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. Significant damage to the work piece may be introduced and high wear rates of the tools are experienced.

Traditional machining methods such as drilling, turning, sawing, routing and grinding can be applied to composite materials using appropriate tool design and operating conditions [1].

Drilling is the most common composite machining operation, since many holes must be drilled in order to install mechanical fasteners.

Machining of the composite materials differs significantly from the machining of conventional materials and their alloys. When machining reinforced composite materials, their behaviour is not only inhomogeneous, but also depends on the properties of the reinforcing elements and those of the matrix, on the fiber orientation and the matrix—reinforcing element ratio [2-4].

Method, means and Drilling Conditions used to determine the Cutting Forces

For this study a stand of experimentations was used (fig. 1, 2).

The machine tools used;
- boring machine GU25;
- power of work: 2.3 kW;
- range of rotations: 28…2 240 rot/min;
- range of advances: 0.08…0.25 mm/rot.

* email: constantinocnarescu@yahoo.com

The characteristics of the splintering tools:
- helical drills: \( \Phi 7, \Phi 8, \Phi 10, \Phi 12, \Phi 14 \) with \( 2\alpha = 130^\circ \) of Rp5 cu HRC 62

The characteristics of the studied polymeric composite material:
- probe structure:
- polyester resin HELIOPOL 4231 ATX
- glass fiber
- polyester resin HELIOPOL 4231 ATX:
  - viscosity (23°C) DIN 53211 (65-80)s
  - gel Time HELIOS KM 3205 (5-11) min
  - acid Number DIN EN ISO 3682 30 mg KOH/g
  - styrene Content DIN EN ISO 3251 (40-45) %
  - density ISO 2811 (1 100-1 150) kg/m\(^3\)
  - flash Point ISO 367 34°C
- Glass fiber CSM-450-1900 (STRATIMAT)
  - is made out of E type glass fiber;
  - time to dissolve the binder in styrene, max.60 s
  - specific weight ISO 4605 4500 daN/m\(^3\)
  - width ISO 5026 (100; 125) ±2 cm
  - humidity ISO 3344 0.2%

In order to measure the axial forces of splintering, it has been used a pickup for measuring the processing forces. The pickup was made in the T.C.M. Department, I.M.S.T. Faculty [5].
For the display of the registration made by the pickup of forces and the pickup of moments, a N2300 electric dynamic tensometer was used.

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

$$K_F = 6.9 \text{ N/div.}$$

**Experimental part**

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

$$F = C_F \times D^{x_F} \times s^{y_F} \times \nu^{z_F} \ \text{[daN]}$$  \hspace{1cm} (1)

This equation has proved to be inappropriate since after the practical estimation of the polytrophic exponents and constants, several tests determinations have 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 were kept constant. It was introduced a speed factor:

$$F = C_F \times D^{x_F} \times s^{y_F} \times \nu^{z_F} \ \text{[daN]}$$  \hspace{1cm} (2)

The $C_F$ constant and the $x_F, y_F, z_F, \nu_F$ polytrophic exponents were estimated. The equation (2) has been linearized using the logarithm:

$$\lg F = \lg C_F + x_F \cdot \lg D + y_F \cdot \lg s + z_F \cdot \lg \nu$$  \hspace{1cm} (3)

Table 1 shows a selection of the most conclusive machinings.

<table>
<thead>
<tr>
<th>Nr.</th>
<th>Hole diameters D, [mm]</th>
<th>Feeding rate s, [mm/rot]</th>
<th>Rotation n, [rot/min]</th>
<th>Drilling speed v, [m/min]</th>
<th>Forces, div.</th>
<th>Forces, [N]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>12</td>
<td>0.25</td>
<td>355</td>
<td>13.38</td>
<td>28</td>
<td>193.2</td>
</tr>
<tr>
<td>2</td>
<td>7</td>
<td>0.25</td>
<td>355</td>
<td>7.8</td>
<td>19</td>
<td>151.8</td>
</tr>
<tr>
<td>3</td>
<td>12</td>
<td>0.125</td>
<td>355</td>
<td>13.38</td>
<td>20</td>
<td>138</td>
</tr>
<tr>
<td>4</td>
<td>12</td>
<td>0.25</td>
<td>710</td>
<td>26.76</td>
<td>25</td>
<td>172.5</td>
</tr>
<tr>
<td>5</td>
<td>10</td>
<td>0.125</td>
<td>710</td>
<td>22.29</td>
<td>16</td>
<td>113.69</td>
</tr>
<tr>
<td>6</td>
<td>8</td>
<td>0.25</td>
<td>355</td>
<td>8.92</td>
<td>23</td>
<td>161.23</td>
</tr>
</tbody>
</table>

**Results and discussions**

Figure 3 displays the variation of the of the axial force against feed rate s, where $v = 13.38 \text{ m/min}$, for different drill diameters, D.

The increment of the forces is exponential with the increment r of the drill diameter and of feed rate, s.

Figure 4 shows the variation of the axial force against feed rate s, where $D = 12 \text{ mm}$ for different drilling speeds of the tool.

The increment of the forces is exponential with the increment of the feed rate.
Figure 5 indicates the variation of the axial force against drill diameter, $D$, where $v = 13.38 \text{ m/min}$, for different feed rates, $s$.

It can be noticed that the axial forces increase exponential with the increment of the drill diameter.

Figure 6 indicates the variation of the axial force against drill diameter, $D$, where $s = 0.25 \text{ mm/rot}$ for different drilling feed speed.

Figures 6 indicates that the axial forces rise exponential with the rise of the drill diameter.

Figure 7 displays the dependence of the axial force on the drilling speed $v$, where $s = 0.25 \text{ mm/rot}$, for different hole diameters.

The axial forces decrease exponential with the increment of the drill speed.

Figure 8 indicates the dependence of the axial force on drilling speed $v$, where $D = 12 \text{ mm}$, for different feed rates, $s$.

It can be noticed that the axial forces decrease exponential with the increment of the drill speed.

Conclusions

From both theoretical and experimental research, the following facts can be deduced:

From both theoretical and experimental researches, the following facts can be deduced:

1. A pickup of forces was used to determine the axial force when drilling into composite materials with polymeric matrix and type STRATIMAT glass fiber;

2. The range of the forces from 0 to 200 N allowed the use of drills with diameters in the range of 7 to 14 mm;

3. For the experiments done to determine the equation of the axial force, from the analysis of the charts there was deduced an exponential increment of the forces of splintering with the increment of the feed rate and the diameter of the drill, and a decrease of the force with the increment of the splintering speed.

4. Concerning the shape of the splinters removed from the material, these were fragmentation splinters.

5. During the experiments, no cooling liquids were used because of their abrasive actions on cutting tool.

References

5. TURDEANU, E., ILIESCU, M., GĂVAN, M., (2005), Captor pentru măsurarea forțelor de prelucrare, B.O.P.I. No. 4;
7. PREDINCEA, N., P. a. (2002), Procede de prelucrare prin așchiere", Editura BREN, București

Manuscript received: 5.04.2007