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ON THE CUTTING FORCES TO THE DRILLING OF THE STAINLESS STEEL W1.4571

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Abstract: *The paper presents the experimental results necessary for the regression relations for the cutting forces when drilling the stainless steel W1.4571. For this purpose a rotate dynamometer was designed, fixed in the conical space of the drilling machine, provided with tensometric traducers linked on an elastic element that assures a sufficient sensibility for the established purpose. The range of the cutting forces of 450 ... 9500 N permitted experiments with drills of 6 ... 32 mm diameters. Through many experiments, the necessity of changing the structure of the relation of the forces was proven, by introducing the relations (2) and (5).*

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

1. INTRODUCTION

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 [3]. 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 requirement [1, 3].

With this object in view, the present paper expounds a series of experimentally found data concerning the drilling of the W1.4571 type stainless steel and the ways and means to determine the cutting forces.

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

The tests were performed using a dynamometer with resistive tensometer transducers. A spring collet type force and moment detecting element was adapted for the dynamometer construction.

The build 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 resistive transducers were placed, inclined at 45° 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 loading of the dynamometer was done on the axial direction and the bore of the drilling shaft. The tensometer bridge gradations were noted.

The cutting conditions during the experiments are given below:

1) The machine tool: a GC_0 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 the Rockwell Hardness Number = 62.

3) 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 6 through 32 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 150 × 20 × 20 E_N 40 M7C, using a special cutting device.

Table 1 shows the percentage chemical characteristics of the stainless steel W1.4571. Table 2 shows the mechanical characteristics of this steel.

Table 1

Percentage Chemical Composition

C	Mn	Si	Cr	Mo	Ni	Ti	S	P
0.023	1.55	0.61	17.0	2.16	12.55	0.33	0.02	0.04

Table 2

Mechanical Characteristics

Tensile Strength R_m [N/mm^2]	Flowing Limit R_{02} [N/mm^2]	Elongation δ [%]	Hardness HB
534	225	54	137

3. EXPERIMENTAL RESULTS AND DATA PROCESSING

Technical literature [2, 4] provided equation (1), which has been the starting point in the analysis of cutting forces:

$$F = C_F \cdot D^{x_F} \cdot s^{y_F}, \text{[N]}, \quad (1)$$

where: D is the tool diameter; s is the tool travel; C_F is a constant; x_F, y_F are polytropic exponents.

This equation has proved to be inappropriate since after the practical estimation of the polytropic exponents and constants, several tests determinations have been performed and have showed a wide result scattering noted under the same cutting conditions [5].

The problem is that during the steel machining at various revolutions, different parameter values were recorded even if all the other machining conditions are kept constant. Therefore, it was introduced a revolution factor and the equation becomes:

$$F = C_F \cdot D^{x_F} \cdot s^{y_F} \cdot n^{z_F}, \text{[N]}, \quad (2)$$

where n is the revolution tool and z_F is a polytropic exponent.

In order to determine the C_F constant and the x_F, y_F, z_F polytropic exponents, the equation (2) has been linearized by using the logarithm:

$$\lg F = \lg C_F + x_F \cdot \lg D + y_F \cdot \lg s + z_F \cdot \lg n. \quad (3)$$

Table 3 shows a selection of the most conclusive machined steel samples of the W1.4571 type.

If the data included in Table 3 are substituted in the equation (3), a linear inhomogeneous system of four equations with four unknowns (x_F, y_F, z_F, $\lg C_F$) is obtained:

$$\begin{cases} \lg C_F + x_F \cdot \lg 24 + y_F \cdot \lg 0.32 + \\ + z_F \cdot \lg 224 = \lg 8333 \\ \lg C_F + x_F \cdot \lg 24 + y_F \cdot \lg 0.12 + \\ + z_F \cdot \lg 224 = \lg 6250 \\ \lg C_F + x_F \cdot \lg 16 + y_F \cdot \lg 0.20 + \\ + z_F \cdot \lg 335 = \lg 5208 \\ \lg C_F + x_F \cdot \lg 12 + y_F \cdot \lg 0.12 + \\ + z_F \cdot \lg 335 = \lg 3854 \end{cases} \quad (4)$$

The system (4) has the following solutions:

$C_F = 8717.16$; $x_F = 0.527$; $y_F = 0.293$;
$z_F = - 0.256$

The axial cutting force formula for the drilling of the W1.4571 type stainless steel is obtained by inserting these solutions in the equation (2):

$$F = 8717.16 \cdot D^{0.527} \cdot s^{0.293} \cdot n^{-0.256}, \text{[N]}. \quad (5)$$

By tracing the cutting force variation diagrams with respect to the work parameters, the diagrams resulted are shown in Figs. 1 to 6, valid only for the stainless steel W1.4571.

In Fig. 1 it is observed that the cutting axial force increases exponentially depending on the tool travel for different tool diameters. In Fig. 2 the axial force decreases exponentially depending on the tool revolution

Table 3

Experimental Results

Experiment Nr.	D [mm]	s [mm/rot]	n [rot/min]	F [N]
1	24	0.32	224	8333
2	24	0.12	224	6250
3	16	0.20	355	5208
4	12	0.12	355	3854

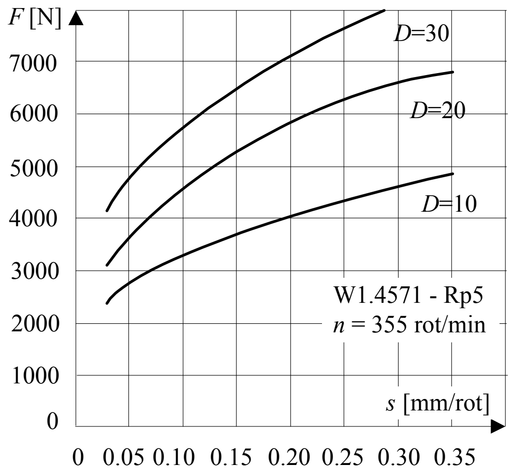

Fig. 1. The axial force variation depending on the tool travel for different tool diameters.

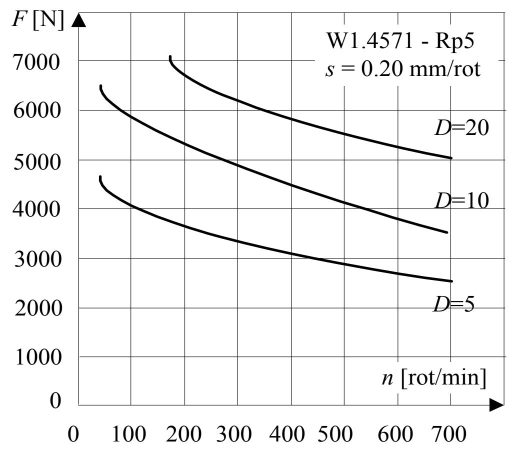

Fig. 2. The axial force variation depending on the tool revolution for different tool diameters.

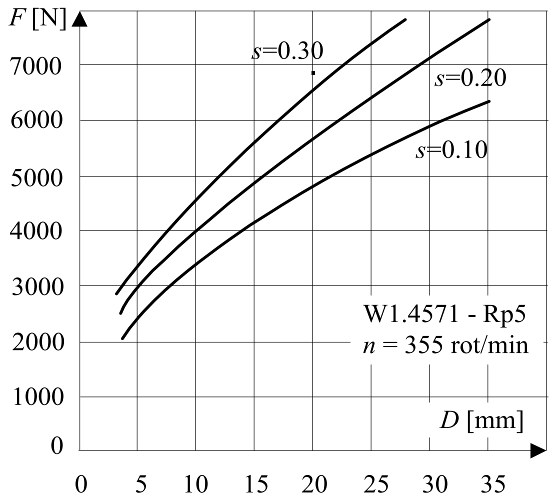

Fig. 3. The axial force variation depending on the tool diameter for different tool travels.

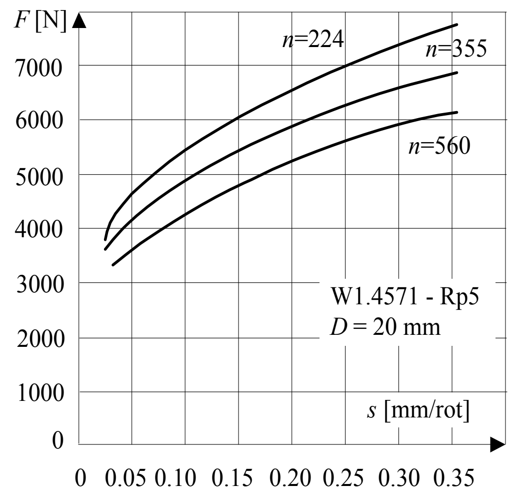

Fig. 6. The axial force variation depending on the tool travel for different tool revolutions.

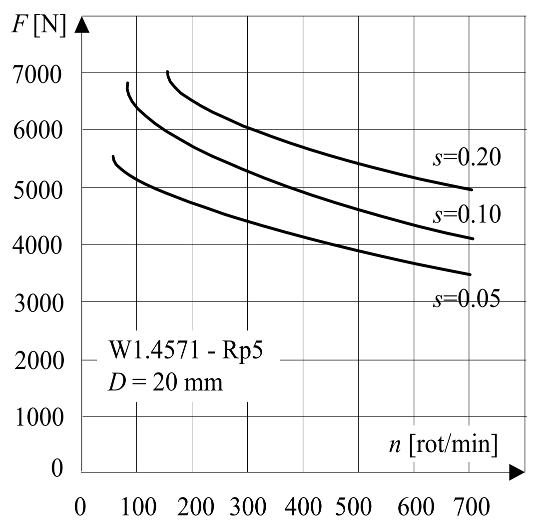

Fig. 4. The cutting axial force variation depending on the tool revolution for different tool travels.

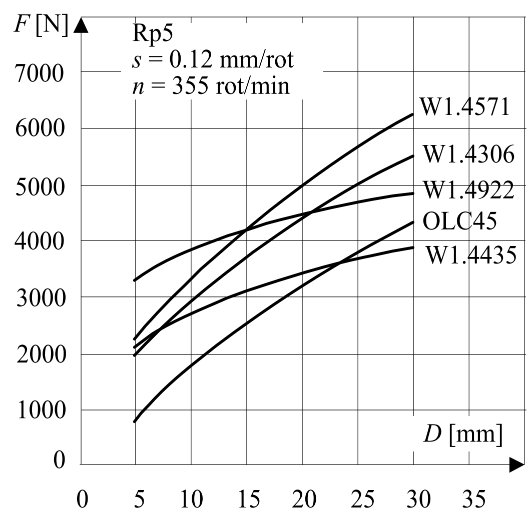

Fig. 7. The cutting axial force variation depending on the tool diameter for different steels types.

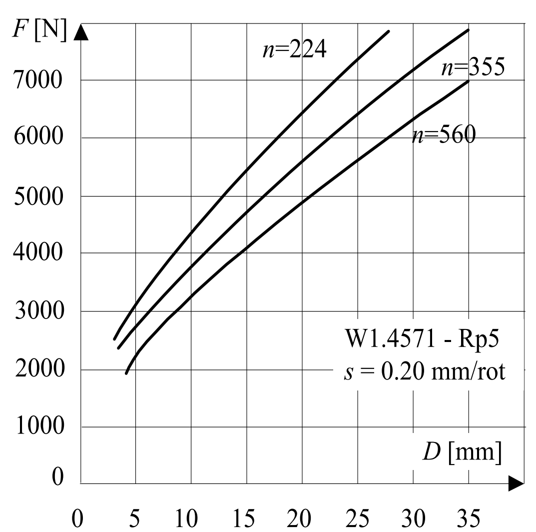

Fig. 5. The axial force variation depending on the tool diameter for different tool revolutions.

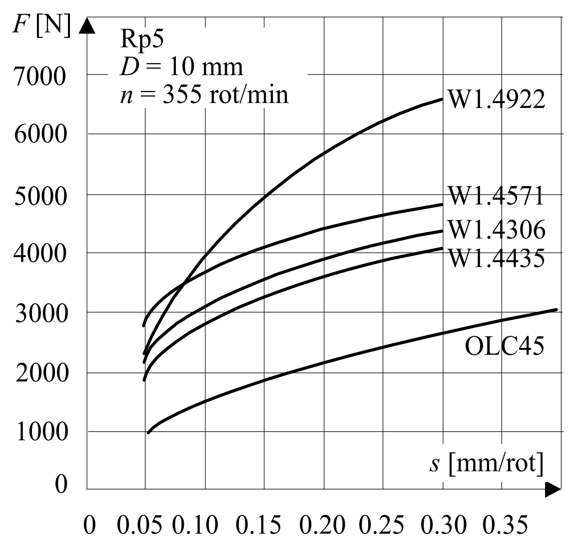

Fig. 8. The cutting axial force variation depending on the tool travel for different steels types.

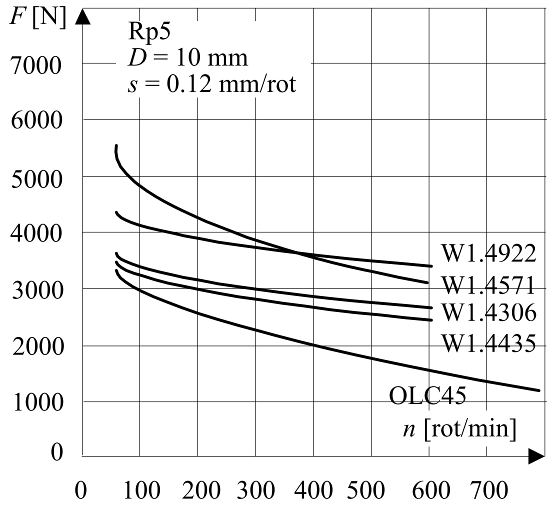

Fig. 9. The cutting axial force variation depending on the tool revolution for different steels types.

for different tool diameters. In Fig. 3 it is observed that the axial force increases exponentially depending on the tool diameters for different tool travels. In Fig. 4 the axial force decreases exponentially depending on the tool revolution for different tool travels. In Fig. 5 it is observed the axial force increases exponentially once the tool diameter increases for different tool revolutions. In Fig. 6 the axial force increases exponentially once the tool travel increases for different tool revolutions.

The cutting force variation diagrams with respect to the parameters of the cutting technology, obtained for another four steels (W1.4306, W1.4435, W1.4922, OLC 45), are shown in Figs. 7 to 9.

Some of these steels has the proper equation of the axial cutting force. For the determination of the expression of this equation it is utilised the method presented in this paper.

The analysis of the Figs. 7 to 9 has emphasized like results for the four stainless steels, but different for the reference steel OLC 45.

The method described in this paper can be also applied to determine the cutting moments at the drilling of the stainless steels, with respect to the specific working conditions.

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 cutting force equation, concerning the stainless steel W1.4571.

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

1) For the axial force determination at the stainless drilling a dynamometer was designed and manufactured; it was a rotative dynamometer fixed in the tapered bore of the drilling shaft foreseen with tensometer transducers attached to an elastic element.

2) Measuring range of forces permitted tests with drill diameters of 5 ÷ 32 mm.

3) By many experimental tests, it was proved the necessity of modifying the structure of the cutting force calculation relation found in the technical literature, i.e. the revolution has to be included with respect to equations (2) and (5).

4) The experimental results prove that the force values increase exponentially with the tool travel and the tool diameters on the hand, and decrease exponentially with the revolution of the cutting tool, on the other hand.

5) The results of this present study can be easy implemented and/or used in further research and used in production, in order to increase the productivity of steel machining activity.

REFERENCES

[1] Lăzărescu, I. (1977). *Teoria aşchierii metalelor şi proiectarea sculelor* (Metal Cutting Theory and Tool Design), Edit. Tehnică, Bucharest.

[2] Popescu, I. (1981). *Fundamentele aşchierii şi generării suprafeţei* (Fundaments of cutting and surface generation), Vol. I and II, University of Craiova.

[3] Vlase, A. (1977). *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), Polytechnic Institute Bucharest.

[4] Vlase, A. (1988). *Calculul analitic al regimurilor de aşchiere la găurire. Îndrumar* (A Guide to the Analytical Calculation of Cutting Processes for Drilling), Polytechnic Institute Bucharest.

[5] Vlase, A., Blăjină, O., Vlase, I. (2004). *Method for determination of the cutting forces and moments to the drilling of the 4NiCr180 steel*, Academic Journal of Manufacturing Engineering, Vol.2, No.3, Edit. Politehnica Timisoara, pp. 49-54.

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