DETERMINATION OF THE CALCULUS RELATIONS OF THE CUTTING TOOL WEAR AND THE CUTTING SPEED AT DRILLING OF THE STEEL 2NiCr185

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Această lucrare prezintă rezultatele experimentale obţinute la găurirea oţelului inoxidabil 2NiCr185. Datele experimentale şi prelucrarea lor ulterioară reprezintă contribuţia originală a autorilor la estimarea unor exponenţi politropici şi la evaluarea termenilor din structura relaţiei de calcul a uzurii sculei aşchietoare. Lucrarea conţine diagrame ale variaţiei uzurii sculei aşchietoare în funcţie de parametrii tehnologici de aşchiere. Din relaţia obţinută, punând condiţia de limitare a uzurii, sunt determinate valorile exacte ale vitezei de aşchiere. Aceste rezultate pot fi luate în considerare în cercetările tehnice teoretice. De asemenea, ele pot fi implementate în activitatea de fabricaţie.

This paper presents the experimental results obtained at drilling of the stainless steel 2NiCr185. The experimental data and their further processing represent the original contribution of the authors to the estimation of the polytropic exponents and to the assessment of the terms from the calculus relation structure of the cutting tool wear. The paper contains graphs for the variation of the cutting tool wear with the parameters of the cutting technology. Putting the condition of the wear limitation, from the obtained relation, the exact values of the cutting speed are determined. These results can be taken into consideration in the theoretical technical research. Also, they can be implemented in the manufacturing activity.

Key words: drilling, cutting tool wear, cutting speed, stainless steel, polytropic exponents.

1. Introduction

The metallic material processing is determined by physical-chemical and technological properties of material and cutting tool [1, 2].

The researches in cutting domain have as purpose the cutting process economic optimization. In time, these allowed to create new materials for tools and sensible choice for the tools geometric parameters and cutting regime [3, 4].

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The use of the stainless steels is increasing with a rapid rate in various technical fields [5]. The chemical and mechanical characteristics of these steels require specific methods for the determination of the relations of the cutting process [6]. But the process difficulty is due to the cutting tool wear which grows in comparison with ordinary steels [7, 8].

For the stainless steels processing it is very important to know the cutting tool wear function. It can be presented in terms of four independent variables: the diameter *D*, the feed *f*, the tool speed *v* and the time of cutting *t*.

This paper presents a method to determine the cutting tool wear function $VB = f(D, f, v_c, t)$ for drilling of the analyzed stainless steel, with respect to the specific working conditions.

2. Means and conditions used for experiments

The means and the conditions using during the experiments were:

- The machine tool: a GC_0 32 DM3 drilling device and a Morse cone 4;
- The cutting tool: Rp5 high-speed steel spiral drill with HRC 62, STAS 575-80;
- The geometric features of the drill have met the requirements of the R1370/2-69 standard, A_1 type cutting, with diameters within the range 10 through 30 mm, $2\kappa = 130^0$, $\alpha = 10^0$;
- The cooling and lubricating fluid: P 20% emulsion.

Table 1 shows the chemical characteristics of the steel 2NiCr185. Table 2 and Table 3 contain the physical and mechanical characteristics of this steel.

Table 1

Percentage chemical composition (%)

C	Cr	Ni	Si	Mn	S	P
0.03	18.5	10.6	1.0	2.0	0.013	0.025

Table 2

Physical characteristics

Density (at 20^0 C) (kg/dm^3)	Elasticity modulus (at 20^0 C) (GPa)	Heat conductivity (W/m ^{0}K)	Specific heat (J/kg ^{0}K)	Electric resistivity (Ω mm^2/m)
7.9	200	15	500	0.73

Table 3

Mechanical characteristics

Stainless steel type	Tensile strength R_m (MPa)	0.2 offset limit R_{02} (MPa)	Ultimate Elongation *A* (%)	Hardness (HB)
2NiCr185	540	180	45	210

3. Experimental results and data processing

The technical literature [2, 9] provided the equation (1), which has been the starting point in the analysis of the cutting tool wear for drilling:

$$VB = C_{VB} \cdot D^{x} \cdot f^{y} \cdot v_c^{z} \cdot t^{w} \quad \text{(mm)} \qquad (1)$$

where: D is the diameter; f is the feed; v_c is the tool speed; t is the time of cutting; C_{VB} is a constant; x, y, z, w are polytropic exponents.

In order to estimate the constant C_{VB} and the polytropic exponents x, y, z, w, equation (1) has been linearized by using the logarithm. One obtained the equation:

$$\lg VB = \lg C_{VB} + x \cdot \lg D + y \cdot \lg f + z \cdot \lg v_c + w \cdot \lg t \qquad (2)$$

Table 4 shows a selection of the most conclusive experimental results obtained for the stainless steel 2NiCr185.

Table 4

Experimental results

Exp. No	D (mm)	f (mm/rot)	n (rot/min)	v_c (m/min)	t (min)	VB (mm)
1	12	0.12	560	21.10	27.4	0.62
2	16	0.20	560	28.13	13.8	0.96
3	20	0.12	560	35.17	17.6	1.26
4	24	0.32	355	26.75	18.3	0.35
5	18	0.12	355	20.06	23.6	0.21
6	12	0.20	560	21.10	14.4	0.64
7	20	0.20	560	35.17	10.2	1.32

If data of the first five experiments from the Table 4 are substituted in the equation (2), then a linear inhomogeneous system of five equations with five unknowns (x, y, z, w, lg C_{VB}) is obtained:

$$\begin{cases} \lg C_{VB} + x \cdot \lg 12 + y \cdot \lg 0.12 + z \cdot \lg 21.10 + w \cdot \lg 27.4 = \lg 0.62 \\ \lg C_{VB} + x \cdot \lg 16 + y \cdot \lg 0.20 + z \cdot \lg 28.13 + w \cdot \lg 13.8 = \lg 0.96 \\ \lg C_{VB} + x \cdot \lg 20 + y \cdot \lg 0.12 + z \cdot \lg 35.17 + w \cdot \lg 17.6 = \lg 1.26 \\ \lg C_{VB} + x \cdot \lg 24 + y \cdot \lg 0.32 + z \cdot \lg 26.75 + w \cdot \lg 18.3 = \lg 0.35 \\ \lg C_{VB} + x \cdot \lg 18 + y \cdot \lg 0.12 + z \cdot \lg 20.06 + w \cdot \lg 23.6 = \lg 0.21 \end{cases} \qquad (3)$$

The system (3) has the following solution:

$C_{VB} = 2.42 \cdot 10^{-3}$; $x = -2.2$; $y = 0.114$; $z = 3.64$; $w = 0.045$

The formula of the cutting tool wear on the tool putting surface at drilling of the steel 2NiCr185 is obtained by inserting the solution in the equation (1):

$$VB = 2.42 \cdot 10^{-3} \cdot D^{-2.2} \cdot f^{0.114} \cdot v_c^{3.64} \cdot t^{0.045} \quad \text{(mm)} \qquad (4)$$

The data of the last two experiments, included in the Table 4, allow the verification of the relation (4).

The relation (4) permits the determination of the wear on the putting surface, in the case of a couple: stainless steel 2NiCr185 - Rp5 high-speed spiral drill, depending on the work parameters and cutting conditions. It allows to establish the values for tool speed, feed, tool diameter and the durability, in conditions of a certain wear.

For different admissible values of the cutting tool wear, given by the specialized literature, the cutting tool speed can be obtained from relation (4) as follows.

a) For spiral drills with the diameter $D \leq 10$ mm, it is recommended $VB = 0.4$ mm [8]; for $t = T$, where T is the economical durability of the cutting tool, one obtains:

$$v_c\big|_{VB=0.4} = \frac{4.06 \cdot D^{0.604}}{T^{0.012} \cdot f^{0.031}} \quad \text{(m/min)} \qquad (5)$$

The economical durability of the cutting tool T at the processing of the steels with Rp5 high-speed steel spiral drills can be selected from the Table 5 [8].

Table 5

Experimental results

Diameter, *D* (mm)	≤ 0.5	0.6÷1.0	1.1÷5	6÷10	11÷15	16÷20	21÷30	31÷40
Durability, *T* (min)	1.0	3.0	7.0	12	17	20	28	45

b) For spiral drills with the diameter $D \in (10, 20]$ mm it is recommended $VB = 0.6$ mm [8]; for $t = T$, one obtains:

$$v_c\big|_{VB=0.6} = \frac{4.54 \cdot D^{0.604}}{T^{0.012} \cdot f^{0.031}} \quad \text{(m/min)} \qquad (6)$$

c) For spiral drills with the diameter $D > 20$ mm it is recommended $VB = 0.8$ mm [8]; for $t = T$, one obtains:

$$v_c\big|_{VB=0.8} = \frac{4.92 \cdot D^{0.604}}{T^{0.012} \cdot f^{0.031}} \quad \text{(m/min)} \qquad (7)$$

By tracing the cutting tool wear function diagrams with respect to the work parameters, using *Maple* software [10], the diagrams resulted are shown in Figs. 1 to 7 valid only for drilling of the stainless steel 2NiCr185 with a Rp5 high-speed steel spiral.

Fig. 1 shows the variation of the cutting tool wear depending on the cutting feed, for different diameters; the wear increases with the feed. Fig. 2 shows the variation of the tool wear depending on the feed, for different tool speeds; the wear increases with the tool speed.

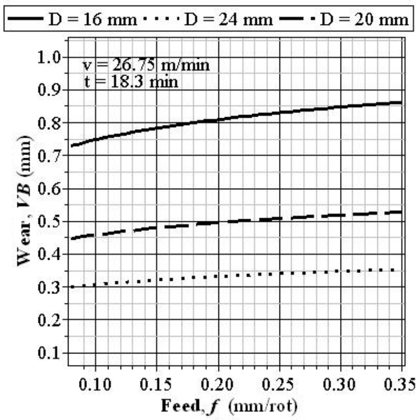

Fig. 1. The wear variation depending on the feed for different diameters.

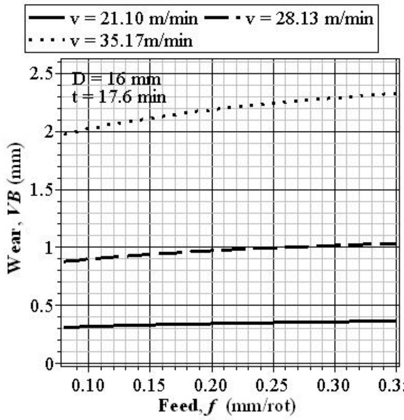

Fig. 2. The wear variation depending on the feed for different tool speeds.

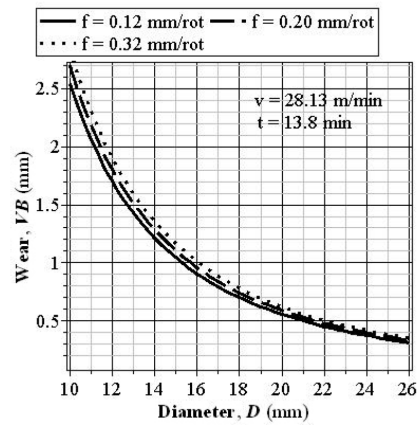

Fig. 3. The wear variation depending on the diameter for different feeds.

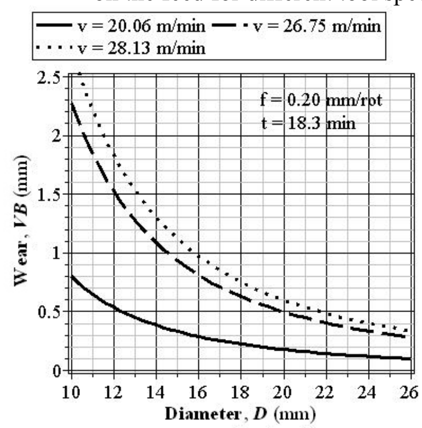

Fig. 4. The wear variation depending on the diameter for different tool speeds.

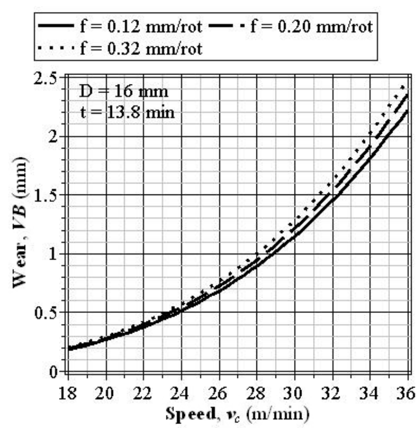

Fig. 5. The wear variation depending on the tool speed for different feeds.

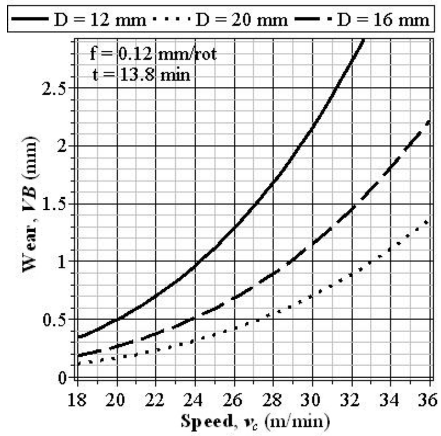

Fig. 6. The wear variation depending on the tool speed for different diameters.

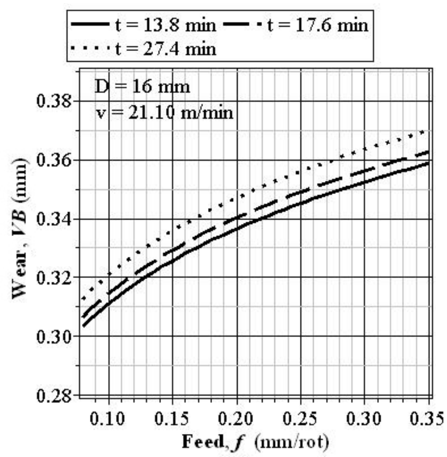

Fig.7. The wear variation depending on the feed for different cutting times.

Fig. 3 shows the variation of the tool wear depending on the diameter, for different feeds; the wear decreases exponentially with the diameter.

Fig. 4 shows the variation of the cutting tool wear depending on the diameter, for different speeds; the wear decreases exponentially with the diameter. Fig. 5 shows the variation of the cutting tool wear depending on the speed, for different feeds; the wear increases exponentially with the speed. Fig. 6 shows the variation of the cutting wear depending on the speed, for different diameters; the wear increases exponentially with the tool speed. Fig. 7 shows the variation of the cutting tool wear depending on the feed, for different cutting times; the wear increases with the feed.

4. Conclusions

The presented method for determining the cutting tool wear *VB*, in certain processing conditions, has the following advantages:

- The reduction of the time for experimental determination of the material and tools amount, that it is more economic that other methods.
- The determinations can be obtained relatively easily and the wear may be measured starting with the first pass.
- The accuracy of the established relations is comparable with other more precise methods that require a bigger amount of materials and tools.

After determining the tool wear function, it the admissible wear on areas of the drills diameter was imposed and the cutting speed was explained.

The obtained formula of the calculus relation of the cutting speed at drilling of the stainless steel 2NiCr185 is very useful for later theoretical research and especially for manufacturing activity. Our further studies aim at solving these problems for another steels classes.

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