# DETERMINATION OF CUTTING MOMENT WHEN WIDENING HOLES IN STAINLESS STEEL 10TiNiCr180

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*Abstract*: This paper presents a series of experimentally establish data regarding the widening of the stainless steel 10TiNiCr180 and the ways and means to fix on the cutting moments with respect to the specific working conditions. The experimental data and their following processing represent the original contribution of the authors to determine the relation of the cutting moment's equation for widening of the used steel. This was modified with respect to the relations of cutting moments available in the 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:* widening, cutting moments, stainless steel, polytropic exponents.

## 1. INTRODUCTION

The metallic material processing is determined by physical-chemical and technological properties of material and cutting tool (Popescu, 2001). The stainless steels used, more and more in various key domains of technique, pose great difficulties for the workshop 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). 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 (Vlase, 2009).

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.

The present paper expounds a new experimental method for determination of the cutting moment at the 10TiNiCr180 type stainless steel widening, in a minimal material and equipment expenditure. A series of experimental studies where carried out in order to determine the above mentioned cutting moment.

The equations used to determine these moments 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 moment while processing other materials, especially in steels applications.

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

The tests were performed using a special dynamometer for the determination of the moments (Vlase et al., 2004). 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 cutting conditions during the experiments are given below:
(1) The machine tool: a GC0 32 DM3 drilling device, the dimensions of the mass are 480x420 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 50x20x20 $E_N$ 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 $\delta$ [%] | Hardness HB |
|---|---|---|---|
| 690 | 265 | 38 | 217 |

## 3. EXPERIMENTAL RESULTS AND OBTAINED DATA PROCESSING

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

$$M = C_M \cdot D^{x_M} \cdot f^{y_M} \cdot a_p^{u_M} \qquad \text{[Nm]} \tag{1}$$

where: $D$ is the drill diameter; $f$ is the cutting feed $a_p$ is the cutting depth and $x_M$, $y_M$, $u_M$ are the exponents constants.

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 under the same cutting conditions (Vlase et al., 2005). 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. It has led to introduce a speed factor thus:

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

In order to the $C_M$ constant and the $x_M$, $y_M$, $u_M$, $z_M$, polytropic exponents were estimated, the equation (2) has been linearized by using the logarithm:

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

Table 3 shows a selection of the most conclusive machined steel samples of this studied steel.

Table 3. Experimental Results

| Exp Nr | $D_i$ [mm] | $D_f$ [mm] | $a_p$ [mm] | f [mm/rot] | n rot/min | v [m/min] | M [Nm] |
|---|---|---|---|---|---|---|---|
| 1 | 12 | 16 | 2 | 0.20 | 224 | 11.25 | 7.7 |
| 2 | 12 | 24 | 6 | 0.20 | 224 | 16.88 | 49.3 |
| 3 | 16 | 24 | 4 | 0.32 | 224 | 16.88 | 38.3 |
| 4 | 16 | 24 | 4 | 0.20 | 355 | 26.75 | 29.9 |
| 5 | 12 | 16 | 2 | 0.12 | 355 | 17.83 | 5.9 |
| 6 | 16 | 24 | 4 | 0.12 | 224 | 16.88 | 24.2 |
| 7 | 12 | 24 | 6 | 0.32 | 355 | 26.75 | 60.6 |

If the data for the first five rows included in Table 3 are substituted in the equation (3), a linear inhomogeneous system (4) of five equations with five unknowns is obtained.

$$\begin{cases} \lg C_M + x_M \lg 16 + y_M \lg 0.20 + u_M \lg 2 + z_M \lg 11.25 = \lg 7.7 \\ \lg C_M + x_M \lg 24 + y_M \lg 0.20 + u_M \lg 6 + z_M \lg 16.88 = \lg 49.3 \\ \lg C_M + x_M \lg 24 + y_M \lg 0.32 + u_M \lg 4 + z_M \lg 16.88 = \lg 38.3 \\ \lg C_M + x_M \lg 24 + y_M \lg 0.20 + u_M \lg 4 + z_M \lg 26.75 = \lg 29.9 \\ \lg C_M + x_M \lg 16 + y_M \lg 0.12 + u_M \lg 2 + z_M \lg 17.83 = \lg 5.9 \end{cases} \tag{4}$$

The system (4) has the following five solutions: the constant $C_M$ = 0.116 and the polytropic exponents $x_M$ = 1.557; $y_M$ = 0.450; $u_M$ = 1.145; $z_M$ = -0.078.

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

$$M = 0.116 \cdot D^{1.557} \cdot f^{0.450} \cdot a_p^{1.145} \cdot v^{-0.078} \quad \text{[Nm]} \tag{5}$$

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 moments variation diagrams with respect to the work parameters, the resulted diagrams are shown in figures 1 to 6 valid only for the stainless steel 10TiNiCr180.

Figure 1 shows the variation of the cutting moment 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 moment increases with the diameter and the feed.

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

Figure 3 shows the variation of the cutting moment depending on the feed, for different values of the diameter. The two parameters kept fixed were the cutting depth and the cutting speed, and we varied the cutting feed and the drill diameter. The latest was given three main values, 16, 20 and 24 mm. The value of the moment increases with the feed and the diameter.

Figure 4 shows the variation of the cutting moment depending on the feed, for different values of the cutting depth. The two parameters kept fixed were the drill 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 moment increases with the cutting feed and the cutting depth.

Figure 5 shows the variation of the cutting moment depending on the cutting depth, for different values of the diameter. The two parameters kept fixed were the cutting feed and the cutting speed, and we varied the cutting depth and the drill diameter. The latest was given three main values, 16, 20 and 24 mm. The value of the moment increases with the cutting depth and the diameter.

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

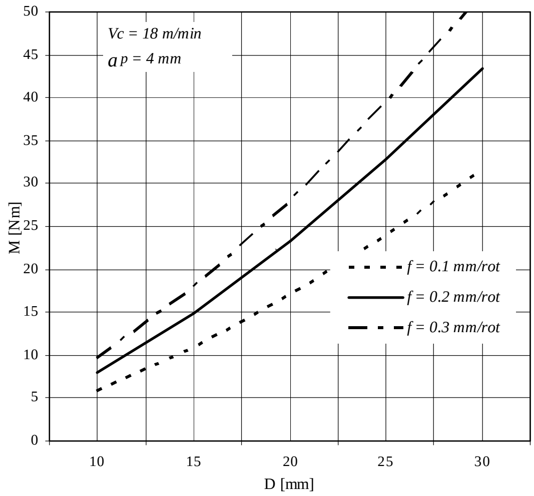


Fig. 1. The moment M variation depending on diameter for different feeds

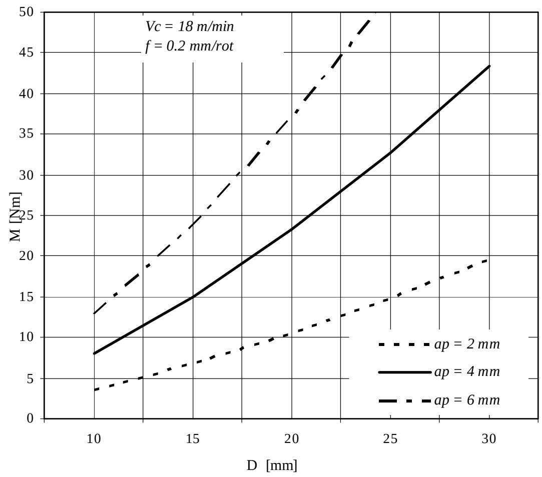


Fig. 2. The moment M variation depending on diameter for different depths

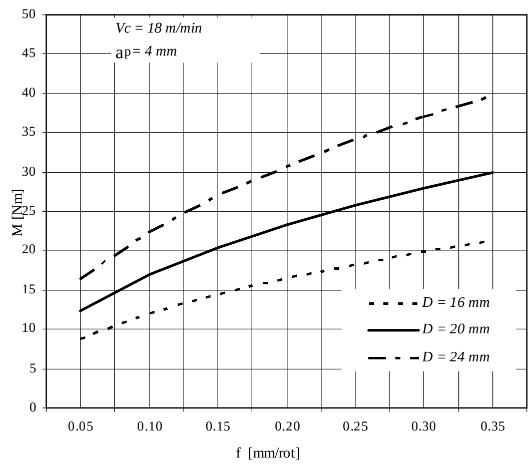


Fig. 3. The moment M variation depending on feed for different diameters

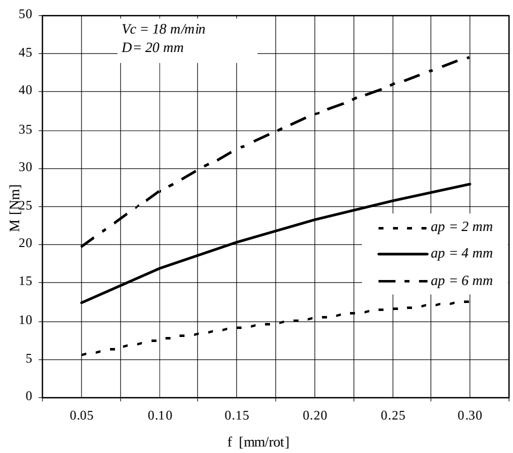


Fig. 4. The moment M variation depending on feed for different depth

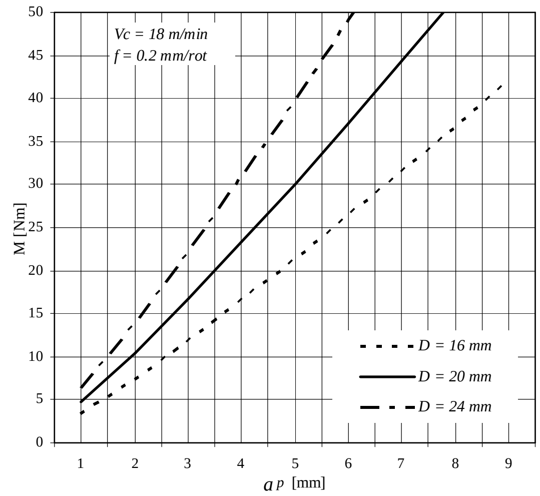


Fig. 5. The moment M variation depending on depth for different diameter

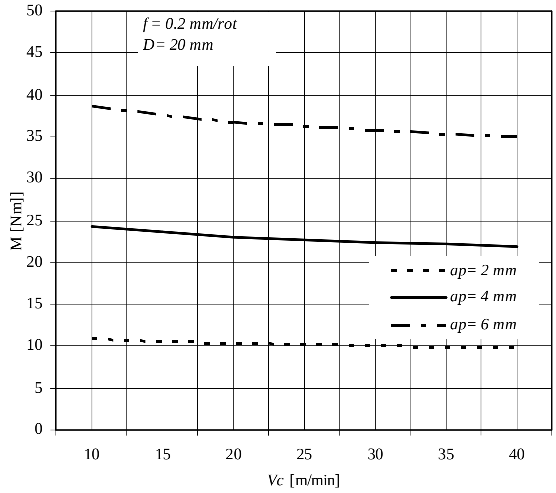


Fig. 6. The moment M variation depending on speed for different depths

## 4. CONCLUSIONS

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

1) For the cutting moment determination at stainless steel widening, a dynamometer was designed and manufactured; this is a rotative dynamometer fixed in the tapered bore of the widening shaft foreseen with tensometer transducers attached to an elastic element.

2) Measuring range of moment permitted tests with diameters within the range 10 through 30 mm.

3) 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 speed has to be included with respect to equations (2) and (5).

4) The experimental results prove the variation of the cutting moment values depending on the parameters of the cutting technology.

5) 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.

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