DETERMINATION OF CUTTING FORCES RELATIONS WHEN WIDENING HOLES IN STAINLESS STEEL 10TiNiCr180

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Abstract: The paper presents a series of experimentally found data concerning the widening of the stainless steel 10TiNiCr180 and the ways and means to determine the cutting forces with respect to the specific working conditions. The experimental data and their subsequent processing represent the contribution of the authors to the estimation of the polytrophic exponents and to the assessment in terms of structure of the cutting forces equation. Afterwards, the paper presents the graphs for the variation of the cutting force components with the parameters of the cutting technology. The obtained results can be implemented in further research, in order to increase the productivity of steel machining.

Keywords: widening, cutting force, stainless steel, polytrophic exponents.

1. INTRODUCTION

The researches in cutting domain have as purpose the cutting process economic optimization. In time, these allowed to create new materials for cutting tools and sensible choice for tools geometric parameters and cutting regime (Popescu, 2001). The use of stainless steels is increasing at a rapid rate in various technical fields. The stainless steels are used not only at a large scale, as buildings construction materials, but also in many other, very different industries, as in medicine, for example for laboratories equipment and instruments and hospitals facilities, up to most well known home appliances and kitchen utensils.

It is well known that, owing to some specific physic-mechanical properties, it is often very problematic in practice to cut stainless steels in industry in terms of deciding the optimal cutting conditions and consume of materials and time (Enache & Minciu, 2003). At the same time, due to the high costs of these steels, their machinability should be studied using rapid cutting methods, capable of assuming minimum tool and material requirement (Vlase, 2009).

The purpose of this paper is analyzing a particular type of material during the cutting process, and obtaining the values of the cutting forces. This will be done while widening the stainless steel 10TiNiCr180. A series of experimental studies where carried out in order to determine the above mentioned cutting forces. The equations used to determine these forces have a new element introduced, the speed, which together with the previous indicators significantly contribute to a more precise calculus (Vlase, 2001). In time, many researchers have experimented cutting various materials by changing the cutting conditions, but it seems that their influence was not significant, and only the speed is bringing an important change when modified. The new equation is to be used this way for any other future determination of forces while processing other materials, especially in steels applications.

2. METHOD, MEANS AND CONDITIONS FOR THE DETERMINATION OF THE CUTTING FORCES

The tests were performed using a special dynamometer for the determination of the forces and moments (Vlase et al., 2004). On the perimeter of the elastic detecting element four equidistant resistive transducers were placed, inclined at 45º with respect to generatrix, in opposite, alternative successively. By using this placement of the transducers, and by connecting them to a bridge, highest measurement sensitivity has been achieved.

The cutting conditions during the experiments are given below:

(1) The machine tool: a GC0 32 DM3 drilling device, the dimensions of the mass are 480×420 and a Morse cone 4 was used.

(2) The cutting equipment: Rp5 high-speed steel spiral drill with Rockwell Hardness Number equal to 62.
(3) The geometric features of the drill have met the requirements of the R1370/2-74 standard, A1 type cutting, with diameters within 10 to 30 mm.
(4) The cooling and lubricating fluid: P 20% emulsion.
(5) The tools have been cut by means of the UAS-200 machine equipped with a stone wheel 50×20×20 E_N 40 M7C, using a special cutting device.
Table 1 shows the chemical characteristics of the steel 10TiNiCr180. Table 2 shows the mechanical characteristics of this studied stainless steel.

Table 1. Chemical Composition, %

C	Cr	Ni	Mn	Si	Ti	S	P
0.10	18	10.5	2.0	1.0	0.8	0.02	0.03

Table 2. Mechanical Characteristics

Tensile strength R_m [N/mm^2]	Flowing limit R_{02} [N/mm^2]	Elongation δ [%]	Hardness HB
690	265	38	217

3. EXPERIMENTAL RESULTS

Technical literature (Popescu, 2001) provided equation (1), which has been the starting point in the analysis of the cutting forces:

$$F = C_F \cdot D^{x_F} \cdot f^{y_F} \cdot a_p^{u_F} \qquad [\mathrm{N}] \tag{1}$$

Where D is the drill diameter, f is the cutting feed, a_p is the cutting depth and x_F, y_F, u_F, are exponents constants.

This equation has proved to be inappropriate since after the practical estimation of the polytrophic exponents and constants, several tests determinations have been performed and have showed a wide result scattering under the same cutting conditions. The problem is that during the steel machining at various speeds, different parameter values were recorded even if all the other machining conditions were kept constant (Vlase et al., 2004). It has led to introduce a speed factor:

$$F = C_F \cdot D^{x_F} \cdot f^{y_F} \cdot a_p^{u_F} \cdot v^{z_F} \qquad [\mathrm{N}] \tag{2}$$

In order to estimate the C_F constant and the x_F, y_F, u_F, z_F polytrophic exponents were estimated, the equation (2) has been linearized by using the logarithm:

$$\lg F = \lg C_F + x_F \lg D + y_F \lg f + u_F \lg a_p + z_F \lg v \tag{3}$$

Table 3 shows a selection of the most conclusive machined steel samples of the stainless steel 10TiNiCr180.
If the data for the first five experiments included in Table 3 are substituted in the equation (3), a linear inhomogeneous system of five equations with five unknowns (lgC_F, x_F, y_F, u_F, z_F,) is obtained, for the cutting force component Fz.

Table 3. Experimental Results

Exp. Nr	D_i [mm]	D_f [mm]	a_p [mm]	f [mm/rot]	n rot/ min	v [m/ min]	F [N]
1	12	16	2	0.20	224	11.25	398
2	12	24	6	0.20	224	16.88	1782
3	16	24	4	0.32	224	16.88	1601
4	16	24	4	0.20	355	26.75	1216
5	12	16	2	0.12	355	17.83	292
6	16	24	4	0.12	224	16.88	695
7	12	24	6	0.32	355	26.75	3008

The system for the force component *Fz* has the form:

$$\begin{cases} \lg C_F + x_F \lg 16 + y_F \lg 0.20 + u_F \lg 2 + z_F \lg 11.25 = \lg 398 \\ \lg C_F + x_F \lg 24 + y_F \lg 0.20 + u_F \lg 6 + z_F \lg 16.88 = \lg 1782 \\ \lg C_F + x_F \lg 24 + y_F \lg 0.32 + u_F \lg 4 + z_F \lg 16.88 = \lg 1601 \\ \lg C_F + x_F \lg 24 + y_F \lg 0.20 + u_F \lg 4 + z_F \lg 26.75 = \lg 1216 \\ \lg C_F + x_F \lg 16 + y_F \lg 0.12 + u_F \lg 2 + z_F \lg 17.83 = \lg 292 \end{cases} \quad (4)$$

And it has the following five solutions: C_F = 300; x_F = 0.0478; y_F = 0.8483; u_F = 1.2478 and z_F = 0.2687

The formula of the cutting force component *Fz* for the widening of the stainless steel 10TiNiCr180 is obtained by inserting these solutions in the equation (2):

$$F_z = 300 \cdot D^{0.0478} \cdot f^{0.8483} \cdot a_p^{1.2478} \cdot v^{0.2687} \qquad [\mathrm{N}] \quad (5)$$

If we verify the function obtained in (5), introducing the data of lines 6 and 7 from the Table 3, we should obtain a very low error, $\varepsilon < 3\%$

By tracing the cutting forces components variation diagrams with respect to the work parameters, the resulted diagrams are shown in figures 1 to 6, and they are valid only for stainless steel 10TiNiCr180.

Figure 1 shows the variation of the cutting force *Fz* depending on the diameter, for different values of the feed. The two parameters kept fixed were the cutting depth and the cutting speed, and we varied the drill diameter and the cutting feed. The latest was given three main values, 0.1, 0.2 and 0.3 mm/rot. The value of the force increases with the diameter and the feed.

Figure 2 shows the variation of the cutting force *Fz* depending on the feed, for different values of the cutting depth. The two parameters kept fixed were the diameter and the cutting speed, and we varied the cutting feed and the cutting depth. The latest was given three main values, 2, 4 and 6 mm. The value of the force increases with the feed and the cutting depth.

Figure 3 shows the variation of the cutting force *Fz* depending on the cutting depth, for different values of the feed. The two parameters kept fixed were the diameter and the

cutting speed, and we varied the cutting the cutting depth and the cutting feed. The force increases exponentially with the cutting depth and the cutting feed.
Figure 4 shows the variation of the cutting force *Fz* depending on the cutting speed, for different values of the cutting depth. The two parameters kept fixed were the diameter and the cutting feed, and we varied the cutting speed and the cutting depth. The value of the force increases with the cutting speed and the cutting depth.
Figure 5 shows the variation of the cutting force *Fz* depending on the feed, for different values of the cutting speed. The two parameters kept fixed were the diameter and the cutting depth, and we varied the cutting feed and the cutting speed. The value of the force increases with the cutting feed and the cutting speed.

Figure 6 shows the variation of the cutting force *Fz* depending on the cutting speed, for different values of the feed. The two parameters kept fixed were the diameter and the cutting depth, and we varied the cutting speed and the cutting feed The value of the force increases with the cutting speed and the cutting feed.

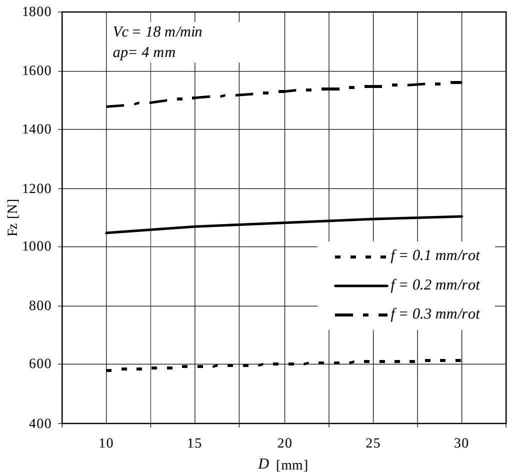

Fig. 1. The force F_z variation depending on the diameter for different feeds

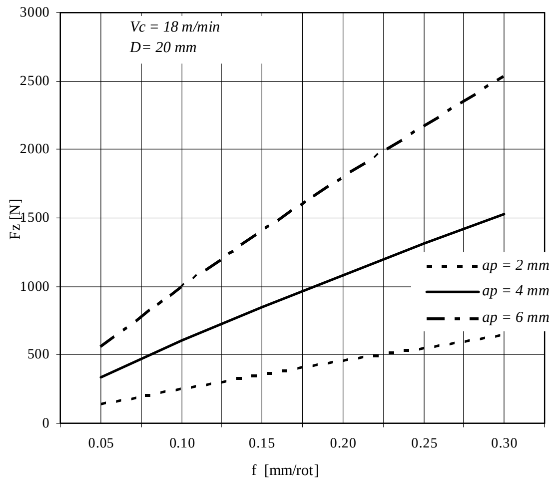

Fig. 2. The force F_z variation depending on the feed for different depth

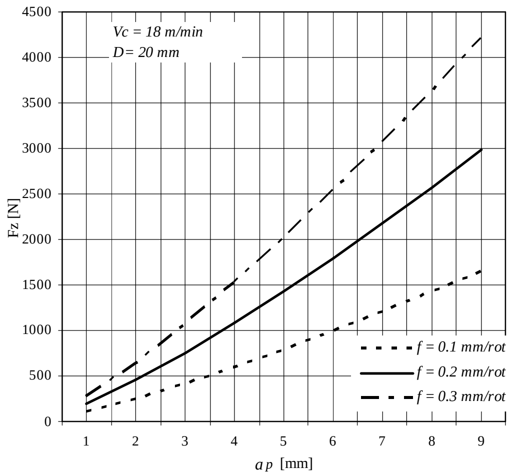

Fig 3 The force F_z variation depending on depth for different feeds

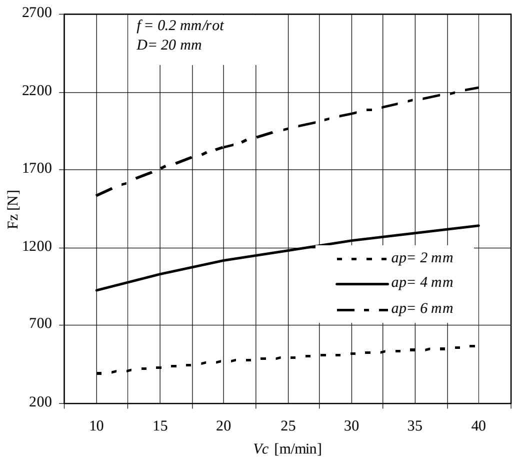

Fig 4 The force F_z variation depending speed for different depth

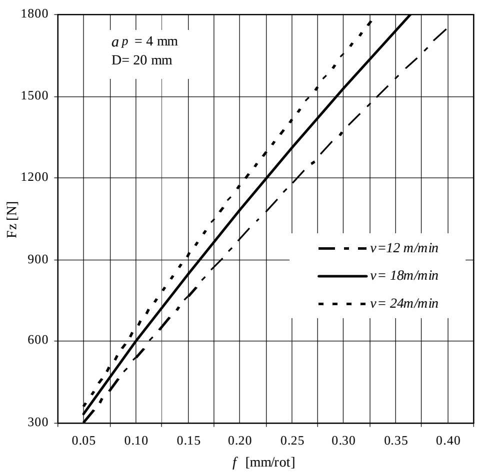

Fig 5 The force F_z variation depending on feed for different speeds

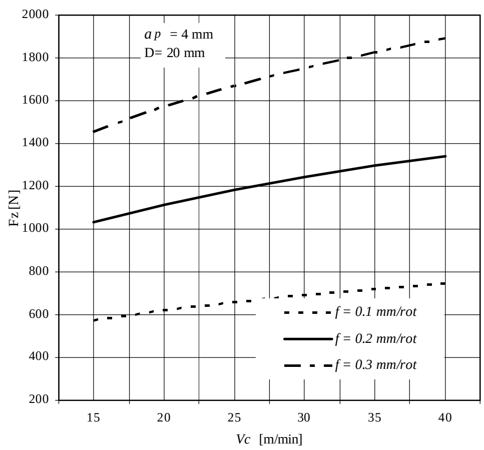

Fig 6 The force F_z variation depending on speed for different feeds

4. CONCLUSIONS

The analysis of the experimental data has led to the following conclusions:

1) For the cutting force determination at stainless steel widening, a special dynamometer was designed and manufactured; the tensometer transducers were attached to an elastic element.
2) By many experimental tests, it was demonstrated the necessity of modifying the structure of the cutting force calculation relation found in the technical literature, meaning that the speed has to be included with respect to equations (2) and (5).
3) The experimental results prove the variation of the cutting forces values depending on the parameters of the cutting technology.
4) The results of the present study can be readily implemented and/or used in further research activity concerning technological parameters for the widening of the stainless steels.

References: 1. Enache, S. & Minciu, C. (2003). The Design of the Cutting Tools with the Aid of Electronic Computer, Ed. Tehnică, Bucharest. **2.** Popescu, I. (2001). Fundaments of cutting and surface generation, University of Craiova. **3.** Vlase, A. (1977). Contributions to the Studies on the Machinability of Cutting Romanian Make Stainless Steels, Doctoral Thesis, Polytechnic Institute Bucharest. **4.** Vlase, A.; Blăjină, O. & Vlase, I. (2004). Method for determination of the cutting forces and moments at the drilling of the 4NiCr180 steel, Academic Journal of Manufacturing Engineering, Vol. 2, No. 3/2004, pp.49-54, Ed. Politehnica Timisoara, ISSN1583-7904. **5.** Vlase A., Blăjină O. & Sime M. (2009). Determination of the regression relation of the cutting forces for widening of the stainless steel 20MoCr130, 13th International Conference ModTech2009 on Modern Technologies, Quality and Innovation - New face of TMCR, ISSN 2066-3919 (ISI Citation index), Iasi-Romania. **6.** Vlase, I. (2001). Contributions on calculating the refractory stainless steels processing indicators. Ph.D. Thesis. Polytechnic University of Bucharest, pp. 56-78.