DETERMINATION OF THE DEPENDENCE RELATION FOR THE MOMENTS AT WIDENING A 36% GLASS FIBER REINFORCED POLYMERIC COMPOSITE MATERIAL

Adriana DAMIAN[1], Ovidiu BLĂJINĂ[2], Aurelian VLASE[3]

Materialele compozite prezintă o serie de avantaje, dar structura lor internă (anizotropie, neomogenitate, ranforsare cu fibre) crează anumite dificultăţi la prelucrarea lor. Suprafeţele prelucrate ale pieselor realizate din materiale compozite polimerice pot avea defecte semnificative. Această lucrare prezintă rezultatele experimentale obţinute şi evaluarea acestora, la prelucrarea prin lărgire a unui material compozit cu matrice polimerică şi ranforsat cu o concentraţie de 36% fibre de sticlă. Relaţia matematică de dependenţă pentru momentul de aşchiere a fost determinată în funcţie de parametrii procesului de aşchiere.

The composite materials have a lot of advantages, but their internal structure (anisotropy, heterogeneity, fiber reinforcement) makes difficult their machining. The processed surfaces of the pieces realized of polymeric composite materials may have significant damages. This paper presents the obtained experimental results and their evaluation when widening a composite material with polymeric matrix and reinforced with 36% concentration of glass fibers. The dependence mathematical relation for the cutting moment was determined; as a function of the cutting process parameters.

Key words: composite material, widening, cutting moment.

1. Introduction

The research in the design and the manufacture of the new materials aim to produce them at a low cost, quality and higher reliability [1]. The use of new materials is a priority for the manufacturers and the users [2]**.** Consequently a great attention is given to the composite materials.

A composite material consists of a matrix, in which a complementary material is dispersed [3, 4]. The characteristics of the composites materials with polymeric matrix are affected, mainly by three factors: the size of the reinforcement element; the number of reinforcement elements; the layout of elements in the matrix polymeric reinforcement [5, 6, 7]. The possibility of modulating the

[1] Eng., High school "Grigore Cerchez", Bucharest, e-mail: adi.damian@yahoo.com
[2] Assoc. Prof., University POLITEHNICA of Bucharest, Department of Machine Manufacturing Technology, Romania, e-mail: ovidiu_blajina@yahoo.com
[3] Prof., University POLITEHNICA of Bucharest, Department of Machine Manufacturing Technology, Romania, e-mail: aurelvlase@yahoo.com

properties of the composite materials is their major advantage [8].

The most important properties achieved for these materials are: failure resistance, wear resistance, density, high temperature resistance, dimensional stability, capacity to damp down vibrations [9, 10]. The composite materials with a polymeric matrix and reinforced with glass fibers have specific mechanical properties, but they raise special problems at their machining [11, 12].

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 [13].

In this paper a composite material with polymeric matrix and reinforced with 36% concentration of glass fibers is analysed. The obtained experimental results and their evaluation when widening the studied material are presented in the paper. The dependence mathematical relation for the cutting moment, valid only for this material, was determined as function of the cutting process parameters.

2. Means and conditions used for experiments

During the experiments we used the following equipment:

- the machine tool: a drilling machine GU25 with power P = 2.3 kW, range of revolutions 28...2240 rot/min, range of tool travels 0.08...0.25 mm/rot;
- the cutting tool: Rp5 (STAS 575-80) high-speed steel spiral drills, covered with TiN, code A520, with HRC 62 and the diameters: ∅6, ∅8, ∅10, ∅12 mm; peak angle 130^0; producer DORMER-Germany;
- the processed material: composite material polyester with resin AROPOL S 599 matrix and reinforced with 36% glass fiber, EC12-2400-P1800(65), produced by SC FIROS SA;
- the experimental stand of determinations for recording the values of the moment variations at different cutting parameters, consisting of the following components (Fig. 1): a transducer for measuring moments, type Hottinger T4A HBM (with the average constant calibration K_M = 21 Nm/V); a MGC amplifier, produced by Hottinger Baldwin Messtechnic; a data acquisition board type DAQ Pad 6020E; PC; LabWIEW software.

According ISO 2078, the product code EC12-2400-P1800(65) has the significance: 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 the following: density: 2.54 g/cm^3; Young's modules: 72400 N/mm^2; ultimate tensile stress: 3450 N/mm^2; thermal expansion coefficient: $5 \cdot 10^{-6}\ {}^oC^{-1}$; heat conductivity: 1.3 $W/(m\ {}^oC)$; specific heat: 840 J/(kgK).

Fig.1. The experimental set-up

3. Experimental results and data processing

The technical literature [14, 15, 16] provided equation (1), which has been the starting point in the analysis of the cutting moments:

$$M = C_M \cdot D^{x_M} \cdot f^{y_M} \cdot a_p^{z_M} \quad [\text{Nm}] \tag{1}$$

where: D is the diameter; f is the feed; a_p is the depth; C_M is a constant; x_M, y_M, z_M are polytropic exponents.

This equation has proved to be inappropriate since after the practical estimation of the polytropic exponents and constant, several tests determinations have been performed and have shown a wide result scattering under the same cutting conditions. During the composite material machining at various speeds, different parameter values were recorded even if all the other machining conditions were kept constant. Therefore a speed factor v_c was introduced:

$$M = C_M \cdot D^{x_M} \cdot f^{y_M} \cdot a_p^{z_M} \cdot v_c^{w_M} \quad [\text{Nm}] \tag{2}$$

In order to estimate C_M constant and the x_M, y_M, z_M polytropic exponents, the equation (2) has been linearized by using the logarithm. The following equation was obtained:

$$\lg C_M + x_M \cdot \lg D + y_M \cdot \lg f + z_M \cdot \lg a_p + w_M \cdot \lg v_c = \lg M \tag{3}$$

Table 1 shows a selection of the most conclusive experimental results obtained for the studied composite material.

Table 1

Experimental results

Exp. No	Diameter D_i [mm]	Diameter D_f [mm]	Feed f [mm/rot]	Depth a_p [mm]	Rotation n [rot/min]	Speed v_c [m/min]	Bridge values [V]	Moments M [Nm]
1	10	12	0.25	1	355	13.38	0.0352	0.739
2	8	12	0.25	2	355	13.38	0.0362	0.760
3	10	12	0.125	1	355	13.38	0.0298	0.626
4	10	12	0.25	1	710	26.76	0.0316	0.664
5	8	10	0.25	1	355	11.15	0.0282	0.592
6	6	10	0.125	2	710	22.30	0.0226	0.475
7	6	8	0.25	1	355	8.92	0.0232	0.458

If data included in Table 1 are substituted in equation (3), then a linear inhomogeneous system of five equations with five unknowns (x_M, y_M, z_M, w_M, lgC_M) is obtained:

$$\begin{cases} \lg C_M + x_M \lg 12 + y_M \lg 0.25 + z_M \lg 1 + w_M \lg 13.38 = \lg 0.739 \\ \lg C_M + x_M \lg 12 + y_M \lg 0.25 + z_M \lg 2 + w_M \lg 13.38 = \lg 0.760 \\ \lg C_M + x_M \lg 12 + y_M \lg 0.125 + z_M \lg 1 + w_M \lg 13.38 = \lg 0.626 \\ \lg C_M + x_M \lg 12 + y_M \lg 0.25 + z_M \lg 1 + w_M \lg 26.76 = \lg 0.664 \\ \lg C_M + x_M \lg 10 + y_M \lg 0.25 + z_M \lg 1 + w_M \lg 11.15 = \lg 0.592 \end{cases} \quad (4)$$

The system (4) has the following solution:

$C_M = 0.051$, $x_M = 1.367$, $y_M = 0.239$, $z_M = 0.039$, $w_M = -0.152$

The formula for the cutting moment for the widening of the studied composite material is obtained by inserting this solution in the equation (3):

$$M = 0.051 \cdot D^{1.367} \cdot f^{0.239} \cdot a_p^{0.039} \cdot v_c^{-0.152} \quad \text{[Nm]} \quad (5)$$

By plotting the diagrams of the cutting moment variation with respect to the work parameters, the resulted diagrams are shown in Figs. 2÷6, valid only for the widening of the studied composite material with a Rp5 high-speed steel spiral.

The Fig. 2 shows the cutting moment variation depending on the feed for different diameters and for constant speed and depth. Fig. 3 shows the

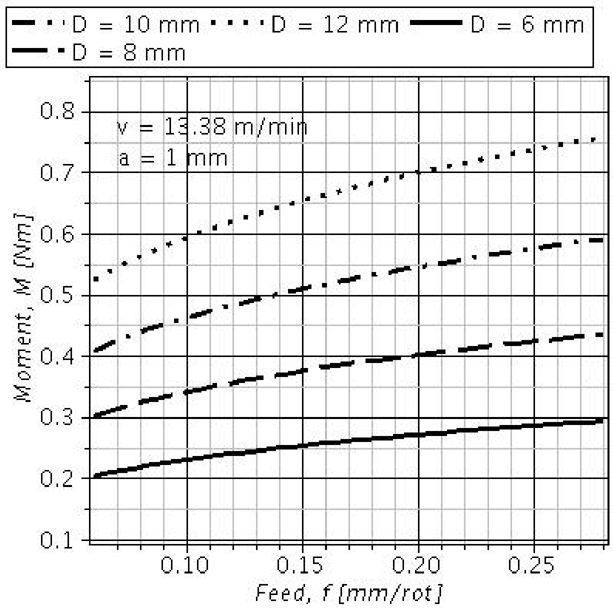

Fig. 2. The moment variation depending on the feed for different diameters

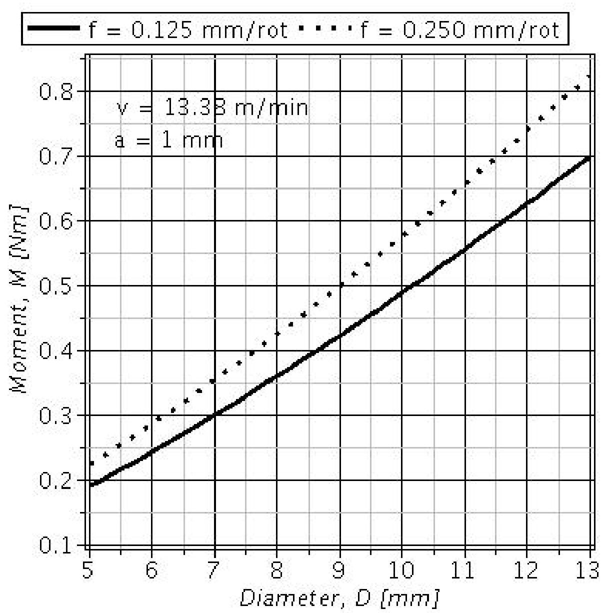

Fig. 3. The moment variation depending on the diameter for different feeds

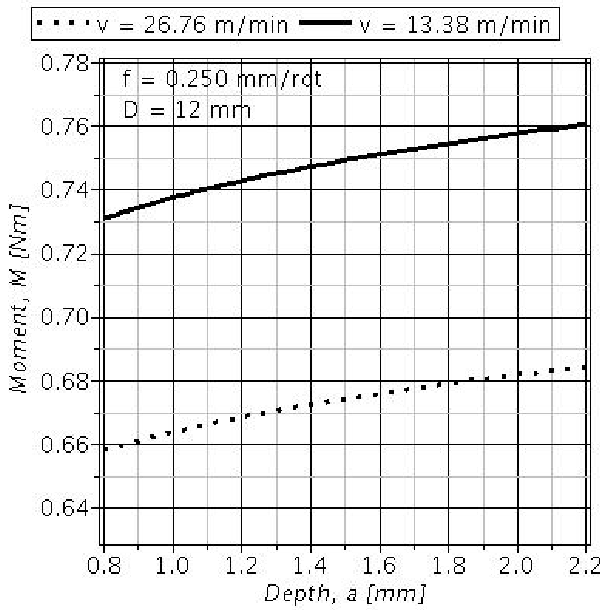

Fig. 4. The moment variation depending on the depth for different tool speeds

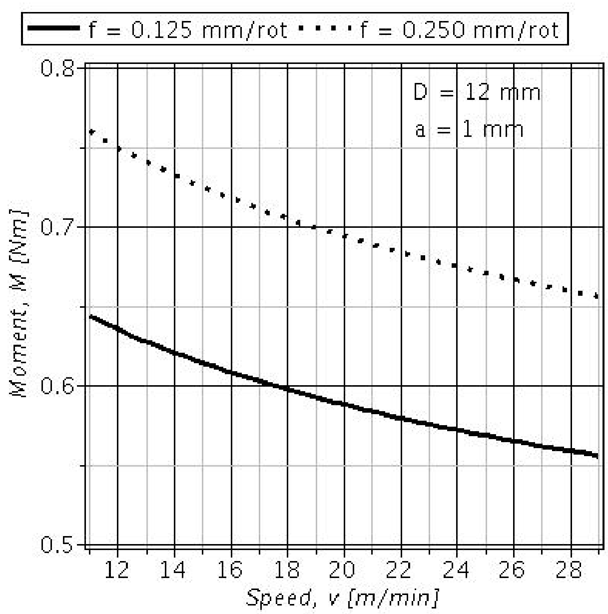

Fig. 5. The moment variation depending on the tool speed for different feeds

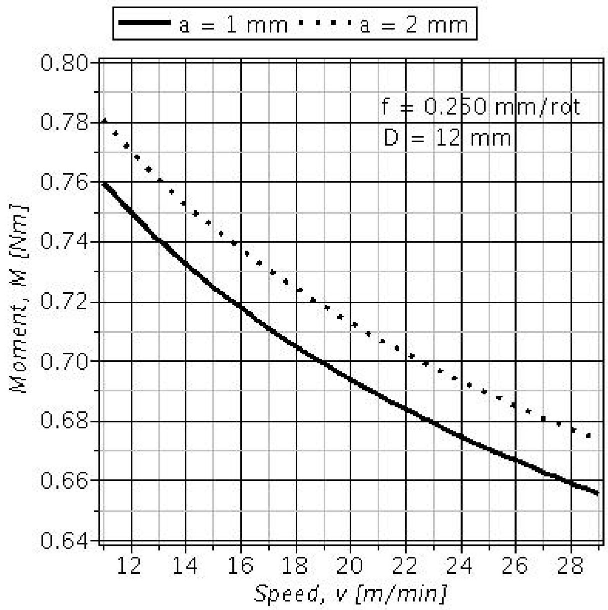

Fig.6. The moment variation depending on the tool speed for different depths

cutting moment variation depending on the diameter for different feeds and for constant speed and depth. Fig. 4 shows the cutting moment variation depending on the depth for different tool speeds and for constant feed and diameter. Fig. 5 shows the moment variation depending on the tool speed for different feeds and for constant diameter and depth. Fig. 6 shows the moment variation depending on the tool speed for different depths and for constant feed and diameter.

4. Conclusions

The experimental results provided the variation of the moments values depending on the parameters of the cutting technology.

By experimental tests, it was demonstrated the necessity of modifying the structure of the cutting force calculation relation found in the technical literature, meaning that the cutting speed has to be included with respect to equations (2) and (5).

The analysis of the dependence relation found above, concerning the widening of the studied composite material, and the diagrams from Figs. 2 to 6, has lead to the following conclusions:

- the cutting moment increases with the feed, for different diameters, if the tool speed and the depth are constant;

• the cutting moment increases exponentialy with the diameter, for different feeds, if the tool speed and the depth are constant;

• the cutting moment increases with the depth, for different tool speeds, if the feed and the diameter are constant;

• the cutting moment decreases with the tool speed, for different feeds, if the diameter and the depth are constant;

• the cutting moment decreases exponentialy with the tool speed, for different depths, if the feed and the diameter are constant.

The results presented in this paper can be taked into consideration in the educational studies and in the theoretical technical research. Also, they can be implemented in the manufacturing activity of these materials. In our further research we intend to study this problem for other steels classes, other processing methods and other specific types of cutting tools.

R E F E R E N C E S

[1] *D. Gay,* Materiaux composites, Ed. Hermes, Paris, 1997.
[2] *D. B. Miracle, S. L. Donaldson,* Composites, ASM Handbook, Volume 21, pp.75-78, 2001.
[3] *M. Mareş,* Materiale compozite (Composites Materials), "Gheorghe Asachi" Technical University of Iaşi, 2002 (in Romanian).
[4] *G. Milton,* The Theory of Composites, Cambridge University Press, England, 2001.
[5] *O. Blăjină et al.*, Modeling the mechanical behavior of composite sandwich plates, Proceedings of the 6-th International Conference of Advanced Manufacturing Technologies ICAMat 2009, pp.113-118 , Ed. BREN, Bucharest, 2009.
[6] *C. Dumitraş*, *C. Opran*, Prelucrabilitatea materialelor compozite, ceramice şi minerale (Processing of the composites, ceramics and mineral materials), Ed. Tehnică, Bucharest, 1994 (in Romanian).
[7] *S. W. Tsaz,* Strength & life of composites, Ed. Aeronautics & Astronautics, Stanford University, USA, 2008.
[8] *A. Vlase,* Calculul analitic al regimurilor de aşchiere la găurire (The analytical calculation of the cutting processes for drilling), Polytechnic Institute Bucharest, 1983 (in Romanian).
[9] *J. M. Berthelot,* Composite Materials. Mechanical Behavior and Structural Analysis*,* Ed. Springer-Verlag, New York, 1999.
[10] *D. V. Rosato,* Reinforced Plastics. Handbook, Elsevier, 2004.
[11] *S. K. Mazumdar*, Composites. Manufacturing-Materials, Product and Process Engineering, CRC Press LLC, 2002.
[12] *J. Murphy,* The reinforced plastics. Handbook, Elsevier Advanced Tehnology, 1998.
[13] *A. Vlase et al.*, Tehnologii de prelucrare pe maşini de găurit (Technologies of processing by using mill drillings), 2nd, Ed. BREN, Bucharest, 2007 (in Romanian).
[14] *S. Hoa,* Principles of the Manufacturing of Composites Materials, Concordia University, USA, 2008.
[15] *I. Popescu,* Fundaments of cutting and surface generation, University of Craiova, 1981.
[16] *A. Vlase,* Ghid pentru calculul analitic al regimurilor de aşchiere la găurire (A guide to the analytical calculation of cutting processes for drilling), Polytechnic Institute Bucharest, 1988 (in Romanian).