ANALYSIS OF THE EVOLUTION OF THE ROUGHNESS OF SURFACES PROCESSED BY TURNING DEPENDING ON THE FUNCTIONAL GEOMETRY OF THE CUTTING TOOL

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Abstract: *The quality of the surfaces obtained during the cutting process can be appreciated from several points of view, but in this paper one aspect is considered, namely the roughness of the surface. In this way, the study aims to analyze how the surface roughness develops as a result of the variation of the functional geometry of the tool at turning with transverse advance. The technological process of turning with transverse advance is realized with a variable cutting speed, and this also causes a variation of the functional geomtry of the tool. Thus, in the paper was established the optimal construction geometry of a lathe knife that can be used for turning a piece of a certain diameter. Under these conditions, there was identified a correlation between the values of the functional geometrical parameters of the knife used for transverse turning and roughness (the quality of the surface).*

Keywords: roughness; modeling; turning; cutting tool; functional geometry

Introduction

The quality of the surface of a piece is a very complex notion and comprises two aspects: the superficial layer geometry which determines the deviations of the real surface from the theoretical surface and the roughness (micro-irregularities) of the real surface, - the state of the surface layer of the surface processed physically (deformation degree, remaining stresses, thermal, chemical, thermochemical treatments, etc.) [1, 2].

Rugosity is the microgeometric measurement of the height variations of a physical surface (according to surface metrology). This measurement is different from the determination of deviations from the correct geometric shape that characterizes surface geometry or undesirable misalignments. Rugidity with high values may be an undesirable feature as it causes increased friction and wear, but it can also be beneficial as it allows the adhesion of the oil film and prevents the formation of welding points between moving surfaces (the phenomenon of grip) [3].

The actual surface profile of a piece can be measured and visualized by various methods: mechanical, optical or optical three-dimensional methods. Rugosity is a measure that determines the condition of a surface, its texture. Surface texture is very important because it directly determines the quality of the executed pieces. There is a link of inverse proportionality between the roughness of a piece's surface and the cost of its execution. That is, the finer the surface of the piece is, the more laborious it is, it requires more precise and better tools and a longer machining time. It is therefore necessary to define and determine the roughness as precisely as possible using the parameters established by the developed standards for surface condition [4, 5].

Influence of the functional geometry of the tool on the roughness of the processed surfaces

Of the many factors that have an influence on the roughness, there are some that are of greater importance, namely: the geometry of the cutting part of the tool; the quality of surface of the cutting part of the tool (including its wear); the cutting regime; the plastic and elastic deformations of the material; stiffness of the elastic processing system; cooling - lubrication fluid.

Machining of the surfaces is the basic technological process for obtaining pieces in the machine building industry. In order to obtain pieces with respect to the required quality requirements it is necessary to use cutting tools with optimal geometry during machining. Projected geometry of cutting tools refers to constructive geometry, but during machining, the geometry becomes functional. Thus, the functional geometry of the tools is the one that greatly influences the process of machining pieces and implies the quality of the pieces obtained. At the present time, special attention is paid to the structural geometry of the tool, without taking into account the fact that the functional geometry of the tool depends on the following parameters: cutting speed, advance speed, workpiece dimensions.

The misunderstanding of the differences between the constructive geometry and the fuctional geometry of a tool can determine the difference between the actual results that occur in the machining process and those obtained in the process modeling stage.

The presence of large values for the component of the cutting speed V and of the longitudinal advance speed Vf, causes a considerable deviation of the direction of the resultant instantaneous velocity Ve in relation to the main direction V, figure 1.

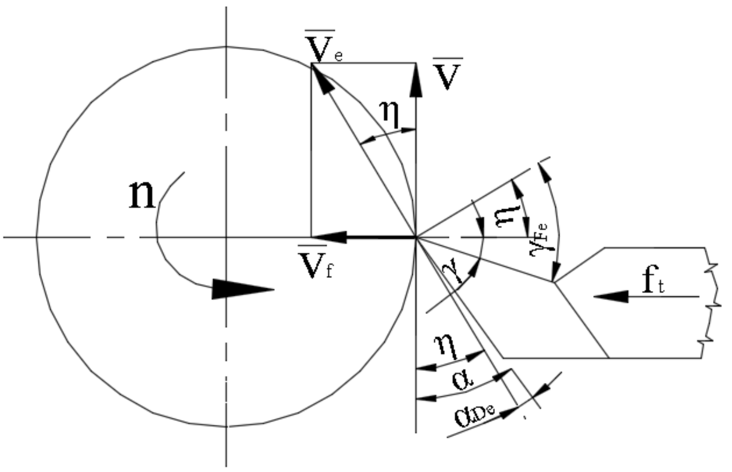

Figure 1. Variation of the settlement angle and functional release in the case of turning with transverse advance

From the one shown in Figure 1, the functional settlement angle α_{De} is smaller than the constructive angle and can take overly small values, they can be canceled or become negative, cases in which the cutting process becomes very difficult to carry out, as a result of the interference between the tool laying surface and the cutting surface. Also, the functional release angle γ_{Fe} is larger than the construction angle and can take overly high values, which can fundamentally influence the machining process.

Modeling the surface rugosity depending on the functional geometry of the cutting tools

The cutting process is very complex and during the cutting process, the angles of settlement and release vary, and this has a great influence on the roughness of the surface, which means that for the same surface we can have different values of roughness.

The functional angles of the cutting tool vary during the cutting process, Figure 1, and this can be mathematically determined by the relationship:

$$\gamma_{Fe} = \gamma + \eta$$
$$\alpha_{De} = \alpha - \eta \quad (1)$$

where: γ – constructive release angle; α – constructive settlement angle; γ_{Fe} – functional release angle; α_{De} - functional settlement angle; η – the angle of the cutting direction

$$tg\,\eta = \frac{v_f}{v_e} = \frac{n \cdot f}{\pi \cdot D_M \cdot n} = \frac{f}{\pi \cdot D_M} \quad (2)$$

$$R_Z = 2r_\varepsilon \sin^2 \frac{\alpha_{De}}{2} \quad (3)$$

where: V_f - advance speed; V_e – the resulting cutting speed; n – speed of the piece, f – the cutting tool advance; D_M – the diameter of the point M on the piece (it is variable at turning with transverse advance); R_z – surface roughness; r_ε – the radius at the top of the cutting tool.

Because during the machining process r_ε can change it value very little (only due to the wear of the cutting tool), thus, in the calculations there was made the notation $2r_\varepsilon = K$, and relation 3 becomes:

$$R_Z = K \cdot \sin^2 \frac{\alpha_{De}}{2} \quad (4)$$

The quantitative dependence between the roughness of the surface processed and the cutting speed (in the case of turning) can be expressed by the relation: ·

$$V = \frac{Cv \cdot Kv}{T^{Xv} \cdot Rz^{Yv}} \quad (5)$$

where: T – durability of the cutting tool; C_v, k_v, x_v and y_v are coefficients and exponents depending on the cutting conditions.

Also, the angle of the cutting direction η can be expressed in a relation of form:

$$tg\,\eta = \frac{v_f}{v} \quad (6)$$

Taking into account the relation (5), the roughness of the surface can be expressed in the next relation:

$$R_z = \frac{C_v \cdot K_v}{T^{xv} \cdot v} \quad (7)$$

Also, by replacing the relation 6 in relation 7 it was possible to obtain the expression of the surface roughness with the relation:

$$R_z = \frac{C_v \cdot K_v}{T^{xv} \cdot v_f} \cdot tg\,\eta \quad (8)$$

Considering the relation (8) and the relation (1), the roughness of the processed surface was expressed by the relations:

$$R_z = \frac{C_v \cdot K_v}{T^{xv} \cdot v_f} \cdot tg(\gamma_{Fe} - \gamma) \quad (9)$$

$$R_z = \frac{C_v \cdot K_v}{T^{xv} \cdot v_f} \cdot tg(-\alpha_{DE} + \alpha) \tag{10}$$

The advance speed of the splintering can be expressed in a relation as:

$$v_f = n \cdot f \tag{11}$$

where: n – speed of the piece, f – the cutting tool advance

For a complete modeling of the roughness dependence on the functional geometry of the cutting tool, the following notation has been made $\frac{C_v \cdot K_v}{T^{xv}} = C$

Thus, given the notations made and the relation (10), the following mathematical model was obtained which allows us to determine the surface roughness dependence on the functional geometry of the cutting tool:

$$R_z = C\frac{1}{n \cdot f} \cdot \frac{tg\gamma_{Fe} - tg\gamma}{1 + tg\gamma_{Fe} \cdot tg\gamma} \tag{12}$$

Table 1. Roughness variation R_{Z} / µm depending on the functional settlement angle $\alpha_{De}{}^{0}$

Advance f, mm/rot	0.50								
Diameter, mm	40	35	30	25	20	15	10	5	1
α_{De}	5.773	5.740^0	5.697^0	5.636^0	5.545^0	5.400^0	5.09^0	4.18^0	3,043^0
R_Z	K•2.53	K•2.50	K•2.46	K•2.41	K•2.33	K•2.21	K•1.97	K•1.33	K•1.7
Advance f, mm/rot	0,70								
Diameter, mm	40	35	30	25	20	15	10	5	1
α_{De}	5.681^0	5.636^0	5.575^0	5.49^0	5.362^0	5.149^0	4.73^0	3.45^0	-6.56^0
R_Z	K•2.45	K•2.41	K•2.36	K•2.29	K•2.18	K•2.11	K•1.70	K•0.9	K•3.2
Advance f, mm/rot	0.90								
Diameter, mm	40	35	30	25	20	15	10	5	1
α_{De}	5.59^0	5.53^0	5,45^0	5.344^0	5.18^0	4.906^0	4.36^0	2.73^0	-9.98^0
R_Z	K•2.37	K•2.32	K•2.26	K•2.1	K•2.04	K•1.83	K•1.44	K•0.5	K•7.56
Advance f, mm/rot	1.2								
Diameter, mm	40	35	30	25	20	15	10	5	1
α_{De}	5.453^0	5.375^0	5.271^0	5.125^0	4.906^0	4.542^0	3.82^0	1.64^0	-14.9^0
R_Z	K•2.26	K•2.19	K•2.11	K•2.1	K•1.99	K•1.57	K•1.11	K•0.2	K•1.6
Advance f, mm/rot	1.4								
Diameter, mm	40	35	30	25	20	15	10	5	1
α_{De}	5.362^0	5.271^0	5.149^0	4.979^0	4.724^0	4.299^0	3.45^0	-9.907^0	-18.01^0
R_Z	K•2.18	K•2.11	K•2.01	K•1.88	K•1.69	K•1.40	K•0.9	K•0.74	K•2.4

Table 2. Roughness variation R_{Z} / µm depending on the functional release angle $\gamma_{Fe}{}^{0}$

Advance f, mm/rot	0.50								
Diameter, mm	40	35	30	25	20	15	10	5	1
γ_{Fe}	5.227^0	5.260^0	5.303^0	5.364^0	5.455^0	5.60^0	5.91^0	6.82^0	14,043^0
R_Z	C•0.01	C•0.011	C•0.013	C•0.016	C•0.18	C•0.02	C•0.04	C•0.08	C•0.40
Advance f, mm/rot	0.70								
Diameter, mm	40	35	30	25	20	15	10	5	1
γ_{Fe}	5.319^0	5.364^0	5.425^0	5.510^0	5.638^0	5.851	6.27^0	7.55^0	17.56^0
R_Z(mm)	C•0.01	C•0.012	C•0.014	C•0.016	C•0.021	C•0.028	C•0.042	C•0.084	C•0.42
Advance f,	0.90								

mm/rot									
Diameter, mm	40	35	30	25	20	15	10	5	1
γ_{Fe}	5.410^0	5.468^0	5.547^0	5.656^0	5.820^0	6.094^0	6.64^0	$8,27^0$	20.98^0
R_Z	C•0.01	C•0.012	C•0.014	C•0.017	C•0.022	C•0.03	C•0.043	C•0.085	C•0.54
Advance f, mm/rot	1.2								
Diameter, mm	40	35	30	25	20	15	10	5	1
γ_{Fe}	5.547^0	5.625^0	5.729^0	5.875^0	6.094^0	6.458^0	8.18^0	9.36^0	25.9^0
R_Z	C•0.01	C•0.012	C•0.014	C•0.017	C•0.021	C•0.028	C•0.061	C•0.083	C•0.42
Advance f, mm/rot	1.4								
Diameter, mm	40	35	30	25	20	15	10	5	1
γ_{Fe}	5.638^0	5.729^0	5.851^0	6.021^0	6.276^0	6.701^0	7.55^0	10.093^0	29.01^0
R_Z	C•0.90	C•0.011	C•0.013	C•0.016	C•0.020	C•0.026	C•0.040	C•0.080	C•0.40

In order to analyze the theoretical dependence of the surface roughness on the functional geometry of the cutting tool it was considered that a piece with diameter D = 40 mm is machined by front turning, adjusting a speed n = 750 rot/min, and the constructive geometry of the cutting tool was $\gamma = 5^0$- constructive release angle, respectiv $\alpha = 6^0$ – constructive settlement angle.

Also, several processing variants with different advances of processing with values between 0.5 and 1.4 mm/rot were analyzed. The results obtained by modeling with the relations (4) and (12) are presented in Table 1 according to the functional settlement angle α_{De} and in Table 2 according to the functional release angle $\gamma_{Fe}\ ^0$.

Conclusions

Following the analysis there can be drawn the following conclusions:

- The value of the roughness R_Z decreases with the decrease of the functional settlement angle α_{De} and the value of the roughness decreases as the advance increases.
- The value of the roughness R_Z decreases with the increase of the functional release angle γ_{Fe} and the value of the roughness decreases as the advance increases.

This influence has the consequence of obtaining a surface whose quality is uneven and also decreases the durability of the cutting tool.

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