U.P.B. Sci. Bull., Series D, Vol. 77, Iss. 3, 2015 ISSN 1454-2358

CALCULUS OF THE RELATIONSHIP OF THE CUTTING MOMENT AT DRILLING OF THE STAINLESS STEEL X22CrMoV12-1

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This article studies the cutting moment at drilling of the stainless steel X22CrMoV12-1 EN 10302-2 (05/2002). The experimental data and their subsequent processing represent the original contributions of the authors to the determination of polytropic exponents and to the assessment in terms of structure of the calculus relation of the cutting moment. The article also contains graphs with the cutting moment variation depending on the parameters of the cutting technology. The results presented in this paper can be taken into consideration in the educational studies and in the theoretical technical research. Also, they can be certainly implemented in the manufacturing activity.

Keywords: drilling, cutting moment, stainless steel, polytropic exponents.

1. Introduction

The stainless steels are used more and more in various key domains of industry [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 involved intense studies to create new materials for cutting tools and sensible choice for the tools geometric parameters and cutting regime [4, 5, 6]. 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 [7, 8].

With this object in view, this paper presents a series of experimentally obtained data concerning the drilling of the stainless steel X22CrMoV12-1 and the ways and means to determine the cutting moments. The cutting moment function M will be determined in the terms of three independent variables (the tool diameter D, the cutting feed f, the tool speed v) for drilling of the analyzed steel, with a HS6-5-2C high-speed steel drill, with respect to the specific working conditions.

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2. Means and cutting conditions used for the experimental tests

The experimental tests were performed using the set-up from Fig. 1 for recording the values of the cutting moment variations at different splintering parameters, consisting of the following components:

- a Kistler Force Plate for measuring the moments;
- a MGC amplifier, produced by Hottinger Baldwin Messtechnic;
- a data acquisition board type DAQ Pad 6020E;
- a PC;
- LabWIEW software.

Fig. 1. The experimental stand of determinations

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

- the machine tool: a GU 25 drilling device, with power P = 2.3 kW, range of revolutions 28 ... 2240 rot/min, range of tool travels 0.08 ... 0.25 mm/rot and with a Morse cone 4;
- the cutting tool: HS6-5-2C high-speed steel drill with the hardness 62 HRC and the diameters: Φ8, Φ10, Φ12, Φ16;
- the geometric features of the drill have met the requirements of the R1370/2-2005 standard, A1 type cutting, with diameters within the range 6 through 30 mm;
- the cooling and lubricating fluid: P 20% emulsion.

Table 1 shows the chemical characteristics of the stainless steel X22CrMoV12-1. Table 2 contains the mechanical characteristics of the studied steel.

Table 1

Percentage chemical composition [%]

C	Si	Mn	P	S	Cr	Ni	Mo	Cu	V	Fe
0.218	0.349	0.57	0.023	0.042	12.11	0.69	1.03	0.062	0.255	rest

Table 2

Mechanical characteristics (at 20^0 C)

Stainless steel	Tensile strength R_m [MPa]	Yield limit R_{02} [MPa]	Elongation at break A [%]	Hardness [HB]
X22CrMoV12-1	960	348	21	311

3. Experimental results and processing data for the cutting moments

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

$$M = C_M \cdot D^{x_M} \cdot f^{y_M} \quad [\text{Nm}]. \tag{1}$$

where: D is the tool diameter; f is the cutting feed; C_M is a constant; x_M, y_M are polytropic exponents.

This equation has proved to be inappropriate since after the practical estimation of the polytropic exponents and the 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. A tool speed factor has been thus introduced:

$$M = C_M \cdot D^{x_M} \cdot f^{y_M} \cdot v^{z_M} \quad [\text{Nm}]. \tag{2}$$

In order to estimate the C_M constant and the x_M, y_M, z_M polytropic exponents, equation (2) has been linearized by using the decimal logarithm. It results the following equation:

$$\lg M = \lg C_M + x_M \cdot \lg D + y_M \cdot \lg f + z_M \cdot \lg v. \tag{3}$$

Table 3 shows a selection of the most conclusive experimental results obtained for the studied stainless steel.

Table 3

Experimental results

Exp. No	Diameter D [mm]	Feed f [mm/rot]	Rotation n [rot/min]	Speed v [m/min]	Cutting moment M [Nm]
1	10	0.125	355	11.15	15.51
2	10	0.08	355	11.15	11.65
3	10	0.125	710	22.30	13.41
4	12	0.08	355	13.38	15.15
5	8	0.125	710	17.83	9.82
6	12	0.08	710	26.75	13.28

If data from the first four experiments from Table 3 are substituted in equation (3), then a linear inhomogeneous system of four equations with four unknowns (x_M, y_M, z_M, lg C_M) is obtained:

$$\begin{cases} \lg C_M + x_M \cdot \lg 10 + y_M \cdot \lg 0.125 + z_M \cdot \lg 11.15 = \lg 15.51 \\ \lg C_M + x_M \cdot \lg 10 + y_M \cdot \lg 0.08 + z_M \cdot \lg 11.15 = \lg 11.65 \\ \lg C_M + x_M \cdot \lg 10 + y_M \cdot \lg 0.125 + z_M \cdot \lg 22.30 = \lg 13.41 \\ \lg C_M + x_M \cdot \lg 12 + y_M \cdot \lg 0.08 + z_M \cdot \lg 13.38 = \lg 15.15 \end{cases}. \quad (4)$$

The above system (4) is compatible, uniquely determined; it has the solution: $C_M = 2.18$; $x_M = 1.65$; $y_M = 0.64$; $z_M = -0.21$.

The formula of the cutting moment for drilling of the stainless steel X22CrMoV12-1, obtained by inserting the above solution in equation (2), is the following:

$$M = 2.18 \cdot D^{1.65} \cdot f^{0.64} \cdot v^{-0.21} \quad [\text{Nm}]. \quad (5)$$

The influence of the cutting tool geometry on the value of the cutting moment is reflected in the above C_M constant.

Data of the last two experiments, included in the Table 3, allow the verification of the formula from equation (5).

Based on the obtained analytical relationship (5), the diagrams of the cutting moment variation with respect to the parameters of the cutting technology, have been drawn by means of the mathematical software *Maple* [10].

The resulted graphs are shown in Figures 2 to 7, valid only for drilling of the stainless steel X22CrMoV12-1 with a HS6-5-2C high-speed steel drill.

Figure 2 shows the variation of the cutting moment depending on the cutting feed f, for three values of the tool diameter D, in condition given by the tool speed v = 11.15 m/min; the cutting moment increases almost linearly with the cutting feed and it increases with respect to the tool diameter.

Figure 3 shows the variation of the cutting moment depending on the cutting feed f, for three values of the tool speed v, in condition given by the tool diameter D = 10 mm; the cutting moment increases with the feed and it decreases with respect to the tool speed.

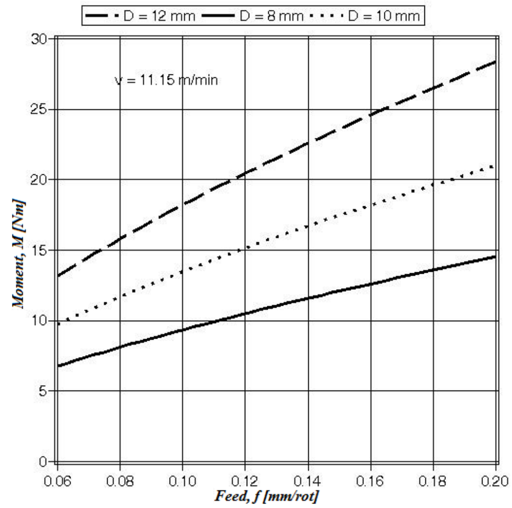

Fig. 2. The moment variation depending on the feed for different tool diameters

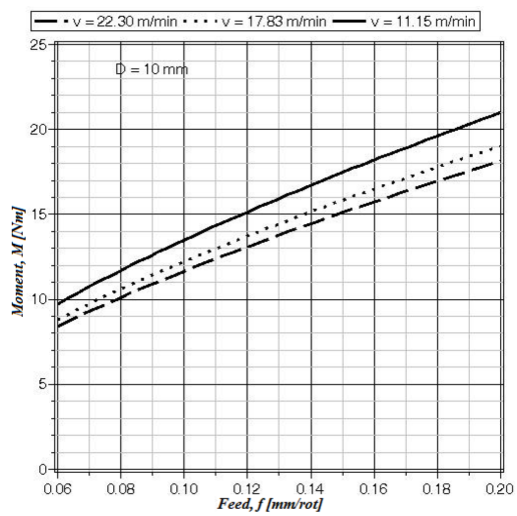

Fig. 3. The moment variation depending on the feed for different tool speeds

Figure 4 shows the variation of the cutting moment depending on the tool diameter D, for two values of the cutting feed f, in condition given by the tool speed v = 11.15 m/min; the cutting moment increases exponentially with the tool diameter and it increases with respect to the cutting feed.

Figure 5 shows the variation of the cutting moment depending on the tool diameter D, for three values of the tool speed v, in condition given by the cutting feed f = 0.125 mm/rot; the cutting moment increases exponentially with the tool diameter and it decreases with respect to the tool speed.

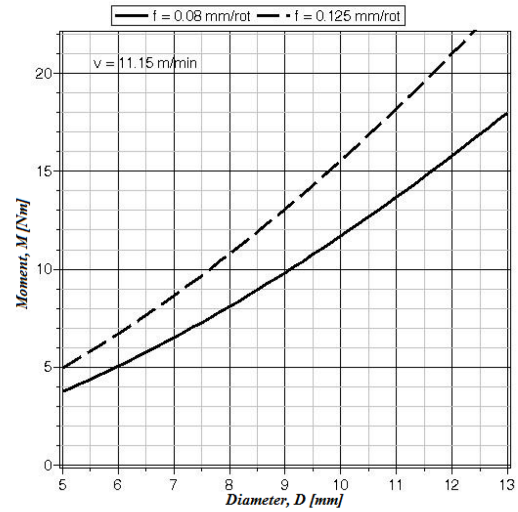

Fig. 4. The moment variation depending on the tool diameter for different feeds

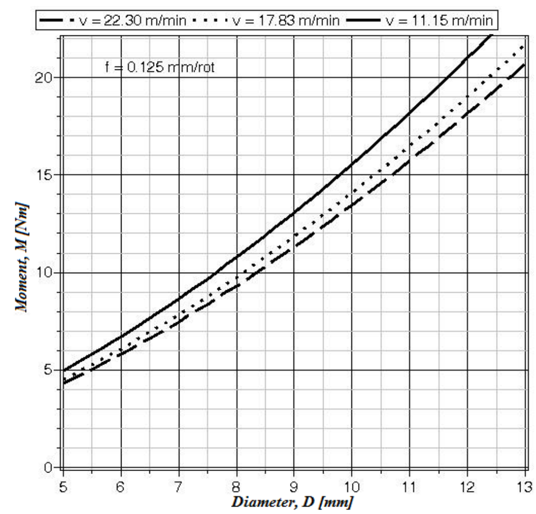

Fig. 5. The moment variation depending on the tool diameter for different tool speeds

Fig. 6 shows the variation of the cutting moment depending on the tool speed *v*, for three values of the tool diameter *D*, in condition given by the cutting feed *f* = 0.125 mm/rot; the cutting moment decreases slowly with the tool speed and it increases with respect to the tool diameter.

Fig. 7 shows the variation of the cutting moment depending on the tool speed *v*, for two values of the cutting feed *f*, in condition given by the tool diameter *D* = 10 mm; the cutting moment decreases with the tool speed and it increases with respect to the cutting feed.

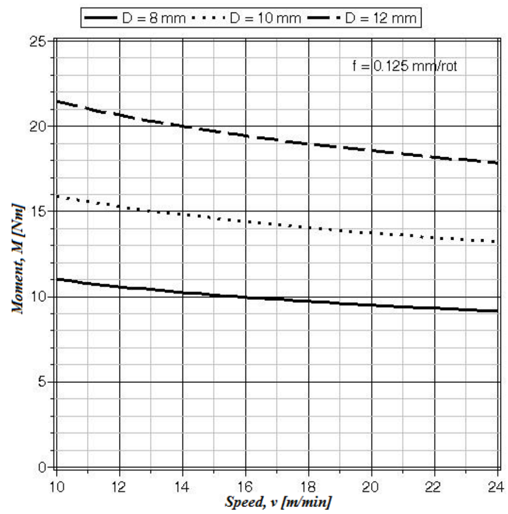

Fig. 6. The moment variation depending on the tool speed for different tool diameters

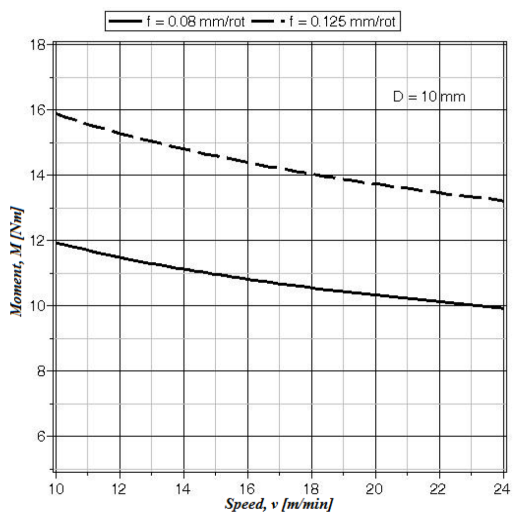

Fig. 7. The moment variation depending on the tool speed for different feeds

4. Conclusions

The experimental data and their processing represent the contribution of the authors to the estimation of the polytropic exponents and to the assessment in terms of structure of the calculus relation of the cutting moment at the drilling of the stainless steel X22CrMoV12-1 with HS6-5-2C high-speed steel drills.

Measuring range of the moments permitted tests with diameters within the range 6 … 30 mm.

By many experimental tests, it was demonstrated the necessity of modifying the structure of the cutting moment calculation relation, found in the technical literature, meaning that the cutting tool speed has to be included with respect to equation (2). The analysis of the obtained relation (5) and the diagrams, concerning the studied stainless steel, show the variation of the cutting moment values depending on the parameters of the cutting technology.

The results presented in this study can be taken into consideration in the educational studies and in the theoretical technical research. Also, they can be certainly implemented in the manufacturing activity. Our further studies will aim to solve these problems also for other classes of steels and cutting machining processes.

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