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INFLUENCE OF SELF-EXCITED VIBRATIONS ON THE SURFACE ROUGHNESS OF WORKPIECES OBTAINED BY LONGITUDINAL TURNING

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Abstract: The workpiece (machined product) functionality is often conditioned by its production quality. The possibility of evaluation quality of processed surfaces in objects obtained by turning, is determined by roughness of processed surfaces. In this paper, the research of the self-excited vibrations influence on the processed surface roughness by longitudinal turning of three different steels: Č 0562, Č 1531 and Č 3990, is presented. In the course of the research, the vibration measurement during the processing of samples and processed surface roughness before and after setting up of self-excited vibrations, was carried out. On the occasion of the occurrence of self-excited vibration (which derived from the workpiece) the most influential factors, when processing longitudinal turning, were investigated. In the analysis we used the cutting depth, cutting velocity and cutting feed. The roughness of machined surfaces was also being compared. The reduction of self-excited vibrations during machining process is reflected on the reduction in roughness and thus improve the quality of machined surfaces that is of primary interest to production.
Keywords: self-excited vibrations, surface quality, roughness

1. INTRODUCTION

Traces of the machined area of the workpiece usually cause vibrations which are results of complexity of the machining process that is affected by many factors (change worn tools, interaction between the tool and workpiece, which causes the mechanical stiffness of dynamic system, etc.).

An adequate method that could predict the machining process behaviour has not worked out yet. The basic requirement that a modern machine tool for turning should provide is processing of components with a given accuracy and quality of machining surfaces. Achieving of desired surface quality is conditioned by the knowledge of the principles of machining by separating particles of material with all its negative and positive factors. For this reason it is necessary to investigate vibrations as one of the factors that negatively affect all segments of the system of machine tool - the tool - workpiece and with it the quality of the machined surface.

2. INFLUENCE OF SELF-EXCITED VIBRATIONS ON THE SURFACE ROUGHNESS OFWORKPIECES OBTAINED BY LONGITUDINAL TURNING

The surface roughness approximately represents traces of cutting tool blades and causes vibration in machining process. Self-excited vibration is a phenomenon that occurs during the machining process itself so that for the reaction in terms of action on the structure assemblies and machine tools elements is hard to realize, and changing the processing parameters (depth, speed and feed rate) reduces productivity. Cutting forces and surface roughness are classified among the most important technological parameters of the machining process.[5] Investigating of the causes, occurrence of self-excited vibrations and to find methods for their elimination, is one of the central research questions in this area. The solution to this problem allowsthe construction of high quality machine tools, and thus the high quality products.[1] The occurrence of self-excited vibration is determined by: a sharp rise in the amplitude of vibration, noise in the cutting zone, changing the shape of chip, a rapidly deteriorating quality of machined surfaces. With its intensity self-excited vibrations define the dynamic behavior of the machine tool and have a negative impact on the quality of the machined surface, and are described by the following differential equation:

$$m\ddot{y} + b\dot{y} + cy = F\left(y,t\right) \quad (1)$$

Disturbing force $F\left(y,t\right)$ is dependent not only on y i t but also in mechanical system vibrations represents the tool geometry, workpiece material, cutting process parameters and the function of the machine tool condition itself as well.

Disturbing force $F\left(y,t\right)$ is dependent not only on y i t but also in mechanical system vibrations represents the tool geometry, workpiece material, cutting process parameters and the function of the machine tool condition itself as well. Disturbing force in the general case can be adopted in the form:

$$F\left(y,t\right) = dF = k_{\delta} d\delta + k_{v} dv_{2} + k_{\Omega} d\Omega \quad (2)$$

where: $F\left(y,t\right) = dF$ - cutting force dynamic component, $k_{\delta}, k_{v}, k_{\Omega}$ thickness coefficient, depth-width, shear speed and circumferential cutting speed in non-stationary cutting conditions, $d\delta$ change of cutting depth, dv_2 change of auxiliary movement speed (displacement), and $d\Omega$ change of the main circular movement in the process of cutting. Analysis shows that the surface roughness decreases when the number of revolutions and feed rate is greater in relation to the cutting depth [4]. However, in real conditions, the dynamic component of the cutting force depends on the change in cutting depth, so that:

$$dF = k_{\delta} d\delta \quad (3)$$

So-called regenerative method of emergence of self-excited vibrations is used for determining of cutting depth differential, Figure 4. According to this model, the cutting depth differential is:

$$d\delta = y\left(t\right) - y\left(t - T\right) \quad (4)$$

where, T - time consonant[3].

Schematic presentation of regenerative effect in the case of turning is shown in Figure 4. Namely, the cutting tool is influenced by static force and cutting resistance dynamic component, which is proportional to the chip thickness and is given by equation (5), depending on phase movement, i.e. angle θ, where:

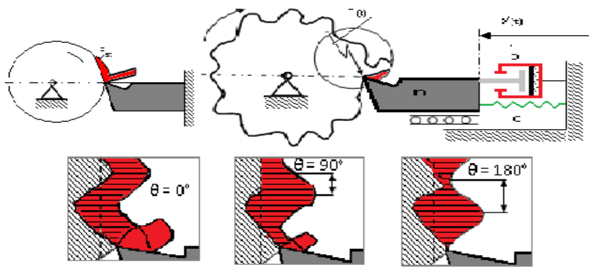

Figure 1. Schematic presentation of regenerative effect [3]

$$\theta = \frac{n}{30} T - 2\pi m \; [\, n(min^{-1}, m = 1,2,3\ldots\,], \quad (5)$$

emerges a sudden jump in vibrations amplitude, specifically forθ= 180°. This phase movement is located between two successive traces of cutting tool[2].

3. EXPERIMENTAL IDENTIFICATION OF SELF-EXCITED VIBRATIONS AND THEIR INFLUENCEON ROUGHNESS OF SURFACES OBTAINED BY LONGITUDINAL TURNING

For identification of the influence of self-excited vibrations on the roughness of machined surfaces obtained by longitudinal turning, an experiment for measurement of vibrations and roughness of machined surfaces before and after the establishment of generating of self-excited vibrations is carried out. Three steel materials with different mechanical characteristics are selected for carrying out the experiment (Table 1).

Table 1. Mechanical characteristics of materials used in experiment

Types of steel	Dimensions of samples	Mechanical characteristics	
		Tensile strength [N/mm²]	Hardness according to Brinell HB
S355JOG3	Ø 30 x 400	580	170
9SMn28		480	190
C45E		700	206

A "thorn" with dimension Ø1x10 mm, of steel Č.6880 is hammered in each workpiece. During the machining process in contact with the tool, this "thorn" causes the emergence of self-excited vibrations.All necessary factors for carrying out the experiment are insured (machine tool – turning-lathe). Machining regime, prepared materials, sensors and measuring device are chosen.

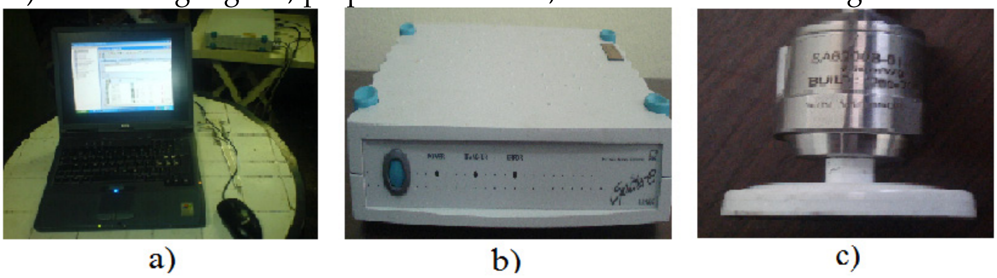

Figure 2. Computer with software for data processing, measurement device "Spider 08"and piezoelectric accelerometer "Metrix SA6200B"

Connecting the computer (Figure 2.a) with measuring, intensifying device "Spider 8" (Figure 2.b) is done. Three sensors "Metrix SA6200B" (Figure 2.c) are connected to „Spider 8".

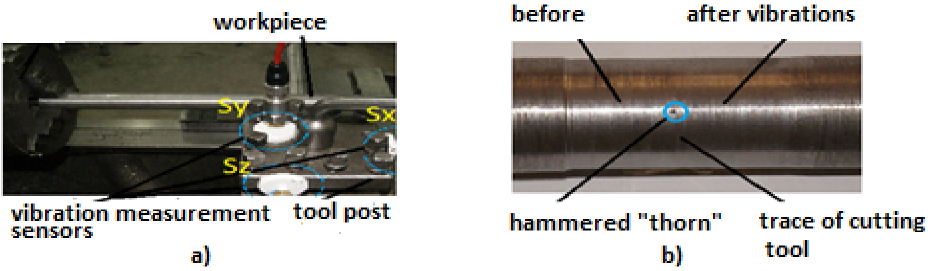

Figure 3. a) mounted sensors for measurement, b) characteristic parts of the workpiece

Three sensors "Metrix SA6200B" (Figure 5.c) are connected to „Spider 8".Then an experimental signal recording is done, primarly to check the flow and the size of the signal from the sensor through he measuring amplifier device on a computer display, Figure 3a. For all three steels the optimal, common parameters were selected (Table 2) After clamping the first prepared piece of steel between chuck and spike, the lathe is set in motion and vibration measurement has begun. Simultaneously, the data about vibration rates using the sensors s_1, s_2 i s_3 that measure vibrations in all three axes x, y i z are obtained. Data collected during the process are monitored through a display computer and automatically saved. With analysis of vibration signals from Figure 3 it can be concluded that the dynamic system behavior we observe acts non stationary.

Table 2. Results of experimental measurements of acceleration and roughness

Type of steel	Machining regimes			Results of measurement			
	Depth [mm]	Cutting speed [n/mm²]	Pace [mm/°]	Vibration a[m/s²]		Roughness R_z [µm]	
				Before self-excited vbration	Afterself-excited vbration	Before self-excited vbration	After self-excited vbration
S355JOG3	0,2	560	0,1	1,13	1,86	16,2	24,9
9SMn28				0,92	1,46	17,3	25,2
C45E				1,32	1,60	19,3	28,6

$$a = \sqrt{a_1^2 + a_2^2 + a_3^2} \tag{6}$$

where: a - total value of acceleration.

Numerical values of tool vibration acceleration in all three axes, which are obtained experimentally for each material individually, are given in Table 2.The value R_z is read on the display of the measurement device “MITUTOYO S-201”. Regimes during the measurement process (processing) were not changed, and processing is performed without the use of coolants. The measurement results are listed in Table 2.

4. CONCLUSION

The theoretical part of this paper gives a brief overview of the quality of the machined surface and roughness as a quality characteristic with the theoretical consideration of its basic parameters. Self-excited vibrations as an inevitable occurrence has an negative influence on the surface quality and roughness in the process of turning with the dynamic behavior and the excited force that is characteristic for such behavior. The basic concepts and potential causes and consequences of vibrations appearance and in the praxisare dealt with. That is why the experimental measurement was done. In the third part of the paper the methodology of determining the level of vibrations is shown, with reference to the methods and measuring equipment used in the process of measuring the intensity of vibrations. The aim of this paper is to show, with the experiment, in what way self-excited vibrations affect the roughness of the surface machined by longitudinal turning. Comparing the experimental data (Table 2) it can be seen that the self-excited vibrations influence on deterioration of roughness in all steel samples at the same cutting parameters. The level of vibration is different for different materials as well as the measured surface roughness and it can be conluded that self-excited vibrations have the influence on the workpiece regardless on its hardness.

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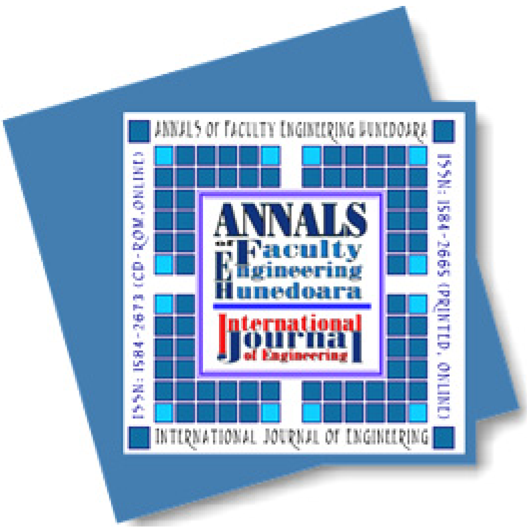

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