Determination of New Equations for Torque when Drilling in Polimeric Materials

CONSTANTIN OCNĂRESCU[1]*, AURELIAN VLASE[1], MARIA OCNĂRESCU[2], GHEORGHE SINDILA[1]
[1]University "Politehnica" of Bucharest, 313 Splaiul Independenţei, 060042, Bucharest, România,
[2] "Doamna Stanca" High School, 52 Porumbacu Str., 060366, Bucharest, România

Composite materials are sometimes harder to machine than metals, because they are anisotropic, not homogenous and their reinforcing fibers are very abrasive. Significant damage to the work piece may be introduced and high wear rates of the tools are experienced while machining. A presentation of the data obtained through experiments and an analysis of the drilling moments when machining composites will be made in this article.

Keywords: the polymeric composite materials, cutting, drilling moments

Today's advanced technology continues to push the limits of conventional materials. Extreme and sometimes conflicting requirements force us to discover materials that can not be combined through known methods.

Polymeric composite materials are such a category of materials, designed especially to face this challenge. From their discovery, the use of composite materials has grown very rapid in certain industrial areas, such as space industry, aircraft, and car industry etc [1].

Polymeric composite materials which contain glass fiber, because of their physical and mechanical properties, raise special problems when it comes to drilling. From another point of view, because of the high cost of these materials, the study on machining must be done using fast methods of drilling which will lead to a minimum consumption of materials [2, 3].

In the current paper, was obtained a series of results obtained in determining the moments that appear when drilling the composite materials with polymeric matrix and glass fibers.

Experimental part

For this, the following experimental stand has been chosen [7, 8, 9]: (fig. 1,2)

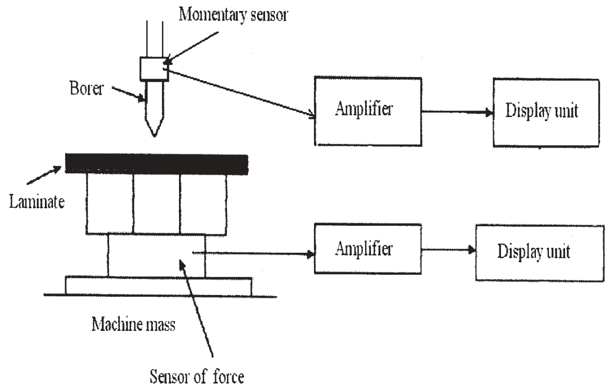

Fig. 1. The schematic representation of the stand of determination

The machine tools used:

Boring machine GU 25

- power of work: 2,3 KW;
- gamma of rotations: 28, 90, 355, 1120; 56, 180, 710, 2240 rot/min;
- gamma of advances: 0,08; 0,125; 0,25 mm/rot;

Specifications drilling tools:

- helical drills: Φ6, Φ8, Φ10, Φ12, with $2\kappa = 130^0$, made by DORMER, (Germany)

Fig. 2. The stand of determination and the registration system

* *email: constantinocnarescu@yahoo.com*

Table 1
EXPERIMENTAL RESULTS

Nr. det.	Hole diameters D, mm	Feed rate s, mm/rot	Rev. n, rot/min	Drilling speeds v, m/min	Torque [Nm] Content fiber glass		
					20%	30%	40%
1	10	0.25	355	11.15	0.819	0.829	0.840
2	6	0.25	355	6.69	0.399	0.409	0.417
3	10	0.125	355	11.15	0.609	0.615	0.622
4	10	0.25	710	22.30	0.714	0.756	0.795
5	12	0.125	710	26.76	0.683	0.717	0.750
6	8	0.25	355	8.92	0.594	0.608	0.625

The characteristics of the polymeric composite material

Probe structure:

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

The composite material is made of reinforcement element: glass fiber EC12-2400-P1800(65), produced by S.C.FIROS SA; (Romania);

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

E = glass type;
C = continual process;
12 = diameter of the monofilament;
2400 = length density – finesse – thread;
P1800 =FIROS cod ;
(65) = length density – finesse - layer;

Matrix: polyester resin AROPOL S 599

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 torque variations at different splintering parameters (tool diameter, feed rate, r.p.m) we have used a computer system consisting of the following (figure 1):

- a transducer for measuring torque type T4A HBM
- MGC amplifier, produced by Hottinger Baldwin Messtechnic;
- data acquisition board type DAQ Pad 6020E;
- PC;
- Lab VIEW software.

A dynamometric key was used to calibrate the torque reader; the key was designed and produced by members of the TCM Desk (U.P. Bucharest); it was also calibrated. [4].

The calibration constant for the Hottinger torque reader is:

K_M = 21Nm/V.

Table 1 shows a selection of the most conclusive machined.

Determination of ecuations for torque when drilling

Technical literature [5, 6] provided equation (1), which has been the starting point in the analysis of cutting moments:

$$M = C_M \times D^{x_M} \times s^{y_M} \quad \text{[Nm]} \qquad (1)$$

This equation has proved to be inappropriate since, after the practical estimation of the polytrophic exponents and constants, values have showed a wide result scattering under the same cutting conditions. Thus, splintering speed has been introduced in the equation:

$$M = C_M \times D^{x_M} \times s^{y_M} \times v^{z_M} \quad \text{[Nm]} \qquad (2)$$

In order to determine the C_M constant and the polytrophic exponents x_M, y_M, z_M, the logarithm function was applied to (2)

$$lgM = lgC_M + x_M lgD + y_M lgs + z_M lgv \qquad (3)$$

In the data included in table 1 are substituted in the equation (3), a linear inhomogeneous system of 4 equations with 4 unknowns (x_M, y_M, z_M, C_M) is obtained:

- *composites materials with polymeric matrix and 20% fiber glass*

$$\begin{cases} \lg C_M + x_M \cdot \lg 10 + y_M \cdot \lg 0.25 + z_M \cdot \lg 11.15 = \lg 0.819 \\ \lg C_M + x_M \cdot \lg 6 + y_M \cdot \lg 0.25 + z_M \cdot \lg 6.69 = \lg 0.399 \\ \lg C_M + x_M \cdot \lg 10 + y_M \cdot \lg 0.125 + z_M \cdot \lg 11.15 = \lg 0.609 \\ \lg C_M + x_M \cdot \lg 10 + y_M \cdot \lg 0.25 + z_M \cdot \lg 22.30 = \lg 0.714 \end{cases} \qquad (4)$$

The system has the following solution:

C_M = 0.059; x_M = 1.606; y_M =0.427; z_M =-0.198;

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

$$\mathbf{M = 0.059 \cdot D^{1.606} \cdot s^{0.427} \cdot v^{0.198}} \text{ [N]} \qquad (5)$$

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*

$$\begin{cases} \lg C_M + x_M \cdot \lg 10 + y_M \cdot \lg 0.25 + z_M \cdot \lg 11.15 = \lg 0.829 \\ \lg C_M + x_M \cdot \lg 6 + y_M \cdot \lg 0.25 + z_M \cdot \lg 6.69 = \lg 0.409 \\ \lg C_M + x_M \cdot \lg 10 + y_M \cdot \lg 0.125 + z_M \cdot \lg 11.15 = \lg 0.615 \\ \lg C_M + x_M \cdot \lg 10 + y_M \cdot \lg 0.25 + z_M \cdot \lg 22.30 = \lg 0.756 \end{cases} \qquad (6)$$

The system has the following solution:

C_M = 0.063; x_M = 1.516; y_M =0.431; z_M =-0.133;

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

$$\mathbf{M = 0.063 \cdot D^{1.516} \cdot s^{0.431} \cdot v^{0.133}} \text{ [N]} \qquad (7)$$

Experiments 5 and 6 were conducted to test the relation of regression (7). Calculation errors were lower than 2%.

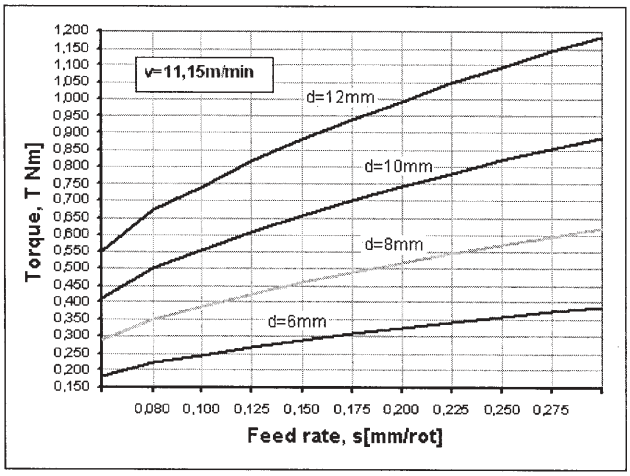

Fig. 3. Shows the variation of torque as a function of feed rate, for different a hole diameters (v=ct)

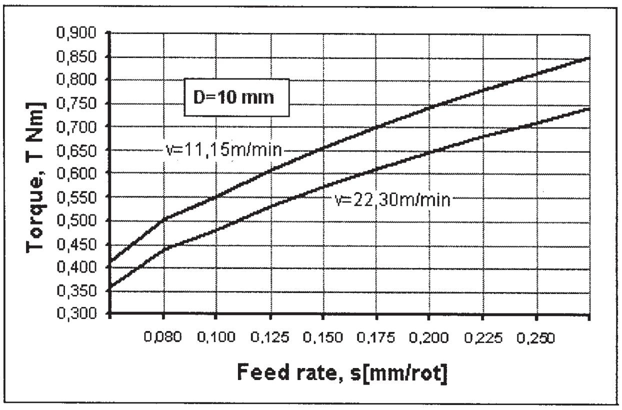

Fig. 4. Shows the variation of torque as a function of feed rate, for different drilling speeds of the tool (D=ct)

- composites materials with polymeric matrix and 40% fiber glass

$$\begin{cases} \lg C_M + x_M \cdot \lg 10 + y_M \cdot \lg 0.25 + z_M \cdot \lg 11.15 = \lg 0.840 \\ \lg C_M + x_M \cdot \lg 6 + y_M \cdot \lg 0.25 + z_M \cdot \lg 6.69 = \lg 0.417 \\ \lg C_M + x_M \cdot \lg 10 + y_M \cdot \lg 0.125 + z_M \cdot \lg 11.15 = \lg 0.622 \\ \lg C_M + x_M \cdot \lg 10 + y_M \cdot \lg 0.25 + z_M \cdot \lg 22.30 = \lg 0.795 \end{cases} \quad (8)$$

The system has the following solution:

$C_M = 0.065$; $x_M = 1.454$; $y_M = 0.440$; $z_M = -0.073$;

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

$$M = 0.065 \cdot D^{1.454} \cdot s^{0.440} \cdot v^{-0.074} \ [N] \quad (9)$$

Experiments 5 and 6 were conducted to test the relation of regression (9). Calculation errors were lower than 2%.

Results and discussions

Diagrams of the variation of torque are shown in figures 3 to 8. These only apply to composite materials with a polymeric matrix and 20% glass fiber.

Figure 3 shows the variation of torque as a function of feed rate *s*, where *v*=11.15m/min for different drill diameters, *D*.

From the graphics, it can be seen that the rise of the torque is exponential with the rise of the drill diameter and of the feed rate, when splintering speed is constant.

Figure 4 shows the variation of the torque as a function of feed rate *s*, where *D*=10mm for different drilling speeds of the tool.

The chart analysis proves that the rise of the torque is exponential with the rise of the feed rate, greater values for the splintering torque being obtained for lower splintering speeds, the same tool diameter being used.

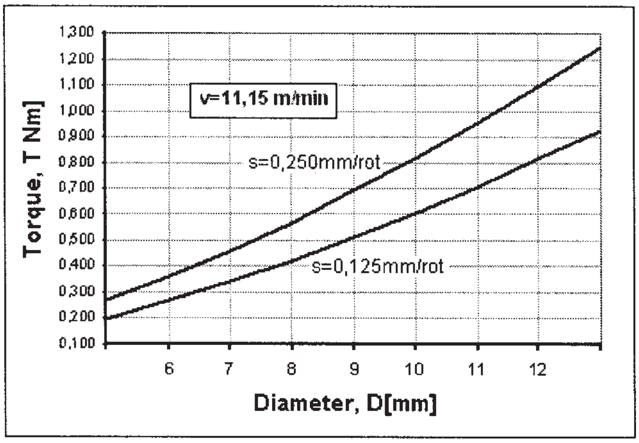

Fig. 5. Shows the variation of torque as a function of hole diameter for different feed rates (v=ct)

Figure 5 shows the variation of torque as a function of hole diameter, for different feed rates, where v=11.15 m/min, for different feed rates.

It can be noticed that the rise of the torque is exponential with the rise of the drill diameter and of the feed rate, s, for v=11.15 m/min.

Figure 6 shows the variation of torque as a function of hole diameter, where s=0.250mm/rot, for different drilling speeds of the tool.

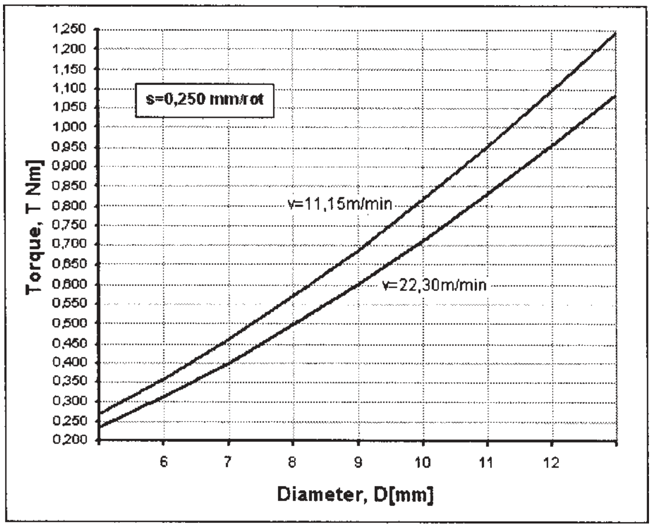

Fig. 6. Shows the variation of torque as a function of hole diameter for different drilling speed (s=ct)

When feed rate is kept constant, the rise of the torque is exponential with the rise of hole diameters, and have lower values, the lower the splintering speed.

Figure 7 shows the variation of torque as a function of drilling speed, where s=0.250mm/rot, for different hole diameters.

If feed is constant, the rise of the torque is exponential with the rise of drilling speed and the drill diameter, higher torque values being obtained for higher drill diameters.Figure 8 shows the diagram of the variation of torque as a function of drilling speeds, where D=10 mm, for different feed rates.

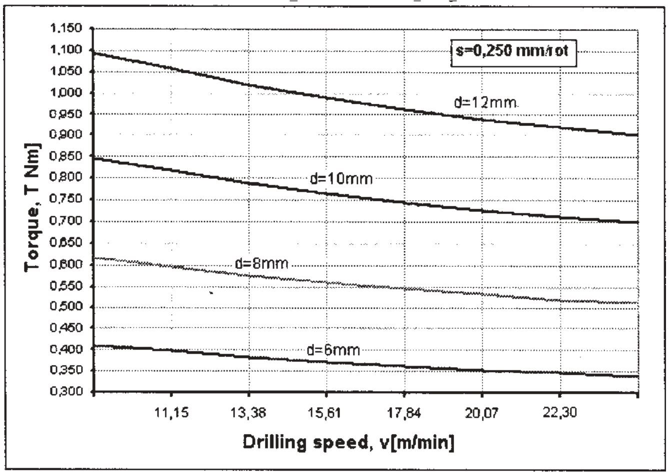

Fig.7. Shows the variation of torque as a function of drilling speed, for different a hole diameters (s=ct)

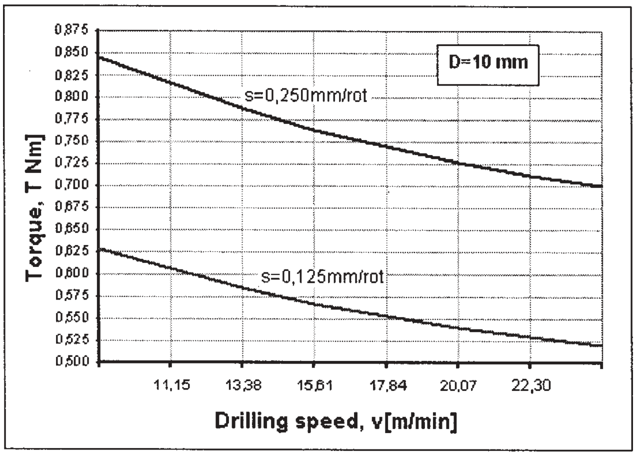

Fig.8. Shows the variation of torque as a function of drilling speed, for different feed rates (D=ct)

If drill diameter is constant, the rise of the torque is exponential with the rise of drilling speeds and feed rates.

Conclusions

From analyzing the variation of torque for the three types of polymeric composite materials (20%, 30% and 40% glass fiber) and from the analysis of the results obtained, the following conclusions can be drawn:

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

- the machining of these types of material requires higher splintering torque, the higher is the concentration of glass fiber;

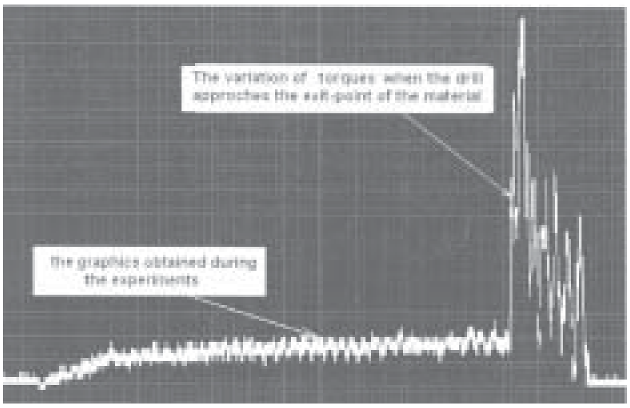

Fig. 9. The variation of splintering torques when drilling

- 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, (fig. 9), that being the moment when the drill, aside of the cutting action, causes the tear of the glass fiber from the material;

- 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 torque for this type of drill are much smaller than for other types;

- during the experiments, no cooling liquids were used because of the abrasive actions which they would do on the cutting tool.

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