Mathematical Models of Force and Torque in Machining 10TiMoNiCr175 Stainless Steel Holes

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Abstract: - For scientific research and / or industrial application it is important to determine mathematical models of force and torque, when machining. Thus, it would be possible to know optimum process parameters values or, even better, to predict force and torque values, once process parameters values set. Machining holes, more specifically drilling and widening, in stainless steel parts is required in many cases but, unfortunately, the existing data published on this topic are very poor and, rather, qualitative ones. So, a study on 10TiMoNiCr175 stainless steel material has been done and the results presented by this paper, mainly considering the wide industrial application of this material in Romanian industry.

Key-Words: - mathematical model, regression, drilling, widening, force, torque, stainless steel

1 Introduction

The corrosion resistance of iron-chromium alloys was first recognized in 1821 by French metallurgist Pierre Berthier, who noted their resistance against attack by some acids and suggested their use in cutlery. There are over 150 grades of stainless steel, of which fifteen are most commonly used. [7], [10].

Stainless steel alloy is milled into coils, sheets, plates, bars, wire, and tubing. Due to material's characteristics, specially high corrosion resistance to various chemical agents and impressive good look, these steel alloys are used in cookware, cutlery, surgical instruments, major appliances and industrial equipments - for example, in sugar refineries. They are also important as an automotive and aerospace structural alloys, as well as construction material in large buildings – see figure 1.

Stainless steel parts usually need machining according to the geometric precision required. These materials are tough ones, with low thermal conductivity and that is why, while machining, high wear of the cutting tool, as well as, important cutting forces values can be noticed [6].

As they are expensive materials, detailed research on their machinability would be opportune, so that optimum process parameters values to be set and, thus, high productivity and low cost machining process to be available.

Drilling and / or widening holes do represent a machining procedure used many times when stainless steel parts need positioning and assembling.

[8]

[7]

[9]

Fig. 1 Examples of stainless steel application

One relevant aspect when machining holes in stainless steel material is represented by the axial force's value (the main cutting force component values) and the torque (rotational moment) value, as well. It is obvious that the higher these values, the poorer machinability properties of the material and the higher energy consumption for the process should be assessed [3].

The authors of this article did find out, by studying specific references, relationships involving cutting force and torque when drilling / widening holes into stainless steel materials. Unfortunately they were mainly qualitative / guidance type ones and when experimentally checking them, high difference (more than 20 %) of the experimental values and the ones estimated by these relationships was noticed [2], [4], [6].

Based on all the aspects mentioned above, it has been considered appropriate the study presented by this paper, meaning new adequate mathematical models of the axial force and torque in machining 10TiMoNiCr175 stainless steel holes. More specifically, the machining procedures considered were drilling and widening (of holes). The material studied is one of great importance (due to its various application) for Romanian industry.

It should be pointed out that all the steps carried in order to obtain the models can be considered as parts of a "procedure" to be followed / applied for any materials type and different machining procedures, whenever dependence relations of machining parameters are worth to be determined.

2 Research Applied Methods

Determining mathematical models for the relationship of parameters specific to a certain machining process, based on experimental results, involves some steps to be followed, as the next one:

- the "definition" of both independent and dependent variables associated to these models [1];
- an appropriate experiments design type to be considered;
- the regression analysis, if available;
- the fitted mathematical model to be obtained.

The mathematical models for axial cutting force and torque in drilling / widening stainless steel material holes, that are mentioned by most of the articles and books dealing with this problem, do look like the ones in relations (1) to (4):

► in drilling

$$F_z = C_F \cdot D^{x_F} \cdot a_f^{y_F} \quad [\text{N}] \tag{1}$$

$$M = C_M \cdot D^{x_M} \cdot a_f^{y_M} \quad [\text{Nm}] \tag{2}$$

► in widening

$$F_z = C_F \cdot D^{x_F} \cdot a_f^{y_F} \cdot f^{z_F} \quad [\text{N}] \tag{3}$$

$$M = C_M \cdot D^{x_M} \cdot a_f^{y_M} \cdot f^{z_M} \quad [\text{Nm}] \tag{4}$$

where:

F_z represents the axial cutting force (dependent variable);

M – the torque (dependent variable);

D – the diameter of the cutting tool, [mm] (independent variable);

a_f – the cutting feed of the process [mm/rot] (independent variable);

f – the cutting depth of the process [mm] (independent variable);

x_F, y_F, z_F, x_M, y_M, z_M - polytropic exponents;

C_F, C_M - constants.

Observations:

- in drilling, the cutting depth equals half of the cutting tool's diameter $\left(f = \frac{D}{2} \right)$;
- the values for the polytropic exponents and constants are specifically determined for each of the studied machining processes (drilling / widening).

Once the values of C_F, C_M, x_F, y_F, (z_F), x_M, y_M, (z_M) determined, when further experimenting with same the values for variables D, a_f and f (in widening) but, with different values for the cutting speed, v, there was noticed that different axial force and torque values were obtained. So, it was assumed that the parameter not mentioned by relations (1) to (4), meaning cutting speed, v, should have a significant role in axial force and torque values' prediction.

In fact, this is the aim of the paper, meaning, presenting the steps followed and, specially, the new mathematical models obtained for the axial force and torque in drilling / widening of holes. The novelty is that it has been considered an important independent variable of the machining process, meaning the *cutting speed v* [mm/rot].

So, the new, original proposed mathematical models are evidenced by relations (5) to (8):

► in drilling

$$F_z = C_F \cdot D^{x_F} \cdot a_f^{y_F} \cdot v^{z_F} \quad [\text{N}] \tag{5}$$

$$M = C_M \cdot D^{x_M} \cdot a_f^{y_M} \cdot v^{z_M} \quad [\text{Nm}] \tag{6}$$

► in widening

$$F_z = C_F \cdot D^{x_F} \cdot a_f^{y_F} \cdot f^{z_F} \cdot v^{w_v} \quad [\text{N}] \tag{7}$$

$$M = C_M \cdot D^{x_M} \cdot a_f^{y_M} \cdot f^{z_M} \cdot v^{w_M} \quad [\text{Nm}] \tag{8}$$

where:

v is the peripheral rotational speed of the cutting tool, usually mentioned as the cutting speed [m/min];

z_F, z_M, (w_F), (w_M) - polytropic exponents;

For obtaining the constants and polytropic exponents' values, relations (5) to (8) must be of linear type and, so, by logarithm they will "turn" into relations (9) to (12), as follows:

► in drilling

$$\lg F_z = \lg C_F + x_F \lg D + y_F \lg a_f + z_F \lg v \tag{9}$$

$$\lg M = \lg C_M + x_M \lg D + y_M \lg a_f + z_M \lg v \tag{10}$$

► in widening

$$\lg F_z = \lg C_F + x_F \lg D + y_F \lg a_f + z_F \lg f + w_F \lg v \tag{11}$$

$$\lg M = \lg C_M + x_M \lg D + y_M \lg a_f + z_M \lg f + w_M \lg v \tag{12}$$

So, it can be mentioned that the first method applied was that of solving a four / five linear equations system – as there were four / five constants to be determined (C, x, y, z and w), four constants for the drilling process and five constants for the widening process.

The second method applied dealt with experiments design and regression analysis – done with a special software, DOE KISS. [5]

Due to limited license rights (as the authors have only the "student version"), there could only be determined regression models with two independent variables, each of them with three "levels'. So, based on the results obtained by solving relations (8) to (12), for the regression analysis there have been considered the two most "significant" variables – for axial force and torque values.

Thus, there were further studied only the D and a_f parameters – for drilling, as well as the D and f parameters – for widening.

The experiments design (Central Composite Design, CCD) is evidenced in table 1.

Regression analysis performed by the software resulted in models like the ones mentioned by relations (13) to (16):

► in drilling

$$F_z = a_0 + a_1 \cdot D + a_2 \cdot a_f + a_{12} \cdot D \cdot a_f + a_{11} \cdot D^2 + a_{22} \cdot a_f^2 \tag{13}$$

Table 1

Experiments Design

	Run	x_1	x_2
Central Composite Design (CCD)	1.	-1	-1
	2.	-1	+1
	3.	+1	-1
	4.	+1	+1
	5.	0	0
	6.	0	0
	7.	-1	0
	8.	+1	0
	9.	0	-1
	10.	0	+1

$$M = a_0 + a_1 \cdot D + a_2 \cdot a_f + a_{12} \cdot D \cdot a_f + a_{11} \cdot D^2 + a_{22} \cdot a_f^2 \tag{14}$$

► in widening

$$F_z = a_0 + a_1 \cdot D + a_2 \cdot f + a_{12} \cdot D \cdot f + a_{11} \cdot D^2 + a_{22} \cdot f^2 \tag{15}$$

$$M = a_0 + a_1 \cdot D + a_2 \cdot f + a_{12} \cdot D \cdot f + a_{11} \cdot D^2 + a_{22} \cdot f^2 \tag{16}$$

The relationship of "coded" variables, x_j and "natural" ones, z_j (z_j = D / a_f / f / v) is (17):

$$x_j = \frac{z_j - \frac{z_{\min} + z_{\max}}{2}}{\frac{z_{\max} - z_{\min}}{2}} \tag{17}$$

where:

$z_{\min}$ is the minimum experimental value

$z_{\max}$ - the maximum experimental value

3 Experiments and Results

In order to make experiments, there was designed and used an experimental system, whose main components are the next – see figure 2 and figure 3.

a) Drilling machine tool, coded GC_032DM_3 with characteristics:

- electric motor of 3.5 kW power;
- working plateau dimensions of 420 × 480 (mm x mm);
- main spindle with a no. 4 Morse cone.
- available rotations values of the drilling tool: 70 ÷ 1400 [rot/min], with 12 geometrical ratio levels variation;
- available cutting feed values: 0.12; 0.20; 0.32; 0.50 [mm/rot].

Fig. 2 Experimental stand - for force and torque study on machining holes

b) Cutting tools made of Rp5 with 62 HRC (Rockwell hardness).

c) IEMI type electronic bridge

- coupled to a data acquisition system, using the graphical programming LabVIEW software.

d) Cooling / lubricating fluid: 20% P emulsion

e) Special rotational dynamometric device, for adequate torque and force values measurement – see figure 3

- individualized by an elastic sleeve with four resistive transducers, each inclined by 45° with respect to the horizontal and vertical axes “attached” to it.

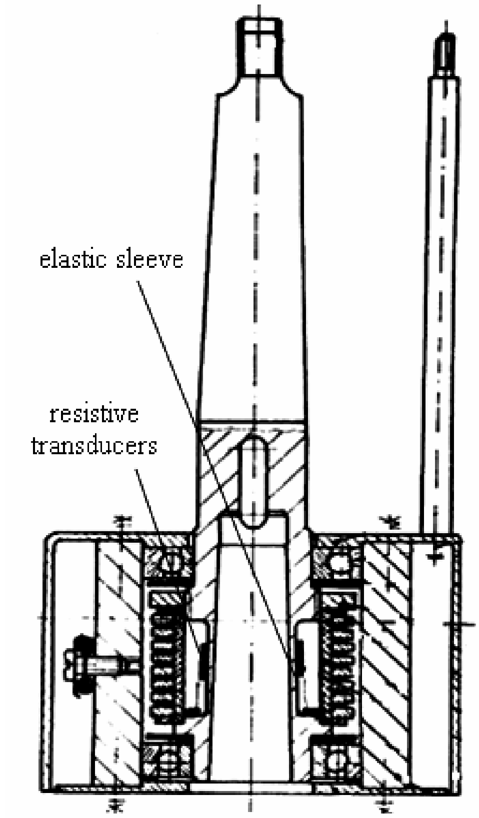


Fig 3 Special rotational dynamometric device

Table 2 Chemical Structure.

C [%]	Mo [%]	Ni [%]	Cr [%]	Mn [%]
0.08	2.50	2.00	17.50	2.0
Si [%]	S [%]	P [%]	Ti [%]	
1.00	0.02	0.04	4.00	

Table 3 Mechanical Characteristics.

Tensile Strength, R_m [N/mm^2]	Flow Strength, Rp_{02} [N/mm^2]	Relative Elongation δ [%]	Hardness, HB
560	240	36.00	220

f) Studied material: 10TiMoNiCr175 (STAS 3583-87) – whose chemical composition and mechanical characteristics are presented in table 2 and, respectively, table 3.

Experimental values obtained for the axial force and torque measurement are shown in the tables below, as follows:

- for the first method considered, that of solving the four / five linear equations systems – see table 4;
- for the second method studied, that of experiments design (CCD) and regression analysis – see table 5.

Table 4

Experimental Results – for the linear equations system method

Exp. No.	Initial hole diameter, D_0 [mm]	Cutting tool diameter, D [mm]	Cutting depth f [mm]	Cutting feed a_f [mm/rot]	Rotational speed n [rot/min]	Cutting speed v [m/min]	Axial force F_z [N]	Torque M [Nm]
Drilling								
1	-	24.00	12.00	0.32	224.00	16.88	9078.00	79.40
2	-	24.00	12.00	0.12	224.00	16.88	6633.00	52.60
3	-	16.00	8.00	0.20	355.00	17.83	5593.00	39.80
4	-	12.00	6.00	0.12	355.00	13.38	4066.00	23.60
Widening								
1	16.00	24.00	4.00	0.12	224	16.88	1163	20.91
2	12.00	16.00	2.00	0.20	355	17.83	513	11.41
3	16.00	24.00	4.00	0.32	224	16.88	1872	30.27
4	18.00	24.00	3.00	0.12	224	16.88	858	17.28
5	16.00	24.00	4.00	0.12	355	26.75	1198	21.60

where: n is the rotational speed of the machine tool's main spindle: $n = \frac{1000v}{\pi D}$ [rot/min]

Table 5

Experimental Results – for the CCD and regression analysis method

Drilling										
Exp. No.	1	2	3	4	5	6	7	8	9	10
Axial force, F_z [N]	3198.98	6658.65	4487.58	9330.31	6238.33	6253.63	4914.78	6885.96	4068.61	6271.86
Torque M [Nm]	41.53	65.83	58.49	92.68	69.33	72.41	54.51	76.57	52.97	83.91

Table 5 - continued
Experimental Results – for the CCD and regression analysis method

Widening										
Exp. No.	1	2	3	4	5	6	7	8	9	10
Axial force, F_z [N]	403.61	840.11	566.19	1177.19	787.68	789.01	620.09	868.79	513.33	791.31
Torque M [Nm]	20.08	31.83	28.28	44.81	33.52	35.01	26.29	37.02	25.61	40.57

Observations: for each experience, replicates number equaled five

4. Mathematical Models

A. For the first method considered, obtained experimental results were further "processed", in order to solve the four / five linear equations systems, required for models' constants and polytropic exponents values determination (C, x, y, z and w) [5].

Knowing that initial dependence relationships were exponential, – relations (5) to (8), there were obtained the mathematical models of axial force and torque, for machining holes in 10TiMoNiCr175 stainless steel material.

► So, in drilling, there are the equations and, consequently, the models that follow - see relations (18) to (21):

$$\begin{cases} \lg 9078 = \lg C_F + x_F \cdot \lg 24 + y_F \cdot \lg 0.32 + \\ \quad + z_F \cdot \lg 16.88 \\ \lg 6633 = \lg C_F + x_F \cdot \lg 24 + y_F \cdot \lg 0.12 + \\ \quad + z_F \cdot \lg 16.88 \\ \lg 5593 = \lg C_F + x_F \cdot \lg 16 + y_F \cdot \lg 0.20 + \\ \quad + z_F \cdot \lg 17.83 \\ \lg 4066 = \lg C_F + x_F \cdot \lg 12 + y_F \cdot \lg 0.12 + \\ \quad + z_F \cdot \lg 13.38 \end{cases} \quad (18)$$

$$\begin{cases} \lg 79.4 = \lg C_M + x_M \cdot \lg 24 + y_M \cdot \lg 0.32 + \\ \quad + z_M \cdot \lg 16.88 \\ \lg 52.6 = \lg C_M + x_M \cdot \lg 24 + y_M \cdot \lg 0.12 + \\ \quad + z_M \cdot \lg 16.88 \\ \lg 39.8 = \lg C_M + x_M \cdot \lg 16 + y_M \cdot \lg 0.20 + \\ \quad + z_M \cdot \lg 17.83 \\ \lg 23.6 = \lg C_M + x_M \cdot \lg 12 + y_M \cdot \lg 0.12 + \\ \quad + z_M \cdot \lg 13.38 \end{cases} \quad (19)$$

$$F_z = 2.52 \cdot D^{0.79} \cdot a_f^{0.32} \cdot v^{-0.25} \text{ [N]} \quad (20)$$

$$M = 4.20 \cdot D^{1.20} \cdot a_f^{0.42} \cdot v^{-014} \text{ [Nm]} \quad (21)$$

► In widening, the equations and the resulting models are the ones presented by relations (22) to (25):

$$\begin{cases} \lg 1163 = \lg C_F + x_F \cdot \lg 24 + y_F \cdot \lg 0.12 + \\ \quad + z_F \cdot \lg 4 + w_F \lg 16.88 \\ \lg 513 = \lg C_F + x_F \cdot \lg 16 + y_F \cdot \lg 0.20 + \\ \quad + z_F \cdot \lg 2 + w_F \lg 17.83 \\ \lg 1872 = \lg C_F + x_F \cdot \lg 24 + y_F \cdot \lg 0.32 + \\ \quad + z_F \cdot \lg 4 + w_F \lg 16.88 \\ \lg 858 = \lg C_F + x_F \cdot \lg 24 + y_F \cdot \lg 0.12 + \\ \quad + z_F \cdot \lg 3 + w_F \lg 16.88 \\ \lg 1198 = \lg C_F + x_F \cdot \lg 24 + y_F \cdot \lg 0.12 + \\ \quad + z_F \cdot \lg 4 + w_F \lg 26.75 \end{cases} \quad (22)$$

$$\begin{cases} \lg 20.91 = \lg C_M + x_M \cdot \lg 24 + y_M \cdot \lg 0.12 + \\ \quad + z_M \cdot \lg 4 + w_M \lg 16.88 \\ \lg 11.41 = \lg C_M + x_M \cdot \lg 16 + y_M \cdot \lg 0.20 + \\ \quad + z_M \cdot \lg 2 + w_M \lg 17.83 \\ \lg 30.27 = \lg C_M + x_M \cdot \lg 24 + y_M \cdot \lg 0.32 + \\ \quad + z_M \cdot \lg 4 + w_M \lg 16.88 \\ \lg 17.28 = \lg C_M + x_M \cdot \lg 24 + y_M \cdot \lg 0.12 + \\ \quad + z_M \cdot \lg 3 + w_M \lg 16.88 \\ \lg 21.60 = \lg C_M + x_M \cdot \lg 24 + y_M \cdot \lg 0.12 + \\ \quad + z_M \cdot \lg 4 + w_M \lg 26.75 \end{cases} \quad (23)$$

$$F_z = 44.5 \cdot D^{0.832} \cdot a_f^{0.485} \cdot f^{1.56} \cdot v^{0.065} \text{[N]} \quad (24)$$

$$M = 1.04 \cdot D^{0.844} \cdot a_f^{0.377} \cdot f^{0.664} \cdot v^{0.070} \text{ [Nm]} \quad (25)$$

Some graphical representations of the obtained mathematical models can be noticed in figure 4 (for the drilling process) and in figure 5 (for the widening process).

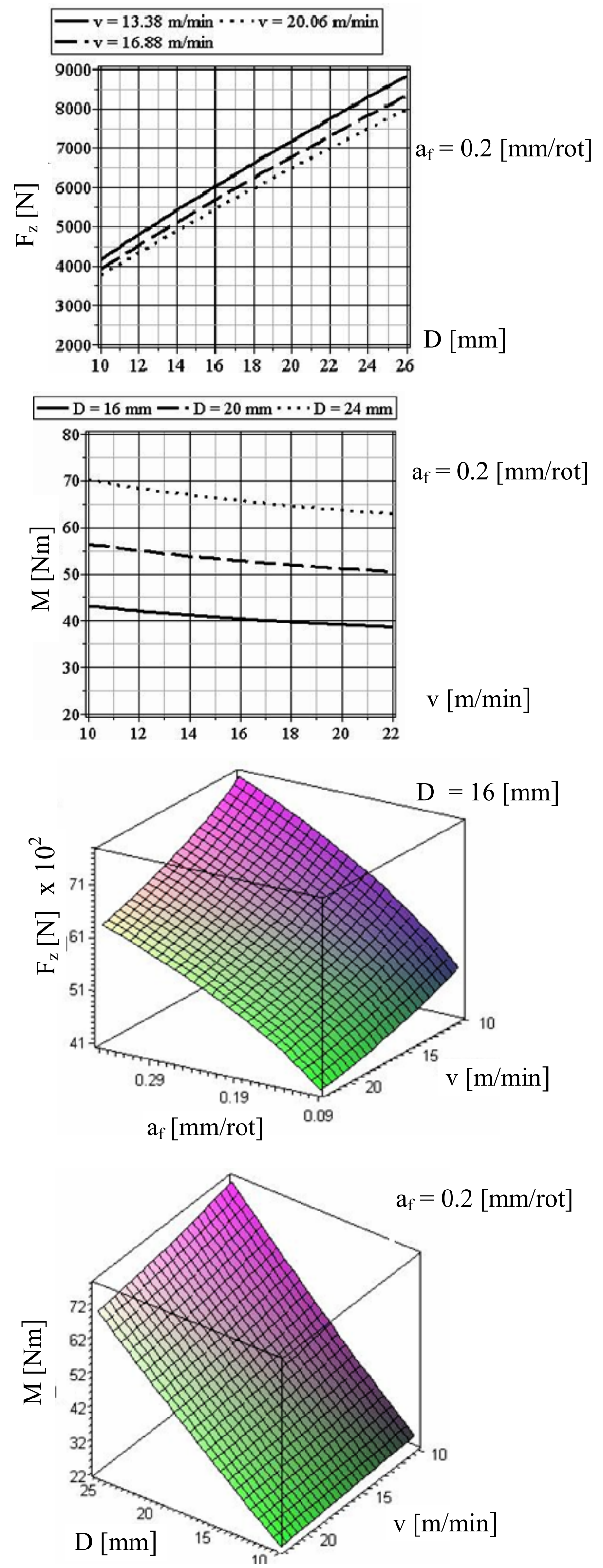


Fig. 4 Graphical representation of F_z and M models - relations (20) and (21)

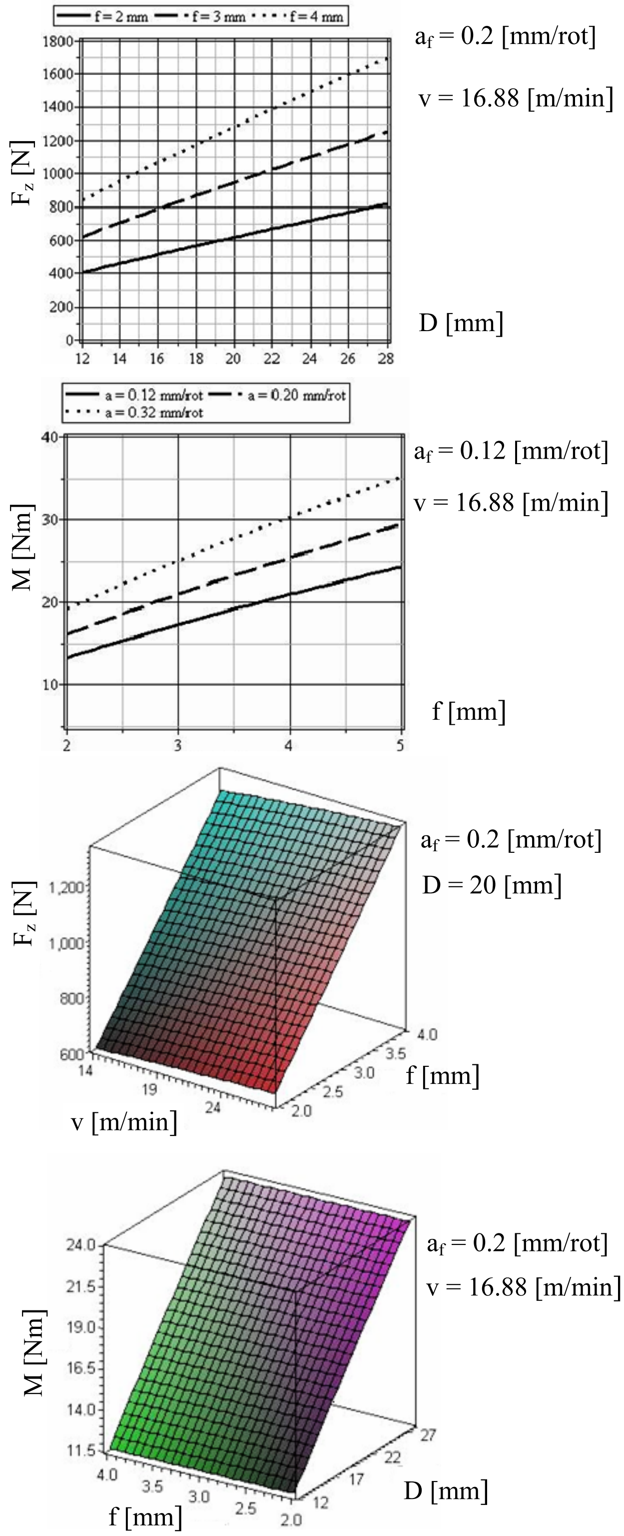


Fig. 5 Graphical representation of F_z and M models - relations (24) and (25)

As observation, there should be mentioned the fact that these graphs were plotted for the variables with higher influence on axial force and torque values. Also, considering the ‘novelty” of proposed models, meaning the influence of v (cutting speed) variable, a graph of it has been presented.

B. One can notice the fact that relations (20), (21) and (24), (25) were obtained by solving classical linear equations system. It means, four / five unknown parameters and, consequently, the need for four / five linear equations systems to be solved. So, an "improvement" of the method to obtain mathematical models was considered to be right.

So, for the new sets of experiments, as mentioned before, there have been considered, both the Central Composite Design of experiments and the regression analysis, performed with the special software, DOE KISS.

The only two independent variables studied were the ones that proved (by previously obtained mathematical models) to strongly influence the dependent variable (axial force or torque). The other independent variables considered by this study, were set to their medium values. All of these are evidenced by table 6.

Table 6

Independent variables values

	Real, z_j			Coded, x_j		
	min	med	max	min	med	max
Drilling						
Cutting tool diameter, D [mm]	12.00	18.00	24.00	-1	0	+1
Cutting feed, a_p[mm/rot]	0.12	0.22	0.32	-1	0	+1
Cutting speed, v [m/min]	15.61			-		
Widening						
Cutting tool diameter, D [mm]	16.00	20.00	24.00	-1	0	+1
Cutting feed, a_p[mm/rot]	0.22			-		
Cutting depth, f [mm]	2.00	3.00	4.00	-1	0	+1
Cutting speed, v [m/min]	22.82			-		

Observations:

- when using the DOE KISS software, there are considered the coded values of the variables studied
- the relationships of coded and real variables, as defined by relation (17) are the next - see (26) and (27):

► in drilling

$$x_1 = \frac{D-18}{6}; \quad x_2 = \frac{a_f - 0.22}{0.10} \qquad (26)$$

► in widening

$$x_1 = \frac{D-20}{4}; \qquad x_2 = f - 3 \qquad (27)$$

- in regression analysis, a factor is considered to have significant influence on the output as long as the P (2 Tail) value is less, or equal, to 0.05.

Examples of the DOE KISS software results, are shown in figure 6.

So, as result of this method, the obtained mathematical models of axial force and torque, for machining holes in 10TiMoNiCr175 stainless steel material are the ones mentioned above – see relations (28) and (29):

► in drilling

$$F_z = 1734.554 - 244.698 \cdot D + 26956.114 \cdot a_f + 576.275 \cdot D \cdot f + 7.769 \cdot D^2 - 45045.6 \cdot a_f^{\,2} \quad [\mathrm{N}]$$

$$M = 0.78 + 5.384 \cdot D + 143.53 \cdot a_f + 4.12 \cdot D \cdot a_f - 0.124 \cdot D^2 - 156 \cdot a_f^{\,2} \quad [\mathrm{Nm}] \qquad (28)$$

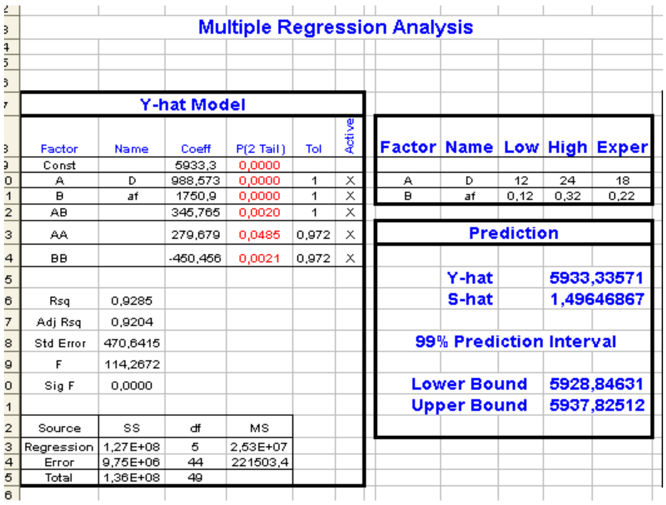
► in widening

$$F_z = 483.107 - 89.432 \cdot D + 344.56 \cdot f + 10.906 \cdot D \cdot f + 2.197 \cdot D^2 - 56.962 \cdot f^2 \quad [\mathrm{N}]$$

$$M = -57.106 + 5.869 \cdot D + 5.642 \cdot f + 0.299 \cdot D \cdot f - 0.136 \cdot D^2 - 0.735 \cdot f^2 \quad [\mathrm{Nm}] \qquad (29)$$

Some graphical representations of the obtained mathematical models can be noticed in figure 7.

The DOE KISS software also enables to get an image of the marginal means plot, as well as the Pareto chart of coefficients. All of these in order to strengthen the influence of the two independent variables, or their interaction, on the output. Examples are shown in figure 8 and figure 9.



Multiple Regression Analysis

Y-hat Model

Factor	Name	Coeff	P(2 Tail)	Tol	Active
Const		5933,3	0,0000		
A	D	988,573	0,0000	1	X
B	af	1750,9	0,0000	1	X
AB		345,765	0,0020	1	X
AA		279,679	0,0485	0,972	X
BB		-450,456	0,0021	0,972	X

Rsq	0,9285
Adj Rsq	0,9204
Std Error	470,6415
F	114,2672
Sig F	0,0000

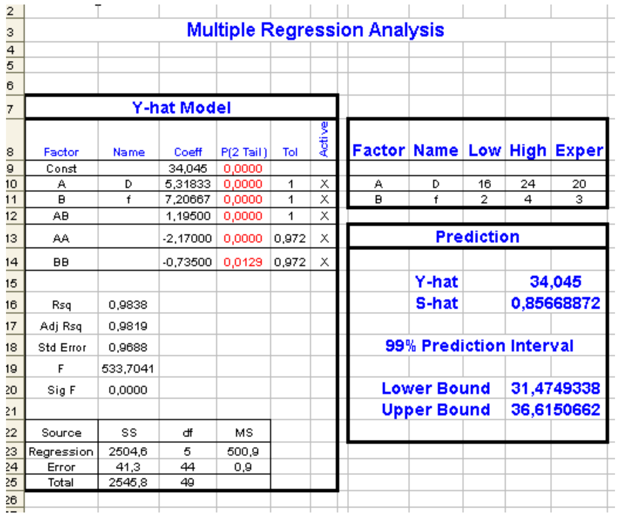
Source	SS	df	MS
Regression	1,27E+08	5	2,53E+07
Error	9,75E+06	44	221503,4
Total	1,36E+08	49	

Factor	Name	Low	High	Exper
A	D	12	24	18
B	af	0,12	0,32	0,22

Prediction

Y-hat	5933,33571
S-hat	1,49646867
99% Prediction Interval	
Lower Bound	5928,84631
Upper Bound	5937,82512

- axial force, F_z, in drilling -



Multiple Regression Analysis

Y-hat Model

Factor	Name	Coeff	P(2 Tail)	Tol	Active
Const		34,045	0,0000		
A	D	5,31833	0,0000	1	X
B	f	7,20667	0,0000	1	X
AB		1,19500	0,0000	1	X
AA		-2,17000	0,0000	0,972	X
BB		-0,73500	0,0129	0,972	X

Rsq	0,9838
Adj Rsq	0,9819
Std Error	0,9688
F	533,7041
Sig F	0,0000

Source	SS	df	MS
Regression	2504,6	5	500,9
Error	41,3	44	0,9
Total	2545,8	49	

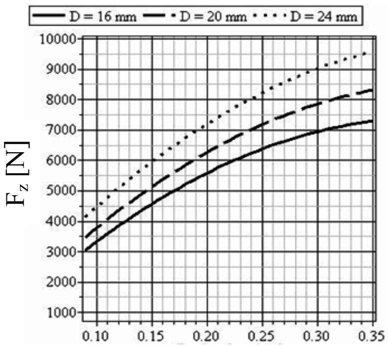
Factor	Name	Low	High	Exper
A	D	16	24	20
B	f	2	4	3

Prediction

Y-hat	34,045
S-hat	0,85668872
99% Prediction Interval	
Lower Bound	31,4749338
Upper Bound	36,6150662

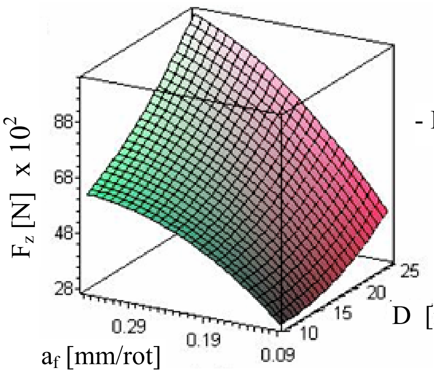
- torque, M, in widening -

Fig. 6 Examples of DOE KISS software - regression analysis results



- F_z in drilling -

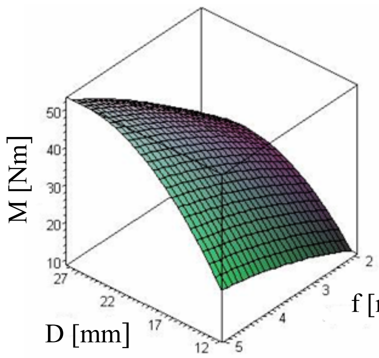
a_f [mm/rot]



- F_z in drilling -

D [mm]

a_f [mm/rot]

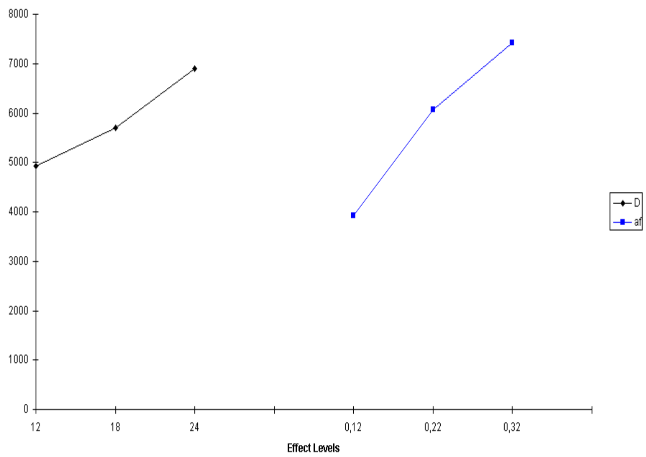


- M in widening -

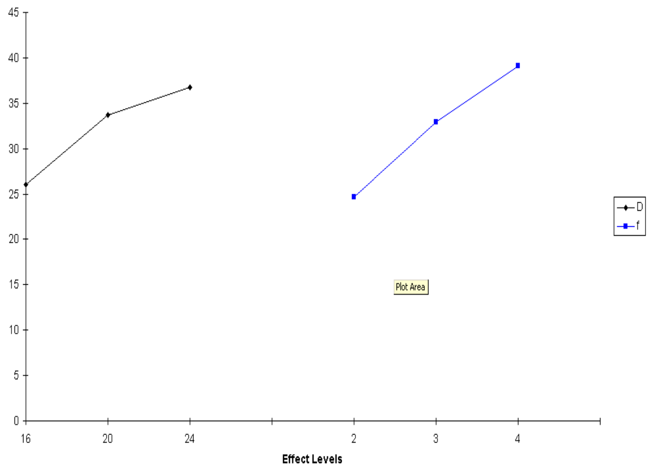
f [mm]

D [mm]

Fig. 7 Graphical representation of F_z and M models - relations (28) and (29)

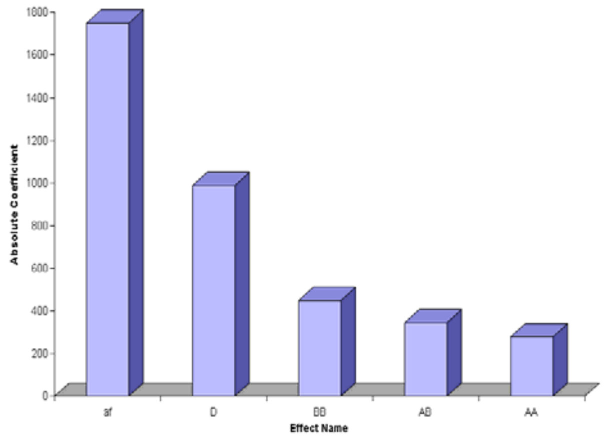


- axial force, F_z, in drilling -

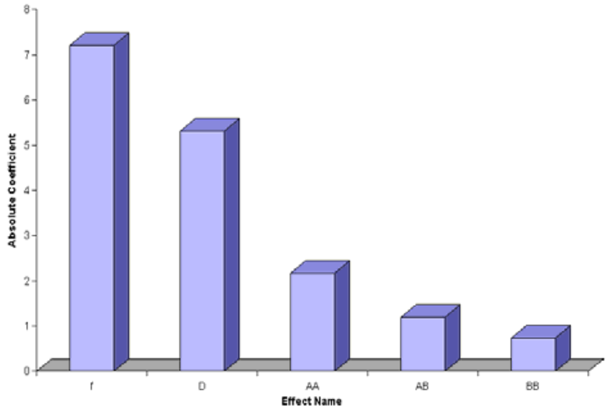


- torque, M, in widening -

Fig. 8 Examples of DOE KISS software - marginal means plots



- axial force, F_z, in drilling -



- torque, M, in widening -

Fig. 9 Examples of DOE KISS software – Pareto chart of coefficients

5 Conclusion

Stainless steels characteristics, like high corrosion resistance to various chemical agents and impressive good look, involve the use of their parts in more and more versatile and challenging industrial fields.

Stainless steel parts usually need machining according to the geometric precision required.

This study is about two methods used for determining new adequate mathematical models of the axial force and torque in machining 10TiMoNiCr175 stainless steel holes. The machining procedures considered were drilling and widening (of holes), while the material studied is one of great importance for Romanian industry.

The first method, consisted in solving the four / five linear equations systems, required for models' constants and polytropic exponents values determination (C, x, y, z and w).

The second method, involved design of experiments (CCD) and regression analysis performed with a special software (DOE KISS).

There were obtained two independent variables polynomial type models and by plotting graphs, it was evidenced their influence, as well as their interaction, on the axial force and torque values.

All the steps carried in order to obtain the new mathematical models can be considered as parts of a “procedure” to be followed / applied for any materials type and different machining procedures, whenever dependence relations of machining parameters are worth to be determined.

Further research involves other process parameters and materials to be studied, as well as the application of obtained models on real time control of the machining processes.

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