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Aspects Regarding the Processed Surface Roughness on Productivity Machine-Tools

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Abstract

Obtaining the established dimensions, tolerances and roughness of the feedstock according to the production design could be realized using various procedures or mechanical processing methods, through one operation in several steps or several operations in a well established order.
In such a context, this paper approaches the methodology of establishing the algorithm for the determination of roughness influence on productivity of the machine tool in the specific working conditions.

Key words: *mechanical processing, productivity, roughness*

Requirements, criteria, objectives

In accordance with STAS 5730/1-75, the state of piece surfaces may be determined by some characteristics expressing the geometrical state as well as the phisico-chemical state of the respective surfaces.

By roughness the irregularity ensemble of a surface having a relatively small step, irregularities which do not make up deviations of geometrical sharper (STAS 5730-75) is clearly understood.

The roughness of a surface is explicitly prescribed only when its delimitation is necessary from point of view of its running and aspect.

In case when the roughness of a surface does not represent running or aspect interests, it is not explicitly prescribed its value resulting implicitly from the manufacture technology applied for the purpose of carrying out the dimensional accuracy and from the general design indications regarding the respective surface state.

In case of prescribing a surface roughness two main aspects will be taken into consideration:
- the roughness influence on the running characteristics of the product (dimensional accuracy running, lastingness, resistance, aspect etc.).
- the roughness influence on the respective product manufacture economy.

The allowed surface roughness of a piece depends on its running part, dimensional tolerances and realization technology. The relation between the roughness and the dimensional tolerances is made evident especially in case of dimensions which make adjustments. The risc of the working productivity in case of cutting processing may be analysed on the basis of the aspects presented in figure 1.

In accordance with the aspects presented in figure 1, the specific importance of the basic time reduction (of machine) t_b will result, with the purpose of risc of the cutting process working productivity.

An accurate operation succession is established when the technical requirements are taken into consideration (table1) making sure the possibility to carry out the operations, as well as the economical requirements (table 2) which minimal expenditures of manufacturing impose.

Table 1. Technical requirements

Crt. Nr.	Requirements
1	Production volume which has to be ensured in a given period
2	Existent material base (or which is not proposed to be acquisited)
3	Dimensional accuracy and the piece surface roughness
4	Elementary surface number which has to be processed and their reciprocal position
5	Technical conditions imposed to the piece by the realization design
6	Coefficient value of global accuracy
7	Intermediary accuracy coefficient value, specific to each operations of mechanical processing.

Table 2. Economical requirements.

Crt. Nr.	Economical requirements	Objective
1	Processing cost (price)	Cost (price) minimization
2	Productivity	Productivity maximization
3	Quality	Quality maximization
4	Running security	Security maximization in exploitation
5	Flexibility degree	Flexibility degree maximization
6	Manufacture cycle	Manufacture cycle minimization
7	The use degree of the tools	The use degree maximization of the tools

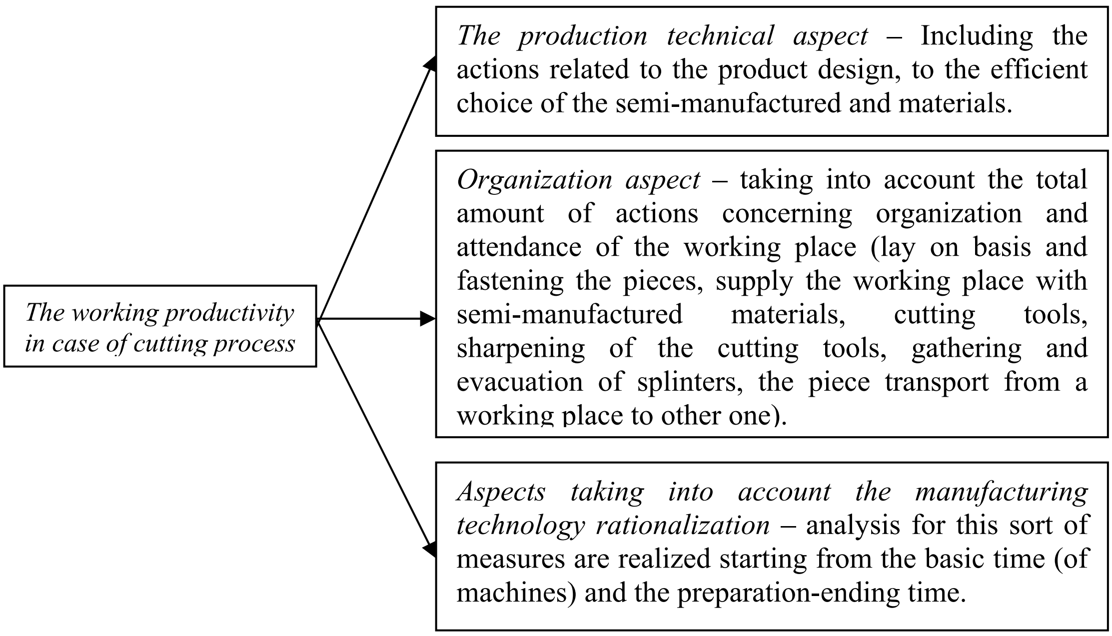

Fig. 1. The working productivity in case of cutting process

Approaching method

The working productivity of the cutting process P_v is established by means of the relationship:

$$P_v = \frac{1}{t_b} \quad (1/\text{min}) \tag{1}$$

where: t_b represents the basic time (of machine), in minutes; t_b is established by the relationship:

$$t_b = \frac{L \cdot i}{n \cdot f} \quad (\text{min}) \tag{2}$$

where: L represents the surface length to be processed by cutting, in mm; i – is the passing number; n – the number of rotations or of double courses of the cutting tool (or of the main shaft of the machine-tool), in rot/min or of double course/min; f – is the cutting advance on a rotation or on double course, in mm/rot or mm/double course;

Accordingly to the calculation relationships in the speciality literature [1], [2], [3], [4], are identified:

- i passing number:

$$i = \frac{A_p}{a_p} \tag{3}$$

where: A_p represents the processing addition, în mm; a_p – is the cutting depth, in mm;

- n – number of rotations or double courses; in case of main rotating motion, is determined:

$$n = \frac{1000 \cdot v_c}{\pi \cdot d} \quad (\text{rot/min}) \tag{4}$$

where: d represents the surface diameter to be processed, in mm; v_c – is the cutting speed, in m/min;

$$v = \frac{C_v}{a_p^{x_v} \cdot f^{y_v}} \quad (\text{m/min}) \tag{5}$$

where: C_v represents a coefficient depending on the material characteristics to be processed and on the active part material of the cutting tool, as well as on the cutting conditions; x_v, y_v – exponents.

Substituting the relationships (2), ..., (5), in relationship (1), is obtained:

$$P_v = \frac{1000 \cdot C_v \cdot a_p^{1-x_v} \cdot f^{1-y_v}}{\pi \cdot d \cdot L \cdot A_p} \quad (1/\text{min}) \tag{6}$$

The cutting advance on a rotation f, may be expressed depending on the roughness of the processed surface by means of the relationship:

$$f = \left(\frac{8 \cdot r_\beta \cdot R_z}{1000} \right)^{1/2} \quad (\text{mm/rot}) \tag{7}$$

where: r_β represents the radius at the tip of the cutting tool, in mm; R_z – the processed surface roughness, in µm.

Substituting the relationship (7), in the (6), it is obtained:

$$P_v = \frac{1000 \cdot C_v \cdot a_p^{1-x_v} \cdot \left(\frac{8 \cdot r_\beta}{1000} \right)^{\frac{1-y_v}{2}} \cdot \left(R_z \right)^{\frac{1-y_v}{2}}}{\pi \cdot d \cdot L \cdot A_p} \quad (1/\text{min}) \tag{8}$$

If it is noted:

$$C_P = \frac{1000 \cdot C_v \cdot a_p^{1-x_v} \cdot \left(\frac{8 \cdot r_\beta}{1000}\right)^{\frac{1-y_v}{2}}}{\pi \cdot d \cdot L \cdot A_p} \tag{9}$$

then the relationship (8) will become:

$$P_v = C_P \cdot \left(R_z\right)^{\frac{1-y_v}{2}} \quad (1/\text{min}) \tag{10}$$

Accordingly to data occurring in the speciality literature [1], [2], [3], [4], the particularities of the relationship (10) are presented in table 3, where the concrete conditions of mechanical processing are taken into account.

Table 3. Calculation relationships in case of cutting process productivity

Material to be processed	Active part material of the cutting tool	Processing conditions		Work conditions, f (mm/rot)	Productivity calculation relationships	
		with cooling	without cooling		with cooling	without cooling
		y_v	y_v			
Steel and Al and Mg alloy	High-speed steel	0,33	0,50	$f \leq 0,25$	$P_v = C_p \cdot R_z^{0,335}$	$P_v = C_p \cdot R_z^{0,25}$
		0,66	0,66	$f > 0,25$	$P_v = C_p \cdot R_z^{0,17}$	$P_v = C_p \cdot R_z^{0,17}$
Malleable iron	High-speed steel	0,25	0,40	$f \leq 0,25$	$P_v = C_p \cdot R_z^{0,375}$	$P_v = C_p \cdot R_z^{0,30}$
		0,50	0,40	$f > 0,25$	$P_v = C_p \cdot R_z^{0,25}$	$P_v = C_p \cdot R_z^{0,30}$
Steel and Al and Mg alloys	Metallic carbides P10	0,20	0,20	$f < 0,3$	$P_v = C_p \cdot R_z^{0,40}$	$P_v = C_p \cdot R_z^{0,40}$
		0,35	0,35	$f = 0,3...0,75$	$P_v = C_p \cdot R_z^{0,325}$	$P_v = C_p \cdot R_z^{0,325}$
		0,45	0,45	$f > 0,75$	$P_v = C_p \cdot R_z^{0,275}$	$P_v = C_p \cdot R_z^{0,275}$

In table 4 the dependence $P_v = f(R_z)$ is presented. In figure 2 the $P_{vi} = f(R_z)$ dependence graphic representation is presented.

According to data obtained from industrial practice, at the same time with the processed surface roughness increase the mechanical processing productivity will increase. In this paper the influence factors may be identified on the basis of the presented algorithms: material to be processed, material and active part geometry of the cutting tool (high speed steel, metallic carbides, the radius size on the tip of the cutting tool, a.s.o.), processing conditions) especially with the cooling medium or without the cooling medium), size of the working advance, size of the cutting depth, a.s.o.

Also, the prescribing of a surface fine roughness leads to the processing productivity decrease and increase of the piece final cost.

Accordingly to the calculation relationships presented in the paper, a series of estimations about the working parameters may be done in order to obtain optimal productivities per processing categories and specific working conditions.

Table 4. Dependence P_v = f(R_z).

Crt. Nr.	R_z (μm)	Productivity calculation relationships			
		$P_{v_1} = C_p \cdot R_z^{0,17}$	$P_{v_2} = C_p \cdot R_z^{0,25}$	$P_{v3} = C_p \cdot R_z^{0,30}$	$P_{v4} = C_p \cdot R_z^{0,40}$
1	0,063	0,625 · C_p	0,501 · C_p	0,436 · C_p	0,331 · C_p
2	0,125	0,702 · C_p	0,595 · C_p	0,535 · C_p	0,435 · C_p
3	0,25	0,790 · C_p	0,707 · C_p	0,659 · C_p	0,574 · C_p
4	0,5	0,888 · C_p	0,841 · C_p	0,812 · C_p	0,757 · C_p
5	1,0	1,0 · C_p	1,0 · C_p	1,0 · C_p	1,0 · C_p
6	2,0	1,125 · C_p	1,189 · C_p	1,231 · C_p	1,319 · C_p
7	4,0	1,265 · C_p	1,414 · C_p	1,515 · C_p	1,741 · C_p
8	8,0	1,424 · C_p	1,682 · C_p	1,866 · C_p	2,297 · C_p
9	12,5	1,536 · C_p	1,880 · C_p	2,133 · C_p	2,746 · C_p
10	25	1,728 · C_p	2,236 · C_p	2,626 · C_p	3,624 · C_p
11	50	1,944 · C_p	2,659 · C_p	3,233 · C_p	4,781 · C_p
12	100	2,187 · C_p	3,162 · C_p	3,981 · C_p	6,309 · C_p
13	200	2,461 · C_p	3,760 · C_p	4,901 · C_p	8,325 · C_p
14	400	2,769 · C_p	4,472 · C_p	6,034 · C_p	10,985 · C_p

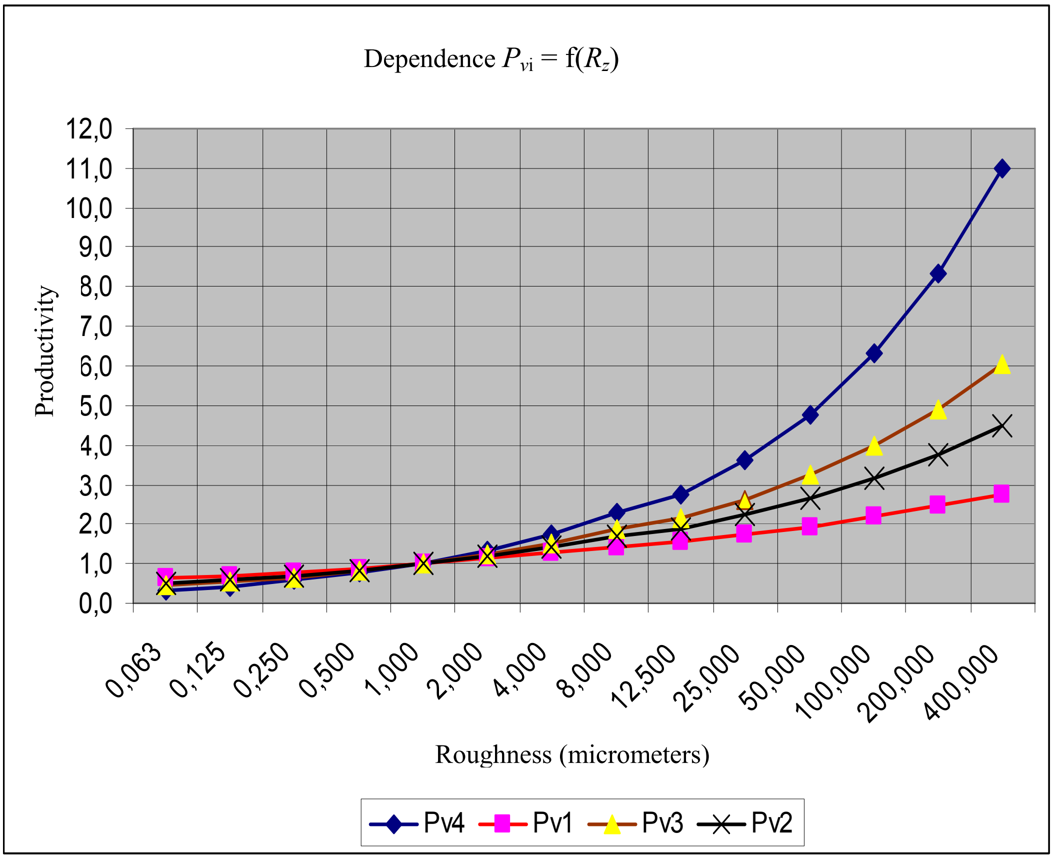

Fig. 2. The P_{vi} = f(R_z) dependence

Conclusions

The final purpose of any cutting processing type consists in obtaining a product of high quality characterized by a dimensional accuracy, accuracy of the geometrical shape and of the surface reciprocal position, by the processed surface roughness, respectively.

In the same effect, the technical progress and the rapid pace of development of the machine construction industry impose more are more exacting conditions. Nowadays, for a correct running of the machine parts, not only the constructive conceptions, but also, the surface quality of these machine parts to be assembled, are decisive.

The objective necessity of producing with a higher and higher productivity, led to a rapid evolution of the present conception of structural realization of the machine tools (machine tools with numerical control) depending in the greatest extent on the specific technology of the different guides which should be processed, and on the production volume.

Structural realization of the notable machine tools (machine tools with numerical control) allows processing's of high productivity on the basis of revaluation of the intrinsic factors in case of machine tools: size of the cutting speed (of the working revolution respectively) size of the working advance, size of the cutting depth.

In these circumstances a problem is imposed regarding the improvement of the other mechanical processing element performances: material and geometry of the cutting tool active part, and the cooling medium, respectively.

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Aspecte privind influenţa rugozităţii suprafeţei prelucrate asupra productivităţii maşinilor-unelte

Rezumat

Obţinerea dimensiunilor, toleranţelor şi a rugozităţii prescrise unei suprafeţe conform desenului de execuţie se poate realiza prin diverse procedee sau metode tehnologice de prelucrare într-o operaţie şi mai multe faze sau în mai multe operaţii, într-o succesiune bine determinată.
Lucrarea abordează, în acest context, stabilirea algoritmului pentru determinarea influenţei rugozităţii prescrise suprafeţei asupra productivităţii maşinii-unelte, în condiţii specifice de lucru.