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STUDY ON DETERMINING THE MOMENTS REGRESSION RELATIONS AT DRILLING IN MINERAL COMPOSITE MATERIALS WITH 2% CONCENTRATION OF GLASS FIBER

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Abstract: *Mineral composite with fiber reinforcements consist of two or more physically combined different natural solid minerals with fiber in order to create a new material whose properties are superior to those of the original material. Mineral composite materials raise several problems when they are machined. The key issues appear when the tool enters and exits from the drilled material. This article presents the obtained results and their evaluation for drilling in mineral composite materials with 2% concentration of glass fiber. The objective of this research is to obtain the dependence mathematical relation for cutting moments as a function of the cutting process parameters.*
Keywords: *drilling, mineral composite materials, moments, regression relations.*

1. INTRODUCTION

When the mineral composite materials are machined the temperature increases and the material properties changes (changes are small or large) [1]. Therefore, the target is to obtain a balance [2], that don't affect the properties of the mineral composite material, between the drilling tool and the drilled composite material. The control of the process parameters is mandatory [3, 4] when mineral composite materials products are machined.
A lot of applications and products were created in the last years using mineral composite materials. Bridges represent the products in which mineral composite materials have the most applicability. The JecComposites [5], a worldwide composite material magazine, had presented many articles with the benefits of using mineral composite materials, like: the June 2012 number "China first all composite public bridge built" (the future development of bridge technology), the May 2012 number "Life Insu-Shell wins best of the best Life environments award" (for the contributions to - textile reinforced concrete - a new life cycle).
The study's on the drilling process of composite materials are made to prevent: delamination, fiber pullout, thermal damage and hole diameter error. A study of the dry high speed drilling process was performed by Sanjay Rawat [6] how presented a machinability maps approach, characterizing the drilling process of woven composites. Using genetic algorithms Ramon Quiza Sardinas studied the optimization of cutting parameters for drilling laminate composite materials [7].
Although, experimental investigation has been done for many composite materials [8, 9], because the large variety on the market, a pattern can't be given for the drilling process.

2. EXPERIMENTAL WORK

Experiment programming involves a careful study and well documented of the process studied. This paper uses two specialized software that allow us to choose an experimentation program and the determination of the regression model.
The two software are: REGS (use for the determination of experimental programs, polynomial regression relations, optimization of the relations and static errors) and DOE PRO XL (use for the determination of experimental programs, polynomial regression relations, optimization of the relations, plotting 2D and 3D, Pareto diagram etc.).
During the experiments we used the following equipment:

- the machine tool: drilling CNC machine FIRST MCV 300 with power P = 11 kW, continuous range of revolutions, continuous range of tool travels;
- the cutting tool: DIN 8039 ISO 5468, high-speed SDS, covered with tungsten type YG8 (equivalent ISO K20) and the diameters: ø5, ø8 and ø12, peak angle 160^{o}, producer ALPEN/MAZKESTAG;
- the processed material: mineral composite material reinforced with 2% concentration glass fiber, concrete matrix B 250, glass fiber type E (OCV^{TM} – P207);
- dynamometric structure: the drilling moments of the mineral composite material were captured with a Kistler dynamometric structure type-9257B.

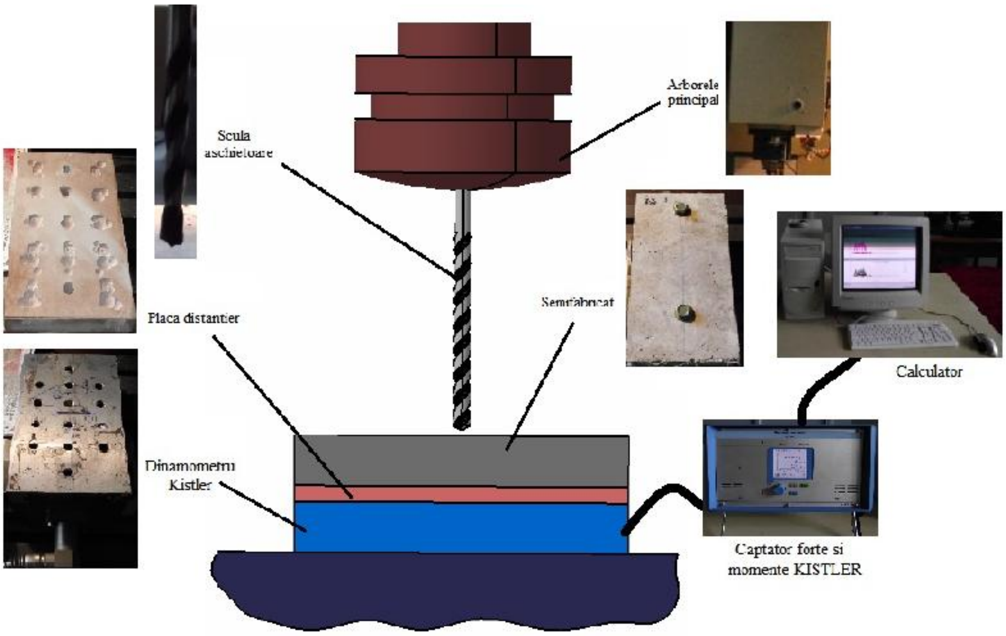

Figure 1: The schematic representation of the determination stand

The experiments were made in the composite laboratories from University Polytechnic of Bucharest faculty of Engineering and Management of Technological System Romania. The schematic representation of the determination stand can be observed in Figure 1.

3. EXPERIMENTAL RESULTS AND DATA PROCESSING

In order to have a good experimental program that we can rely on we have used three independent natural variable with three levels of variation: tool diameter D [mm], feed rate f [mm/rot] and drilling speed v_c [m/min], Table 1.

Table 1: Independent natural variable with three levels of variation

Natural variable	Cod	Codification level		
		-1	0	1
tool diameter D [mm]	X_1	5	8	12
feed rate f [mm/rot]	X_2	0,08	0,12	0,16
drilling speed *vc*, [m/min]	X_3	9,424	16,86	30,159

For every software used we have created one experimental program. In Table 2 we have the experimental program (with three independent natural variable and three codification levels) for REGS and in Table 3 we have the experimental program (with three independent natural variable and two codification levels) for DOE PRO XL.

Table 2: REGS experimental program

X_i / nr. exp.	X_1	X_2	X_3
1	1	-1	-1
2	-1	1	-1

3	-1	-1	1
4	1	1	1
5	0	0	0
6	0	0	0

Tabel 3: DOE PRO XL experimental program

nr. exp. \ X_i	X_1	X_2	X_3
1	-1	-1	-1
2	-1	-1	1
3	-1	1	-1
4	-1	1	1
5	1	-1	-1
6	1	-1	1
7	1	1	-1
8	1	1	1

3.1. Experimental results obtained with REGS

The starting point equation used for REGS software in the analysis for the cutting moments at drilling in mineral composites materials with 2% concentration glass fiber, [10, 11]:

$$M_z = C_M \cdot D^{x_M} \cdot f^{y_M} \cdot v_c^{z_M}\text{, in Nm} \qquad \textbf{(1)}$$

where:
M_z – axial moment, in Nm;
D – tool diameter, in mm;
f - feed rate, in mm/rot;
v_c - drilling speed, in m/min;
In order to estimate the C_M constant and the x_M, y_M, z_M polytropic exponents the equation (1) has been linear zed by using the logarithm:

$$\lg C_M + x_M \lg D + y_M \lg f + z_M \lg v_c = lg M_z \qquad \textbf{(2)}$$

In the Table 4 we have the results obtained according the experimental program used for REGS:

Table 4: Experimental results REGS

Experimental program			Tool diameter: D, [mm]	Feed rate: f, [mm/rot]	Drilling speed: v_c, [m/min]	M_z [Nm]
D	f	v_c				
1	-1	-1	12	0.08	9.42	1,07
-1	1	-1	5	0.16	9.42	0,32
-1	-1	1	5	0.08	30.16	0,23
1	1	1	12	0.16	30.16	0,99
0	0	0	8	0.12	16.86	0,55
0	0	0	8	0.12	16.86	0,55

After the regression analysis of REGS software we have obtained the next regression relations at drilling in mineral composite materials with 2% concentration of glass fiber:

$$M_z = 0{,}05818 \cdot D^{1{,}5289} \cdot f^{0{,}1984} \cdot v_c^{-0{,}18}\text{, in Nm} \qquad \textbf{(3)}$$

3.2. Experimental results obtained with DOE PRO XL

The starting point equation used for DOE PRO XL software in the analysis for the cutting moments at drilling in mineral composites materials with 2% concentration glass fiber, [12]:

$$M_z = a_0 + a_1 D + a_2 f + a_3 v_c + a_{12} Df + a_{13} Dv_c + a_{23} f v_c + a_{123} Df v_c\text{, in Nm} \qquad \textbf{(4)}$$

where:
M_z – axial moment, in Nm;
D – tool diameter, in mm;
f - feed rate, in mm/rot;

v_c - drilling speed, in m/min;
a_0, a_1, a_2, a_3, a_{12}, a_{13}, a_{23}, a_{123} – politropic exponets
In the Table 5 we have the results obtained according the experimental program used for DOE PRO XL:

Table 5: Experimental results DOE PRO XL

Experimental program			Tool diameter: D, [mm]	Feed rate: f, [mm/rot]	Drilling speed: v_c, [m/min]	M_z [Nm]
D	f	v_c				
-1	-1	-1	5	0.08	9.42	0.28
-1	-1	1	5	0.08	30.16	0.23
-1	1	-1	5	0.16	9.42	0.32
-1	1	1	5	0.16	30.16	0.26
1	-1	-1	12	0.08	9.42	1.07
1	-1	1	12	0.08	30.16	0.88
1	1	-1	12	0.16	9.42	1.23
1	1	1	12	0.16	30.16	1.01

After the regression analysis of DOE PRO XL software we have obtained the next regression relations at drilling in mineral composite materials with 2% concentration of glass fiber:

$$M_z = -0.259 + 0.103D - 0.595f + 0.002v_c + 0.230Df - 0.0008Dv_c + 0.0025fv_c - 0.0017Dfv_c, \text{ in Nm} \quad \textbf{(5)}$$

4. ANALYSIS OF THE RESULTS

Diagrams of the variation of the moment are shown in Figures 2 to 7, according the regression relations determined (3) and (5). These only apply to mineral composite materials with 2% concentration glass fiber.

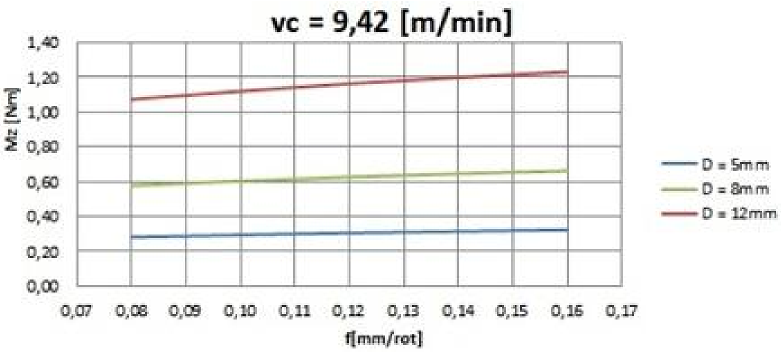

Figure 2: The variation of moment as a function of feed rate, for different tool diameter, (v_c=constant)

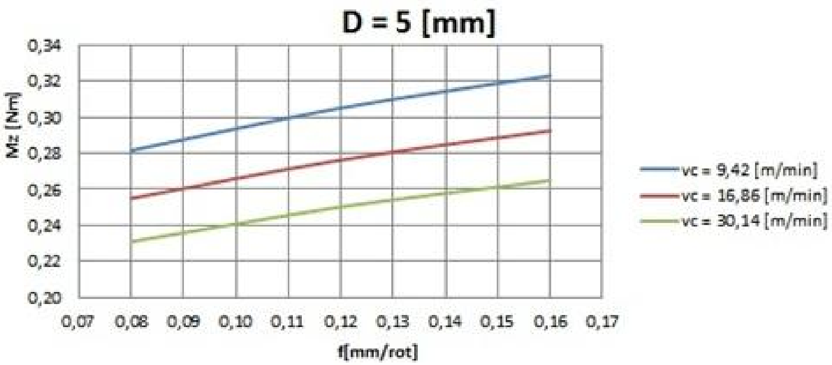

Figure 3: The variation of moment as a function of feed rate, for different drilling speed, (D=constant)

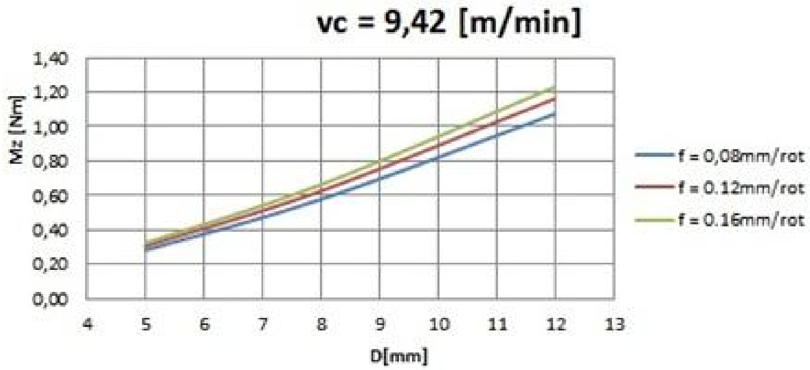

Figure 4: The variation of moment as a function of tool diameter, for different feed rate, (v_c =constant)

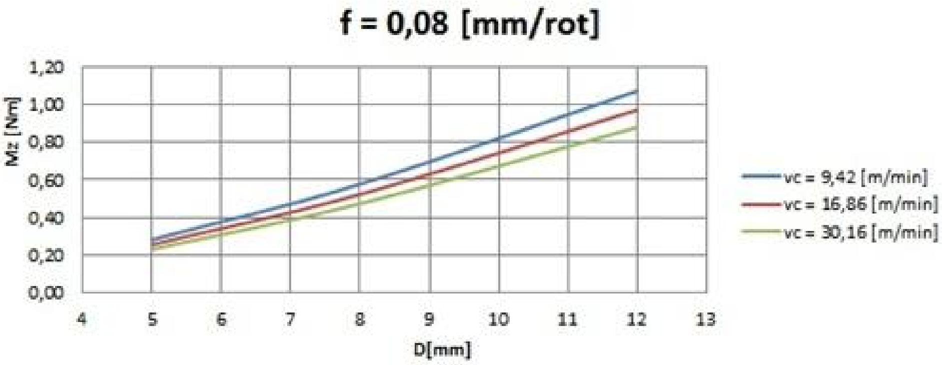

Figure 5: The variation of moment as a function of tool diameter, for different drilling speed, (f =constant)

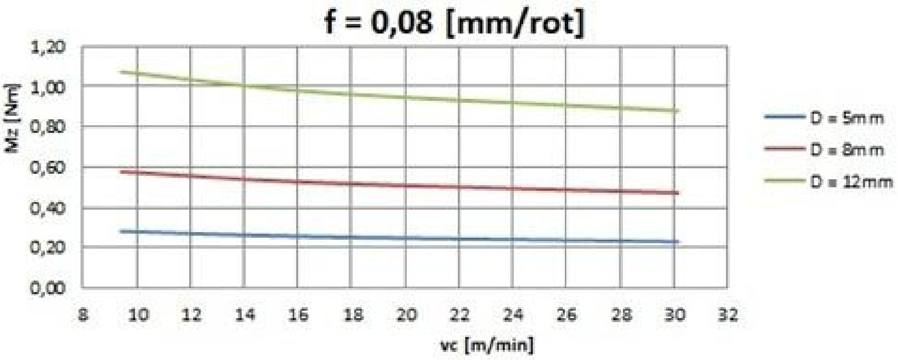

Figure 6: The variation of moment as a function of drilling speed, for different tool diameter, (f =constant)

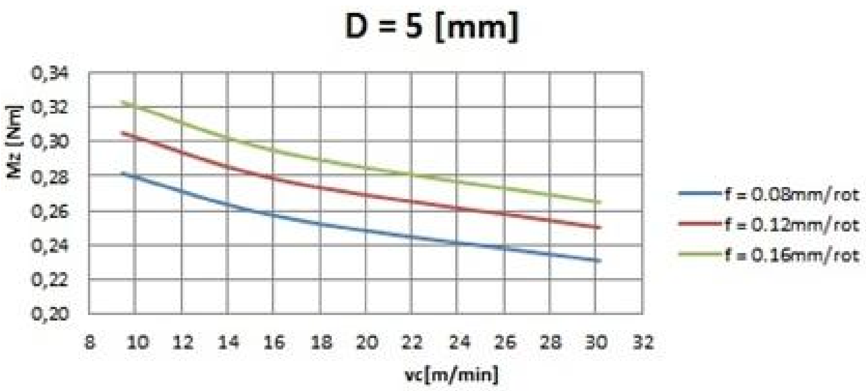

Figure 7: The variation of moment as a function of drilling speed, for different feed rate, (D =constant)

Analiasing the 2D figure of dependence, from Figure 2 to 7, betwen the drilling moment M_z[Nm] and a parameter of the drilling process the others remeining constant, for products made from mineral composite materials with 2% concentration glass fiber we can see:

- the drilling moment M_z[Nm] is increseing with the tool diameter and the feed rate;

- when the drilling speed is increasing the values recorded of the drilling moment M_z[Nm] are decresing.

5. CONCLUSION

This paper presents a study on determining the moments regression relations at drilling in mineral composite materials with 2% concentration of glass fiber. Analyzing the results obtained we can see that:
- the drilling moment M_z[Nm] is increesing with the tool diameter and the feed rate;
- when the drilling speed is increasing the values recorded of the drilling moment M_z[Nm] are decresing;
- all the parameter taken in consideration have semnificativ influence on the values registreted;
- the process parameters with bigest influence are de tool diameter, the feed rate and the drilling speed;
- the drilling moments values recorded are similar to the ones of other types of composite materials (biocomposite, with polimeric matrix etc.).

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 implemented in the manufacturing activity of these materials.

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