XVI IMEKO World Congress
Measurement - Supports Science - Improves Technology - Protects Environment ... and Provides Employment - Now and in the Future
Vienna, AUSTRIA, 2000, September 25-28

APPLICATION OF ELECTRICAL METROLOGY METHODS FOR EXAMINATIONS OF MACHINE TOOLS

I. Dudas and T. Csermely
Department of Production Engineering, University of Miskolc
H-3515 Miskolc, Hungary

Abstract: The Hungarian products must satisfy the increasing quality demands being in Hungary and in abroad. Developing the quality of the machine production is essential requirement of competitiveness of the Hungarian industry. The Department of Production Engineering applies a wide range of the Computer Aided Industrial Metrology and Quality Assurance Softwares in education and in research. The paper introduces some methods for solving of the quality assurance tasks.
Keywords: machine tools, electrical metrology methods

1 INTRODUCTION

The static and dynamic behaviour of plastic forming and cutting machine tools determines the quality of the workpiece produced. The accuracy of manufacturing is effected on the deviation of the main forming movements occurring between the workpiece and the tool.

The aim of the examination was to decrease the geometric and kinematic errors of the machine tools, furthermore to decrease the displacements, which are caused by the static and dynamic load as well.

2 APPLICATION OF ELECTRIC METROLOGY

By the use of the method, developed by us, the dynamic stiffness of the press could be increased in that extent, so they satisfied the requirements prescribed to the precision press as well. The deviation from the designed drawing of the workpieces produced on machine tool, beyond the geometric and kinematic errors of the machine tool, are effected on a lot of factors. We mention only some: direction, extent and feature of the static and dynamic load; the displacements of the machine tool elements (frames, slides, spindles, rams, spherical shells, etc.) because of the effect of the load.

The static stiffness of the frame can even be calculated with good approximation, however the behaviour of the dynamic damping and stiffness can be estimated with great uncertainty when the period of design. Well, the newest results of mechanical methods can help for design the construction with optimum layout, but the controlling/verification of the dynamic features of the real relations can only be done by the measurement method, applied by us, on the prototype version of the machine tool.

The inaccuracy of the dimensions of the produced workpiece is resulted from the non-appropriate stiffness of the machine tool. When the dynamic stiffness is smaller than the required value, it causes the non-wished vibrations. If these vibrations added to each other, their result are the error of the surface roughness of the workpiece; the reduction of tool life, and even the failure of the tool.

Consequently, the goodness of the machine tool, when loads are changing, is one of the more important qualifying standpoints. This is the precondition of satisfying of the more and more increasing demand of the users and the increase of the cutting power.

Our main concept is the measuring technique as a tool is used for creating of our developing goals. The tasks are begun by electronic measuring technique methods and later when we solved them we generalise of our results in the solution research of theoretical relations.

There will be shown the examination of two concrete equipment's in the following sub-chapters. One of them is an eccentric press family type DKS having welded rigid frame. We made our examination on one member of this press family called 25 GH.

The other equipment was a copying lathe type KDM-A-18 produced by GF.

We will show different examining methods for these equipment's which are different in there construction and operating principle. The methods, which will be shown, can be applied for other type machine tools as well.

2.1 Measuring of the elastic deformations of machine tools

Specific elastic deformation measurement of the machine tools was performed in case of static and dynamic load. We consider the static deformation measurement of eccentric presses as the case of elastic deformation related to F = 0 Hz, so that we defined automatically the magnitude with the measuring of the dynamic elastic deformation. The specific elastic deformation or reciprocal stiffness means the displacement brought about by unit force.

The machine tool is interpreted as transfer circuit according to the concepts of control technique. So the transfer characteristic of the machine tool is characterised on the basis of the frequency transfer function of the elastic deformation. In accordance with it the qualification of the plastic forming machine tool is performed in the view of the stability of the deformation processes and possibilities of forming of induced vibration.

In order to determine the elastic deformation and its reciprocal value – the dynamic stiffness – of the machine tool, it was induced with variable force of increased frequency of sinusoidal type but with the maximum amplitude and we measured the displacement amplitudes brought about by the induction in the direction of the force and perpendicularly to it. The measuring configuration shown in Fig. 1. was applied for the elastic deformation measurement of the eccentric press.

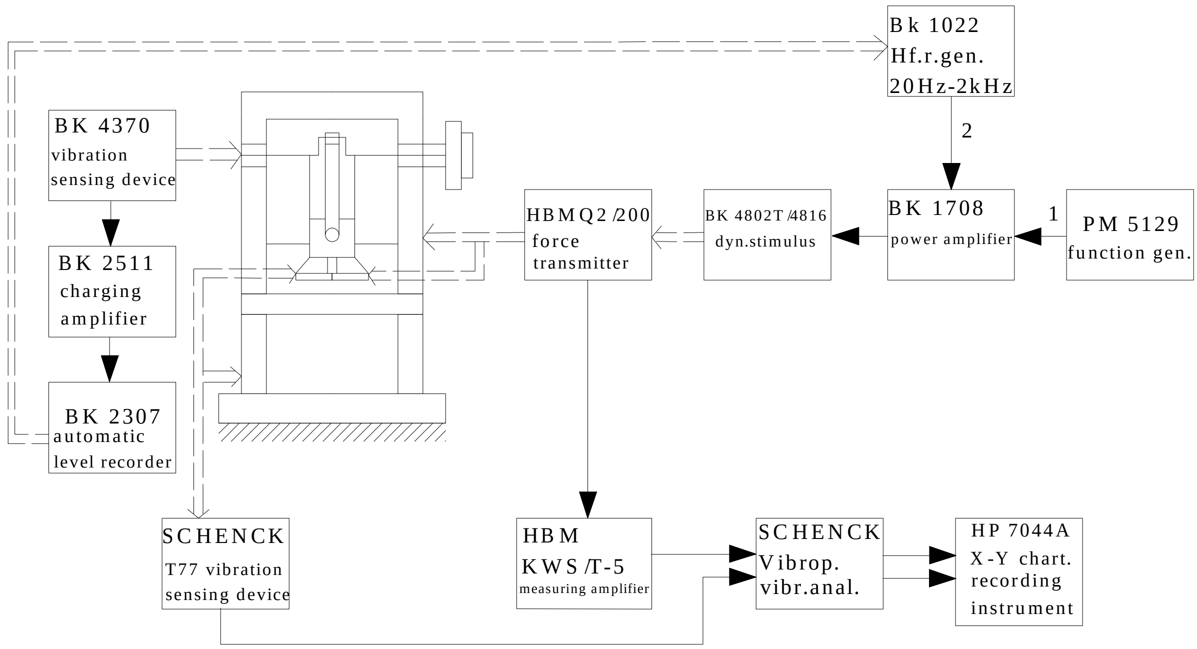


Figure 1. Vibration analysis of eccentric press type DKS

The signal from the signal generator of low frequency type Philips was linked to electrodynamics load inductor with power amplifier type Brüel-Kjaer. The clamping place of the tool of the machine tool was induced into the three direction by gauge force metre converter.

In the generating eigendirections, and in two directions perpendicular to it the vibration amplitude were measured by electrodynamics acceleration sensing device type Scheck T23 and the registration was made by the piezoelectric acceleration sensing device type Brüel-Kjaer. The output signals. The output signals of the charging and the measuring amplifiers were recorded by automatic level recorders and measuring magnetophons. Interposing of the Fourier vibration analyser type Scheck Vibroport we had the direct possibility to draw the amplitude-phase curves (Fig. 2) by the x-y chart-recording instrument type HP 7044.

Simultaneous registration of the answer response vibration amplitude related to the generating force of sinusoidal amplitude made the transferring function possible to the determined with direct locus. By the use of the applied electric measuring technique methods the displacements and the dynamic stiffness matrix of the eccentric press type DKS-25 GH. The general equations, which describe the relative elastic deformation, can be determined in every position of the parts to be examined of the machine tool.

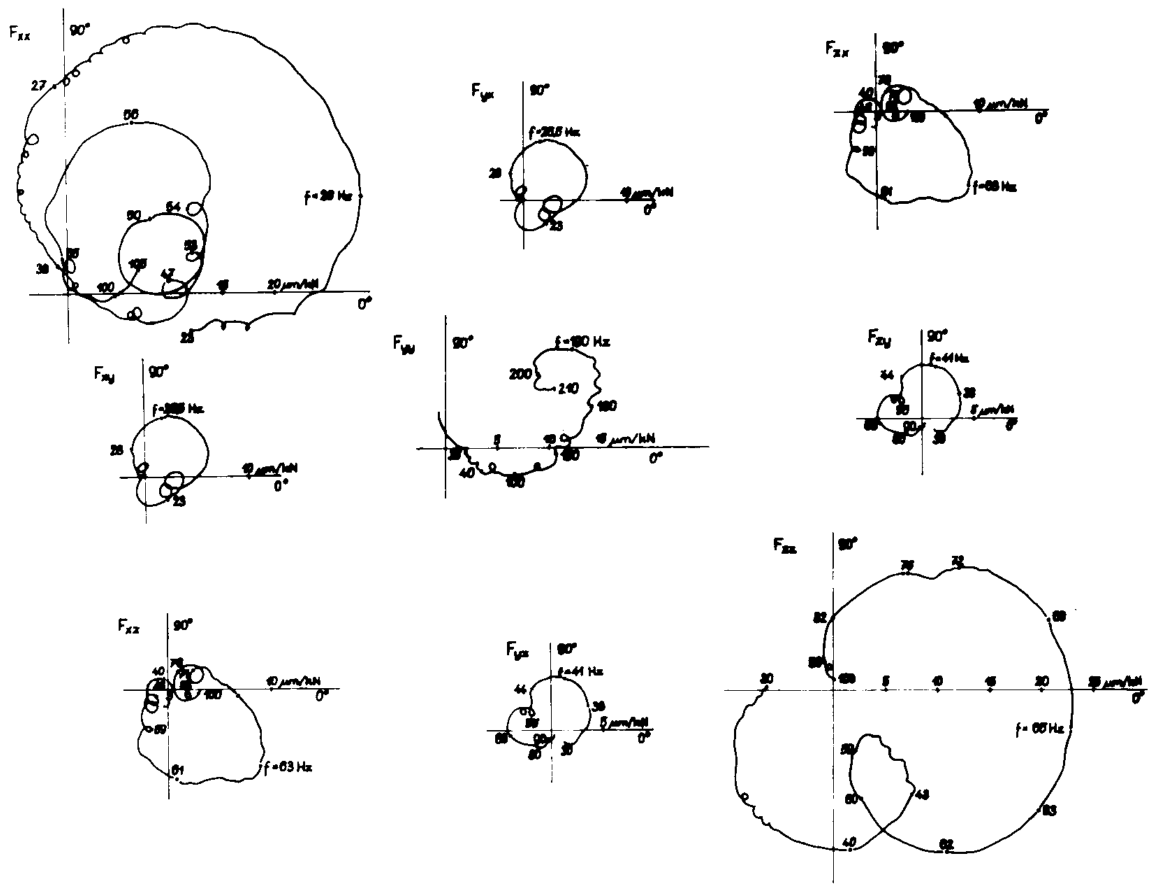


Figure 2. Dynamic stiffness matrix

As the simulation of the different loading (e.g. pressing force, cutting force, punching force, bending force, striking force, striking force, shearing force) at the tool clamping place of the plastic forming machine tools the elastic displacement brought about with sinusoidal loading effect of changing direction and magnitude is determined by

$$\vec{t} = \underline{\underline{D}} \cdot \vec{F}$$

In details:

$$[u;v;w] = \begin{bmatrix} D_{xu} & D_{yu} & D_{zu} \\ D_{xv} & D_{yv} & D_{zv} \\ D_{xw} & D_{yw} & D_{zw} \end{bmatrix} \cdot \begin{bmatrix} F_x \\ F_y \\ F_z \end{bmatrix}$$

where:

- $\vec{t}$: displacement vector. Its components are the displacements in the 3D orthogonal co-ordinate system matched to the machine in the direction of u, v, w.
- $\underline{\underline{D}}$: 3 x 3 matrix of the changing characteristic of displacement and force.

  From its 9 eigenfrequency 3 in the main diagonal contains the direct, and the other six the cross frequency characteristics.
  The first index sign show the direction of the stimulus, while the second sign shows the direction of translation of the displacement perception. At linear systems – as in the case of machine tools tested by us – the matrix is symmetrical, so

  $$D_{xv} = D_{yu}; \qquad D_{xw} = D_{zu}; \qquad D_{yw} = D_{zv}$$

- $\vec{F}$: the vector of stimulus/generating force.

2.2 Examination of vibration pattern of machine tools

The measuring set up is shown on Fig. 3 which was used for examination of vibration pattern – of main spindle of coping lathe type KDM-A-18 made by GF – by use of sinusoid stimulus force. From the vibration pattern of the tubular shaft of the main spindle we determined the resonance modal points and amplitudes related to bucking half-wave. The measured critical frequencies were compared to those, which were calculated from the kinematic chain of the machine tool.

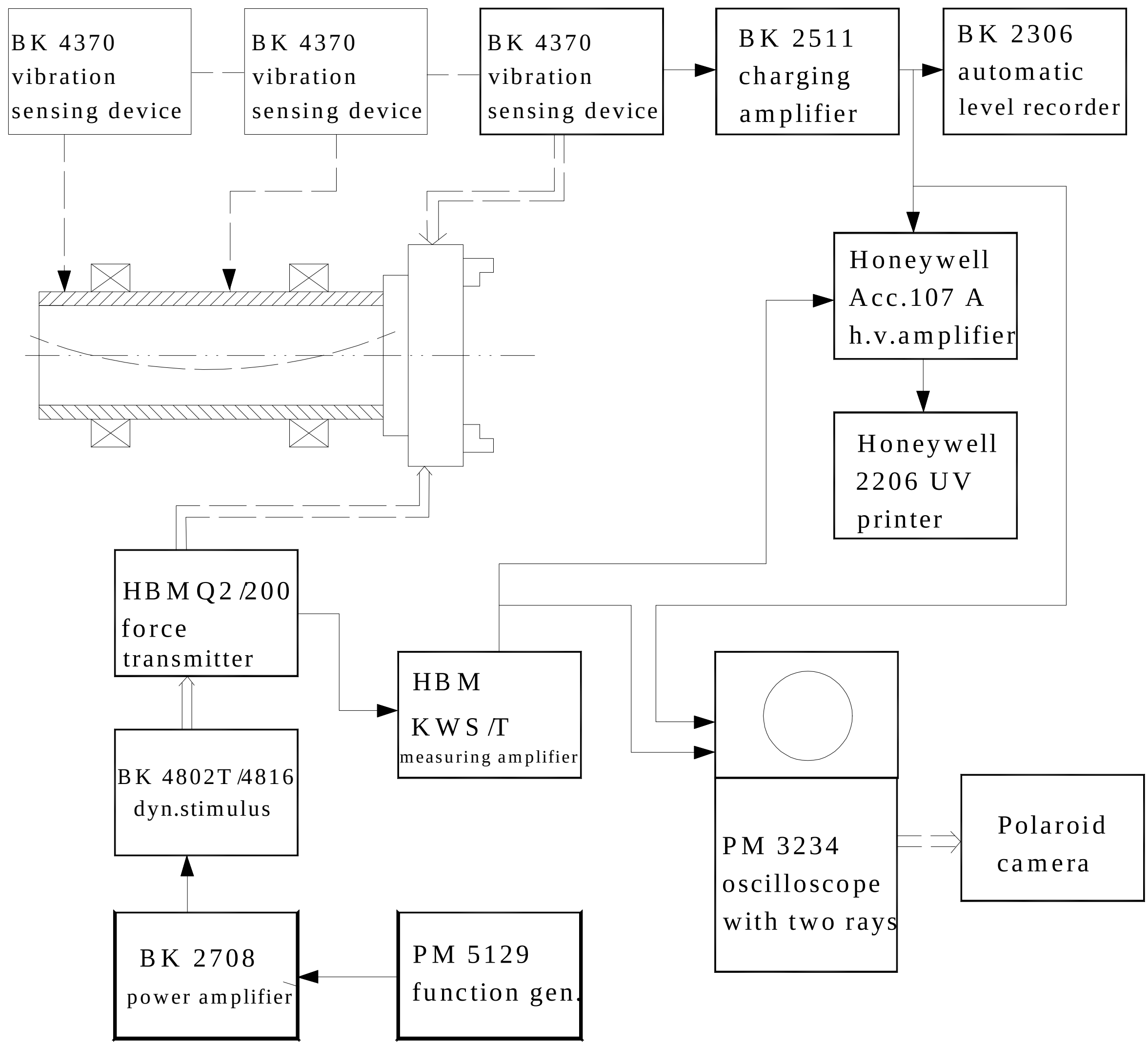
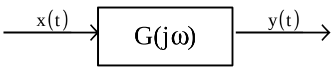


Figure 3. Examination of GF copying lathe

On the base of the measuring experience we made the change of the main part and executed the other important changes, which improved the dynamic relations. Figures 4 and 5 show the vibration amplitudes and the Nyqvist diagram related to the horizontal load.

From the amplitude phase diagram recorded on X-Y chart-recording instrument we determined the translational function and the spatial dynamic stiffness matrix of the system.



G(jω)

It is valid for the frequency characteristic – complex characteristic of a general system
Output signal (2); Input signal (3)

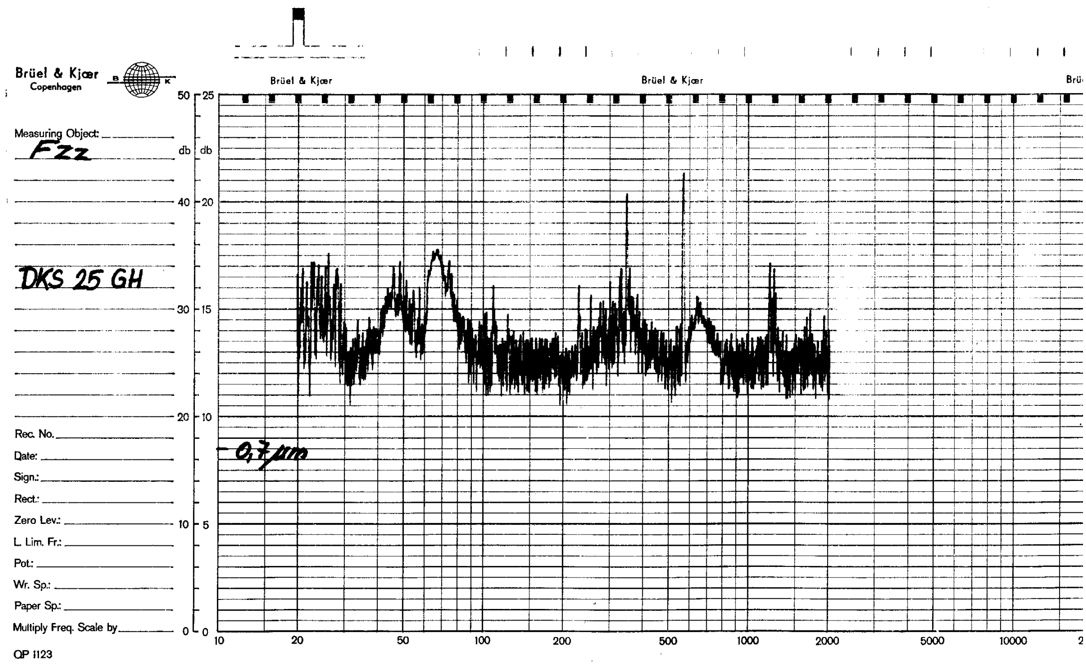


Figure 4. Horizontal vibration spectrum of GF copying lathe

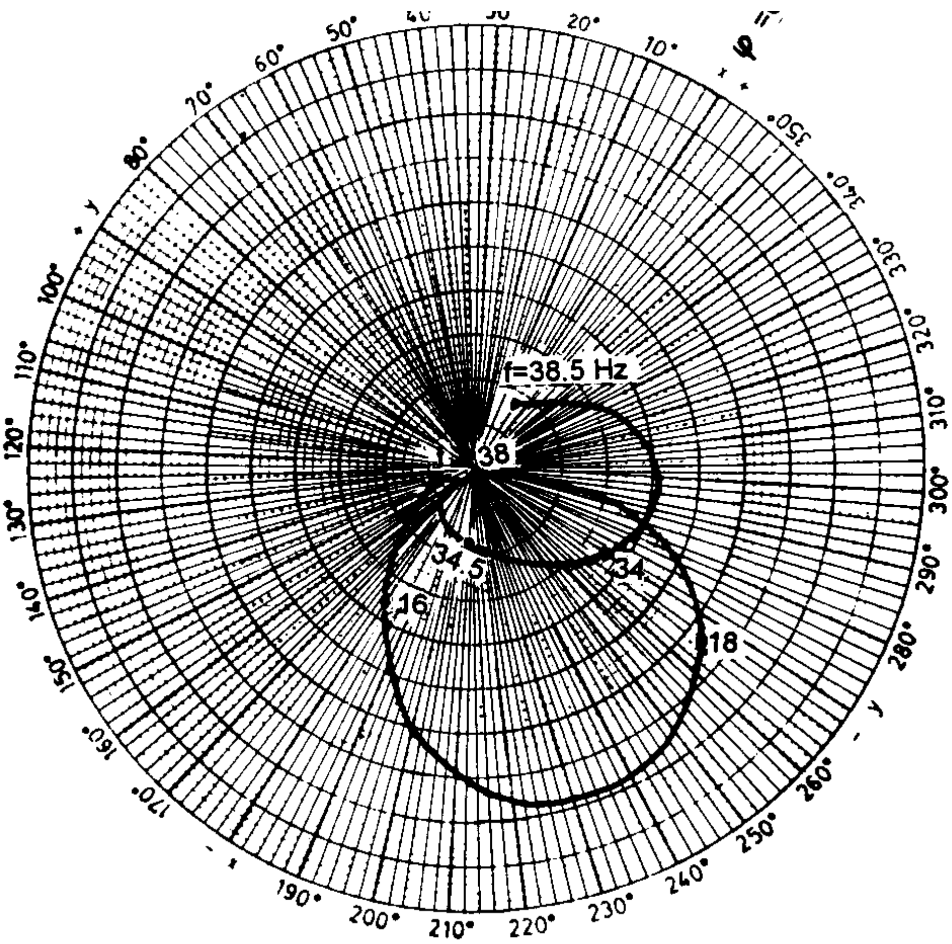


Figure 5. Measured Nyquist diagram of GF copying lathe at the place of bearing next to the chuck

$$G(j\omega) = \frac{F\{\quad (2) \quad\}}{F\{\quad (3) \quad\}} = \frac{F\{y(t)\}}{F\{x(t)\}} = \frac{\int_{-\infty}^{\infty} y(t)\, e^{-j\omega t} dt}{\int_{-\infty}^{\infty} x(t)\, e^{-j\omega t} dt} = \frac{E_y(j\omega)}{E_x(j\omega)}$$

Complex energy spectrum of the input signal: $E_x(j\omega)$
Complex energy spectrum of the output signal: $E_y(j\omega)$

For the time function it is valid, that: $x(t) = y(t) \equiv 0 \begin{cases} t < t_1 \\ t > t_2 \end{cases}$ Consequently

Complex energy spectrum divided by integration time results the complex power spectral density:

$$G(j\omega) = \frac{E_y(j\omega)}{E_x(j\omega)} = \frac{\int_{t_1}^{t_2} y(t)\, e^{-j\omega t} dt}{\int_{t_1}^{t_2} x(t)\, e^{-j\omega t} dt}$$

3 SUMMARY

Related, that on the base of our previous measurements we could make more perfect the construction which improved the dynamic stiffness – perpendicular to the forming main direction – of the machine tool which has fundamental effect on the accuracy of guiding of the tool. The recordings show that the showed eccentric press type DKS-25, having welded rigid frame, satisfies the requirements prescribed to the precision press as well.
By the measuring method showed in this paper – we think – we managed to present some new results of the machine tool development by the use of up-to-date electronic measuring technique.

REFERENCES

[1] Weck, M., Klaus T.: Dynamisches Verhalten spanender Werzeugmaschinen. Einflussgrössen. Beurteilungverfahren, Messtechnik, Berlin, Springer- Verlag 1977
[2] Schenk GmbH: Vibroport operating manual
[3] I. Dudas, T. Csermely: Vibration Analysys of Drilling Tools, ISMTII '98 Fourth International Symposium Sept. 2-4.1998 Miskolc Hungary, pp.:499-503
[4] I. Dudas, T. Csermely, G. Varga: The use of electric metrology methods for determination of dynamic features of machine tools, GÉP, 1996, Vol. XLVIII, No.:7. pp.:35-37

AUTHORS: Prof. D.Sc. Illes DUDAS and Dr. Tibor CSERMELY, Department of Production Engineering, University of Miskolc, H-3515 Miskolc-Egyetemvaros, Hungary, Phone Int ++36 46 565 160, Fax Int ++ 36 46 364 941, E-mail: ggytdi@gold.uni-miskolc.hu