$$k_j = \left(1 - \left|r_{1j}\right|\right) .. \qquad \left(1 - \left|r_{j,j-1}\right|\right) \tag{4}$$

The final relation as follows:

$$Q_i = \sum_j \frac{a_{ij} - u_j}{s_j} k_j \tag{5}$$

Q_i - resulting value that is set so the size of the value of this dimensionless number indicating the quality level of the i-th matched object

a_{ij} - value of the j-th variable of i-th object

u_j - artificial vector, it is the smallest value of the column

s_j - standard deviation, does dimensionless expression

k_j - reductive constant, calculated on the basis of multiple correlation

2.1.1. Application of the method multicriterial evaluation for selected product

Multicriterial evaluation method was verified on 14 gearboxes. MS EXCEL was used to get results. Basic types gearboxes and compared their properties are shown in Table 1.

TS 031 444 type E – single reduction worm gear with motor

EZ – single reduction worm gearbox with electric motor

ZAP.E – single reduction worm gearbox with electric motor

ZAP.C – worm gearbox with the front countershaft with electric motor

ZAP.D – worm gearbox with worm countershaft with electric motor

	A	B	C	D	E	F	G	H	I	J	K
TS031 444 typ E, a=50, u=10	-340,8	93,7	20,9	1,88	0,25	16,8	890	58	1,8	2,5	6,5
TS031 444 typ E, a=63, u=16	-471,6	56,8	71,2	1,31	0,55	21	910	70	2	3,4	10
TS031 444 typ E, a=80, u=10	-606	68,5	87,8	1,68	0,75	38	705	66	2	3,3	15,5
EZ 80, u=63	-996	11	126	2,5	31	0,25	690	55	2	2,7	10
EZ 100, u=31	-1303,2	30	256	2,2	51	1,1	930	74	2	4,1	15,5
ZAP.E a=32, u=10	-301,2	61,4	5	2,8	0,04	2,18	635	34	1,8	1,6	4,5
ZAP.E a=40, u=20	-344,4	33,8	24,4	1,5	0,12	5,52	0,12	44	2,2	2	7,2
ZAP.E a=50, u=16	-388,8	44,4	39	1,4	0,25	7,39	690	55	2	2,7	11,3
ZAP.E a=50, u=250	-354	3,7	124	0,8	0,09	10,67	895	47	1,7	2,2	4,5
ZAP.E a=80, u=315	-420	2	272	1,3	0,12	27,28	0,12	44	2,2	2	7,2
ZAP.E a=100, u=250	-564	2,8	449	1,5	0,25	42,7	690	55	2	2,7	11,3
ZAP.E a=50, u=40	-336	34,8	47	1,1	0,25	8,72	1380	64	1,9	3,4	6,2
ZAP.E a=63, u=50	-372	13,3	60	1,7	0,12	13,71	0,12	44	2,2	2	7,2
ZAP.E a=50, u=50	-336	27,2	43	1,2	0,18	8,72	1350	60	1,8	3,2	5

Tab. 1 Matrix of input data for multicriteria evaluation

A – price in €
B – output shaft
C – torque at low-speed shaft
D – operating coefficient

E – power transmission
F – gearbox weight in kg
G – speed
H – efficiency in %

I – running torque/nominal torque
J – current running/current nominal
K – motor weight in kg

u:	-1303,2	2	5	0,8	0,04	0,25	0,12	34	1,7	1,6	4,5
a:	-509,5	34,53	116,09	1,63	6,07	14,57	697,53	55	1,97	2,7	8,71
s:	280,98	26,81	121,5	0,532	14,75	12,83	425,1	10,98	0,153	0,682	3,547

Tab. 2 Table artificial vector, average, standard deviation

r[x,y]	x: 1	2	3	4	5	6	7	8	9	10
y: 1										
2	0,181									
3	-0,447	-0,577								
4	-0,460	0,288	-0,066							
5	-0,955	-0,167	0,295	0,502						
6	0,157	-0,011	0,539	-0,326	-0,418					
7	-0,099	0,259	-0,124	-0,157	0,135	-0,144				
8	-0,522	0,254	0,138	-0,161	0,434	0,144	0,618			
9	-0,159	-0,303	0,238	0,024	0,074	0,200	-0,770	-0,106		
10	-0,577	0,150	0,167	-0,124	0,512	0,048	0,660	0,973	-0,123	
11	-0,719	0,102	0,406	0,209	0,533	0,326	-0,005	0,636	0,346	0,626

Tab. 3 Triangular matrix of correlation coefficients

T[x,y]	1	2	3	4	5	6	7	8	9	10	11
1	+*	+**	-**	+	-	+	+	+	-**	-	-*
2	+	+**	-	-*	-	+	+	+**	+	+**	+
3	-	+**	-	+	-	+**	+	+**	+	+**	+**
4	-**	-**	+	+**	+**	-**	-	+	+	+	+
5	-**	-	+**	+**	+**	-**	+	+**	+	+**	+**
6	+*	+**	-**	+**	-	-**	-	-**	-**	-**	-**
7	+	-	-*	-	-	-*	-**	-**	+**	-**	-
8	+	+	-*	-	-	-	-	+	+	+	+*
9	+	-**	+	-**	-	-	+	-*	-**	-*	-**
10	+	-**	+**	-*	-	+**	-**	-**	+**	-**	-
11	-	-**	+**	-	-	+**	-	+	+	+	+*
12	+*	+	-	-**	-	-	+**	+**	-	+**	-*
13	+	-**	-	+	-	-	-**	-**	+**	-**	-
14	+*	-	-*	-**	-	-	+**	+	-**	+*	-**

Tab. 4 The significance level indicators

The correlation coefficient is a measure of linear dependence measures the strength of statistical dependence between two numerical variables. The correlation coefficient can take values from interval <-1.1>. If the correlation coefficient is equal to 0, it means that the variables studied, there is no relationship. If it is equal to one, so quantities are directly dependent on each other, an increase of one variable gives rise to another, where is equal to -1, an increase of one variable causes a drop in second term.

Based on the level of significance of variables we can determine the parameters in which the product is weak (sign -) and where it has strengths.

k1	1
k2	0,81855
k3	0,23387
k4	0,35902
k5	0,01327
k6	0,15086
k7	0,36536
k8	0,04773
k9	0,00662
k10	0,00099
k11	0,00330

Tab. 5 Table reduction constants

Q1	8,0932
Q2	6,4239
Q3	6,5955
Q4	3,5951
Q5	3,4538
Q6	7,3388
Q7	5,2169
Q8	5,9244
Q9	4,6080
Q10	4,5746
Q11	5,3025
Q12	6,2332
Q13	4,7924
Q14	5,9730

Tab. 6 The resulting values

On the basis of a calculation in MS Excel, the resultant of values is listed in Table 6. The program is set up so that the product with the largest value is considered to be the best. The table shows that the best product is on the first place and it has the biggest value.

3. CONCLUSION

Multicriterial evaluation method is based on the qualifications of product parameters using different evaluation indicators. Multicriterial advantage of this method is that it enables to include the influence of various factors with the most diverse physical economic and other characteristics. Using this method we can find out which product is the most competitive of the file.

4. ACKNOWLEDGEMENTS

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Original Scientific Paper

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MATLAB ALGORITHMS FOR THE LIGHTING CONTROL ON THE CONSTANT VALUE

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Abstract: *The solar energy as the part of the state energy management is increasingly going into a lead of analysis and planning by alternative ways of obtaining energy. Without doubts it is one of the cleanest forms of energy. However, its usage entails a number of disadvantages as the seasonality and the dependence on the weather conditions. It is necessary to take these specificities into account during designing the systems involved in using this forms of energy. This contribution is orientated on simulation of light conditions during summer and winter days for needs in development and measurement lightening systems in cowered areas. The results from laboratory conditions are going to be used by improvement of greenhouse lightening systems.*

***Key words** :solar energy, lighting control, Matlab*

1. INTRODUCTION

The Solar energy is inherent part of our existence on the Earth. Its influence on the planet follows us almost everywhere. The production of energies which are necessary for our life (biomass energy, dry mass of economically significant plants) or energies useful for functioning of society is closely linked to the sunlight radiation. Almost all kinds of alternative energy sources are direct or indirect effect of sunlight energy (wind energy, water energy, or energy of biomass).

On the Earth surface falls continually energy flow 1,8 .1017 of Watts. When we re-count this flow into the time units, we get the number 1,52. 109 TW.h.y-1. It means that the sun emits in one hour more energy that human society consumes in one year. On the 1 m2 of surface falls approximately 1,373 kW (it depends on the position location). This number is called "solar constant".

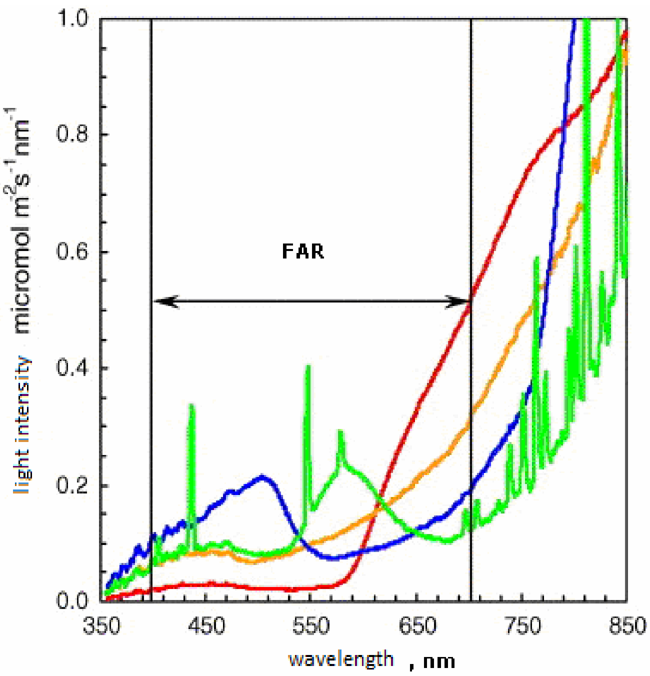
The amount of emission impacted on the unit of earth's surface is not equal to the solar constant. It is mainly affected by the sun location in the sky (above the horizon during the day), seasons, weather conditions and also the amount of impurities in the air. Therefore, the amount of incident energy per unit area varies during the year. We can divide this radiation in three components like a direct sunlight (not changing the direction), diffuse (it disperses on particles of water vapor and dust and reflected (from buildings, objects, water levels and ground).

Plants use the light spectral area between 400 – 710 nm (Photosynthetically Active Radiation PAR) . This area is most useful for its growth. In the spectral area between 750 – 1200 nm plants reflected 40 – 60% of incident radiation. (KOSTREJ A KOL, 1992)

On the PAR assignation we can use the common equation:

PAR = 0,46 x GR

PAR - Photosynthetically Active Radiation



GR - Global radiation

Fig. 1 PAR area for individual color components.

2. MATERIALS AND METHODS

For the algorithms development we used existing knowledge about day light conditions for the specific area (the south – west part of Slovakia). On this base we created the simulation model which serves for algorithms development in laboratory conditions. Simulation algorithm use equations represented the day summer light conditions for the common growing unit. With using of mathematical statistic methods we become equation (figure 2) for the day light conditions simulation.

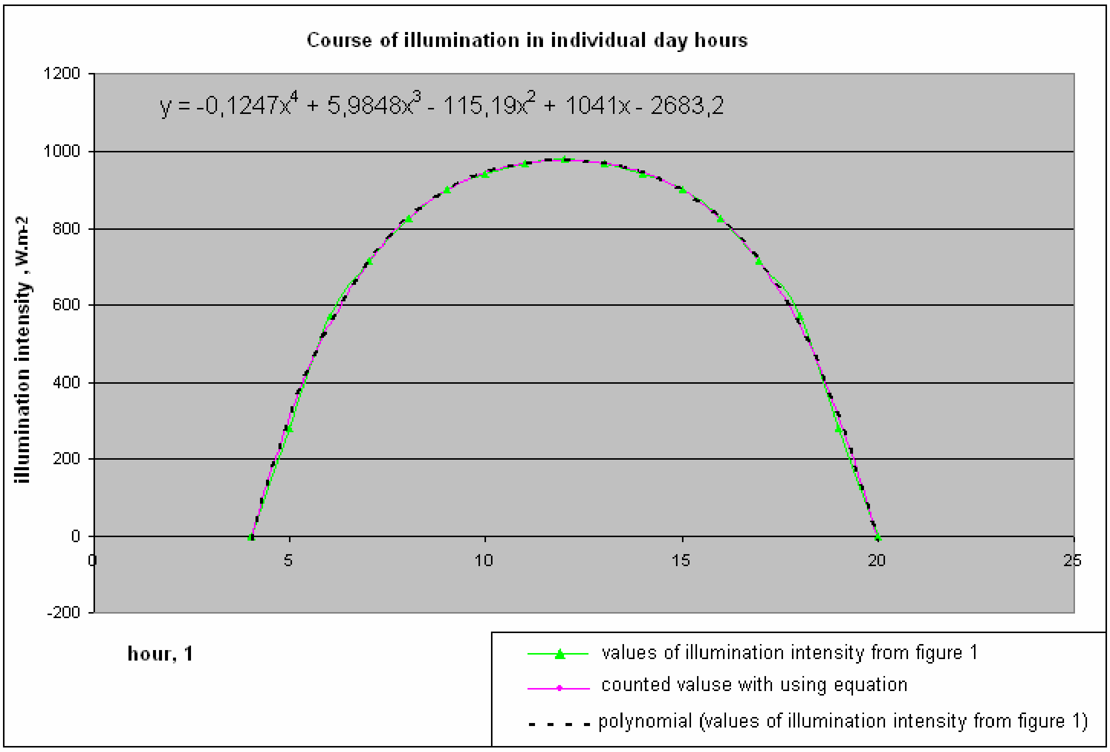


Fig. 2 Calculation of equation for illumination during the month July.

Obtained equation is with using of MATLAB function recounted on the simulation interval and in simulation, circuit (figure 3) converted into simulated day light course. This circuit use 10-bit digital to analog converter implemented in microcontroller SILABS C8051F330 and subsequently controlling of halide lamp (U=230V, P=500W) with using of smart switching relay. The final simulating course is in the sense of the original course (simulation points programmed into microcontroller).

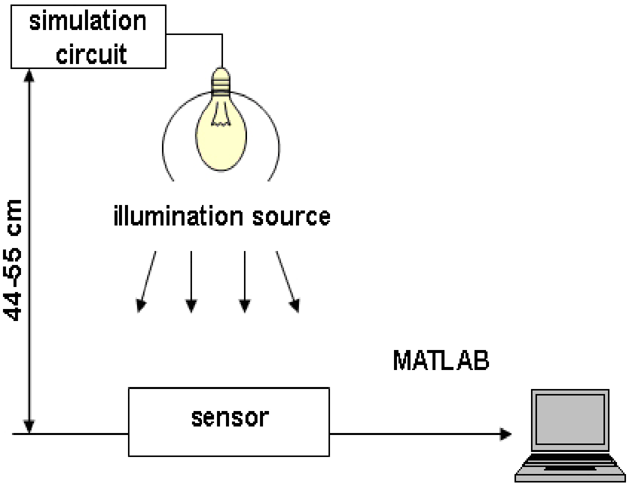


Fig. 3 The block scheme of the light simulation

3. LIGHT MEASUREMENT WITH MATLAB

On the PAR measurement we will use the calibrated sensor and MATLAB conversion which enable us to reach the results in appropriate units of radiation (W.m-2). The illumination sensor was developed at Department of Electrical engineering, Automation and Informatics of Faculty of Agricultural engineering of Slovak Agricultural University in Nitra. It is semiconductor pyranometer based on silicon photodiode with enhanced sensitivity in the shortwave spectral area (400 – 700nm) which is installed in the capsule under interference filter. The filter does not transmit the radiation under 400nm and above 700nm in the whole area of diode sensibility. The combination of correction filters and their thickness were designed with computer program to ensure the minimal aberrance from ideal course. The sensor is by calibration protocol loaded with resistance R=3300 Ω. Then the voltage 1mV on the sensor output means PAR radiation 4, 32 W.m-2.

Measuring board which ensures data collection from sensor and additive thermometers was developed at the department too. Its base is microcontroller communicated with PC through USB interface. 24 bits delta - sigma analog to digital converter serves on converting the voltage value from optical sensor. The microcontroller sends data from thermometers and converter into PC. In the MATLAB program was developed chain for measuring and regulating of artificial lightening (figure 4).
circuit

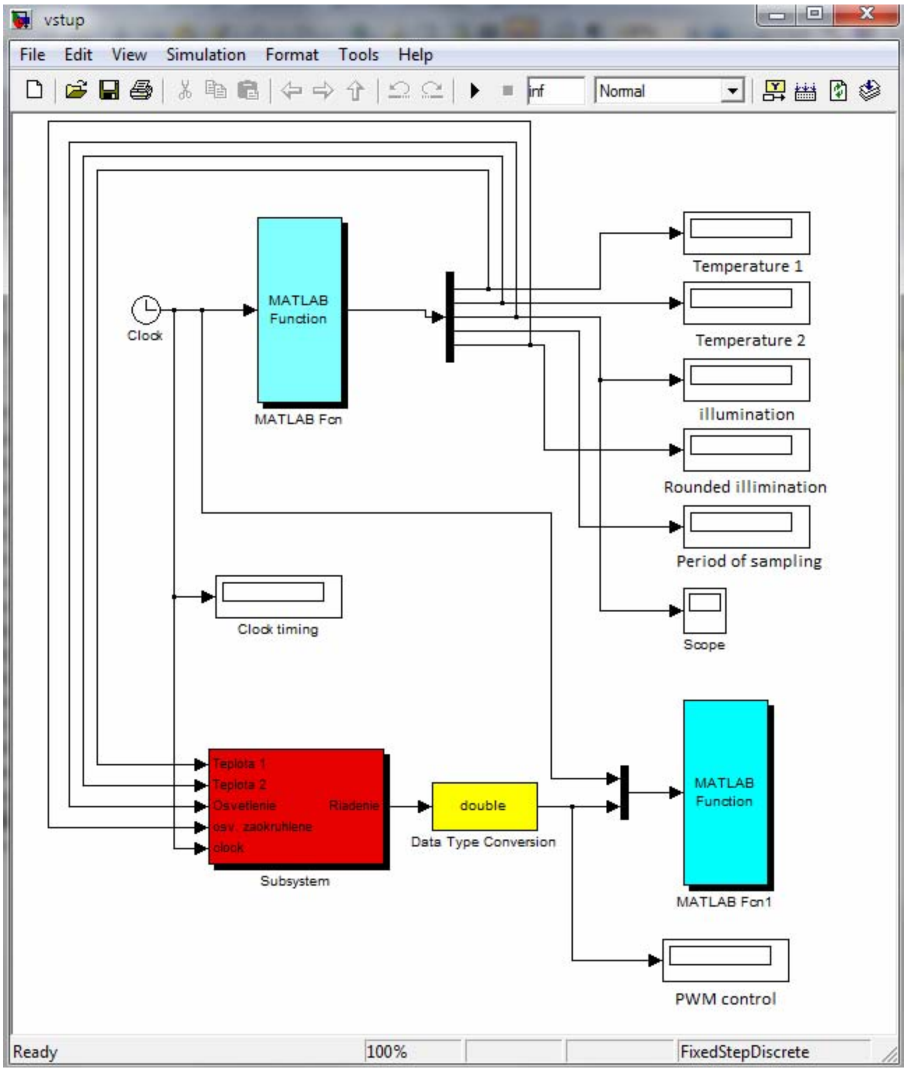


Fig. 4 MATLAB measuring chain for illumination measurements and control.

3.1 The control of illumination on the constant PAR value

On the constant PAR value control we use actuating device and halide low voltage lamp (U=24V, P=150W) set in simulating and measurement MATLAB function so that by the maximal control PWM bit (PWM = 255) what is the maximal light power of the bulb is the corresponding PAR intensity 20W.m^{-2}. On this PAR value is set the control in the MATLAB algorithm too. The simulation is set for the maximal simulated PAR value 25W.m^{-2}. The algorithm for the constant value PAR control use measured data about actual illumination in the system and with using of the differential variable is continuously adding the actuating intervention (PWM controlling bit) and approximates actual PAR value to the requested. The setting of requested PAR value is directly MATLAB program with entering the differential constant into the controlling function. For the higher values of illumination in the laboratory conditions is necessary to use more powerful light sources.

The actuating device for switching of the additional light source consists of MOS FET transistor and isolating optocoupler. The controlling PWM information comes directly from measuring PC, MATLAB program. With using of the measuring board and this actuating device is converted on the electric current through the bulb.

3.2 Measurement of lighting control to a constant value of FAR

Measurement was made in laboratory conditions and the constant value of PAR light was 20 W.m^{-2}. By measurement we used the measuring and controlling board, the circuit for the daylight simulation, circuit for controlling the output actuating value and the MATLAB algorithms for collecting data and counting the results of PWM byte and sending it into actuating device. The measuring period was approximately 5 minutes and during this period two simulation cycles of day and night were changed (from the view of daylight conditions simulation). On the figure 5, we can see the dependence between PWM controlling bit from the changing simulated illumination as an attempt of the system to preserve the constant set value of the lightening.

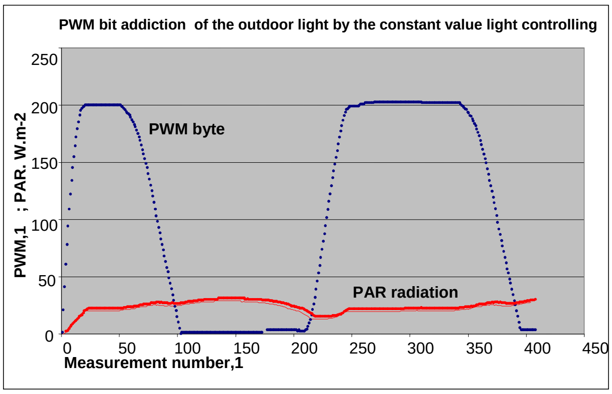


Fig. 5 PWM bit addiction of the outdoor light by the constant value light controlling.

On the figure 6, we can see the functionality of the PWM byte increasing velocity by the lightening control to a constant value and course of the increasing illumination in the system on the requested value of PAR, 20 W.m^{-2}.

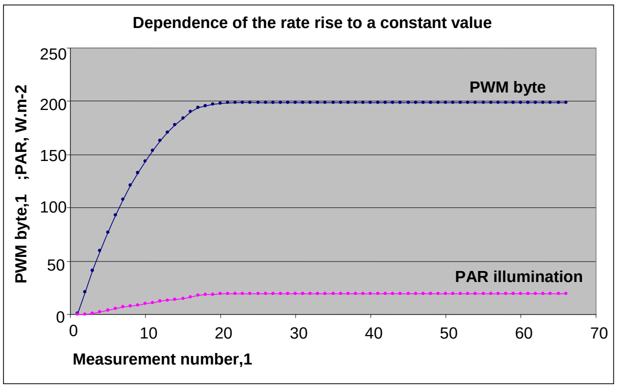


Fig. 6 Dependence of the PWM and PAR rise speed.

4. CONCLUSION

From the course on the figure 6, we can see the slow reaction of the system after starting the light regulation. The reaching of the PAR value 20 W.m^{-2} is in the area of 20 th measuring sample after start what means by the sample period duration 1 s the time 20 s. From the long time view and for the slowly changing actions will be this speed sufficient. However by the fast actions as the light changing is, could be this speed insufficient. By plants and greenhouse, illumination for the need for ensuring sufficient light could be this speed adequate. From measurements displayed on the figure 5, we can see PWM course (blue one) calculated with our algorithm, its increase and attempt to hold the illumination on the requested value. As we can see from courses, the slow speed influence of algorithm is visible mainly by fast changes of simulated illumination. Here occurs variable overshoot of system (we can see the wavy course). In the area behind sample, number 200 is the outdoor simulated illumination falling and the task for system is to hold the set value. In this area is possible to see pulse overshot into the negative values (by comparison with set value 20 W.m^{-2}). For removing of these limitations is possible to make some arrangements like program adaptability into the algorithm. The adaptability will by the predefined changes (rising or falling) make more suitable regulating interventions. General removal of this insufficiency will be reach with using of fuzzy regulation algorithms with predefined regulating rules. For adaptive illumination regulation in greenhouses is this design applicable. The big income by using this type of algorithm will be the energy saving in cases when the illumination it greenhouse area reach the value over the plants needs for their best growing.

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Original Scientific Paper

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OPERATING EXPERIMENT OF SEWAGE WATERS CLEANING IN U.S. STEEL KOSICE, S.R.O. BLAST FURNACE CIRCUIT

Received: 11 September 2010 / Accepted: 15 March 2011

Abstract: *The contribution analyses the operating experiment of sewage water cleaning in U.S. Steel Kosice, s.r.o. blast furnace circuit, which was realized to reduce sewage water pollution, where also Technical University participated. It describes the principle of used equipment involvement, parameters of experiment and based on results of analysis it declares the usability of mentioned electrolytic method. In experimental part aluminium and iron electrodes in various combinations were tested to maximally effectively influence oxidation-reduction processes. In conclusion it gives proposal to situation solution in U.S. Steel Kosice, s.r.o. blast furnace circuit on the base of conducted experiments.*

Key words: *liquids, liquid infiltration, electrical conductivity, oxidation, electrochemistry.*

1. INTRODUCTION

The need of waste water cleaning in blast furnace circuit of sedimentation tank (U.S. Steel Kosice, s.r.o.) resulted from long-term contamination of these waters mainly by soluble substances, as well as high presence of chlorides and cyanides. After each circulation of the waters these concentrations are increasing and therefore the insertion of electrolytic water purification would standardize the soluble substances, eliminate flotate and therefore it could be effective for long-term re-use of the water. Previous experiments were carried out on different industrial waste waters [1][2], mainly on rolling emulsions [3][4], waste waters from heating industry [5][6][7], some in drinking water treatment equipments [8]. The aim of the contribution is to outline the methodology of solution of the waste waters in the blast furnace circuit of U.S. Steel Kosice and propose a solution based on the realised experiments.

2. MATERIALS AND USED EXPERIMENTAL METHODS

2.1 Experiment description

Equipment for waste water treatment was connected by bypassing two places of water circuit:

a) input channel of waste water from the blast furnace circuit from sedimentation tank marked DORR,

b) output channel of waste water from the blast furnace circuit from sedimentation tank marked DORR.

The experiment was carried out on pilot facility designed with using patent solution and utility model [9][10][11], whose carriers are physical persons involved in implementation and which was borrowed to Faculty of Mechanical Engineering. Experimental wastewater cleaning was carried out on different types of electrodes (three sets) and tests were carried out in three modes, which were subjected to analyse 23 samples of purified water and 9 bilge samples, measurements realized by [12][13].

Based on the schedule, tests were carried out during working days, 10.7., then preparation 17.7., 18.7., 1.8. and 4.8., the schedule was also influenced by weather conditions. Samples of water and bilge at the outlet were collected continuously, initial analysis was performed in real time (sedimentation) on experimental workplace, bilge and waste water samples were further analyzed in accredited laboratory of LABORtest, U.S. Steel Kosice, s.r.o..

2.2 Principle of used technology

The principle of used technology is based on electrolysis with aid of patented electrode design, by effect of which comes to oxidation-reduction reactions, flotation of organic substances and sedimentation by effect flocculants from electrode materials and thereby to significant reduction of soluble and insoluble substances in water [14].

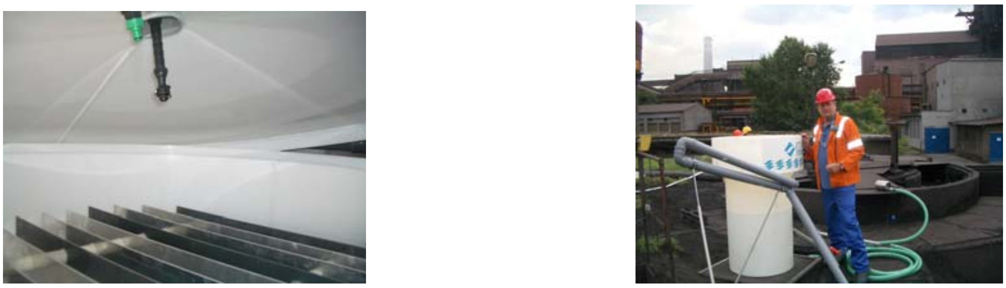


Fig. 1 Installation of a pilot device

Metal electrodes were placed in universal holder, which allowed switch the type of electrodes material, their distance and branchement. Metal electrodes with dimensions 330x330 mm, 2 mm and 3 mm thick plates, two kinds of electrode material: steel and aluminium sheets were used in the experiment. Electrode spacing was 80 mm. Features of the experiment are listed in Tab. 1.

2.3 Conditions of individual experiments

Sample 1 consists of raw water from washing machine. Sample 2, 3, 4 - water is modified electrolytically discontinuously with variable duration of treatment on electrodes in combination Al-Fe in design shown on Fig. 2. Dimensions of electrodes were 330 x 330 mm; separation distance 80 mm, duration of electrolysis and the flow are in Tab. 1. Samples were collected after specified period of sedimentation /10 min./. Parameters of experiment are reported in Tab. 1.

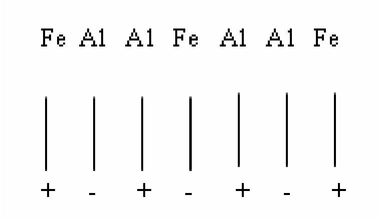


Fig. 2. Way of placement and connection of electrodes I

Sample 5 (water) was treated by continuous way and it was collected after 20 min. of electrolysis and 10 min. of sedimentation. Parameters of experiment are reported in Tab. 1. Sample 6 is unmodified water from DORR. Samples 7, 8, 9, 10, 11 (water) was continuously treated on Al electrodes. Parameters of the experiment are reported in Tab. 1.

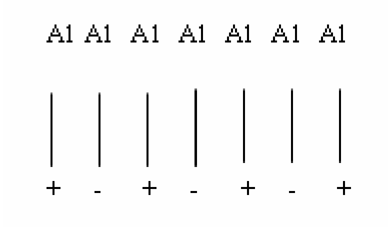


Fig. 3. Way of placement and connection of electrodes II

Sample 12 is unmodified water from DORR. Samples 13, 14, 15, 16 (water) was continuously treated on Al electrodes with reduced distance between them 40 mm. Parameters of experiment are reported in Tab. 1. Sample 17 is unmodified water from DORR. Samples 18, 19 were treated on iron electrodes. Parameters of experiment are reported in Tab. 1.

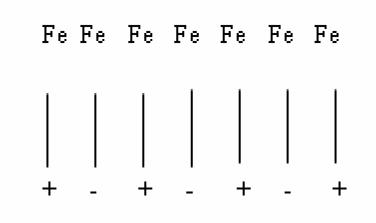
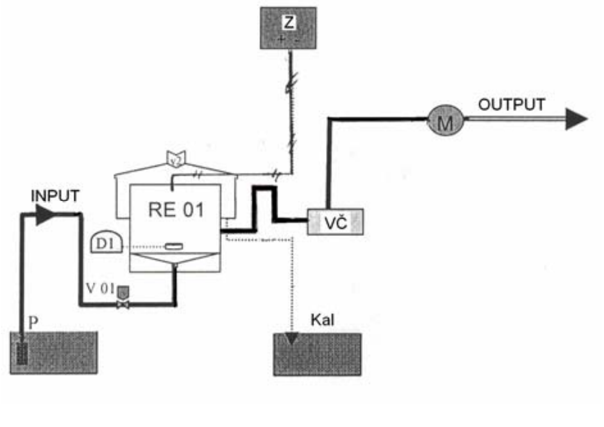


Fig. 4. Way of placement and connection of electrodes III.

Sample 20 is unmodified water from washing machine. Sample 21 was long term treated on iron electrodes. Parameters of the experiment are reported in Tab. 1. Sample 22 is unmodified, diluted washing water in ratio 1:1 with clean water. Sample 23 is water is treated after this dilution. Parameters of the experiment are reported in Tab. 1.



RE - electrocoagulation reactor
VČ - displacement pump
KH - bilge management
D - blowers
V - choke ventil
P - submersible pump
Z - electric power supply
M - measuring
Kal - waste

Fig. 5 Connection of experimental equipment for sewage waters cleaning from blast furnace circuit

3. RESULTS

Performed experiments and measurements confirmed expected results from sewage water cleaning with electrolytic methods. Based on protocols and measurements it is possible to say that this electrolytic method is suitable for:

- cations removing (metal ions) of group III. to XIII. of periodic table,
- acceleration of sedimentation of suspended solids up to about 66%,
- removal of soluble substances, colloidal particles of organic nature,
- removal of soluble substances in lower RL concentration (anions and cations), and it is less suitable for:
- removal of chlorides of alkali and alkalines.

Sample No.:	Test date	Flow [l/min]	I/U [A/V]	Type of el. koag.	Time of el. koag. [min]	Sedimentation [min]	Note	Sample marking
1	17.7.						Unmodified washing machine water	Input1
2	17.7.		180/24	Discontinuous	8	10	Al – Fe electrodes	Input1
3	17.7.		180-24	Discontinuous	4	10	Al – Fe electrodes	Output2
4	17.7.		180-24	Discontinuous	2	10	Al – Fe electrodes	Output3
5	17.7.	160	180/24	Continuous	20	10	Al – Fe electrodes	Konti 2(5)
6	18.7.						Unmodified DORR water	Input1
7	18.7.	160	180/24	Continuous	30	20	Al –Al electrodes	Konti 2(20)
8	18.7.	64	180/24	Continuous	30	20	Al –Al electrodes	Output1
9	18.7.	29	180/24	Continuous	30	20	Al –Al electrodes	Output2
10	18.7.	20	180/24	Continuous	30	20	Al -Al electrodes	Output3
11	18.7.	13,7	180/24	Continuous	30	20	Al -Al electrodes	Output4
12	1.8.						DORR water	Sample1
13	1.8.	20,7	170/13	Continuous	10	20	Al –Al electrodes	Sample2
14	1.8.	20,7	170/13	Continuous	30	20	Al –Al electrodes	Sample3
15	1.8.	43,9	180/13	Continuous	30	20	Al –Al electrodes	Sample4
16	1.8.	43,9	180/12	Continuous	30	20	Al - Al electrodes distance. 4 cm	Sample5
17	4.8.						Unmodified DORR water	Sample1
18	4.8.	38,7	165/15	Continuous	30	30	Fe – Fe electrodes	Sample2
19	4.8.	11,1	165/15	Continuous	30	30	Fez – Fez electrodes	Sample3
20	4.8.						Unmodified washing machine water	Sample4
21	4.8.	37,5	165/15	Continuous	30	30	Fez – Fez electrodes	Sample5
22	4.8.						Unmodified diluted water	Sample6
23	4.8.		105/19	Discontinuous	20	30	Water1:1 El. Fez – Fez	Sample7

Table 1. Description of samples

Water 1:1 - 160 l Industrial water from hydrant + 160 l water from gas washing machine.

type	Unit		Input			Output		Effect.
		Avg.	Dev.	Dev.%	Avg.	Dev.	Dev.%	met. %
pH		7,24	0,22	3,07	7,23	0,13	1,82	0,20
Total cyanides (CN-)	mg/l	0,02	0,01	66,67	0,04	0,03	80,36	-110,00
N-NH4+	mg/l	95,88	23,70	24,71	92,58	17,02	18,38	3,45
Chlorides (Cl-)	mg/l	3260,17	531,11	16,29	3431,44	321,72	9,38	-5,25
Solutes (RL at 105oC)	mg/l	8127,00	1259,67	15,50	8744,82	952,30	10,89	-7,60
Solutes (RL at 550oC)	mg/l	6733,00	1082,33	16,08	7258,24	567,70	7,82	-7,80
Dissolutes	mg/l	651,97	635,16	97,42	77,44	34,13	44,08	88,12
Conductivity	mS/cm	11,14	1,91	17,16	11,57	1,07	9,24	-3,85
Fe	mg/l	10,13	11,94	117,83	5,97	4,94	82,61	41,03
Pb	mg/l	0,45	0,27	59,56	0,29	0,09	30,04	35,62
Zn	mg/l	19,88	25,25	127,04	9,24	9,70	105,03	53,53
Ca	mg/l	840,00	592,00	70,48	1402,31	850,89	60,68	-66,94
Mg	mg/l	160,40	64,48	40,20	331,69	225,37	67,95	-106,79
Sulphates	mg/l	383,20	66,88	17,45	431,31	52,90	12,26	-12,55

Table 2. Experiments statistical evaluation

4. CONCLUSIONS

Experiment results showed that results of electrolytic disposal of sewage waters by electrolytic methods would have shown better parameters of released water at longer period of sedimentation than 10 minutes, because part of pollutants is found in sediment. In future, experiments should continue with electrolytic methods in combination with other methods of wastewater cleaning [15]**Error! Reference source**

not found., based on recommended practices set up pilot plant of technological cleaning line with capacity 1/10 of required flow rate (approximately 100m^3/h) and at pilot plant start-up use blast furnace water after one cycle from filling change in the circuit as starting water, not in current state of pollution.

5. ACKNOWLEDGEMENTS

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Original Scientific Paper

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CONCENTRATION OF SOLID AEROSOLS IN WORKING ENVIRONMENT

Received: 01February 2009 / Accepted: 02 June 2009

Abstract: *Solid aerosols are very important as one of factor of working environment. Methodology of dust measurement in working environment is not united but some deciding factors must be observed. In the paper there is described possibility how can be realized measurement of concentration solid aerosol in working environment.*

Key words: *measurement, solid aerosols, concentration*

1. INTRODUCTION

There are things floating around in the air. Most of them, you cannot even see. They are a kind of air pollution called solid aerosols. In fact, it may be the air pollutant that most commonly affects people's health.

Measurement of solid aerosols in working environment is unnecessary for assessment of concentration of solid aerosols in working environment and next measures for reducing exposition of solid aerosols.

2. FRACTION OF SOLID AEROSOL

The most important factors of dust measurement are:

- location,
- time,
- time of taking sample.

Particles can come in almost any shape or size, and can be solid particles or liquid droplets. We divide particles into two major groups. These groups differ in many ways. One of the differences is size. For measurement in working environment are desirable divide solid aerosols to two size fractions:

- respirable,
- inhalable.

Respirable fraction is created by the particles with diameter to 2,5 µm. Inhalable fraction is created by the particles which is possible inhalate by the nose or mouth (respirable fraction is included).

3. PROCES OF MEASUREMENT

After the fraction assessment which is going to be measured is necessary to set location for sample taking and have to be executed decision if stationary or personal sample taking will be realized. Stationary sample taking is dust sample taking whole time of measurement realized at one station. This station is chosen by the experienced person or this station is desired by the state institutions.

Equipment for personal sample taking is placed directly to worker and solid aerosol are taking by sampling equipment near the respiratory tract of worker during whole working period.

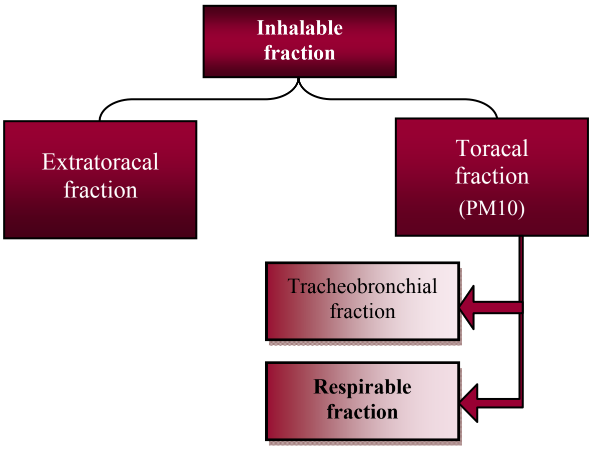

Fig. 1 Fraction of solid aerosols

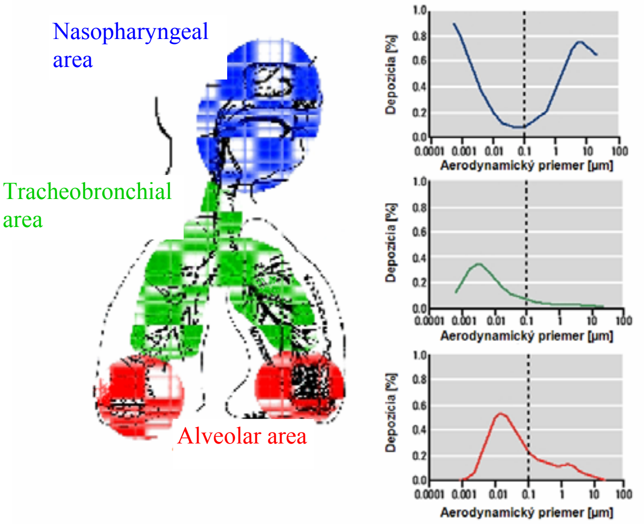

Fig. 2 Assumed deposition of inhalable aerosols in human body

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On the base of employer request realized measurement of solid aerosol was executed at the determined working stations.

The scope of the measurement was assessment of overall concentration of solid aerosols in the air in working environment during the welding operations and next comparison with limit values.

Acquired value will be decided for workers classification to risk groups.

3.1 Description of working environment

Company where is measurement executed is concerning about production and assembly of steel constructions. Employers are mainly welders, fitter, setter and help workers.

Measurement was executed in component building 90 x 21 m. Building consist of three main parts: storehouse of materials, shearing workstation, assembly workstation where measurement was realized (Fig.2). Building is self ventilated and there are also added air compressors.

Disposition of working station and working places where was measurement executed are displayed in Fig. 3 (P1, P2, P3 are places where measurement was realized).

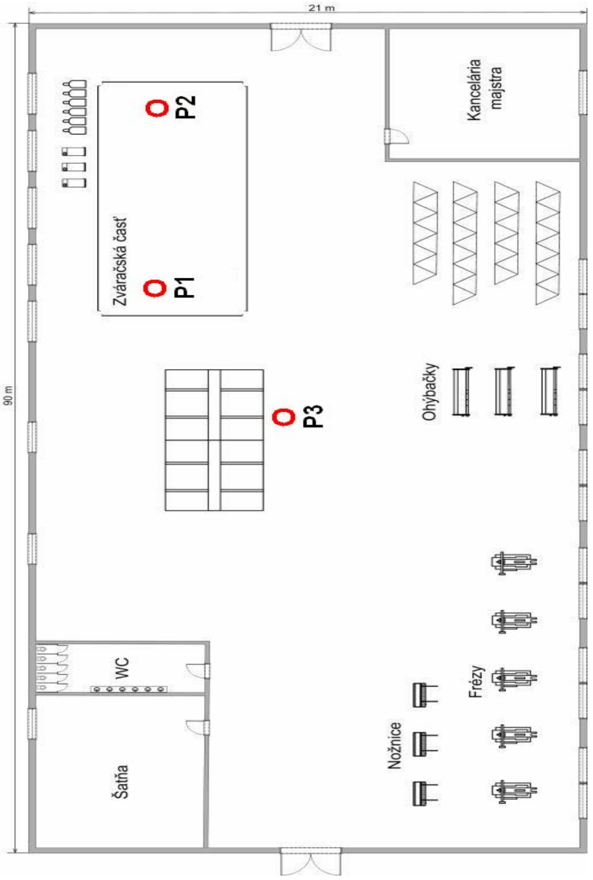

Fig. 3 Disposition of working station and working places

3.2 Execution of the measurement

During welding operations are produced different pollutants, Influence of these pollutant to human health is very negative. Other negative influence to welders is noise, vibrations, physical weight, radiation and unsuitable working positions but the most negative factor is inhalation of solid aerosols.

Unnecessary condition for measurement is important period of measurement. Span of measurement have to be at least 75 % of working period. During this period is acquired sample which is representative. Measurement was scoped for assessment of concentration of solid aerosols by personal sampling.

Used equipment:

- personal sampling pumps AirCheck 2000,
- sampling heads IOM for sampling inhalable and respirable fractions of solid aerosols,
- glass microfibre filters GMF,
- calibrated air flowmeter DC-Lite.

System for sampling is displayed in Fig. 4 with detail of sampling head.

Fig. 4 Sampling system

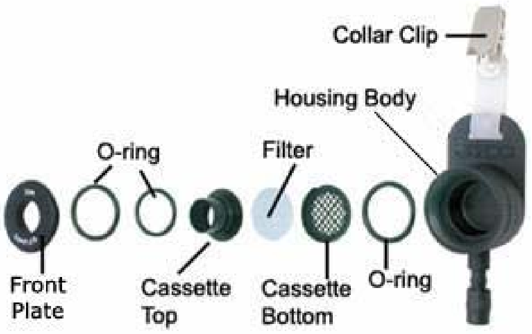

Fig. 5 Detail of sampling head IOM

Concentration of solid aerosols in the air is evaluated by gravimetric method. The case with filter has to by weight before and after measurement. Difference between weigh before and after is weight of solid aerosols. Proportion between weight of solid aerosols and airflow is assessed concentration of solid aerosols in working environment. Personal sampling air pumps were placed to three workers, two welders and one fitter. For each working position was realized three samplings. After the sampling was determined capacity of the air intake air pumps. And after the measurement were always changed filters. The used filters were subsequently in laboratory evaluated by the gravimetric method. Each filter was signed by numeric symbols. Time average concentration of solid aerosols was appointed from acquired three samples.

The concentration of solid aerosols is also based on weather conditions, such as temperature, humidity and wind direction.

During the measurement were captured microclimate conditions. Microclimate conditions during the measurement are displayed in table 1.

Time of measurement (h)	Temperature (°C)	Atmospheric pressure (kPa)	Relative humidity (%)	Airflow velocity (m.s^{-1})
P1				
9:30	14,8	98,4	38,3	0,16
11:00	15,0	98,4	35,5	0,15
13:30	15,8	98,4	31,5	0,09
P2				
9:30	14,5	98,4	38,1	0,16
11:00	15,7	98,4	35,1	0,19
13:30	15,6	98,4	32,5	0,14
P3				
9:30	14,7	98,4	36,1	0,13
11:00	15,3	98,4	36,1	0,07
13:30	15,2	98,4	33,6	0,06

Table 1. Microclimate conditions

During measurement were also captured macroclimate conditions.

Macroclimate conditions were sampling before and after measurement of concentration solid aerosols. Macroclimate conditions are displayed in table 2.

Time of measurement (h)	Temperature (°C)	Atmospheric pressure (kPa)	Relative humidity (%)	Airflow velocity (m.s^{-1})
7:50	4,1	98,4	57,2	0,55
13:40	7,4	98,4	47,8	1,78

Table 2. Macroclimate conditions

4. RESULTS OF MEASUREMENT

In Slovak republic limits of solid aerosols are appointed in government directive. Allowed limit of concentration solid aerosols for welding operations is 5 mg/m^3. After measurement in laboratory was appointed time average concentration of solid aerosols, and concentration was compared with allowed limits.

Results are displayed in table 3.

Sampling point	Time of measurement (h)	Overall concentration of solid aerosol (mg.m^{-3})	Time average of concentration solid aerosol (mg.m^{-3})
P1	8:00 – 9:30	0,173	4,22
	9:30 – 11:00	0,176	3,74
	11:00 – 13:30	0,286	5,37
P2	8:00 – 9:30	0,172	9,54
	9:30 – 11:00	0,176	11,56
	11:00 – 13:30	0,296	7,45
P3	8:00 – 9:30	0,173	5,84
	9:30 – 11:00	0,177	3,66
	11:00 – 13:30	0,296	4,26

Table 3. Results of sampling

Results of sampling and valid limits are compared in table 4. One value is above the limit which is parliamentary.

Sampling point	Time-weighted average of overall concentration (mg.m^{-3})	Limit (mg.m^{-3})	Suitable or unsuitable
P1	4,90	5,00	suitable
P2	9,70	5,00	**unsuitable**
P3	4,84	5,00	suitable

Table 4. Valid limits

Measurement findings show that allowed limits get over for working position P2 – welder and due this reason have to be executed unnecessary measures. Other two working positions (P1 and P3) are under the allowed limit.

4.1 Proposed measures

Due the reason of exceeded allowed limits (almost double) have to be executed next measures:

- increase performance of air climate equipment,
- use personal protective equipment (for example: respirators),
- change the risk group of workers (replaced from 2nd group to 3rd) and it means often medicine control, wage supplements.

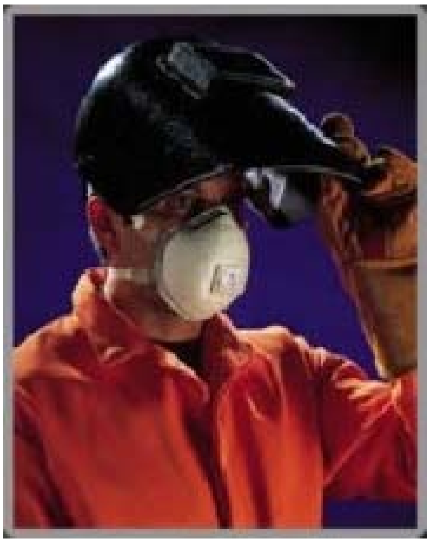

Fig. 6 Personal protective equipment

5. CONCLUSION

Final decision which measure will be realized in the concrete workstation is up to management. If measures are sufficient, will be shown after the next measurement of concentration solid aerosols. Very important are also preventive arrangements (modification of technological process, modification of exposition).

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Preliminary Note

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INFLUENCE OF THE SIZE OF ORGANIZATION TO THE QUALITY OF FACTORS IN COMPARISON TO THE SUPPLIERS IN THE QUALITY SYSTEM

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Abstract: *Suppliers are important connection and link in "the value delivery system" to the consumer. They supply organization and its competitors with necessary resources for production of goods and services. Development of suppliers can significantly affect many aspects of business of organizations. Fostering of good business relationships with suppliers is the task of all who are in contact with them. Suppliers should be included into the quality management system, and document the responsibility for the quality of their deliveries.*

The scope of this paper is to show what the organizations acquired with introduced and certified quality system in relations with suppliers. Special attention will be directed towards the influence of the size of organizations to increment of quality factors in relations with suppliers.

Key words: *size of organization, quality system, suppliers, influential factors*

1. INTRODUCTION

One of the most important characteristics of present world on the whole is extremely fast changes imposed by the wealthiest countries, but even less developed countries follow them "closely". Global changes in the market, new technologies, new manufacturers and suppliers, bigger and bigger demands by the customers, cause new style of system management where the management must find effective and fast solutions. This means, to produce what the market wants with a certain level of quality, acceptable price and deadline and with continuous increment of satisfaction of customers and other interested sides.

Whether the quality is a problem or resource of some organization depends of the basic standpoint towards quality in the organization. Today, over million organizations in over 176 countries [1], have decided to confirm their management quality system by a certificate of quality system according to ISO 9001:2008. These standards are also based on eight quality management principles, where one of these principles is "mutually beneficial relationships with suppliers". Mutually beneficial relationship tries to nurture itself because of the basic reason that suppliers provide products and services which are going into business processes, meaning that in large extent they affect the quality of business processes materialized through a product or service. Therefore, special attention and responsibility is paid to determination of eligibility and selection of suppliers for products and services.

Specifically, the relentless pressures to reduce costs have forced organizations to find innovative ways for offering high performances of its products at low prices. This has led organizations to assess the role of their suppliers in the supply chain as a possible source of increased profitability and reducing costs. However, reducing costs and improving the total value cannot be observed as an isolated initiative. Organizations need to understand that there are limitations in terms of how the supplier can reduce its prices, and still remain viable.

The traditional relationship between the organization and suppliers should be converted into the one that is helping to build closer ties and fostering continuation of cooperation between both parties to their mutual benefit. Collaborative relationship means a readiness of both parties to discuss future plans, a readiness to understand business processes of each other, determination for sharing in mutual long-term strategy and an agreement for sharing in savings which are generated by joint activities. So, there must be a change of culture in which the top management and anyone else in organization who interact with suppliers begin to treat suppliers as partners but not servants. This means communication and cooperation, which is bidirectional starting from product design to the delivery to the final user.

The scope of this paper is to determine what have the organizations that introduced quality system according to demands of ISO 9000 standards acquired in relations with suppliers (which benefits they have experienced) as well as how the size of organizations affect the relationships with suppliers. The assumption is that large organizations, and especially service organizations, achieved better relationship with their suppliers than the small organizations. There are many reasons for this, and one of the primary ones is that large organizations are still greater and more regular customers, and thus probably more stable for payment.

2. METHODOLOGY OF RESEARCH

Research of the effects of B&H organizations which have introduced and certified their quality system according to demands of standard ISO 9001:2000 is defined in this paper as empirical research (because authors have chosen direct observation of selected segment from the real environment and analysis of collected information in it) [2]. For collection of quantitative information was used one of four main ways – a questionnaire. Authors shaped the questionnaire in a way to have it as simple as possible, thorough and reliable, made in the way of claims and questions so that its filling needs as less time as possible. In the view of time dimension the research was limited only with one time point, i.e. research of the time review, while from the point of view of originality the research goes towards research with primary performance because it is based on original empirical data. It is one of the first researches on that area in selected environment (B&H) and in such volume. The research is structured in the way to enable comparison or possible repeated performance after certain time, and in time it could become starting research (starting point) of study which could be continued on that "follow-up study" [5].

2. 1. Triangulation method

During integral research presented in [16] authors used triangulation method. It refers to the usage of more than one approach in procedures of researches in the purpose of strengthening of trust into results of researches. Webb and Denzin defended the fact that ***the hypothesis verified-experienced by more methods is more worth from the one that is verified-experienced by only one method***. Denzin recognizes four sorts of triangulation: methodological triangulation, data triangulation, triangulation of research and theoretical triangulation. [6]

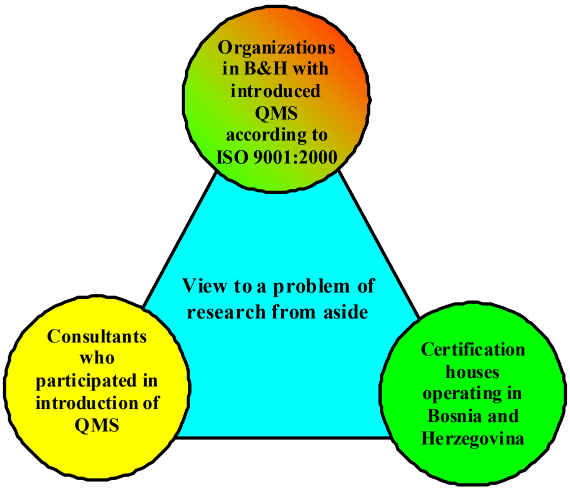

Fig. 1 Overview of triangulation method used in paper [2,3]

In this paper **data triangulation** is used in a way that authors could gathered information on the same issue from various sources, as well as the usage of different kind of information (qualitative and quantitative) collected by various methods. Information that refers to the problem of research of effects acquired by organizations in B&H was given by the following sources (Figure 1) [2].:

- Organization with certified quality system according to ISO 9001:2000,
- Consultants who worked on preparation of those organizations for introduction of quality system, and
- Certification houses that certified those systems.

2.2. The conduction of the information collection plan

The postal questionnaire was selected for information collection. Table 1 shows described conduction. As for the phone and personal contacts authors limited themselves to remind and ask people to fill questionnaires and return them. In this way could be fulfilled one of the key conditions for objectivity of research.

Statistical population - for the organizations - for the consultants - - for the certification houses	- organizations in B&H which posses introduced QMS according to requirements of standard ISO 9001:2000 - consultants who operate in the area of B&H - certification houses which operate in the area of B&H
Unit of the sample	Individual organization, consultant and certification house
Limits of sampling - for the organizations - for the consultants - for the certification houses	660 organizations from the population (from B&H) 70 consultants (addresses from authors data base) 14 houses (addresses from authors data base)
Size of the sample - for the organizations - for the consultants - for the certification houses	- planned out of 120-150 units – 204 units achieved - planned and achieved 31 units - planned 10 units – 11 units achieved
Procedure of sample choosing	Random sampling inside the population
Researching instrument	Structural questionnaires
Acceptance of the researched factor	Mark of the factor ≥3,70
Method of information collection	Combined postal method, supported phone calls and contacts through certification houses and ministries

Table 1. The conduction of the information collection plan [2,3,4]

3. REPRESENTATIVENESS OF THE SAMPLE

As for the organizations the situation is as follows: Regarding the activity all organizations gave the answer, and the structure is as follows (Figure 2): eighty two (40,2%) organizations were service organizations, 24 (11,8%) were mainly service organizations, 72 (35,3%) were manufacturing organizations and 26 of them (12,7%) were mainly manufacturing organizations. This means that authors received closely the same sample for manufacturing and service organizations, that is insignificantly more service and mainly service (52%) organizations in comparison to manufacturing and mainly manufacturing (48%). **This points to a change of belief that only or mainly manufacturing organizations dominate in the certification process.** [2,3].

Answers to a question regarding the sort of company were as follows: Answers to a question regarding number of employees were as follows (Figure 3): eighty seven organizations have got up to 50 employees (42,65%), 81 have got between 51 and 250 employees (39,7%) and 36 organizations have got more than 250 employees (17,65%). Here it can be seen that every group for itself can represent minimal statistical sample. [2,3,4].

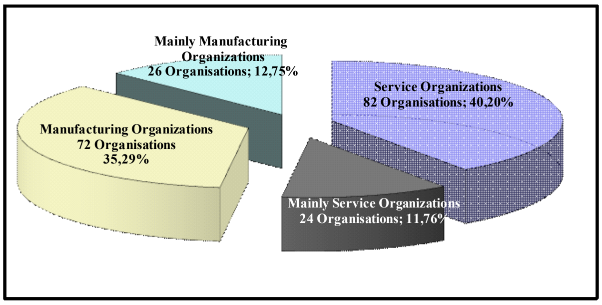

Fig. 2 Overview of organizations per activity [2,3,4]

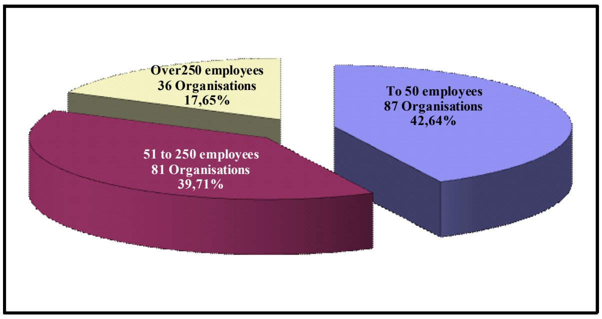

Fig. 3 Overview of organizations per number of employees [2,3,4]

Answers to question regarding the year of acquiring of the certificate: Sixty two organizations (30,4%) acquired certificate in the period 1997-2003 and 142 organizations (69,6%) acquired certificate in the period 2004-2008. [2,3,4].

4. RESULTS OF THE RESEARCH

4.1. Influence of introduced quality system to the factors of quality of supplier

Suppliers are very important link in entire chain of production. Total result of the whole process for having the final product depends on suppliers' quality, timely delivery and satisfaction. Correspondents had to answer to eight questions about the influence of standard to the factors of quality of suppliers. Persons who filled that questionnaire from 191 organizations gave information about it. Out of those 191 there were 115 (60%) business-functional managers, 15% of them were chief managers – directors of organizations, and others were managers for quality in organizations.

Table 2. shows parallel analysis of the influence of standard to factors on quality of suppliers. Marks were given by the organizations – their functional managers, consultants and certification houses. Average marks given by the certification houses are pretty identical with marks given by the functional managers from organizations as well as with marks given by the consultants. Certification houses graded only one factor as bellow the average, which is: "Response and accuracy of suppliers are improved", and consultants gave "negative" mark to the factor of "Satisfaction of suppliers has increased", while the organizations graded all factors positively. Everybody gave the best mark, i.e. first place to the factor of "Procedure for selection of suppliers". Change occurred on next two places where the consultants gave better marks to a factor of "Better quality of supplying function" than to a factor of "Improvements of partnership relations with suppliers". Consultants as well as certification houses identically graded these two factors.

The biggest change occurred at question of "Improvement of response and accuracy" where the certification houses made difference for 0,41 point in comparison to organizations, and 0,37 point in comparison to the consultants.

4.2. The influence of size of organizations to the achieved factors with suppliers

In the continuation we will take a look at the results that organizations have achieved and consider them mostly in terms of the size of organization. Besides the size of organization, this work [2] considers the influence of activity (manufacturing or service organization) as well as the year of acquiring the certificate, that is introduction of quality system into organization.

Table 3. presents the influence of number of employees to better quality of a part of purchasing function as well as to the procedure for selection of supplier. The Table shows that there were big differences made where large organizations (with over 250 employees) achieved significantly better results compared to medium and small organizations.

Influence of the size of organization on a better quality of the purchasing function		AV	SD
1.	With over 250 employees	4,15	0,51
2.	With 51-250 employees	3,96	0,56
3.	With less than 50 employees	3,78	0,80
Influence of the size of organization on selection procedure for suppliers		SV	SO
1.	With over 250 employees	4,26	0,67
2.	With 51-250 employees	4,11	0,69
3.	With less than 50 employees	4,11	0,65

AV – Average Value; SD – Standard Deviation

Table 3. Influence of number of employees to the quality of a part of purchasing function and procedure for selection of supplier [2]

Improvement of purchasing function as well as a very good selection of supplier did not adequately made an impact on shortening the ordering time AV 3,82; and SD 0,86. When crossing the factors it was noticed that large organizations with over 250 employees achieved the effects in ordering time with AV 3,94; compared to medium organizations with 51 to 250 employees where AV is 3,74.

Table 4. presents the influence of number of employees to the completeness and reliability of supply. The Table again shows that large organizations (with over 250 employees) achieved significantly better results compared to medium and small organizations. The mark of organizations considering the influence of standard to improvement of response and accuracy of the suppliers is 3,81; and SD is high 0,79. Although 73% of organizations opted for a mark 4 or 5, marks of organizations are very dispersed around average value.

	Factor/Marks	Answers given by the organizations			Answers given by the consultants			Answers given by the certific. houses		
		AV	SD	rank	AV	SD	rank	AV	SD	rank
1.	Quality of the part of supplying function is better	3,92	0,68	3	3,90	0,61	2	4,00	0,47	2
2.	Procedure for selection of supplier is improved	4,14	0,67	1	4,20	0,55	1	4,20	0,63	1
3.	Time of ordering performance is shorter	3,82	0,86	6	3,83	0,75	6	3,80	0,42	4
4.	Quality of supply has improved	3,88	0,77	5	3,87	0,65	4	3,80	0,63	6
5.	Response and accuracy are improved	3,81	0,79	7	3,77	0,73	7	3,40	0,52	8
6.	Reliability of suppliers has improved	3,89	0,79	4	3,83	0,66	5	3,80	0,42	4
7.	Satisfaction of suppliers has improved	3,79	0,78	8	3,67	0,76	8	3,70	0,48	7
8.	Partnership relations with suppliers have improved	3,99	0,78	2	3,87	0,73	3	4,00	0,47	3

AV – Average Value; SD – Standard deviation;

Table 2. Parallel overview of the influence of introduced quality system to the factors on quality of suppliers [2,3]

Influence of the size of organization to reliability of supply		AV	SD
1.	With over 250 employees	4,03	0,68
2.	With 51-250 employees	3,91	0,69
3.	With less than 50 employees	3,79	0,86
Influence of the size of organization na pouzdanost dobave		SV	SO
1.	With over 250 employees	4,03	0,73
2.	With 51-250 employees	3,84	0,64
3.	With less than 50 employees	3,77	0,93

Table 4. Influence of number of employees to completeness and reliability of supply [2]

In the crosses of factors, the highest AV was achieved by service organizations which acquired certificate before year 2003 and which have over 250 employees (AV is 4,06), and the lowest value was given to organizations which acquired certificate in the period after year 2004 and which hire up to 50 employees (AV is 3,47).

Satisfaction of suppliers received a score of AV 3,79; and SD is high 0,78, and this represents the lowest value among the factors of quality of suppliers, but still satisfactory. In the crosses of different factors we noticed only the influence of the year of acquiring the certificate.

Table 5. presents influence of number of employees to partnerships with suppliers. It is again evident that large organizations developed better partnerships than medium and small organizations.

Influence of the size of organization on partnership with suppliers		AV	SD
1.	With over 250 employees	4,15	0,67
2.	With 51-250 employees	4,04	0,67
3.	With less than 50 employees	3,88	0,89

Table 5. Influence of number of employees to improvement of partnerships with suppliers [2]

5. CONCLUSIONS

Introduced quality system in BH organizations had a positive impact on all investigated factors related to suppliers. The philosophy and relations must lead to a "win-win" results for both the organization and suppliers. Any other approach, such as traditional scenario in which negotiations are one-sided, will be resulted and will affect an overall performance in the value chain.

Large organizations have achieved better results in their relations with suppliers compared to medium and small organizations. This can be interpreted precisely with their size, or the need for bigger quantities of supply in comparison to small and medium organizations.

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Preliminary Note

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INTELLIGENT PRODUCTION SYSTEMS AND CLAMPING SYSTEMS FOR INTELLIGENT PRODUCION SYSTEMS

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Abstract: *Within solving the project „Intelligent Assembling Cell“ in the Institute of Production Systems and Applied Mechanics this paper goes into concepts like production system, intelligent production system, clamping system. Further it addresses characteristics, division and requirements of clamping systems used in intelligent production systems.*

One of the project aims „Intelligent Assembly Cell“ is to replace the existing pneumatic clamp placed on the work board in the workplace of the Cartesian robot by a clamping device suitable for working in intelligent production systems.

Key words: *production system, flexible production system, intelligent production system, clamping system*

1. INTRODUCTION

Before mentioning clamping device for intelligent production systems it is necessary to clarify the terms: production system, flexible production system and intelligent production system. The mentioned terms are not clearly defined in any standard and this is a reason of their different interpretation in literature.

The paper also addresses the concept of clamping system what is actually one of subsystems of the production system. The clamping system itself consists of main and auxiliary structural elements, driving mechanism, control system including monitoring elements. Clamping systems determined for intelligent production systems have to satisfy special requirements.

2. TERM OF PRODUCTION SYSTEM

2.1 Production System

The term of production system is not clearly defined, in available literature there appear even several definitions of the term – production system.

For example the production system can be understood as units beginning from an individual machine and group of machines up to the whole plant including construction and assembly.

Another interpretation of the term: The production system can be defined as a group of production machines consisting of several subsystems the role of which is to execute a specified production process aimed at processing a semi-product into a required finished product.

Production system can be divided into two main subsystems:

- subsystem providing for the production process itself,
- subsystem providing for preparation and control of the production process.

Based on production process it is possible to divide the production system core into individual subsystems:

- control and information,
- technological,
- handling and transport,
- measurement and checking,
- storage.

2.2 Flexible Production System

Analogous to the term of production system also the term of flexible production system is not clearly defined and that´s why there are various interpretations in literature.

The flexible production system is represented by minimum three or more machines and is characterized by a lower degree of flexibility that means a closer assortment of components made in bigger lots (small-lot and lot production).

It also is stated that a groupment of several flexible production cells or flexible production cells and modules formed mostly by CNC machines and connected via one common transport and control system can be named a flexible production system.

Flexible production systems can be divided into three basic types:

- flexible production cells,
- flexible production systems,
- flexible production lines.

All above mentioned types of flexible production system are in principle of the same composition and consist of individual subsystems:

- control and information,
- technological,
- handling and transport,

- measurement and checking,
- storage.

2.3 Intelligent Production System

Artificial intelligence is explained as an attribute of technical systems (it can be talked about machine intelligence). Artificial intelligence is an attribute of the system artificially created by a human, characterized by an ability to distinguish things, phenomena and situations, analyze relations between them and create so an internal world model where these systems exist.

Characterization of artificial intelligence enables to determine explicitly and appoint partial theoretical tasks falling withing artificial intelligence. Artificial, the so called machine intelligence includes tasks like recognition and processing of visual information or language, automatic planning, solving of tasks by consideration, adaptation and learning, expert systems, communication with computer in natural language.

Intelligent system is a system with intelligence that enables it to know and understand reasons of changes, utilize these information for learning and adapt to changed conditions.

Intelligent systems with machine intelligence include systems able:
- to learn from data and acquire knowledge from data,
- store acquired knowledge, and
- make use of acquired knowledge.

Intelligent production system can be regarded as the highest development level of flexible production systems which must be equipped with means and methods giving a certain intelligence degree to these subsystems.

Or it is stated that the intelligent production system can be defined as a system able to respond to various situations occurring in production that means change in shape of the component being made, change in dimensions, sudden transfer to another type of product etc. The specific reaction can be reached by means and elements of machine intelligence that should be contained in individual subsystems of the intelligent production system.

Ability to process the primary information entering the system by means of sensors or intelligent sensory elements is an attribute of production monitoring systems.

Monitoring is an integral part of today´s production systems, the so called systems of new generation, intelligent production systems.

3. CLAMPING SYSTEMS FOR INTELLIGENT PRODUCTION SYSTEMS

Clamping system is one of production system subsystems. Having explained terms of production system, flexible production system and intelligent production system it can be said that clamping system for intelligent production systems must serve as a classical clamp and in addition it must be equipped by a control system including monitoring elements and drives.

Clamping system consists of:
- main elements (clamp body, moving parts, grip etc.),
- auxiliary structural elements (screws, pins, stops etc.),
- driving mechanism (e.g. pneumatic),
- control system including monitoring elements (various sensors).

Generally, clamps have to satisfy following functions:
- position the workpiece,
- fix the workpiece taking regard to action of forces and moments during production process.

Intelligent clamps must provide for following functions:
- check presence of grip in case of replaceable grip,
- check grip position to be able to insert the workpiece,
- position the workpiece,
- check presence of workpiece,
- fix the workpiece with regard to action of forces and moments during production process,
- check clamping of workpiece, value of clamping strength,
- self-diagnose driving system and in case of need to report the condition of the clamping system to the superior control system.

4. FLEXIBLE PRODUCTION CELL

In the Institute of Production Systems and Applied Mechanics – Department of Technological Equipment and Systems there is a flexible production cell (Fig. 1.) which consists of 2 main subsystems:
- 3-axial portal SMC robot,
- shelf stacking machine.

Fig. 1 Present status of flexible production cell in UVSM

4.1 3-axial portal SMC robot

The kinematic chain of the 3-axial portal SMC robot consists of translational kinematical couples with a motion possibility in axes X,Y,Z. This arrangement of kinematical couples enables maximum utilization of working place and positioning is relatively precise. Bad access to individual components is a disadvantage of this system.

The robot´s working place is shaped like a block with dimensions 1000x1000x300mm. The supporting frame and four legs are made of dural profiles. The supporting frame includes a grooved height-adjustable working board. Grooves in the working board serve for fixing the stand of tools for automatic tool replacement, tool magazine, rotary unit, pneumatic clamp, etc. The robot´s load capacity is 10 kgs.

3-axial portal SMC robot consists of (fig. 2):
- robot driving mechanism,
- robot control,
- stand of tools for automatic tool replacement,
- tool magazine,
- rotary unit,
- pneumatic clamp,
- finger magazine,
- AHC unit (AHC – system for automatic finger replacement).

Fig. 2 SMC robot

4.2 Shelf stacking machine

The shelf stacking machine is placed on the right robot side. Its frame is made of dural profiles. The pallets made of thick plexiglass are placed on legs in the shelf stacking machine. Capacity of the shelf stacking machine is 13 pallets of 250x250mm with maximum weight of 3 kgs. Components exchange between the shelf stacking machine and the robot is provided by a rotary unit – a swivelling table. Removal of pallets from the stacking machine to the swivelling table is done by means of a travelling linear pneumatic manipulator.

Shelf stacking machine consists of (fig. 3):
- shelf,
- mobile linear pneumatic manipulator.

Fig. 3 Shelf stacking machine

Pneumatic clamp

Pneumatic clamp (Fig. 4.) is placed on the work board in the workplace of the Cartesian robot and serves for clamping of components. Grip drive of the clamp is ensured by means of linear double-acting rolls. Grip movement is synchronized through the geared transmission. At present this clamp is not equipped with means and elements of machine intelligence; well it doesn´t meet the basic requirement of clamps determined for intelligent production systems.

Fig. 4 Present status of pneumatic clamp in the flexible production cell

5. CONCLUSION

One of the project goals „Intelligent Assembly Cell“ is to replace the existing pneumatic clamp by a clamping device suitable for working in intelligent production systems. This objective will be achieved by sensory equipment of the mentioned clamp as well as other parts of the flexible production cell. Control of both the flexible production cell and clamp will be able to receive process information and properly respond to stimulations from all system sensors.

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