DETERMINATION OF THE CALCULUS RELATION OF THE AXIAL CUTTING FORCE AT DRILLING OF THE STEEL 2NiCr185

Bogdan VLASE[1], Ovidiu BLĂJINĂ[2], Aurelian VLASE[3]

Lucrarea prezintă o serie de date experimentale obținute la găurirea oțelului inoxidabil 2NiCr185 şi mijloacele pentru determinarea forței de aşchiere axială cu respectarea condițiilor specifice de lucru. Datele experimentale şi prelucrarea ulterioară reprezintă contribuția originală a autorilor la determinarea relației de calcul a forței axiale la găurirea oțelului studiat. Aceasta a fost modificată în raport cu relația forței de aşchiere axială existentă în literatura tehnică pentru oțelurile obişnuite. Rezultatele obținute pot fi utilizate în activitatea de producție cu scopul de a mări productivitatea prelucrării oțelului inoxidabil.

The paper presents a series of experimentally obtained data at drilling of the stainless steel 2NiCr185 and the means for the determination of the axial cutting force with respect to the specific working conditions. The experimental data and the following processing represent the original contribution of the authors to determination of the calculus relation of the axial cutting force for drilling of the studied steel. It was modified with respect to the relation of the axial cutting force available in the technical literature for common steels. The obtained results can be used in production activity, in order to increase the productivity of the stainless steel machining.

Key words: drilling, axial cutting force, stainless steel, polytropic exponents.

1. Introduction

The stainless steels are used more and more in various key domains of technique [1]. The processing of these steels is determined by their specific physical-chemical characteristics and by their technological properties [2, 3].

The great difficulties for the cutting of the stainless steels involve intense studies to create new materials for tools and sensible choice for the tools' geometric parameters and cutting regime [4, 5].

[1] Eng., University POLITEHNICA of Bucharest, Department of Machine Manufacturing Technology, Romania, e-mail: bvlase@yahoo.com

[2] Assoc. Prof., University POLITEHNICA of Bucharest, Department of Machine Manufacturing Technology, Romania, e-mail: ovidiu_blajina@yahoo.com

[3] Prof., University POLITEHNICA of Bucharest, Department of Machine Manufacturing Technology, Romania, e-mail: aurelvlase@yahoo.com

On the other hand, due to the high costs of these steels their machinability should be studied using rapid cutting methods capable of assuming minimum tool and material requirements [6, 7, 8].

With this object in view, the present paper extends a series of experimentally found data concerning the drilling of the stainless steel 2NiCr185 and the means to determine the cutting forces.

The axial cutting force function can be presented in terms of three independent variables: the diameter *D*, the feed *f*, and the tool speed *v*.

The paper presents a method for determining the axial cutting force function $F_z = f(D, f, v)$ for drilling of the analyzed stainless steel, with respect to the specific working conditions.

2. Means and conditions used for experiments

The tests were performed using an experimental set-up for recording the values of the force variations at different splintering parameters, consisting of the following: a built dynamometer with strain gauges for measuring the forces; a MGC amplifier, produced by Hottinger Baldwin Messtechnic; a data acquisition board type DAQ Pad 6020E; PC; LabVIEW software.

The built dynamometer is a rotating one, being fixed by a taper shank in the tapered bore of the drilling shaft. On the perimeter of the elastic detecting element, four equidistant strain gauges were placed, inclined at 45^0 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. In order to calibrate the dynamo-meter, the following items were used: a standard dynamometer; a taper rod (TC-01-03), axial and tangential loading device. The loading of the dynamometer was done on the axial direction.

The gauging of the pickup of forces was made with a lab dynamometer which bears a maximum loading of 10 kN and compression value of 0.01 mm. An average constant calibration for the forces was obtained: K_F =130 [N/V].

The means and the cutting conditions during the experiments are given below:

- the machine tool: a GC_0 32 DM3 drilling device a Morse cone 4;
- the cutting tool: Rp5 high-speed steel spiral drill (STAS 575-90) with the Rockwell Hardness Number = 62;
- 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;
- the cooling and lubricating fluid: P 20% emulsion.

Table 1 shows the chemical characteristics of the steel 2NiCr185 (STAS 3583-87). Table 2 contains the physical characteristics of this steel. Tabel 3 shows the mechanical characteristics of the steel.

Table 1

Percentage of 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)	Young's 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	Ultimate tensile R_m (MPa)	Yield limit R_{02} (MPa)	Elongation A (%)	Hardness (HB)
2NiCr185	540	180	45	210

3. Experimental results and data processing

The technical literature [9, 10] provided the equation (1), which has been the starting point in the analysis of the axial cutting forces for drilling:

$$F_z = C_F \cdot D^{x_F} \cdot f^{y_F} \quad [\mathrm{N}]. \tag{1}$$

where: D is the diameter; f - the feed; C_F - a constant; x_F, y_F - polytropic exponents.

This equation has proved to be inappropriate, since, after the practical estimation of the polytropic exponents and constants, several tests determinations were performed and showed a wide result scattering under the same cutting conditions. The problem is that during the stainless steel machining at various speeds, different parameter values were recorded even if all the other machining conditions were kept constant. That is why a speed factor was introduced as follows:

$$F_z = C_F \cdot D^{x_F} \cdot f^{y_F} \cdot v^{z_F} \quad [\mathrm{N}]. \tag{2}$$

In order to estimate the constant C_F and the polytropic exponents x_F, y_F, z_F equation (2) has been linearized using the logarithm. The following equation was obtained:

$$\lg F_z = \lg C_F + x_F \cdot \lg D + y_F \cdot \lg f + z_F \cdot \lg v. \tag{3}$$

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

Table 4

Experimental results

Exp. No	Diameter D [mm]	Feed f [mm/rot]	Rotation n [rot/min]	Speed v [m/min]	Cutting force F_z [N]
1	16	0.12	224	11.25	4429
2	16	0.20	224	11.25	5545
3	16	0.12	355	17.83	4210
4	24	0.32	224	16.88	8592
5	20	0.12	355	22.30	4786
6	18	0.20	224	12.66	5938

If data of the first four experiments from Table 4 are substituted in equation (3), a linear inhomogeneous system of four equations with four unknowns (a_F, b_F, c_F, lgC_F) is obtained:

$$\begin{cases} \lg C_F + x_F \cdot \lg 16 + y_F \cdot \lg 0.12 + z_F \cdot \lg 11.25 = \lg 4429 \\ \lg C_F + x_F \cdot \lg 16 + y_F \cdot \lg 0.20 + z_F \cdot \lg 11.25 = \lg 5545 \\ \lg C_F + x_F \cdot \lg 16 + y_F \cdot \lg 0.12 + z_F \cdot \lg 17.83 = \lg 4210 \\ \lg C_F + x_F \cdot \lg 24 + y_F \cdot \lg 0.32 + z_F \cdot \lg 16.88 = \lg 8592 \end{cases} . \quad (4)$$

The system (4) has the following solution: C_F = 2230; x_F = 0.68; y_F = = 0.44; z_F = -0.11

The formula of the axial cutting force for the drilling of the studied stainless steel 2NiCr185 is obtained by inserting the above solution in equation (2):

$$F_z = 2230 \cdot D^{0.68} \cdot f^{0.44} \cdot v^{-0.11} \quad [\mathrm{N}] . \quad (5)$$

The data of the last two experiments, included in Table 4, allows the verification of the formula from relation (5).

The diagrams of the cutting axial force variation with respect to the work parameters, plotted using *Maple* software [11], are shown in Figs. 1 to 5. They are valid only for drilling of the stainless steel 2NiCr1850 with a Rp5 high-speed steel spiral.

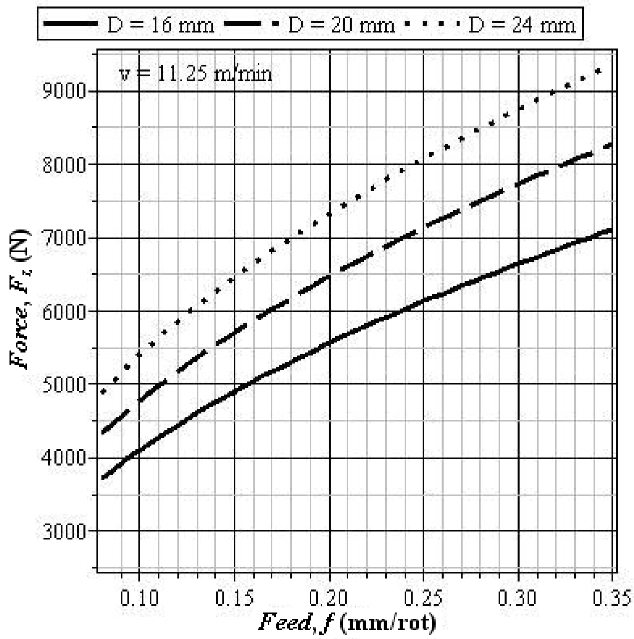

Fig. 1. The axial force variation depending on the feed for different tool diameters.

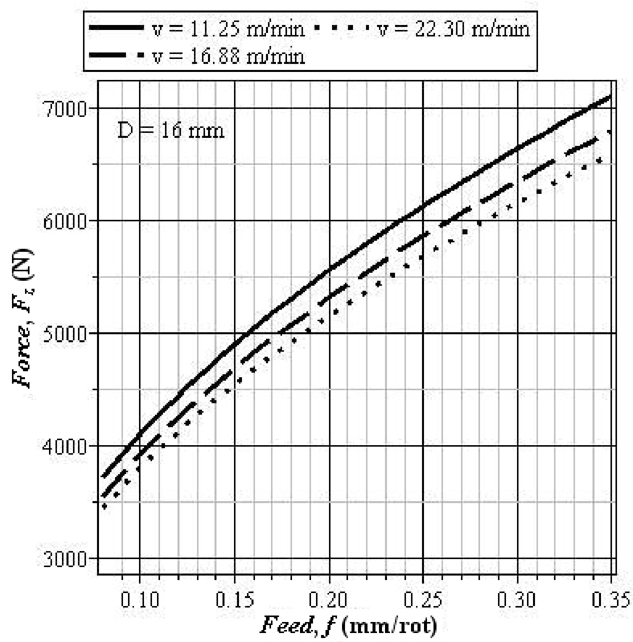

Fig. 2. The axial force variation depending on the feed for different tool speeds.

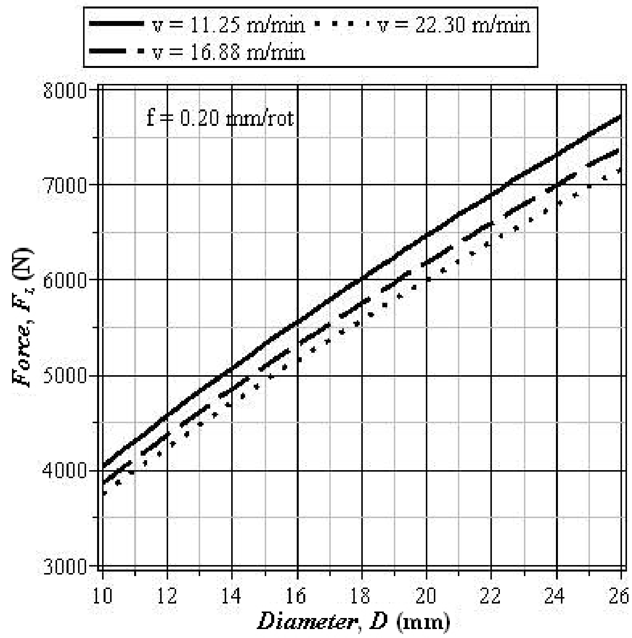

Fig. 3. The axial force variation depending on the diameter for different tool speeds.

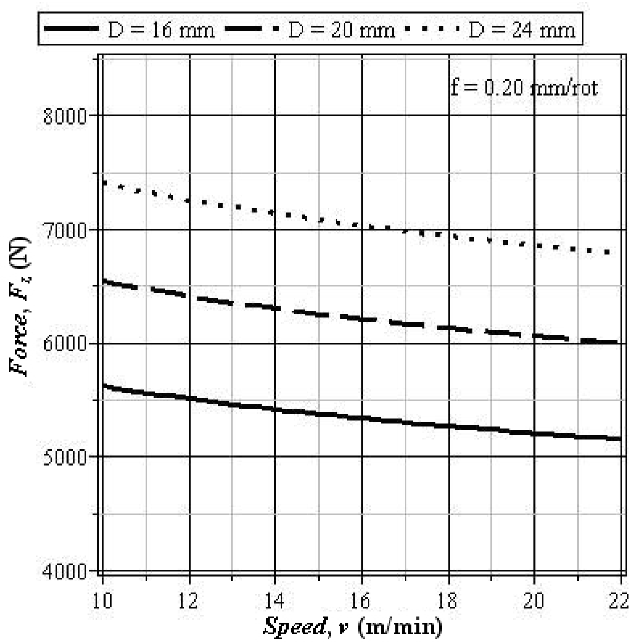

Fig. 4. The axial force variation depending on the tool speed for different diameters.

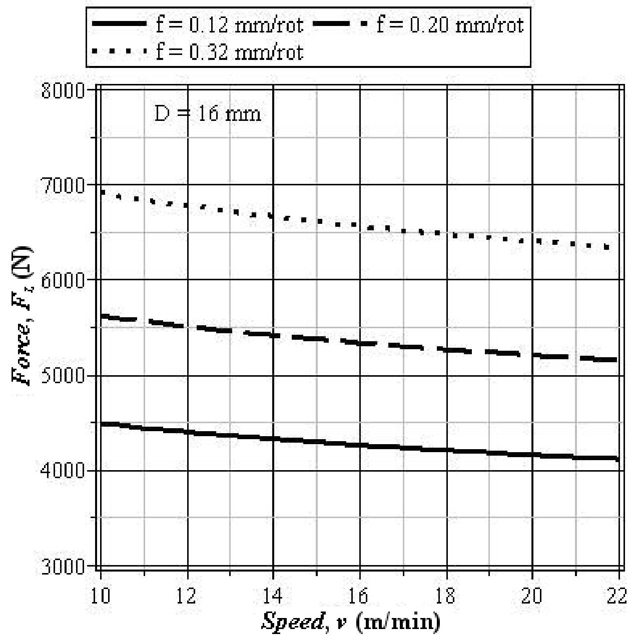

Fig. 5. The axial force variation depending on the tool speed for different feeds.

Fig. 1 shows the axial cutting force variation depending on the feed for different tool diameters. Fig. 2 shows the force variation depending on the feed for different tool speeds. Fig. 3 shows the force variation depending on the diameter for different tool speeds. Fig. 4 shows the force variation depending on the tool speed for different diameters. Fig. 5 shows the force variation depending on the tool speed for different feeds.

4. Conclusions

The experimental data and their subsequent processing represent the contribution of the authors to the estimation of the polytropic exponents and to the assessment in terms of structure of the axial cutting force formula, concerning the drilling of the stainless steel 2NiCr185.

For the axial force determination at the drilling of the stainless steels, a dynamometer was designed and manufactured; it has a rotative dynamometer fixed in the tapered hole of the drilling shaft which uses strain gauges attached to an elastic element.

After many experimental tests, it was proved the necessity of modifying the structure of the cutting axial force calculation relation for drilling, found in the technical literature, i.e. the tool speed has to be included with respect to equations (2) and (5).

The analysis of the relation (5) concerning the drilling of the stainless steel 2NiCr185 with a Rp5 high-speed steel spiral, and the diagrams from Figures 1 to 5, have lead to the following conclusions:

- the axial force increases with the feed, for different diameters, if the tool speed is constant;
- the axial force increases with the feed, for different tool speeds, if the diameter is constant;
- the axial force increases exponentialy with the tool diameter, for different tool speeds, if the feed is constant;
- the axial force decreases with the tool speed, for different diameters, if the feed is constant;
- the axial cutting force decreases with the tool speed, for different feeds, if the diameter is constant.

The results of this study can be easily implemented in further research and then, used in production, in order to increase the productivity of the steel machining.

R E F E R E N C E S

[1] *N. Predincea*, Procedee de prelucrare prin aşchiere (Cutting machining processes), ISBN 973-9493-39-4, Editura BREN, Bucureşti, 2002. (in Romanian)
[2] *R. Schnadt*, Austenitischen Stahlfräsen, ZWF CIM **Vol.86**, No.6, Verlag, 312-315, ISSN 0932-0482, München, 1991.
[3] *E. Trent, P. Wright*, Metal cutting, 4th Edition, Butterworth Heinemann, ISBN 0-7506-7069-X, Boston, 2000.
[4] *S. Kaldor, A. Ber*, A Criterion to Optimize Cutting Tool Geometry, CIRP Annals – Manufacturing Technology **Vol.39**, Issue 1, Elsevier, 131-136, ISSN 0007-8506, 1990.
[5] *I. Tănase*, Scule aşchietoare (Cutting tools), ISBN 978-973-648-849-8, Editura BREN, Bucureşti, 2009. (in Romanian)
[6] *C. Barlier, L. Girardin*, Memotech productique, materiaux et usinage, Ed. Casteilla, ISBN 2-7135.2051.7, Paris, 1999.
[7] *D. A. Stephenson*, Material Characterization for Metal-Cutting Force Modelling, ASME Journal of Engineering Materials and Technology **Vol.111**, 210-219, ISSN 0094-4289, Washington University, 1998.
[8] *A. Vlase*, *C. Neagu*, *C. Stăncescu*, *I. Luncaş*, Tehnologii de prelucrare pe maşini de găurit (Processing technologies on drills), ISBN 978-973-648-633-3, Editura BREN, Bucureşti, 2007. (in Romanian)
[9] *A. Vlase*, Contribuţii privind studiul prelucrabilităţii prin aşchiere a oţelurilor inoxidabile de producţie indigenă (Contributions to the studies on the machinability of cutting romanian make stainless steels, PhD Thesis, Polytechnic Institute Bucharest, 1977.
[10] *J. Wang, J. Sha, H. Shi*, Development of New Drilling Force Models, Proceedings of the International Symposium on Manufacturing Science and Technology for the 21 Century, International Academic Publishers, 171-178, ISBN 7-80003-306-6, Beijing, 1994.
[11] *O. Blăjină*, Maple în matematica asistată de calculator (Maple in computer aided mathematics), Editura Albastră, ISBN 973-650-007-1, Cluj-Napoca, 2001. (in Romanian)