DETERMINATION OF THE DEPENDENCE RELATION FOR THE FORCES AT DRILLING IN COMPOSITE MATERIALS WITH POLIMERIC MATRIX AND 24% CONCENTRATION OF GLASS FIBERS

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Materialele compozite ridică probleme deosebite la prelucrare, deoarece ele sunt anizotropice, neomogene şi fibrele lor de ranforsare sunt foarte abrazive. În timpul prelucrării lor pot apare defecte semnificative ale pieselor şi se înregistrează valori mari ale uzurii sculelor. Acest articol prezintă rezultatele experimentale obţinute şi evaluarea acestora, la prelucrarea prin găurire a unui material compozit cu matrice polimerică şi o concentraţie de 24% fibre de sticlă. A fost determinată relaţia matematică de dependenţă pentru forţa de găurire ca funcţie de parametrii procesului de aşchiere.

Composite materials raise specific problems when machining them, because they are anisotropic and not homogenous, and their reinforcing fibers are very abrasive. Significant damages to the work pieces may be introduced and high wear rates of the tools are experienced while machining. This article presents the obtained experimental results and their evaluation when drilling a composite material with polymeric matrix and 24% concentration of glass fibers. The dependence mathematical relation for drilling force is determined, as function of cutting process parameters.

Key words: composite materials, drilling, cutting force.

1. Introduction

The need for high performance materials has lead to the development of composite materials. Being materials that are believed, to replace metals, and considering their characteristics and future-prospect, great attention should be given to the composite materials [10].

The 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, 13].

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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 [6, 9]. In most cases, the composite material consists of a matrix, in which a complementary material is dispersed [2, 7]. The properties that we try to achieve with this material are: failure resistance, wear resistance, density, high temperature resistance, dimensional stability, capacity to damp down vibrations [4, 8, 12].

The composite materials which contain glass fibers, because of their specific physical-mechanical properties, raise special problems when splintering machining is used [5, 14]. 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, 16].

In this paper, are presented result obtained in determining the splintering force when drilling composite materials with polymeric matrix and 24% concentration of glass fibers.

2. Means and conditions used for experiments

During the experiments we used the following equipments:

- 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 with the Rockwell Hardness Number = 62 and diameters: ∅6, ∅8, ∅10 ∅12 mm;
- the processed material: composite material polyester with resin AROPOL S 599 matrix and glass fiber EC12-2400-P1800(65), produced by SC FIROS SA;
- the experimental set-up (Figure 1) for recording the values of the force variations at different splintering parameters, consisting of the following: a transducer for measuring forces, made by the T.C.M. Department, of the I.M.S.T. Faculty [4]; a MGC amplifier, produced by Hottinger Baldwin Messtechnic; a data acquisition board type DAQ Pad 6020E; PC; LabWIEW software.

The gauging of the pickup of forces was made with a lab dynamometer which bears a maximum loading of 10 kN compression value of 0,01 mm. An average constant value of gauging for the forces was obtained: K_F = 6.9 N/div.

The product code, 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 the following:

- Mass density: 2.54 g/cm^3;
- Young’s modulus: 72400 N/mm^2;

Fig.1. The experimental set-up

- Ultimate tensile strength: 3450 N/mm^2;
- thermal expansion coefficient: $5{\cdot}10^{-6}\,{}^{o}C^{-1}$;
- heat conductivity: 1.3 W/(m ^{o}C);
- specific heat: 840 J/(kgK).

3. Experimental results and data processing

The technical literature [5, 11, 15] provided the equation (1), which has been the starting point in the analysis of cutting forces:

$$F = C_F \cdot D^{x_F} \cdot f^{y_F} \quad [N] \tag{1}$$

where: D is the diameter; f is the feed; C_F is a constant; x_F, y_F are polytropic exponents.

This equation has proved to be inappropriate since after the practical estimation of the polytropic exponents and constants, several tests determinations have been performed and have showed a wide result scattering under the same cutting conditions. The problem is that during the composite material machining at various speeds, different parameter values were recorded even if all the other machining conditions were kept constant. It has led to introduce a speed factor was introduced:

$$F = C_F \cdot D^{x_F} \cdot f^{y_F} \cdot v_c^{z_F} \quad [N] \tag{2}$$

In order to estimate the C_F constant and the x_F, y_F, z_F polytropic exponents, the equation (2) was linearized using the logarithm.
The following equation (3) was obtained:

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

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 [mm]	Feed f [mm/rot]	Rotation n [rot/min]	Speed v_c [m/min]	Tensometer bridge values [V]	Real cutting forces F [N]
1	6	0.25	355	6.69	6.87	47.40
2	10	0.25	355	11.15	14.03	96.81
3	10	0.125	355	11.15	10.42	71.90
4	10	0.25	710	22.30	12.45	85.90
5	12	0.125	710	26.76	11.98	82.66
6	8	0.25	355	8.92	10.15	70.04

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

$$\begin{cases} \lg C_F + x_F \lg 6 + y_F \lg 0.25 + z_F \lg 6.69 = \lg 47.40 \\ \lg C_F + x_F \lg 10 + y_F \lg 0.25 + z_F \lg 11.15 = \lg 96.81 \\ \lg C_F + x_F \lg 10 + y_F \lg 0.125 + z_F \lg 11.15 = \lg 71.90 \\ \lg C_F + x_F \lg 10 + y_F \lg 0.25 + z_F \lg 22.30 = \lg 85.90 \end{cases} \qquad (4)$$

The system (4) has the following solution:

$C_F = 7.178$, $x_F = 1.569$, $y_F = 0.429$, $z_F = -0.173$

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

$$F = 7.178 \cdot D^{1.569} \cdot f^{0.429} \cdot v_c^{-0.173} \quad [\mathrm{N}] \qquad (5)$$

By tracing the diagrams of the cutting axial force variation with respect to the work parameters, the resulted diagrams are shown in Figures 2÷ 6, valid only for the studied composite material.

Figure 2 shows the cutting force variation depending on the feed for different diameters and for a constant tool speed. Figure 3 shows the cutting force

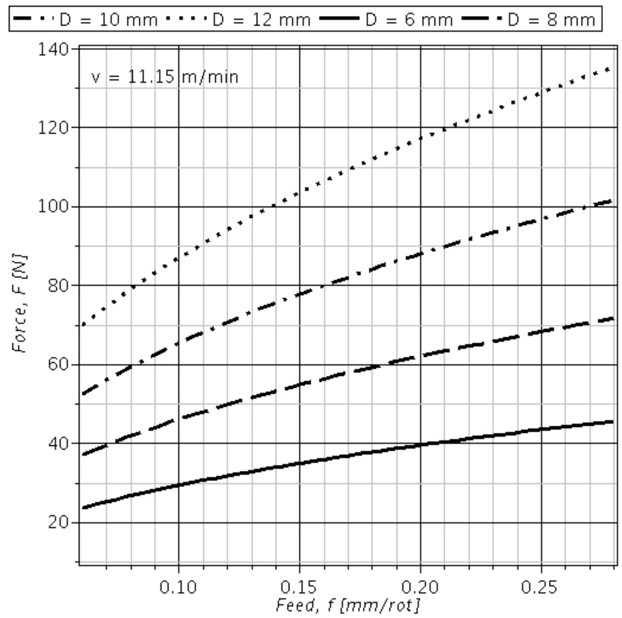

Fig. 2. The force variation depending on the feed for different diameters

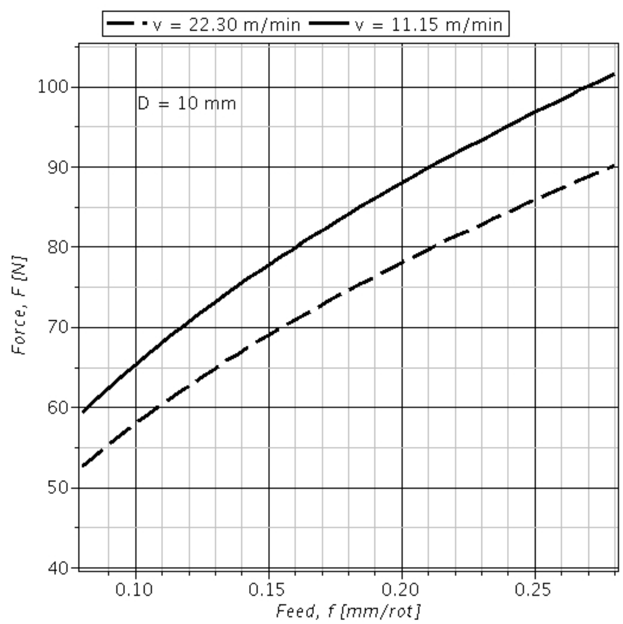

Fig. 3. The force variation depending on the feed for different tool speeds

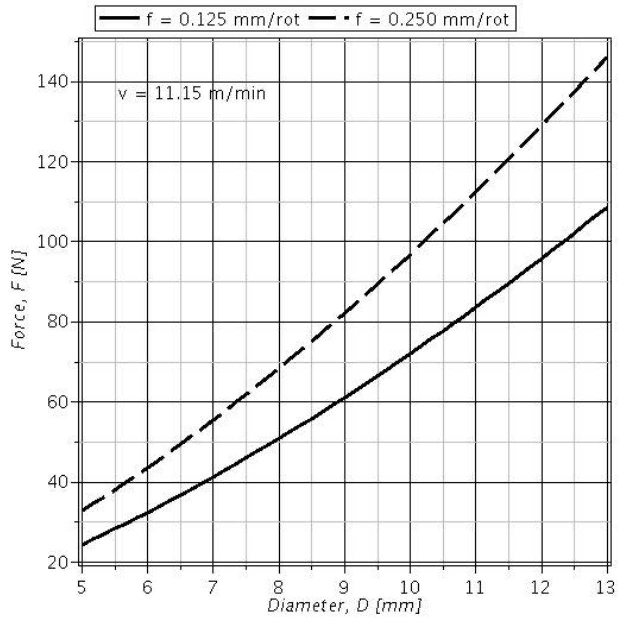

Fig. 4. The force variation depending on the diameter for different feeds

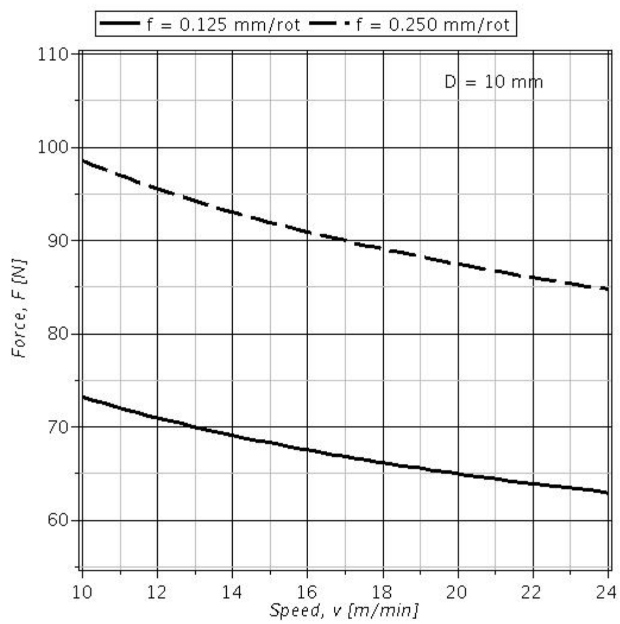

Fig. 5. The force variation depending on the tool speed for different feeds

variation depending on the feed for different tool speeds and for a constant diameter. Figure 4 shows the cutting force variation depending on the diameter for different feeds and for a constant tool speed. Figure 5 shows the cutting force variation depending on the tool speed for different feeds and for a constant diameter. Figure 6 shows the cutting force variation depending on the tool speed for different diameters and for a constant feed.

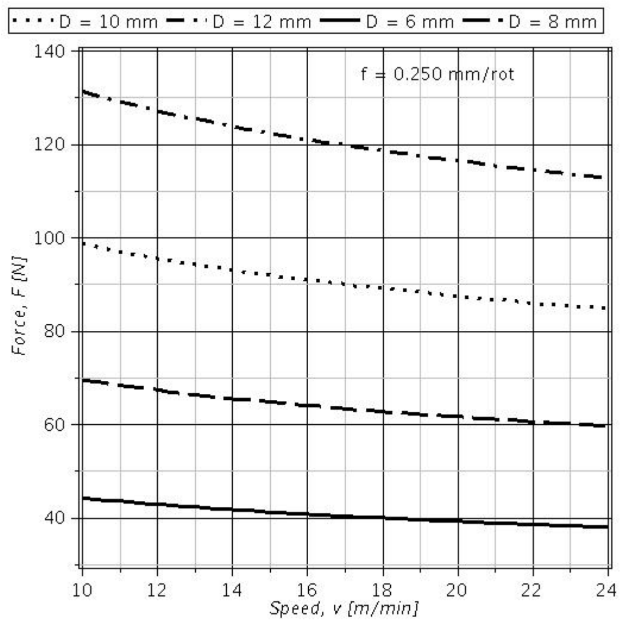

Fig.6. The force variation depending on the tool speed for different diameters

4. Conclusions

The experimental results prove the variation of the axial drilling force 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 equations (2) and (5).

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

- the cutting force increases with the feed, for different tool diameters, if the tool speed is constant;
- the cutting force increases with the feed, for different tool speeds, if the

tool diameter is constant;

- the cutting force increases exponentialy with the tool diameter, for different feeds, if the tool speed is constant;
- the cutting force increases exponentialy with the tool diameter, for different tool speeds, if the feed is constant;
- the cutting force decreases with the tool speed, for different feeds, if the tool diameter is constant;
- the cutting force decreases with the tool speed, for different tool diameters, if the feed is constant.

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 readily implemented in the manufacturing activity of these materials. Our further studies aim these problems for another composite materials classes.

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