

DETERMINING THE DRILLING FORCE REGRESSION AT DRILLING COMPOSITES MATERIALS

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ABSTRACT: Composite materials are used extensively because of their higher strength to weight ratios and, when compared to metals, offer new opportunities for design. However, being non-homogenous, anisotropic and reinforced with very abrasive fibers, these materials are difficult to machine. In this current article is present a comparative study of results obtained in determining the drilling force regression at drilling a tree types composites material with polymeric matrix and fiber glass.
KEY WORDS: composite materials, polymeric matrix and fiber glass, drilling force

1 INTRODUCTION

The quest for ultraperformant materials has lead to the development of composite materials. Being materials that, is believed, will replace metals, and considering their characteristics and future-prospect, great attention should be given to composite materials.

Composite materials are the first materials with the internal structure designed by man, not only in their molecular chain, but also giving them great strength in preferential directions.[1]

The major advantage of composite materials is the possibility of modulating their properties and thus the possibility of obtaining a large variety of materials, for whatever technical application is needed [2]. In most cases, the composite consists of a matrix, in which a complementary material is dispersed. The properties that we try to achieve with this material are: break resistance, wear resistance, density, high temperature resistance, dimensional stability, capacity to damp down vibrations.

Composite materials which contain glass fiber, because of their specific fizio-mechanical properties, raise special problems when splintering machining is used. From another point of view, because of the high cost of these materials, the study on machining must be made using quick splintering methods, which have the least material consumption [3, 4]

In this paper, there will be brought to your attention a series of result obtained in determining the splintering force when drilling into three types of composite materials with polymeric matrix and different concentration of glass fiber.

2 METHOD, MEANS AND DRILLING CONDITIONS USED WHEN DETERMINING THE FORCES

For this, the fallowing experimental stand has been chosen: (Figure1)

Figure 1. The image of the stand of determinations with the force moment pickup and the registration system

Drilling machine used:

- drilling machine GU 25
  - - power of work: 2,3 KW;
  - - gamma of rotations: 28…2240 rot/min;

- - gamma of advances: 0,08….0,25 mm/rot.

Specifications drilling tools:

- helical drills: Φ6, Φ8, Φ10, Φ12, with 2κ= 130^0, made by DORMER

Material properties are the fallowing:

- probe structure:
  - polyester resin AROPOL S 599
  - glass fiber EC12-2400-P1800(65), produced by SC.FIROS SA;

The product code of **EC12-2400-P1800(65)**, according with ISO 2078, is the following:

E = glass type;

C = continual process;

12 = diameter of the monofilament (/);

2400 = length density - finesse;

P1800 =FIROS cod ;

(65) = length density - finesse;

The main properties of the EC12-2400-P1800(65), are:

- Density: 2,54 g/cm^3
- Longitudinal elasticity constant: 72400 N/mm^2
- Resistance to traction: 3450 N/mm^2
- Terminal expansion coefficient: $5\ 10^{-6}\ {}^0C^{-1}$
- Heat conductivity: 1,3 W/(m ^{0}C)
- Specific heat: 840 J/(kg K)

In order to record the values of the force variations at different splintering parameters (tool diameter, feed rate, r.p.m) we have used a computer system consisting of the following:

A transducer for measuring forces, made by the T.C.M. Desk, of the I.M.S.T Faculty. [5]

MGC amplifier, prodused by Hottinger Baldwin Messtechnic;

- Data acquisition board type DAQ Pad 6020E;
- PC;
- LabVIEW software

The gauging of the pickup of forces was made with a lab dynamometer which bears a maximum loading of 10kN compression read on a comparator with dial with the division value of 0.01 mm and an average constant value of gauging for the forces was obtained:

K_F = 6.9 N/div.

3 EXPERIMENTAL RESULTS AND DATA PROCESSING

Technical literature [6, 7] provided equation (1), which has been the starting point in the analysis of cutting forces:

$$F = C_F \times D^{x_F} \times s^{y_F}\ [daN] \qquad (1)$$

This equation has proved to be inappropriate since after the practical estimation of the polytrophic exponents and constants, several tests determinations has been performed and have showed a wide result scattering under the same cutting conditions.

During the machining at various speeds, different parameter values were recorded even if all the other machining conditions are kept constant. It was introduced a speed factor:

$$F = C_F \times D^{x_F} \times s^{y_F} \times v^{z_F}\ [\text{daN}] \qquad (2)$$

In order to the C_F constant and the x_F, y_F, z_F, polytrophic exponents were estimated, the equation (2) has been linear zed by using the logarithm

$$\lg C_F + x_F \cdot \lg D + y_F \cdot \lg s + z_F \cdot \lg v = \lg F \qquad (3)$$

Table 1 shows a selection of the most conclusive machined.

Table 1. Experimental results

Nr. det.	Hole diameters d, mm	Feed rate s, mm/rot	Rotation n, rot/min	Drilling speeds v, m/min	Forces [N] Content fiber glass 20%	30%	40%
1	10	0,25	355	11,15	96,35	97,52	98,82
2	6	0,25	355	6,69	46,94	48,11	48,82
3	10	0,125	355	11,15	71,64	72,35	72,82
4	10	0,25	710	22,30	84	88,94	93,88
5	12	0,125	710	26,76	82,45	86,24	90,12
6	8	0,25	355	8,92	71,64	72,59	73,52

In the data included in Table 1 are substituted in the equation (3), a linear inhomogeneous system of 4 equations with 4 unknowns (x_F, y_F, z_F, lg C_F) is obtained:

-composites materials with polymeric matrix and 20% fiber glass

$$\begin{cases} \lg C_F \cdot x_F \lg 10 + y_F \lg 0{,}25 + z_F \lg 11{,}15 = \lg 96{,}35 \\ \lg C_F \cdot x_F \lg 6 + y_F \lg 0{,}25 + z_F \lg 6{,}69 = \lg 46{,}94 \\ \lg C_F \cdot x_F \lg 10 + y_F \lg 0{,}125 + z_F \lg 11{,}15 = \lg 71{,}64 \\ \lg C_F \cdot x_F \lg 10 + y_F \lg 0{,}25 + z_F \lg 22{,}3 = \lg 84 \end{cases} \quad (4)$$

The system has the following solution

C_F =6,945; x_F =1,581; y_F =0,428; z_F=-0,173;

The axial cutting force formula for the drilling is obtained by inserting this solution in the equation (2):

$$F = 6{,}945\ D^{1{,}581}\ s^{0{,}428}\ v^{-0{,}173}\ [N] \quad (5)$$

Experiments 5 and 6 were conducted to test the relation of regression (5). Calculation errors were lower than 2%.

-composites materials with polymeric matrix and 30% fiber glass

$$\begin{cases} \lg C_F + x_F \lg 10 + y_F \lg 0{,}25 + z_F \lg 11{,}15 = \lg 97{,}52 \\ \lg C_F + x_F \lg 6 + y_F \lg 0{,}25 + z_F \lg 6{,}69 = \lg 48{,}11 \\ \lg C_F + x_F \lg 10 + y_F \lg 0{,}125 + z_F \lg 11{,}15 = \lg 72{,}35 \\ \lg C_F + x_F \lg 10 + y_F \lg 0{,}25 + z_F \lg 22{,}3 = \lg 88{,}94 \end{cases} \quad (6)$$

The system has the following solution:

C_F =7,439; x_F =1,516; y_F =0,431; z_F = -0,133;

The axial cutting force formula for the drilling is obtained by inserting this solution in the equation (2):

$$F = \mathbf{7{,}439} \cdot \mathbf{D}^{1{,}516}\ \mathbf{s}^{0{,}431}\ \mathbf{v}^{-0{,}133}\ [N] \quad (7)$$

Experiments 5 and 6 were conducted to test the relation of regression (5). Calculation errors were lower than 2%.

- composites materials with polymeric matrix and 40% fiber glass

$$\begin{cases} \lg C_F + x_F \lg 10 + y_F \lg 0{,}25 + z_F \lg 11{,}15 = \lg 98{,}82 \\ \lg C_F + x_F \lg 6 + y_F \lg 0{,}25 + z_F \lg 6{,}69 = \lg 48{,}82 \\ \lg C_F + x_F \lg 10 + y_F \lg 0{,}125 + z_F \lg 11{,}15 = \lg 72{,}84 \\ \lg C_F + x_F \lg 10 + y_F \lg 0{,}25 + z_F \lg 22{,}3 = \lg 93{,}88 \end{cases} \quad (8)$$

The system has the following solution:

C_F =7,636; x_F =1,454; y_F =0,440; z_F =-0, 074;

The axial cutting force formula for the drilling is obtained by inserting this solution in the equation (2):

$$F = \mathbf{7{,}636} \cdot \mathbf{D}^{1{,}454}\ \mathbf{s}^{0{,}440}\ \mathbf{v}^{-0{,}074}\ [N] \quad (9)$$

Experiments 5 and 6 were conducted to test the relation of regression (5). Calculation errors were lower than 2%.

4 ANALYSIS OF THE RESULTS

Diagrams of the variation of forces are shown in Figs. 2 to 6.

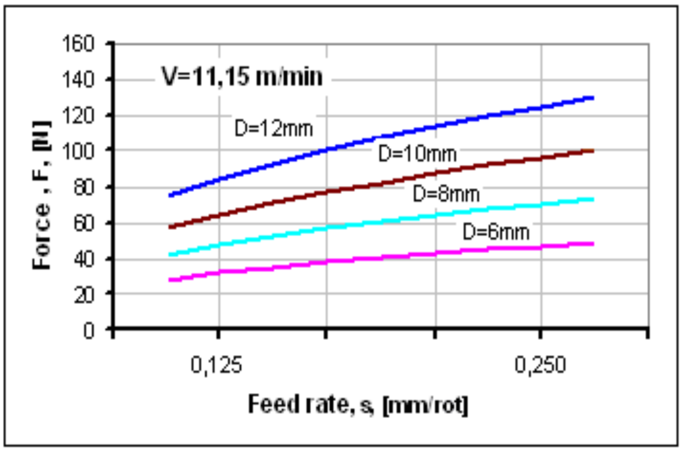

Figure 2. Shows the variation of axial force as a function of feed rates, for different drill diameter (v=ct)

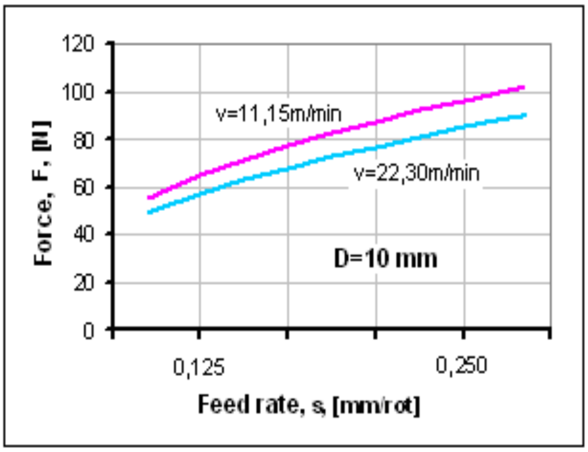

Figure 3. Shows the variation of axial force as a function of feed rates, for different drilling speeds of the tool (D=ct)

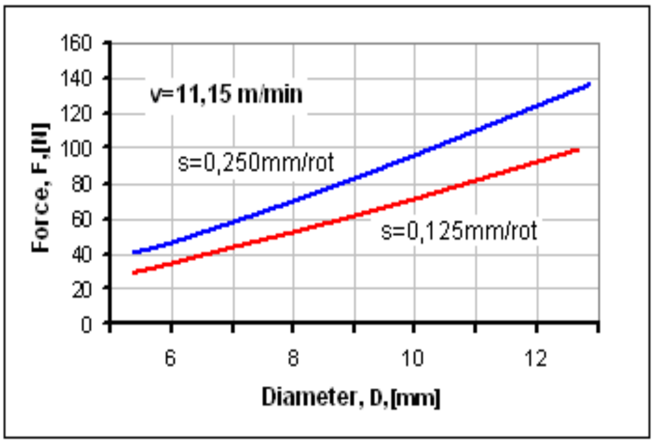

Figure 4. Shows the variation of axial force as a function of drill diameter, for different feed rates (v=ct)

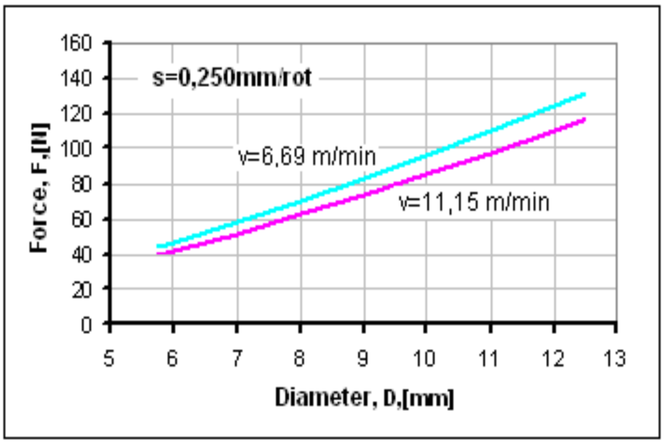

Figure 5. Shows the variation of axial force as a function of drill diameter, for different drilling speeds of the tool (s=ct)

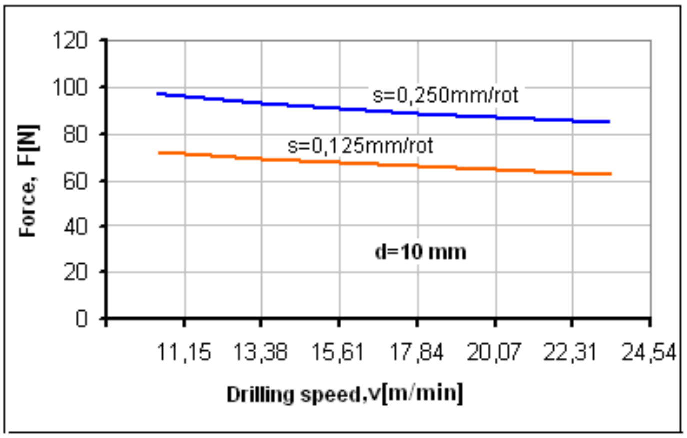

Figure 6. Shows the variation of axial force as a function of drilling speed, for different feed rates (d=ct)

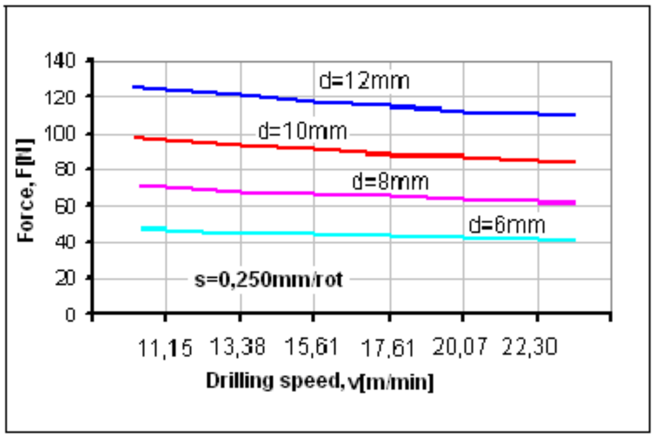

Figure 7. Shows the variation of axial force as a function of drilling speed, for different drill diameter (s=ct)

Figure 2 shows the variation of the axial force as a function of feed rate *s*, where *v*=11,15m/min for different drill diameters, *D*. The rise of the forces is exponential with the rise of the drill diameter and of the feed rate, s.

Figure 3 shows the variation of the axial force as a function of feed rate *s*, where *D* = 10 mm for different drilling speeds of the tool. The rise of the forces is exponential with the rise of the feed rate.

Figure 4 shows the variation of the axial force as a function of drill diameter, *D*, where *v*=11,15m/min, for different feed rates, *s*. It can be noticed that the axial forces rise exponential with the rise of the drill diameter.

Figure 5 shows the variation of the axial force as a function of drill diameter, *D*, where *s*=0,25mm/rot for different drilling feed speed. It can be noticed that the axial forces rise exponential with the rise of the drill diameter

Figure 6 show dependence on the axial force as a function of drilling speed v, where D = 10mm, for different feed rates, s. It can be noticed that the axial forces subtract exponential with the rise of the drill speed.

Figure 7 show dependence on the axial force as a function of drilling speed *v*, where *s*=0,25mm/rot, for different hole diameters. The axial forces subtract exponential with the rise of the drill speed.

5 CONCLUSIONS

From the analysis of the results, the following important conclusions can be drawn:

- In order to determine the axial forces that appear when drilling into composite materials, a transducer for measuring forces was used, made by the T.C.M. Desk, of the I.M.S.T Faculty;

- Because forces between 0 and 100 N could be measured, during the experiments, drills with the diameter of 6,8,10 and 12 mm were used;

- From analyzing the graphics, an exponential growth of the forces could be notices, as the feed rate and drill diameter increased. However, an exponential decrease in forces can be seen, when the splintering speed increases;

- The machining of these types of material require higher splintering force, the higher the concentration of glass fiber.

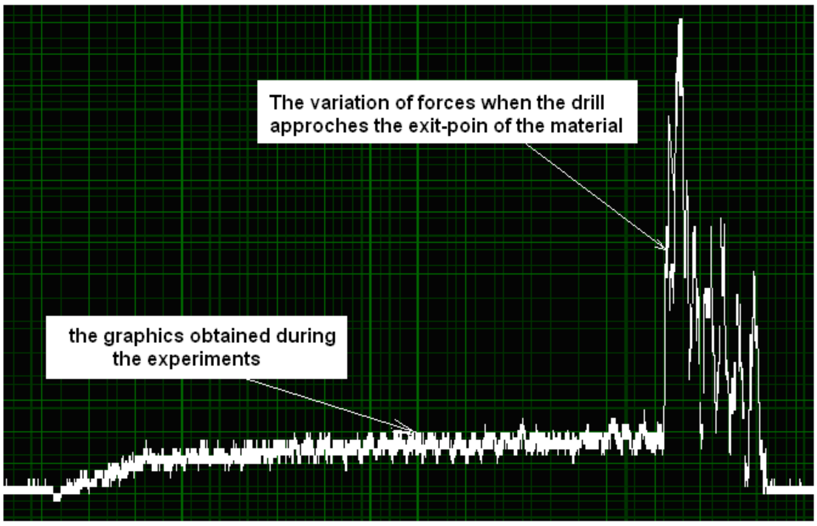

Figure 8. The variation of splintering forces when drilling

After analyzing the graphics obtained during the experiments, it has been noticed that the density of maximum splintering forces is greater, the higher the concentration of glass fiber;

- The maximum and minimum values of the forces are exactly equal, as seen from the graphics; the maximum values represent the forces present when the drill cuts through the glass fiber; the minimum values for the forces are recorded when the drill cuts through the matrix;

- From the graphics, it can be seen that, as the drill approaches the exit-point of the material, there is an area of random recordings, that being the moment when the drill, aside of the cutting action, causes the tear of the glass fiber from the material, (Figure7);

- Although the result of the drilling with this type of drill does not meet high standards regarding the exit-surface of the hole, it must be mentioned that the values for the recorded forces for this type of drill are much smaller than for other types;

- Regarding the form of the splinters tore from the material, these are fragmenting splinters, which can be easily removed.

6 REFERENCES

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