NEW FUNCTIONS OF THE SURFACE ROUGHNESS WHEN CUTTING THE STAINLESS STEEL 10NICR180 AND OLC45

Aurelian Vlase[1], Bogdan Vlase[1] & Ruxandra Balan[1]

[1] University POLITEHNICA of Bucharest, Department of Machine Manufacturing Technology, Splaiul Independentei 313, 060042, Sector 6, Bucuresti, Romania

Corresponding author: Bogdan Vlase, bvlase@yahoo.com

Abstract: The paper presents the experimental results and their evaluation when cutting the stainless steel 10NiCr180 and standard steel OLC45, the latest as for comparison. Later on, the regression mathematical relations for roughness Ra are determined, as a function of cutting process parameters, using a standard finishing cutting tool. The study contains three tables, two regression functions and six graphs with the roughness R_a variation, according to the evolution of cutting parameters.
Key Words: roughness, cutting, regression.

1. INTRODUCTION

Improving the products quality represents a very important objective during the fabrication processes. This particular aim solves various issues as functioning quality, offers a pleasant exterior aspect and also materials fast selling process, ensuring so a short cycle of fabrication.
In this view, it is recommended that the product and technology designers should base their daily work on high research results in the field of processed surfaces quality, issue presently so controversial among specialists from developed countries all over the world (Krivouhov, 1977), (Vlase,1989).
When speaking about "processed surface quality", there are two terms to be considered: the external aspect, which determines the physical and mechanical properties of the superficial level of the material; and the geometrical aspect, which determines the real geometry of the processed surface (Enache, 1980).
This paper wishes to approach the second parameter, respectively the way of variation of surfaces micro-geometry according to the cutting parameters when processing the stainless steel 10NiCr180 and standard steel, OLC45, the latest as a reference material.

2. CUTTING CONDITIONS

Cutting machine: lathe no. SN 400x1500;
Cutting tool: straight finishing knife STAS 6378-80, with active side of metallic carbon P10; Cutting tool geometrical parameters: κ=50, κ_1=50, α=8, α_1=8, γ=0, λ=0, r=1.5m;
Researched materials: stainless steel 10NiCr180, having the chemical, physical and mechanical characteristics presented in Tables 1 and 2; and OLC45, having the characteristics presented within the same tables;
Cutting depth, a_p: varies in 0.2 and 0.6 mm interval;
Feed, f: varies in 0.1 and 0.3 mm/rot interval;
Rotation, n: varies in 460 and 1200 rot/min interval;
Cutting speed, v_c: varies in 72.2 and 188.4 m/min interval.

Table 1. The chemical characteristics of the two researched materials

Researched materials	Chemical composition [%]						
	C	Ni	Cr	Mn	Si	S	P
10NiCr180	**0.11**	**9.5**	**18.4**	**1.9**	**0.82**	**0.016**	**0.03**
OLC45	**0.45**	**0.3**	**0.32**	**0.65**	**0.23**	**0.04**	**0.04**

Table 2. The mechanical characteristics of the two researched materials

Researched materials	Tensile Strength, R_m, [N/mm^2]	Flowing Limit, R_{02}, [N/mm^2]	Elongation, δ, [%]	Hardness, HB
10NiCr180	**745**	**484**	**34.2**	**202**
OLC45	**680**	**496**	**14.6**	**220**

3. THE EXPERIMENTAL RESULTS

The experiments took place in the researches laboratory TFP, of Polytechnic University of Bucharest, according to the cutting conditions above mentioned at chapter 2. The roughness measurement was carried out using a SURFTEST-B-MITUTOYO. The experimental results are presented in table 3.

Table 3. Experimental Results

No	Cutting depth, a_p, [mm]	Feed, *f*, [mm/rot]	Rotation *n*, [rot/min]	Probe diameter, *d*, [mm]	Cutting speed, v_c, [m/min]	Researched materials: 10NiCr180	Researched materials: OLC45
						Roughness, R_a, [μm]	Roughness, R_a, [μm]
1	0.20	0.10	1200	48	180.86	1.58	1.79
2	0.60	0.10	1200	48	180.86	1.72	2.02
3	0.20	0.30	1200	48	180.86	2.00	3.54
4	0.20	0.10	460	48	69.33	1.98	3.07
5	0.60	0.30	460	48	69.33	2.75	6.84
6	0.40	0.10	1200	48	180.86	1.67	1.94

4. THE DETERMINATION OF THE REGRESSION FUNCTIONS OF ROUGHNESS R_a

To find the regression functions of the roughness R_a, according to the cutting parameters, by keeping the active side geometry of the cutting tool, as per STAS 6378-80, we begin by using the special formula found in this particular field (Enache, 1980):

$$R_a = C_a \cdot a_p^{\ x} \cdot f^{\ y} \cdot v_c^{\ z} \quad [\mu m] \qquad (1)$$

If we processed this function by linearizing it through logarithms, and the by introducing the experimental results from Table 3 one by one, we can obtain a four equations system, with four unknown parameters: C_r, *x*, *y* and *z*.

For the stainless steel 10NiCr180, we have:

$$\lg C_a + x\lg 0.2 + y\lg 0.1 + z\lg 180.86 = \lg 1.58$$

$$\lg C_a + x\lg 0.6 + y\lg 0.1 + z\lg 180.86 = \lg 1.72 \qquad (2)$$

$$\lg C_a + x\lg 0.2 + y\lg 0.3 + z\lg 180.86 = \lg 2.00$$

$$\lg C_a + x\lg 0.2 + y\lg 0.1 + z\lg 69.33 = \lg 1.98$$

or, in a simplified form:

$$\lg C_a - 0.699x - y + 2.257z = 0.199$$

$$\lg C_a - 0.222x - y + 2.257z = 0.235 \qquad (3)$$

$$\lg C_a - 0.699x - 0.523y + 2.257z = 0.301$$

$$\lg C_a - 0.699x - y + 1.841z = 0.297$$

By solving the system, we will have:

C_a=9.954
x =0.075
y=0.214
z= –0.236

In this way, the new function found is:

$$R_a = 9.954 \cdot a_p^{\ 0.075} \cdot f^{\ 0.214} \cdot v_c^{\ -0.236} [\mu m] \qquad \mathbf{(4)}$$

For the OLC45 material, we have:

$$\lg C_a + x\lg 0.2 + y\lg 0.1 + z\lg 180.86 = \lg 1.79$$

$$\lg C_a + x\lg 0.6 + y\lg 0.1 + z\lg 180.86 = \lg 2.02 \qquad (5)$$

$$\lg C_a + x\lg 0.2 + y\lg 0.3 + z\lg 180.86 = \lg 3.54$$

$$\lg C_a + x\lg 0.2 + y\lg 0.1 + z\lg 69.33 = \lg 3.07$$

By solving the equations system, we obtain:

C_a=164
x=0.11
y=0.62
z= –0.56.

In this way, the new function found is:

$$R_a = 164 \cdot a_p^{\ 0.11} \cdot f^{\ 0.62} \cdot v_c^{\ -0.56} [\mu m] \qquad (6)$$

It can be observed that for both found functions, (4) and (6), the cutting depth, a_p, and the feed, f, have positive exponents and that the cutting speed, v_c, has a negative exponent, which signifies that the roughness parameter R_a exponentially increases when the cutting depth and feed are growing and exponentially decreases when the speed lowers.
This can be observed also from the diagrams Fig. 1 to 6, for the stainless steel 10NiCr180.

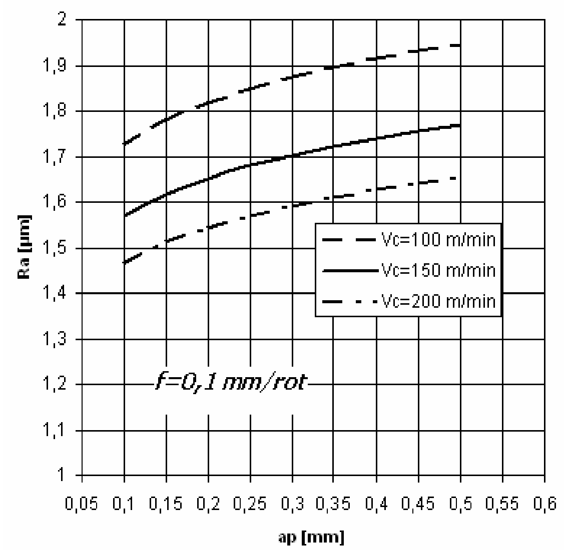

Fig. 1. The roughness R_a variation depending on the cutting depth for different speeds

Figure 1 shows the variation of the roughness depending on the cutting depth, for different speeds and constant feed. The parameter kept fixed was the cutting feed, and we varied the cutting depth and the cutting speed. From the above graphic, it can be observed that the roughness R_a exponentially increases when the cutting depth a_p is also increasing.

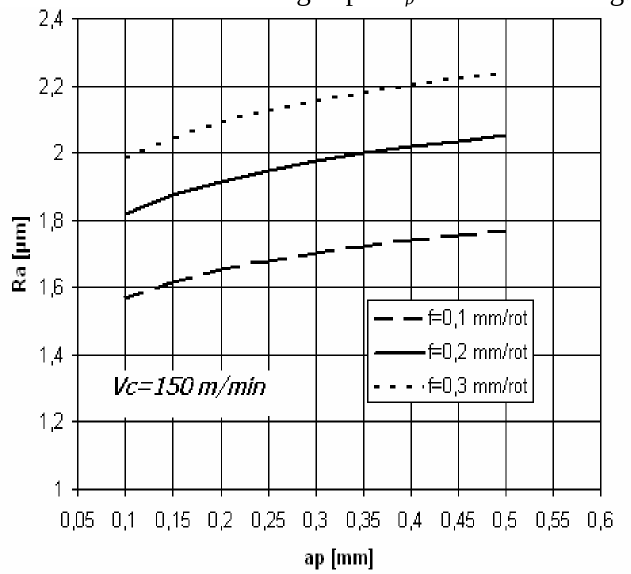

Fig. 2. The roughness R_a variation depending on the cutting depth for different feeds

Figure 2 presents the variation of the roughness R_a when keeping a constant speed of turning the material, of 150m/min and varying the feed (with three main values: 0.1 mm/rot, 0.2 mm/rot and 0.3 mm/rot) and the cutting depth, within a large domain from 0.10 mm, to 0.50 mm.

It can be observed that the roughness R_a, as explained at Figure 1, had also exponentially increased, but in a softer manner.

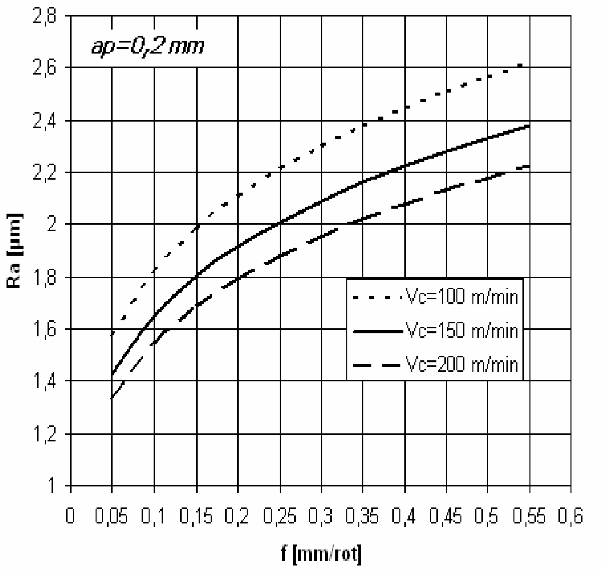

Fig. 3. The roughness R_a variation depending on the cutting feed for different speeds

Figure 3 presents the variation of the roughness R_a when keeping the turning depth constant, at 0.2 mm, but varying the cutting speed (in three steps: 100 m/min, 150 m/min and 200 m/min) and the feed, in a large interval from 0.10 mm/rot to 0.50 mm/rot.

The roughness R_a also increased exponentially, following the same pattern of the two previous graphics, but this time the increase was more obvious

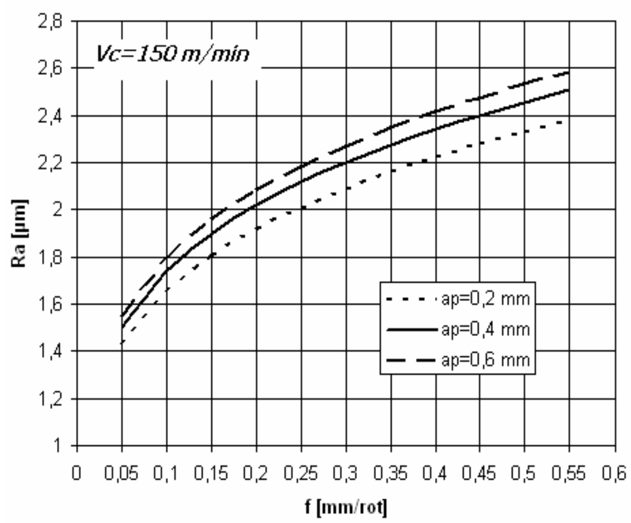

Fig. 4. The roughness R_a variation depending on the cutting feed for different depths.

Figure 4 presents the variation of the roughness R_a when keeping a constant speed of turning the material, of 150m/min and varying the cutting depth (with three main values: 0.2 mm, 0.4 mm and 0.6 mm) and the turning feed, within a large domain from 0.10 mm/rot, to 0.50 mm/rot.

It can be observed that the roughness R_a had also exponentially increased, more abruptly than any other variation previously presented in the Figures 1-3.

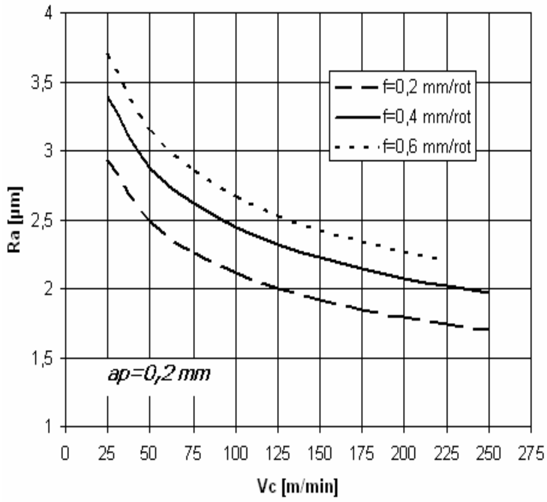

Fig. 5. The roughness R_a variation depending on the cutting speed for different feeds

Figure 5 presents the variation of the roughness R_a when keeping a constant depth for turning the material, of 0.2 mm and varying the cutting feed (with three main values: 0.2 mm/rot, 0.4 mm/rot and 0.6 mm/rot) and the turning speed, within a large domain from 25 m/min, to 250 m/min.

It can be observed that the roughness R_a had exponentially decreased, in an abruptly way, completely different from the other graphics presented above.

Below, Figure 6 presents the variation of the roughness R_a when keeping a constant feed for turning the material, of 0.1 mm/rot and varying the cutting depth (with three main values: 0.2 mm, 0.4 mm and 0.6 mm) and the turning speed, within a domain from 75 m/min, to 250 m/min.

It can be observed that the roughness R_a had a similar exponentially decreasing, as presented in Figure 5.

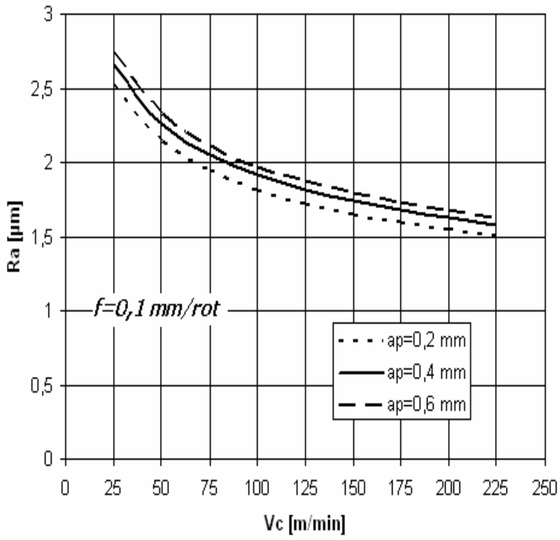

Fig. 6. The roughness R_a variation depending on the cutting speed for different depths

The roughness variation for the steel OLC45 are presented in Figure 7 to 12

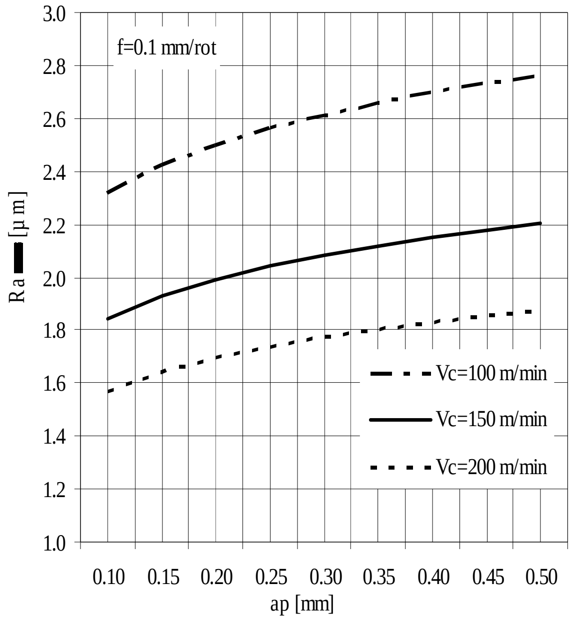

Fig. 7 The roughness R_a variation depending on the cutting depth for different speeds

Figure 7 shows the variation of the roughness depending on the cutting depth, for different speeds and constant feed. The parameter kept fixed was the cutting feed, and we varied the cutting depth and the cutting speed. From the above graphic, it can be observed that the roughness R_a exponentially increases when the cutting depth a_p is also increasing.

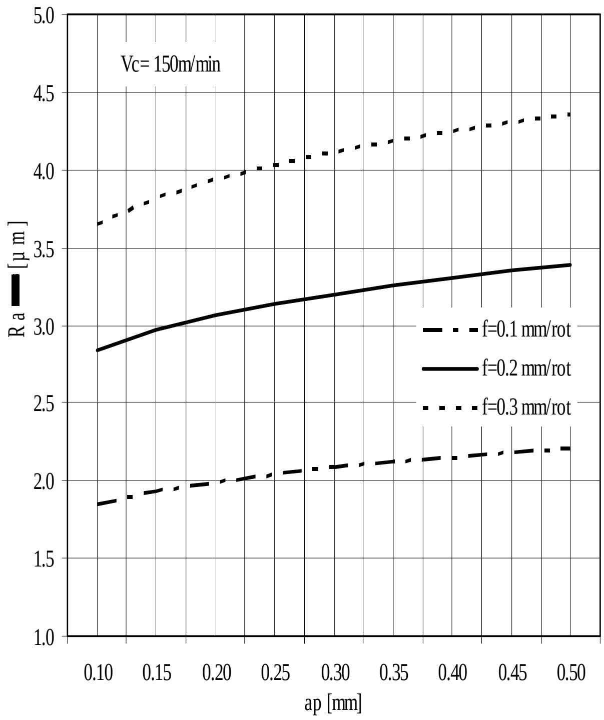

Fig. 8 The roughness R_a variation depending on the cutting depth for different feeds

Figure 8 presents the variation of the roughness R_a when keeping a constant speed of turning the material, of 150m/min and varying the feed (with three main values: 0.1 mm/rot, 0.2 mm/rot and 0.3

mm/rot) and the cutting depth, within a large domain from 0.10 mm, to 0.50 mm.

It can be observed that the roughness R_a, as explained at Figure 7, had also exponentially increased, but in a softer manner.

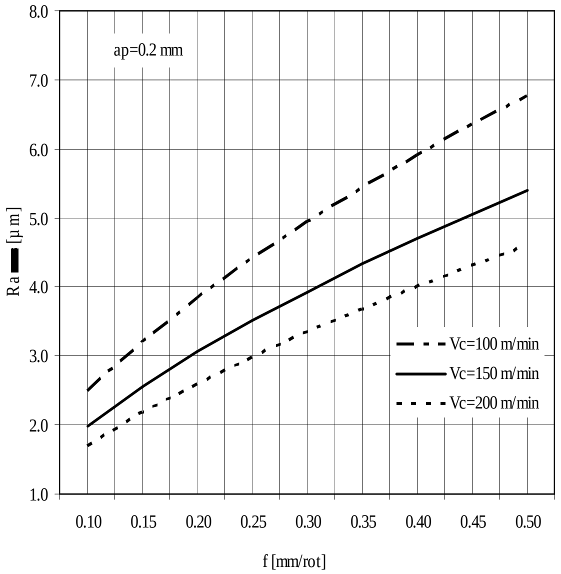

Fig. 9 The roughness R_a variation depending on the cutting feed for different speeds

Figure 9 presents the variation of the roughness R_a when keeping the turning depth constant, at 0.2 mm, but varying the cutting speed (in three steps: 100 m/min, 150 m/min and 200 m/min) and the feed, in a large interval from 0.10 mm/rot to 0.50 mm/rot.

The roughness R_a also increased exponentially, following the same pattern of the two previous graphics, but this time the increase was more obvious

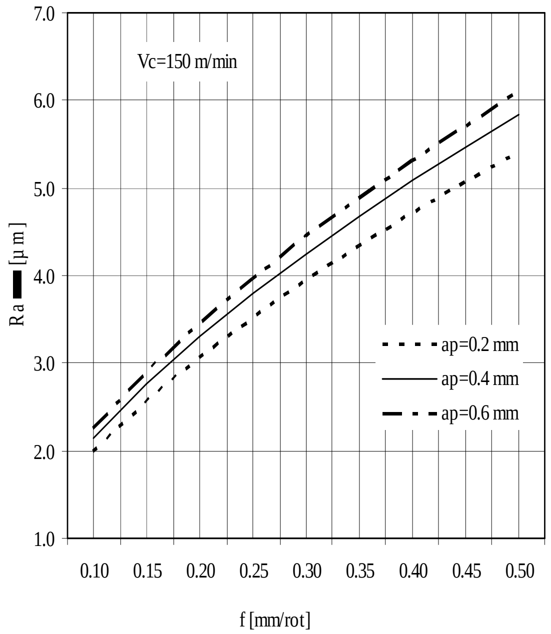

Fig. 10 The roughness R_a variation depending on the cutting feed for different depths

Figure 10 presents the variation of the roughness R_a when keeping a constant speed of turning the material, of 150m/min and varying the cutting depth (with three main values: 0.2 mm, 0.4 mm and 0.6 mm) and the turning feed, within a large domain from 0.10 mm/rot, to 0.50 mm/rot.

It can be observed that the roughness R_a had also exponentially increased, more abruptly than any other variation previously presented in the Figures 7-9.

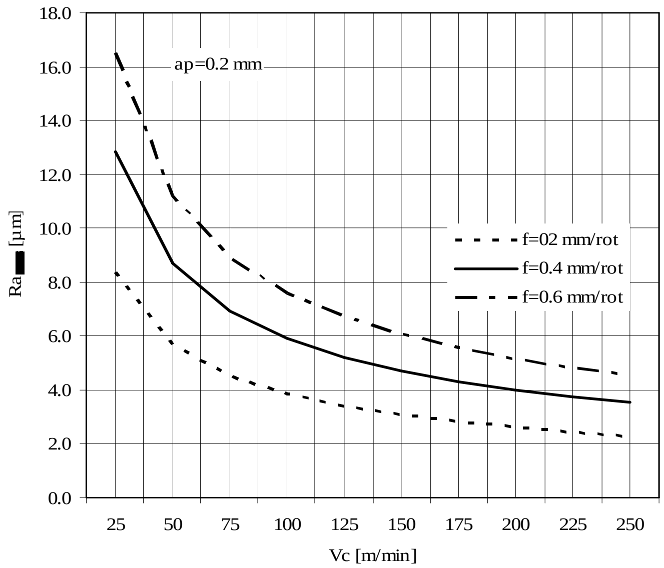

Fig.11 The roughness R_a variation depending on the cutting speed for different feeds

Figure 11 presents the variation of the roughness R_a when keeping a constant depth for turning the material, of 0.2 mm and varying the cutting feed (with three main values: 0.2 mm/rot, 0.4 mm/rot and 0.6 mm/rot) and the turning speed, within a large domain from 25 m/min, to 250 m/min.

It can be observed that the roughness R_a had exponentially decreased, in an abruptly way, completely different from the other graphics presented above.

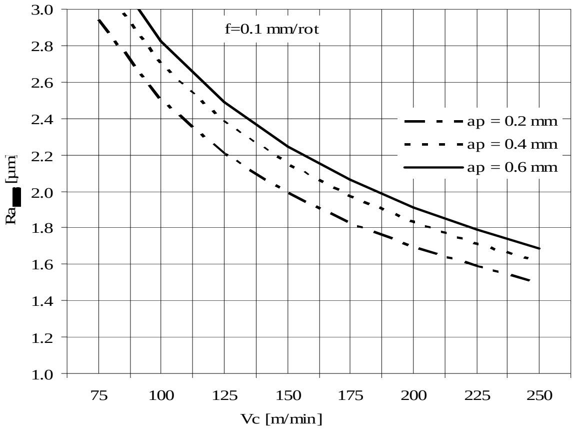

Fig. 12 The roughness R_a variation depending on the cutting speed for different depths

Figure 12 presents the variation of the roughness R_a when keeping a constant feed for turning the material, of 0.1 mm/rot and varying the cutting depth (with three main values: 0.2 mm, 0.4 mm and 0.6 mm) and the turning speed, within a domain from 75 m/min, to 250 m/min.

It can be observed that the roughness R_a had a similar exponentially decreasing, as presented in Figure 11

5. CONCLUSIONS

Taking into account that processing technologies are studied mostly not by a "generalist", but by each specialist, from his own point of view, according to his objective, we are trying to cover the processing issue from a larger angle, which can satisfy each participant's needs. For this particular study, we had chosen the stainless steel 10NiCr180. The roughness measurement was carried out using a SURFTEST-B-MITUTOYO equipment.

Having in view the actual level of researches in the stainless steels cutting processing, the insufficient data when deciding the optimal conditions of cutting is obvious.

In other words, the machine-tools maker is interested mainly in cutting forces and moments; the cutting tools producer in wear level of his tools; the power specialist by the energy consumption; the technology engineer by the cutting times; the economist by the financial resources and revenue, etc. For determinating the roughness R_a , we have chosen the complete mathematical functions, which include the cutting speed.

Through logarithm processing, we have obtained linear equations, and by inserting the experimental results, we have gained simple systems of four equations, with four unknown parameters.

Table 3 clearly presents the experimental results when measuring the roughness, having set the cutting parameters. From these values, it can be seen that the roughness varied within a range of values, from 0.70 µm to 2.38 µm.

Six graphs were drawn by combining one fixed parameter and varying other two. One of the varying parameters was considered the X-axis and the other given three determinated values.

By analyzing the regression functions found above and the diagrams Fig.1 to 12, we can conclude that:

- in all cases, the roughness R_a exponentially increases when the cutting depth, a_p, and feed, f, are growing;
- in all cases, the roughness R_a exponentially decreases when the cutting speed, v_c, lowers;
- when processing the stainless steel 10NiCr180, the highest influence on roughness, Ra, is represented by the cutting speed, as its exponent is the highest, as absolute value, and then followed by the feed, f, and the cutting depth, a_p;
- when processing the carbon steel OLC45, as a comparison material, the highest influence on roughness, R_a, is represented by the feed, f, and then followed by the cutting speed, v_c, and cutting depth, a_p;

Comparing the two steel materials we can underline that:

- in Fig.1 and 7, the roughness evolution, when increasing the cutting depths and for various speeds, is exponential, but the values are smaller for 10NiCr180;
- in Fig.2 and 8, the roughness evolution, when increasing the cutting depth and for various feeds, is exponential, but the values are smaller for 10NiCr180;
- in Fig.3 and 9, the roughness evolution, when increasing the cutting feed and for various speeds, is exponential, but the values are smaller for 10NiCr180;
- in Fig.4 and 10, the roughness evolution, when increasing the cutting feed and for various depths, is exponential, but the values are smaller for 10NiCr180;
- in Fig.5 and 11, the roughness evolution, when increasing the cutting speed and for various feeds, is exponential, but the values are smaller for 10NiCr180;
- in Fig.6 and 12, the roughness evolution, when increasing the cutting speed and for various depths, is still exponential, but the values are smaller for 10NiCr180.

6. REFERENCES

1. Diacenko, P.A. (1982). *The surfaces quality when processing metallic materials,* Technical Publishing House, pp. 79-85, Bucharest
2. Enache, St. (1980). *The processed surfaces quality*. Technical Publishing House, pp. 123-135, Bucharest
3. Krivouhov, V.A. (1977) *Obrabatavaemosti rezaniem jaroprocinich I titanovih splavov* (cutting process of alloys of titanium), Masghiz.
4. Vlase, A. (1976). Determination of some cutting parameters influences on surfaces quality when processing the stainless steels. *The 2nd National Conference of Machine Tools,* pp. 178-180, Bucharest
5. Vlase, A (1989). *Lathes processing technologies.* Technical Publishing House, pp. 96, Bucharest.
6. Popescu, I. (1981). *Fundaments of cutting and surface generation,* pp. 37, University of Craiova
7. Enache,S. and Minciu, C. (1983). *The Design of Cutting Tools with the Aid of Electronic Computer*, pp. 73, Editura Tehnică, Bucharest.

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