New Equations for Determining Tool Wear when Machining Polymeric Materials

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In the generation of new materials replaceing the metals, taking into account their characteristics and future perspectives, one should pay a special attention to the composite materials, which were named consolidated plastic materials, just a short time ago. This paper emphasizes that the quality of the drilling tools and the geometry of their active part, the dimensional precision and of geometric form and also the quality of the surfaces processed by drilling, depend especially on the nature of the composite material and of the reinforcing fibers.

Keywords: composite material, drilling, machining, wear

It is well-known that the processing by drilling of the composite materials has sometimes difficult problems at production, because of the specific physical and mechanical properties.

During the processing of the reinforced composite materials, their behaviour depends on the various properties of the reinforcement elements and of the matrix, of the fiber orientation and the volume report matrix-reinforcement elements.

At present, the polymeric composite materials present a real scientific and technical interest and this fact justifies the research development in this field and also the production of such materials.

On account of this fact, the polymeric composite materials have become essential for the development of important domains such as: microelectronics, medical technology and spatial constructions [1, 2].

Following this tendency and from an economical point of view, it can be noticed the necessity of improving the methods of economical acquisition of these materials, respectively of research and of mathematical and practical determination of a coefficient or a global indicator (as it is named in the literature), which defines and includes in the best way all the factors of influence that appear during the processing. The present paper wishes to define this indicator thoroughly and to open new paths in the research concerning the polymeric composite materials.

Experimental part

The equipment used in the research of the determination methods of the processing indicators were[3]:

The machine tools used

Boring machine GU25:
- power of work: 2.3 KW;
- gamma of rotations: 28; 90; 355; 1120 rot/min;
  56; 180; 710; 2240 rot/min
- gamma of advances: 0.08; 0.125; 0.25 mm/rot;

The characteristics of the drilling tools

Consulting the catalogues of the firms that produce tools for the drill of the polymeric composite materials reinforced with glass fibers, the following drills have been chosen for the ulterior determinations:

- helical drills: Φ6, Φ8, Φ10, Φ12, Φ14 with $2k = 130^0$, made by Dormer, (Germany).

The characteristics of the polymeric composite material

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

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;

matrix: polyester resin AROPOL S 599.

After 200 drills, with a certain drill and at certain parameters (advance, rotation), the wear of the drill was measured the drill sharpened and then the geometry of the drill controlled.

This cicle with: processing at drill, measuring of the wear of the drill, the sharpening of the drill and then the control of the geometry of the tool repeated by varying in turns:

-the advance s, mm/rot;
-the rotation, n, rot/min;
-the speed of drilling, v, m/min;
-the diameter of the tool, D, mm;
-the drilled length, l, mm

-and they registered the data for the wear of the drills made of rapid steel (with or without Ti), at the drill of the polymeric composite material, executed from polyester resin AROPOL S 599, reinforced with glass fibers EC12-2400-P1800(65), w the rotation, n, rot/min;

-the speed of drilling, v, m/min;
-the diameter of the drill D, mm;
-the drilled length, l, mm

The data for the wear of the drills made of rapid steel (with or without Ti), at the drill of the polymeric composite material, executed from polyester resin AROPOL S 599, reinforced with glass fibers EC12-2400-P1800(65), with a concentration of 40% glass fibers were registered.

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It is mentioned that the value of the perforated length, respectively 2000mm (200 drills x 10 mm) was kept constant.

It can be noticed again the apparition of speed as an essential element in the mathematical determination of the processing indicators, having also an important influence in the determination of the values of wear of the drilling tool at drilling.

Technical literature [4, 5] provided equation (1), which has been the starting point in the analysis of wear at the drill:

$$VB = C_{VB} \cdot D^{x_{VB}} \cdot s^{y_{VB}} \cdot v^{z_{VB}} \cdot \tau^{w_{VB}} \text{ [mm]} \quad (1)$$

where:

D is the diameter of the tool, mm;

s- the advance s, mm/rot;

v- the speed of drilling, m/min;

n – the rotation, n, rot/min;

τ - the time, min.

C_{VB}, x_{VB}, y_{VB}, z_{VB}, w_{VB}, are constants depending on the drilling device quality, the semi-finished product, and the drilling conditions.

By logarithming ec (1) we obtain:

$$\lg VB = \lg C_{VB} + x_{VB} \cdot \lg D + y_{VB} \cdot \lg s + z_{VB} \cdot \lg v + w_{VB} \cdot \lg \tau \quad (2)$$

Table 1 shows a selection of the most conclusive machining.

The results in table 1 are inserted in relation (2) and it was obtained the following unequal linear system of 5 equations with 5 unknown quantities (x_{VB}, y_{VB}, z_{VB}, w_{VB}, C_{VB}), which is used to determine the relation of regression of wear at the drill of a composite material reinforced with 40% glass fiber, using a drill made of tool rapid steel (HSS), without titanium:

$$\begin{cases} \lg C_{VB} + x_{VB} \cdot \lg 12 + y_{VB} \cdot \lg 0{,}125 + z_{VB} \cdot \lg 42{,}223 + w_{VB} \cdot \lg 14{,}28 = \lg 0{,}348 \\ \lg C_{VB} + x_{VB} \cdot \lg 8 + y_{VB} \cdot \lg 0{,}125 + z_{VB} \cdot \lg 28{,}149 + w_{VB} \cdot \lg 14{,}28 = \lg 0{,}296 \\ \lg C_{VB} + x_{VB} \cdot \lg 12 + y_{VB} \cdot \lg 0{,}125 + z_{VB} \cdot \lg 42{,}223 + w_{VB} \cdot \lg 28{,}56 = \lg 0{,}819 \\ \lg C_{VB} + x_{VB} \cdot \lg 12 + y_{VB} \cdot \lg 0{,}08 + z_{VB} \cdot \lg 42{,}223 + w_{VB} \cdot \lg 22{,}32 = \lg 0{,}313 \\ \lg C_{VB} + x_{VB} \cdot \lg 12 + y_{VB} \cdot \lg 0{,}125 + z_{VB} \cdot \lg 13{,}383 + w_{VB} \cdot \lg 45{,}07 = \lg 0{,}468 \end{cases} \quad (3)$$

The system has the following solutions:

$C_{VB} = 0.030$; $x_{VB} = -0.578$; $y_{VB} = 1.473$; $z_{VB} = 0.978$; $w_{VB} = 1.235$.

The relation of regression of wear at the drill of a polymeric composite material reinforced with 40% glass fibre, using a drill made of tool rapid steel from (HSS), without titanium, is:

$$\mathbf{VB} = 0{,}030 \cdot \mathbf{D}^{-0{,}578} \cdot \mathbf{s}^{1{,}473} \cdot \mathbf{v}^{0{,}978} \cdot \boldsymbol{\tau}^{1{,}235} \quad (4)$$

The determinations 6 and 7 were made for checking the relation of regression (4). This way, the errors in calculation were under 2%.

To determine the relations of regression for the wear at drill using a helical classical drill made of tool rapid steel (HSS), with titanium, in processing a polymeric composite material reinforced with 40% glass fiber, the following relation is used:

Table 1

EXPERIMENTAL RESULTS MADE AT THE STUDY OF WEAR OF THE DRILLING TOOLS AT THE DRILL OF THE POLYMERIC COMPOSITE MATERIALS REINFORCED WITH 40% FIBER GLASS

Nr. det.	Diameter D, mm	Feed rate, s, mm/rot	Rotation n, rot/min	Drilling speeds v, m/min	Drilled length l, mm	Time τ, min	Wear VB, mm with titan	Wear VB, mm without titan
1	12	0,125	1120	42,223	200drills x10mm= 2000mm	14,28	0,145	0,348
2	8	0,125	1120	28,149	200 drillsx10mm= 2000 mm	14,28	0,126	0,296
3	12	0,125	1120	42,223	400 drillsx10mm= 4000mm	28,56	0,356	0,819
4	12	0,08	1120	42,223	200drills x10mm= 2000mm	22,32	0,132	0,313
5	12	0,125	355	13,383	200drills x10mm= 2000mm	45,07	0,206	0,468
6	10	0,250	355	11,152	200drills x10mm= 2000mm	22,54	0,222	0,515
7	6	0,08	1120	21,111	200drills x10mm= 2000mm	22,32	0,102	0,232

$$\begin{cases} \lg C_{VB} + x_{VB} \cdot \lg 12 + y_{VB} \cdot \lg 0{,}125 + z_{VB} \cdot \lg 42{,}223 + w_{VB} \cdot \lg 14{,}28 = \lg 0{,}145 \\ \lg C_{VB} + x_{VB} \cdot \lg 8 + y_{VB} \cdot \lg 0{,}125 + z_{VB} \cdot \lg 28{,}149 + w_{VB} \cdot \lg 14{,}28 = \lg 0{,}126 \\ \lg C_{VB} + x_{VB} \cdot \lg 12 + y_{VB} \cdot \lg 0{,}125 + z_{VB} \cdot \lg 42{,}223 + w_{VB} \cdot \lg 28{,}56 = \lg 0{,}356 \\ \lg C_{VB} + x_{VB} \cdot \lg 12 + y_{VB} \cdot \lg 0{,}08 + z_{VB} \cdot \lg 42{,}223 + w_{VB} \cdot \lg 22{,}32 = \lg 0{,}132 \\ \lg C_{VB} + x_{VB} \cdot \lg 12 + y_{VB} \cdot \lg 0{,}125 + z_{VB} \cdot \lg 13{,}383 + w_{VB} \cdot \lg 45{,}07 = \lg 0{,}206 \end{cases} \quad (5)$$

The solution of the system (5) leads to determine the polytropic exponents x_{VB}, y_{VB}, z_{VB}, w_{VB} and the constant C_{VB}, such as:

$C_{VB} = 0.013$; $x_{VB} = -0.652$; $y_{VB} = 1.507$; $z_{VB} = 0.998$; $w_{VB} = 1.296$

So, the relation of regression of wear at the drill of a polymeric composite material reinforced with 40% glass fiber, using a drill made of tool rapid steel from (HSS), with titanium, is:

$$\mathbf{VB} = 0{,}013 \cdot \mathbf{D}^{-0{,}652} \cdot \mathbf{s}^{1{,}507} \cdot \mathbf{v}^{0{,}998} \cdot \boldsymbol{\tau}^{1{,}296} \quad (6)$$

There were also checked the relative errors of measurement for the two experimental supplementary determinations, registering values under 2%.

Results and discussions

The figures 1-7 represent the variation of the wear of the drilling tool at the drill of the polymeric composite material with 40% glass fiber, depending on the parameters of the system of drilling at drill.

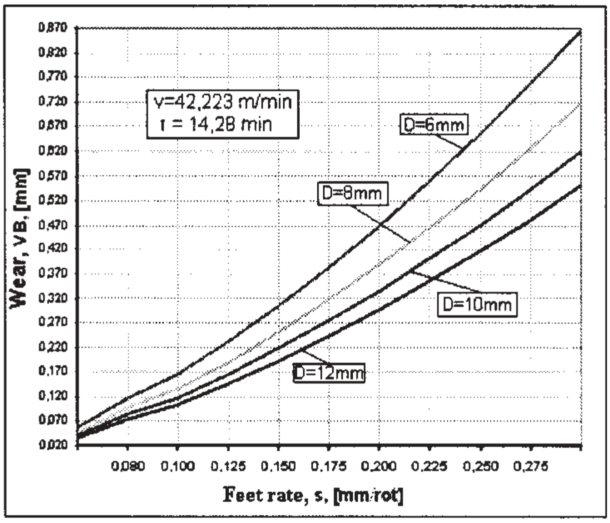

Fig.1. The variation of wear as a function of feed rates for different diameters of drill

Figure 1 represents the dependence of wear to the feed rate, s, in conditions given by v=42.223m/min, τ = 14.28 min, for different values of the diameter of the drill, D.

The wear of the drilling tool exponentially grows at the same time with the growth of the feet rate, obtaining bigger wear when the diameters of the drilling tools are smaller and the speed and time of drilling are constant.

Figure 2 represents the dependence of wear to the feet rate, s, in conditions given by D = 12 mm, τ = 14.28 min, for different values of the drilling speed, v.

The wear of the drilling tool grows exponentially at the same time with the growth of the feet rate, registering bigger wears when the drilling speeds are bigger, if the diameter of the drill and the duration of drill are constant.

Figure 3 represents the dependence of wear to the diameters of the drilling tools, in conditions given by

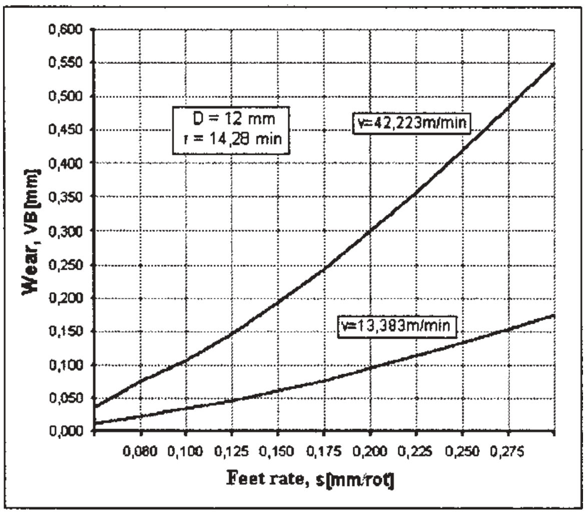

Fig.2. The variation of wear according to the feet rate for different drilling speeds of the tool

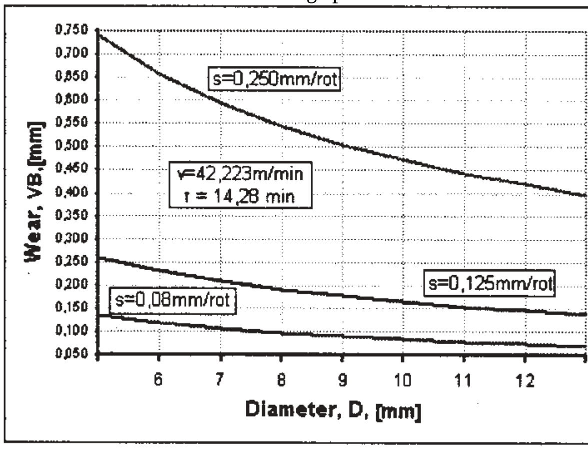

Fig. 3. The variation of wear according to the diameter of the drill for different feet rate

v=42.223m/min, τ =14.28 min, for different values of the feet rate, s.

The wear of the drilling tool exponentially decreases at the same time with the growth of the diameters of the drilling tools, registering bigger wears when the feet rate is bigger, if the speed and time of drilling are constant.

Figure 4 represents the dependence of wear to the diameters of the drilling tools, in conditions given by s=0.125mm/rot, τ = 14.28 min, for different values of the drilling speed, v.

The wear of the drilling tool exponentially decreases at the same time with the growth of the diameters of the drilling tools, registering bigger wears when the drilling speeds are bigger, if the feet rate and duration of drilling are constant.

Figure 5 represents the dependence of wear to the drilling speed, in conditions given by D= 12 mm, τ = 14.28 min, for different values of the feet rate, s.

The wear of the drilling tool exponentially grows at the same time with the growth of the speeds of work, registering bigger wears when the feet rate is bigger, if the diameter of the drill and the perforated length are constant.

Figure 6 represents the dependence of wear on the time of drilling, in conditions given by s=0.125mm/rot,

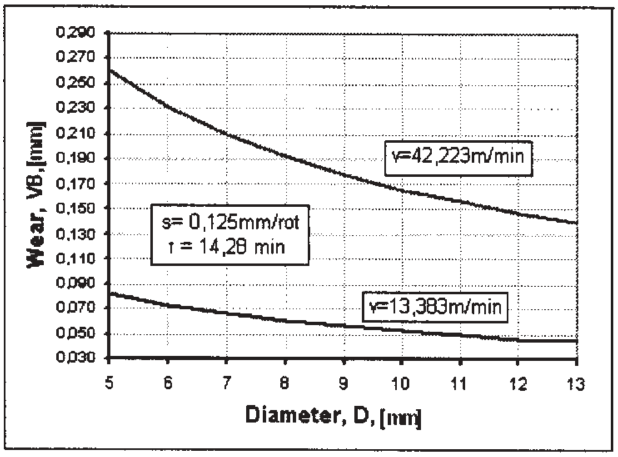

Fig. 4. The variation of wear according to the diameter of the drill for different drilling speeds

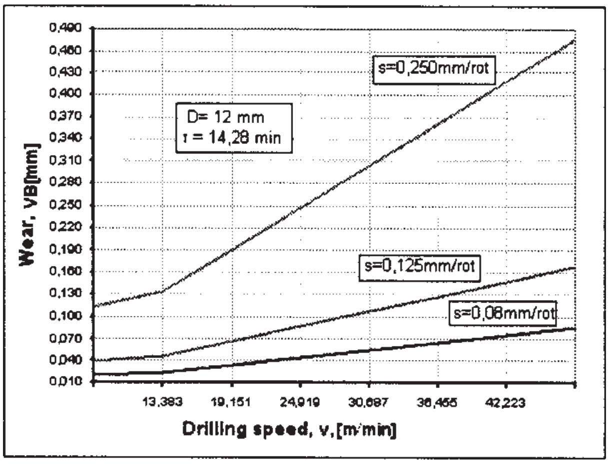

Fig. 5. The variation of wear according to the drilling speed for different feet rate

v=42.223m/min, for different values of the diameters of the tools, D.

The wear of the drilling tool exponentially grows at the same time with the growth of the time of drilling and it is bigger when the diameters of the drills are smaller, if the system of drilling is the same, namely the advance and speed of drilling.

Conclusions

After analyzing the wear of the drilling tools at the drill of a polymeric composite material reinforced with 40% glass fibers, varying in turns every parameter of the system

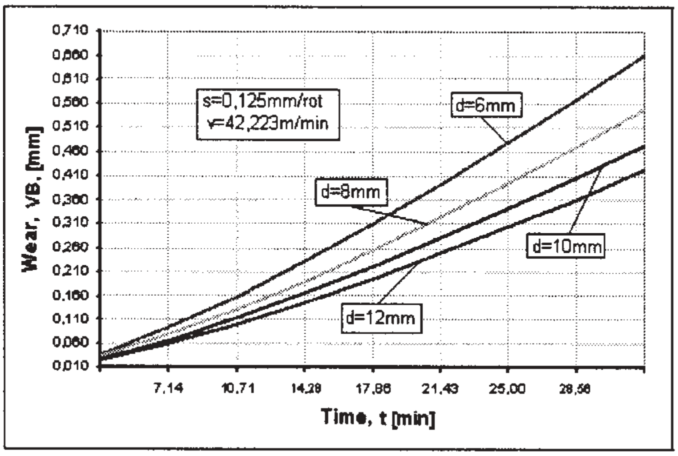

Fig. 6. The variation of wear according to the time of drilling for different diameters of the drills

of drilling, the rest of the parameters remaining constant, the following conclusions could be drawn:

- the wear of the drilling tools at the drill of the polymeric composite materials reinforced with glass fibers, is bigger when the advance, the speed of drilling and the time of drill are bigger and the tools with smaller diameters are worn out more;

- the wear of the tools with or without TiN was also researched and some experimental data were obtained, which help us to come to the conclusion that the processing of the polymeric composite materials reinforced with glass fibers should be done with drilling tools covered with TiN, so that their wear becomes smaller.

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