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MATHEMATICAL MODELING OF INFLUENCE BETWEEN SURFACE ROUGHNESS AND THERMOELECTRIC CURRENT

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Abstract: *In making an "on-line" diagnosis on turned surfaces, was used mathematical modeling in order to establish the regression functions showing the relationship between the roughness and the thermoelectric current, more precisely, between intensity of thermoelectric current and roughness or between roughness and voltage. This paper presents mathematical models able to evaluate the surfaces quality by measuring the thermoelectric current appeared in the cutting area, in turning, using regression techniques.*
Key words: *mathematical model, surface roughness, thermoelectric current, regression functions*

1. INTRODUCTION

The measurement of surface state evaluates the defects of surface inevitably generated during the manufacture of parts. A good knowledge of these defects allows manufacturing the parts with the precision and quality required, in the best economic conditions.

The thermoelectric effect or thermoelectricity encompasses three separately identified effects: the Seebeck effect, the Peltier effect and the Thomson effect. The thermoelectric effect is the direct conversion of temperature differences from the cutting area to electric voltage. We can make an analogy between the phenomena appeared in thermocouple and what happens during the cutting process.

In literature there are studies showing the influence of the cutting regime on thermoelectric current. Novelty brought by this work represents the mathematical modeling of dependence between roughness and the thermoelectric current. The thermoelectric current can easily be measured during the cutting process on conventional machine tools, enabling the assessment of roughness in real time and identify the causes that lead to lower quality areas turned, in order to take the necessary measures.

For assessing roughness by indirect methods, the relationships between roughness and voltage or intensity of thermoelectric current were determined, using specific software for processing experimental data. The methods used were: the direct method for measurement by contact of the surface roughness, before and after processing and natural thermocouple method for measuring voltage and intensity of thermoelectric current. Further research will lead to automation of taken over data, by building a data acquisition unit.

2. DESIGN OF THE EXPERIMENT

We measure the values of voltage and the thermoelectric current intensity in turning of 42MoCr11 alloy, thanks to a modified cutting regime. We didn't quantify the vibrations effect on the experimental studies carried out and we also didn't use cooling liquid (dry cutting). Experimental investigations were conducted on cylindrical surfaces, separated by gorges. The work piece of 42MoCr11 alloy has 52 mm in diameter and 310 mm length.

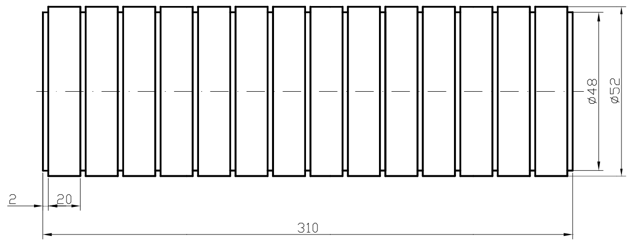

Fig. 1. The configuration and the dimensions of the work piece

In order to measure accurately the thermoelectric current in turning was adjusted the centering peak of the work piece by constructing a collector with copper brushes.

The processing was performed on a conventional machine tool, with changeable tool inserts – TNMG 22 04 08 – P15, chosen by CoroGuide and CoroKey - PC programs ($\alpha = 7^o$; $\gamma = 6^o$; $\kappa_r = 93^o$; $\kappa_r = 27^o$; $\lambda_s = -6^\circ$; $r_\varepsilon = 0{,}8$ mm).

To measure voltage U or intensity of the thermoelectric current I, was used a professional digital multimeter Metrix MX 54. The roughness of the processed surface was measured using a Diavite –11 rugosimeter.

3. RESULTS ANALYSIS

3.1 Determine the form of regression functions

Regression is the technique of processing experimental data to obtain quantitative relationships between a dependent variable y and one or more independent variables x1, x2, ..., xn, such that y = f (x1, x2, ..., xn).

Functions were established basing on experimental measurement of the output variables that are correlated with the inputs into the process by geometric regression.

In accordance with literature recommendations (Liteanu & Rîcă, 1985; Darwish,. 1997; Puertas & Perez, 2003), the general form of regression functions in turning process, when studying the influence of three independent variables on the dependent variable, may be a function of the following form:

$$y = \beta_0 \cdot \prod_{j=1}^{k} xi_j^{\beta_j} \cdot \prod_{j=k+1}^{m} \beta_j^{xi_j} \qquad (1)$$

Multiple linear regression is chosen for the mathematical modeling of the intensity depending on the cutting regime parameters in logarithmic coordinates.

Intensity function in logarithmic coordinates, determined by the working environment MathCAD is the following:

$$y = b_0 + b_1 x_1 + b_2 x_2 + b_3 x_3 + \varepsilon \qquad (2)$$

where: $x_1 = \ln(v_c)$; $x_2 = \ln(f)$; $x_3 = \ln(a_p)$; ε includes perturbation variables.

In order to determine the regression coefficients, was applied the *method of least squares*, using the MathCAD work.

With these coefficients, we obtain a function of the form (2) and then, applying a logarithmic function, a function of the form (1).

In this work was found the geometric regression function with three variables (cutting speed v_c, feed f and depth of cut a_p), according to relationship (1).

The experimental plan used for turning 42MoCr11 steel is organized on two levels and contains a total of 18 experiments, four experiments being necessary for the calculation of systematic errors (Cîrstoiu, 2007).

3.2 „Intensity of thermoelectric current” process function analysis

Expression of intensity function I, in logarithmic coordinates, determined using MathCAD program is as follows:

$$z = 1.665 + 0.264\cdot x1 + 0.104\cdot x2 + 0.079\cdot x3 \qquad (3)$$

where: z = lnI, x1 = lnv_c ; x2 = lnf ; x3 = lna_p.

By applying inverse logarithmic function relationship (3) one gets to (4).

$$I = 5.286\cdot v_c^{(0.264)}\cdot f^{(0.104)}\cdot a_p^{(0.079)} \ [\mu A] \qquad (4)$$

Figure 2 shows the 3D representation, using „Mathematica” program, of the function determined by geometric regression, while the depth of cut is constant, a_p = 1.5 mm.

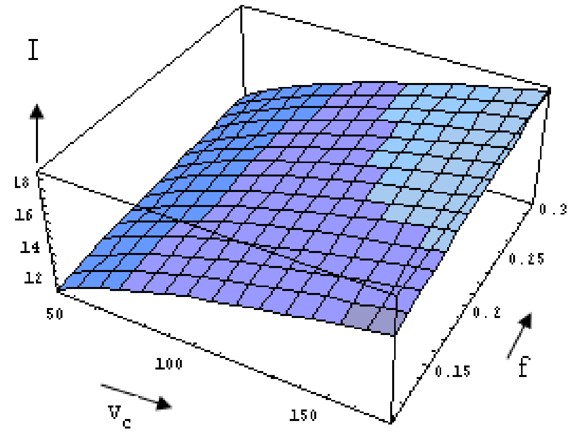

Fig. 2. The representation of intensity I, calculated with (4), depending on cutting speed v_c and advance f

3.3 „Voltage” process function analysis

Voltage U function in logarithmic coordinates, determined by the working environment MathCAD is the following:

$$z = 1.829 + 0.23\cdot x1 + 0.094\cdot x2 + 0.065\cdot x3 \qquad (5)$$

where: z = lnU ; x1 = lnv_c; x2 = lnf ; x3 = lna_p .

By applying inverse logarithmic function relationship (5) one gets (6).

$$U = 6.228\cdot v_c^{(0.23)}\cdot f^{(0.094)}\cdot a_p^{(0.065)} \ [mV] \qquad (6)$$

A similar representation of the figure 2 has voltage.

3.4 Relations between roughness and termocurent

Similarly, was obtained the relationship (7) indicating the Ra roughness parameter dependence of the cutting regime parameters (Cîrstoiu, 2007).

$$R_a = 29.283\cdot v_c^{(-0.224)}\cdot f^{(0.854)}\cdot a_p^{(0.14)} \ [\mu m] \qquad (7)$$

From relations (4), (6), (7), for f = 0.208 mm/rot; a_p = 1.5 mm, such relations are obtained between roughness and the thermoelectric current:

$$R_a = 5.539\cdot v_c^{(-0.488)}\cdot f^{(0.75)}\cdot a_p^{(0.061)}\cdot I \qquad (8)$$

$$R_a = \frac{1.74872\cdot I}{v_c^{0.488}} \qquad (9)$$

$$R_a = 6.228\cdot v_c^{(-0.454)}\cdot f^{(0.76)}\cdot a_p^{(0.075)}\cdot U \qquad (10)$$

$$R_a = \frac{1.46966\cdot U}{v_c^{0.454}} \qquad (11)$$

In Figure 3 was represented in 3D roughness Ra changes depending on the speed v_c and intensity I, while the other parameters of cutting regime are kept constant. A similar representation of the figure 3 has Ra changes depending on the speed v_c and voltage U.

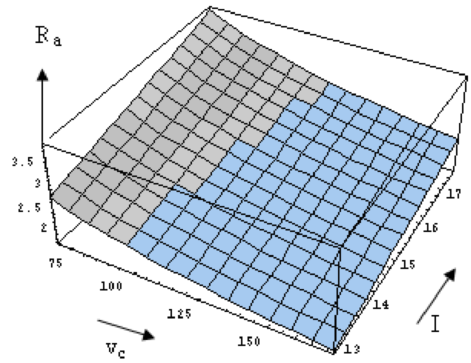

Fig. 3. The representation of the dependence between roughness and intensity of thermoelectric current

4. CONCLUSIONS

Increases of the intensity or voltage of thermoelectric current values indicate a deterioration of surface quality, reflected in the increasing values of roughness parameter Ra. Therefore it is the thermoelectric current a true indicator of the normal state of the cutting process, in terms of quality of processed surface. Further research will have as results: increasing speed of experimental data acquisition and accuracy of results, by using a microcontroller, automating data acquisition and processing, optimizing technological processes.

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