THE CUTTING MOMENTUM VARIATION ANALYSIS IN ROUGHING BORONG PROCESSING

Aurelian VLASE[1], Adrian GHIONEA[1], Raluca NITA[2], Ionut DIMACHE[2]

1. University Politehnica of Bucharest, Faculty Machine and Manufacturing Systems,
2. SC ICTCM SA, University Politehnica of Bucharest,

avlase@yahoo.com, adrianghionea@yahoo.com, ralu_magda@yahoo.com

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Abstract: The diversity of materials workable through cutting operations has determined the process parameters and the workability indicator optimization. Their determination is all the more so necessary for the wide application materials, such as the stainless steels, materials characterized of durability, hygiene, recyclability and low percent of toxicity. The studies are approached through experimental also analytical methods. The present paper brings some contributions in studies related to the processing of the stainless steel X12CrNiTi18.9, for the particular technological process of boring, defining in the same time the regression relation which defines the variation of the cutting momentum with the main process parameters, using experimental data.

1. INTRODUCTION

The usage of the stainless steels is more and more introduced in various domains, and therefore studied more detailed [1,3,6], every paper had brought important contributions to the development of the researches regarding the processing performances improving from this group of materials.

Every paper approaching this domain brought contributions to the optimum processing conditions establishing and for this it is necessary to bring contributions in determining the cutting forces and momentums [2,4], the factors involved in the level of cutting tool edge wear, in vibrations level and in final in the efficiency of the cutting process.

Cutting conditions, the cutting forces and momentums still represent a difficult issue so far, in terms of deciding the optimal cutting conditions and consumption of materials and time. The theoretical and experimental data determined so far have proven useful in choosing the processing parameters: cutting parameters, operation periods, resources and costs [7]. They are also used in choosing in production optimization strategies [8,9]. The different practical cases proved the data for deciding the optimal conditions of cutting are insufficient and don't cover all the situations met in practice. Stainless steels usage fields are: chemical industry, aeronautics, food industry, corrosion resistant equipments.

The aim of this article is to analyze and establish the cutting momentum variation during the cutting process with the parameters D_c, the diameter of drill, f_n, the cutting feed, a_p, the cutting depth and x_M, y_M, u_M, z_M, polytrophic coefficients, for the stainless steel X12CrNiTi18.9. In the equations used to determine the cutting momentums a new element is introduced, element that represents the cutting speed, which together with the previous indicators contribute to a more precise calculus that improves the variations of the momentum with the processed parameters [5]. The regression relation determined in this paper is useful in the cutting momentum variation analysis according to its parameters, through graphic representations and numeric tables.

2. METHODS AND CUTTING CONDITIONS

There is a great diversity of cutting tools used for the hole-enlarging technological process application: roughing or finishing. They are fixed or adjustable [10]. The tools used in that operation have the edge geometry suited for the working materials: low-alloyed or highalloy steel, stainless steel, austenitic steel, cast iron, aluminum alloys, iron based materials, nickel based materials, extra hard steels.

For the cutting momentum measurement, a special rotating dynamometer was designed and made, and then fixed into the conical hole of the drilling machine. The device registered both axial forces and cutting momentums.

The resistive transducers were hard fixed on the elastic element, at 90° and 45° in different directions, alternating successively. By using this position of the transducers and their bridge connection, a maximum accuracy of the momentum's measurement was obtained. When scribing the log graph for the momentums, a line with sufficient precision is obtained. In this situation, two extreme points were chosen to determine the line slope using the relation: KM = 5.562 daN mm/div.

Cutting equipments used in the experiments are given below: • main cutting machine: drilling machine GCo32DM3, with table dimensions 480x420 and Morse Cone 4; • cutting tool: elliptical drill made from rapid steel Rp5, HRC=62; • tool's geometrical parameters: 2Ke=140°- as represented in fig. 1; • the rest of them are in concordance with STAS R1370/2-69, grinding AI type, diameters between 6mm and 32mm; • coolant: emulsion 20%; • the tool grinding was operated on the drill sharpening machine;

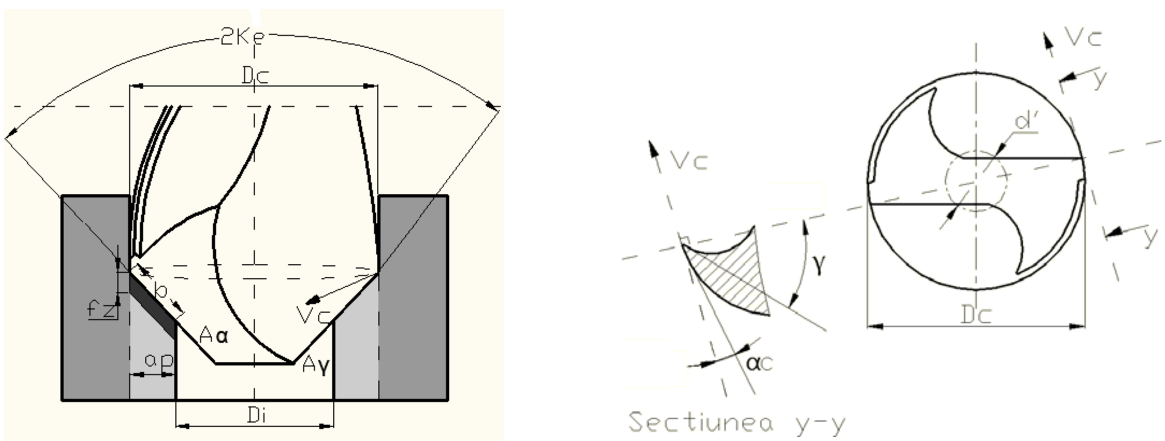

Fig. 1 Tools geometrical elements and process parameters

The chemical and mechanical properties of X12CrNiTi18.9 are presented in the table 1 and table 2.

Cutting conditions were rigorously established taking into consideration that the analyzed parameter has influences from cutting parameters, the tool's geometrical parameters and from tool's and work piece material features.

In addition, it allows the analytic study of the evolution of thrust and torque in terms of the different cutting parameters, such as the cutting speed and the feed speed. This analytic model also allows the determination of the influence of the drill geometry on thrust and torque in drilling.

Table 1 The chemical composition of X12CrNiTi18.9

Chemical composition [%]							
C	Ni	Cr	Mn	Si	S	P	T
0.13	9.42	17.5	1.8	1.6	0.013	0.036	0.24

Table 2 The Mechanical characteristics of X12CrNiTi18.9

Tensile Strength, Rm, [N/mm^2]	Flowing limit, R_{02} , [N/mm^2]	Elongation, δ, [%]	Hardness, HB
528	315	53	147

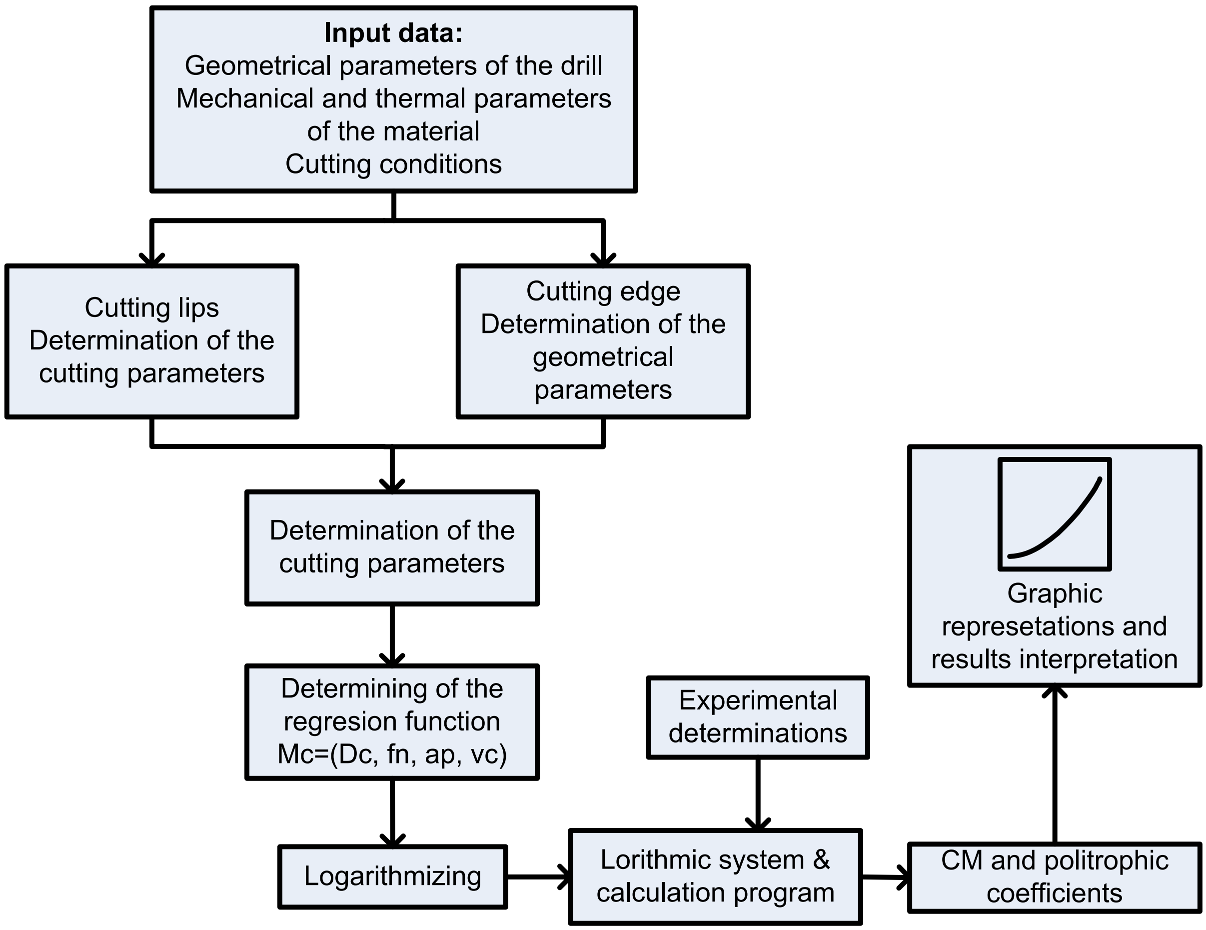

Fig. 2 Cutting momentum flow chart

For determining the numerical values necessary for representing the cutting momentum variation with the process parameters the steps indicated in fig. 2 are covered.

3. EXPERIMENTAL RESULTS AND ANALYSES

In standard determination of cutting momentums for drilling, the relation used (Romagnolo, 1973) is:

$$M_C = C_M \cdot D_C^{x_M} \cdot f_n^{y_M} \cdot a_p^{u_M} . \quad \text{[Nm]} \quad (1)$$

Where C_M is a constant, D_c is the diameter of drill, f is the cutting feed, a_p is the cutting depth, and x_M, y_M, u_M , polytrophic coefficients, which are exponents constants.
As this relation doesn't fully satisfy the present studies, especially in the drilling of stainless steels, regarding the practical determination of the constants and the polytrophic exponents, a new parameter had to be taken into account.

By analyzing various results while enlarging the piece with different speeds, keeping the other processing conditions, we observed that there have been obtained different results [5].
Therefore, a more correct relation for the momentums would be:

$$M_C = C_M \cdot D_C^{x_M} \cdot f_n^{y_M} \cdot a_p^{u_M} \cdot v_c^{z_M} \text{ . [Nm]} \quad (2)$$

In order to determine the parameters C_M, x_M, y_M, z_M, the equation (2) was processed by logarithm:

$$\lg(M_C) = \lg(C_M) + x_M \cdot \lg(D_C) + y_M \cdot \lg(f_n) + u_M \cdot \lg(a_p) + z_M \cdot \lg(v_c) \quad (3)$$

From the total of experimental determinations, five main results were selected, as being the most representative for X12CrNiTi18.9; they are presented in table 3.
By replacing the values from table 3, were are presented the experimental values, into equation (2) we obtain a linear, non homogenous system with five equations and five unknown parameters:

$$\begin{aligned}
\lg(17.0) &= \lg(C_M) + x_M \cdot \lg(24) + y_M \cdot \lg(0.12) + u_M \cdot \lg(4) + z_M \cdot \lg(16.88) \\
\lg(21.4) &= \lg(C_M) + x_M \cdot \lg(24) + y_M \cdot \lg(0.20) + u_M \cdot \lg(4) + z_M \cdot \lg(26.75) \\
\lg(25.2) &= \lg(C_M) + x_M \cdot \lg(24) + y_M \cdot \lg(0.32) + u_M \cdot \lg(4) + z_M \cdot \lg(16.88) \quad (4) \\
\lg(29.5) &= \lg(C_M) + x_M \cdot \lg(24) + y_M \cdot \lg(0.20) + u_M \cdot \lg(6) + z_M \cdot \lg(16.88) \\
\lg(36.4) &= \lg(C_M) + x_M \cdot \lg(16) + y_M \cdot \lg(0.20) + u_M \cdot \lg(2) + z_M \cdot \lg(11.25)
\end{aligned}$$

In the next stage the numerical values are determined for the five unknown quantities. Thus to determine the polytrophic coefficients x_M, y_M, z_M and u_M, and the constant of material C_M, the system of equations can be solved in MathCAD, using the *lsolve* function, and the following solutions resulted: x_M=1.11, y_M=0.40 , z_M=0.055, u_M=0.85 and C_M= 0.306.
Introducing these solutions into equation (2), the final momentum relation is given for enlarging the X12CrNiTi18.9.

$$M_C = 0.306 \cdot D_C^{1.11} \cdot f_n^{0.40} \cdot a_p^{0.85} \cdot v_c^{0.055} \ . \quad (5)$$

The graphs of momentum's variations according to working parameters are shown in figures 3 to 9.
Figure 3 shows the variation of the momentum depending on the cutting feed, for different drill diameters. The two parameters kept fixed were the cutting depth and the cutting speed, and we varied the cutting feed and the drill diameter, for which were considered three main values, 10, 20 and 30 mm. The momentum grew with the feed

Table 3: Results for the cutting parameters of X12CrNiTi18.9

No.	D_i [mm]	D_c [mm]	a_p [mm]	f_n [mm/rot]	n_c [rot/min]	v_c [m/min]	M_c [Nm]
1	16	24	4	0.12	224	16.88	17.0
2	16	24	4	0.20	355	26.75	21.4
3	16	24	4	0.32	224	16.88	25.2
4	12	24	6	0.20	224	16.88	29.5
5	12	16	2	0.20	224	11.25	7.2
6	12	24	6	0.32	355	26.75	36.4
7	12	16	2	0.12	355	17.83	6.1

and the diameter. The graphics for each diameter were rather different in terms of momentum values.
Figure 4 shows the variation of the momentum depending on the cutting speed, for different drill diameters. The two parameters kept fixed were the cutting depth and the cutting feed, and we varied the cutting speed and the drill diameter, for the same values given above. The momentum slightly increased with the speed and the diameter. The graphics for each diameter were different in terms of momentum values.
Figure 5 shows the variation of the momentum depending on the cutting feed, for different cutting speeds. The two parameters kept fixed were the cutting depth and the drill diameter, and we varied the cutting feed and the speed, for which were considered three main values, 10, 20 and 30 m/min. The momentum increased logarithmically with the feed and the speed. The graphics for each speed were rather similar in terms of momentum values.

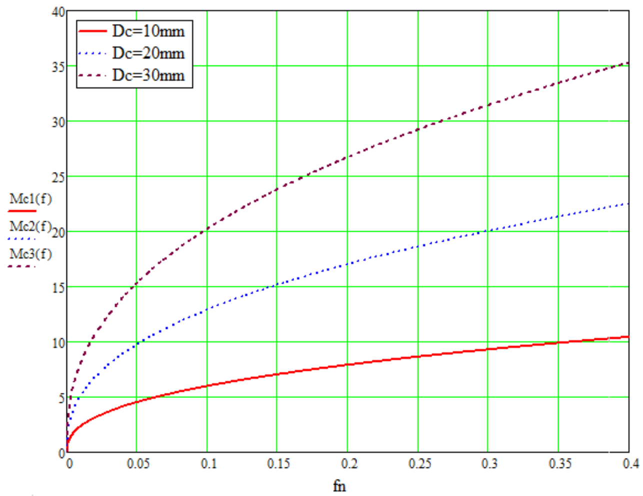

Fig. 3. The momentum variation depending on the cutting feed for different drill diameters

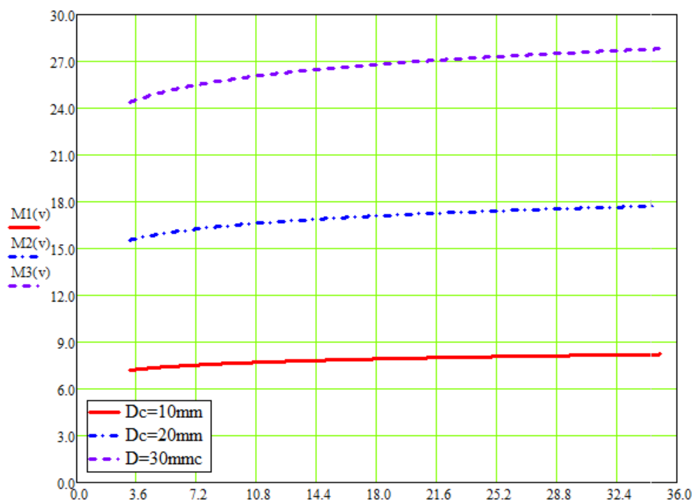

Fig. 4. The momentum variation depending on the cutting speed for different drill diameters

Figure 6 shows the variation of the momentum depending on the drill diameter, for different cutting speeds. The two parameters kept fixed were the cutting depth and the cutting feed, and we varied the drill diameter and the cutting speed. The latest was given three main values, 10, 20 and 30 m/min. The momentum increased with the speed and the diameter. The graphics for each speed were almost linearly in terms of momentum values
Figure 7 shows the variation of the momentum depending on the cutting speed, for different cutting feeds. The two parameters kept fixed were the cutting depth and the drill diameter, and we varied the cutting speed and the feed. The latest was given three main values, 0.1, 0.2 and 0.3 mm/rot. The momentum slightly increased with the speed and the feed. The graphics for each feed were rather different in terms of momentum values.
Figure 8 shows the variation of the momentum depending on the drill diameter, for different cutting feeds. 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 momentum increased abruptly with the feed and the diameters. The graphics for each feed were rather different in terms of momentum values.
In table 4 we calculated the cutting momentum values for different drill diameters, cutting feed and cutting depth, for the cutting speed 16.88 m/min.

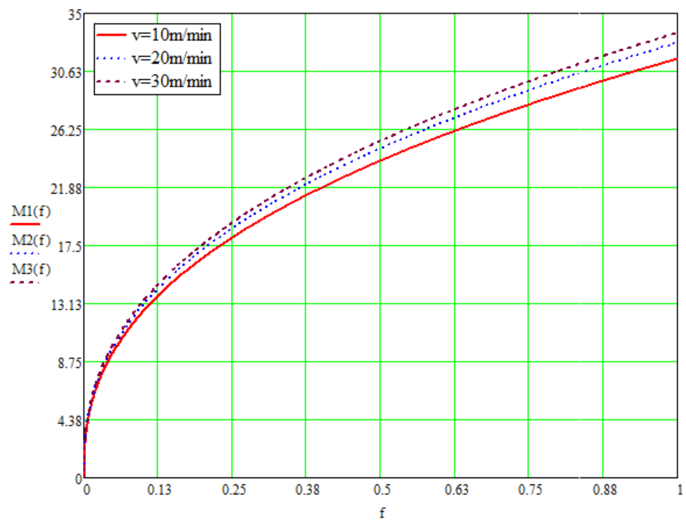

Fig. 5. The momentum variation depending on the cutting feed for different speeds

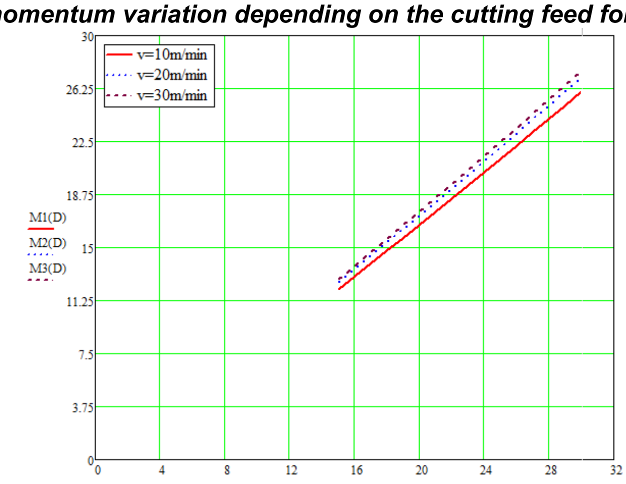

Fig. 6 The momentum variation depending on the drill diameter for different speeds

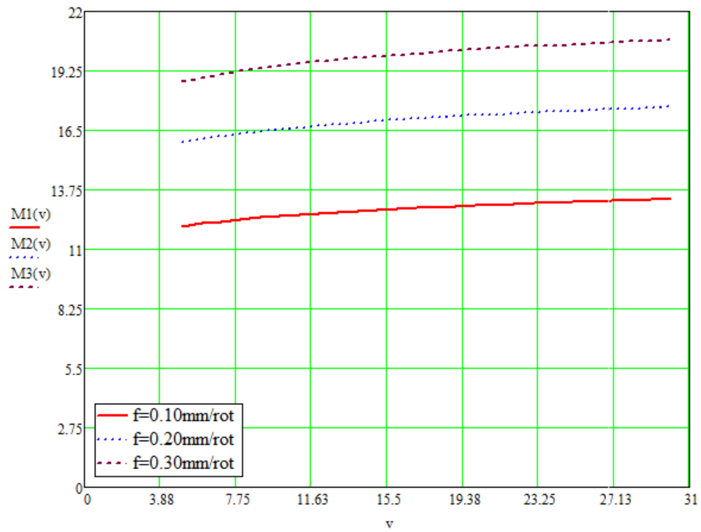

Fig. 7. The momentum variation depending on the cutting speed for different feeds

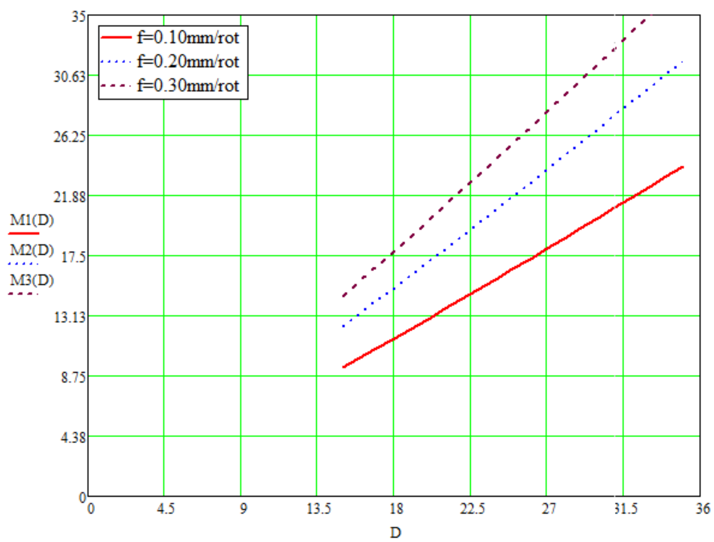

Fig. 8. The momentum variation depending on the drill diameter for different feeds

Table 4 Cutting momentum values

D_c	a_p=4 f_n=0.12	a_p=4 f_n=0.18	a_p=4 f_n=0.22
	M_C		
21	15.08	17.75	19.24
22	15.89	18.69	20.26
23	16.69	19.64	21.28
24	17.50	20.59	22.31
25	18.31	21.54	23.35
26	19.12	22.50	24.39

4. CONCLUSIONS

After presenting the chemical and physical characteristics of the studied material, the stainless steel X12CrNiTi18.9, a short description of the cutting tools, the working equipment and the measuring means was presented. After logarithmic operations applied to the cutting momentum equations and after inserting the experimental results, we have obtained a simple system of 5 equations, with 5 unknown parameters, which was solved in MathCAD, using the *lsolve* function. The momentum variation given by the process and tool parameters is shown in graphs above. The instruments used for the cutting momentum determination were a dynamometer with elastic trap and a resistive transducer specially designed. The measuring domain for the torque momentum was approx. between 4 Nm and 40 Nm, allowing experiments for drill diameters from 6 mm to 32 mm. The different experimental determinations demonstrated the necessity of altering the mathematical relation for the cutting momentums, in terms of speed as a new element. Because all the exponents have positive values, the momentum increases proportional with D_C, f_n, a_p and v_C; D_C has the greatest value, having the biggest influence on the momentum from the four exponents.

Table 3 shows very clearly the experimental results when measuring the momentums, having set the cutting parameters. From these values, it can be seen that the momentum vary within a small range of values, from 6.1 Nm to 36.4 Nm;

Momentum graphs were drawn by combining two fixed parameters and varying other two. One of the varying parameters was the X axis and the other given three determined values. From the graphs analysis became obvious that the momentum increases proportionally not only with the speed and feed, but also with the diameter of the cutting tool. The results can be used in further standard studies for a range of stainless steels. The final forms of the momentum functions presented in this paper can be used for various materials and cutting conditions. It offers a solid basis for continuing the researches in material cutting domain and proves the necessity of using the speed in determining various parameters of cutting process. This study is one of the beginning steps for developing standard forces and momentums functions for other materials.

5. REFERENCES

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