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STUDY OF DRILLING GFRP COMPOSITES USING A TWIST DRILL: THRUST FORCE AND TORQUE

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Abstract: *The use of Fiber Reinforced Plastics (FRP) has diversified over the last years. Generally developed for aerospace and other high-tech applications, composites have new applications in the automotive industry and, generally, in the engineering market. Thus, good quality and cost-effective manufacturing of FRP composites becomes imperative. This paper presents a study on cutting forces and torque in drilling a technologically new made uni-directional glass fiber reinforced composite with a standard twist drill made of metal carbide, depending on the main cutting regime parameters.*

Key words: *GFRP, twist drill, thrust force, torque*

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1. INTRODUCTION

Manufacturing Fiber Reinforced Polymer (FRP) composite materials can be classified as primary and secondary manufacturing. Though most of the composite products are made to a near-net shape using any of the primary manufacturing processes, such as hand-layup, compression molding, pultrusion, and filament winding, secondary manufacturing in terms of cutting sometimes becomes unavoidable. The heterogeneity and anisotropy of the composites with polymer matrix and long fiber make extremely difficult to obtain the final form by cutting process. Thus, hole making becomes a part of the product development cycle. A number of techniques have been used to make holes in composite laminates, but conventional drilling by far is the most widely accepted method. Drilling of FRP composite materials presents a lot of questions to the engineers and scientists. The efforts have been made in the direction of optimization the operating variables and conditions for minimizing the drilling induced damage (Singh et al, 2008).

Drilling holes is an important machining operation for the assembly operations in intricate composite parts.

For tool cost reasons, the twist drill used for machining metallic materials was chosen to drill long fibers composite structures.

The drilling operation is strongly influenced by the behavior of fibers under the action of the tool. Indeed, excessive tool wear and the damage induced in the workpiece (delamination, loosening of the fibers, matrix burning, etc.) limit the cutting operations of these materials.

The material removal modes and the mechanisms of associated rupture differ according to the relative angle *h* between the cutting direction, (v_c,v_f) and the direction of fibers. The local observation in real time of these mechanisms is not easy and it does not facilitate the construction of ideal theoretical models. There is not much literature available regarding the physical phenomena which describe the interaction between tool material and composites during the drilling operation. In drilling metallic materials, the physics of material removal is associated with the phenomenon of plasticity. The action of the twist drill in the case of the long fiber composites is more complex because it produces different phenomena of material removal and also of the damage which can extend in the composite part. During the drilling of a

Stiffness and transverse contraction (dry condition)		
Modulus of elasticity, $E_{0°}$	23000/28000	
Modulus of elasticity, $E_{90°}$	8500	
Modulus in shear	3000	
Poisson's ratio, $\nu_{0°,90°}$		0.23
Poisson's ratio, $\nu_{90°,0°}$		0.09

Tab.1. Material properties (www.fiberline.com)

Rotation Speed	Feed rate	Nominal power (S1)	Nominal torque
36000 rpm	40 m/min	32 kW	16 Nm

Tab.2 MIKRON HSM 600U maximum parameters

unidirectional laminated plate, the angle *h* varies from one moment to the other and from a point to the other of the cutting edge so the earlier studies in the field of metal cutting cannot be extrapolated to composite materials, especially FRP materials. The mechanical properties of the constituents (fiber, matrix and fiber/matrix interface) and the fiber orientation relative to the cutting direction are playing a role in the overall behavior of the composite (Lasri 2009), (Zitoune et al, 2005).

2. EXPERIMENTAL RESEARCH DATA

The experiments were performed at University Bordeaux 1, Laboratoire Génie Mécanique et Matériaux de Bordeaux, France. The machined material is a glass fiber reinforced plastic (GFRP) obtained by pultrusion, with approximately 60% glass content, provided by Fiberline with very good mechanical properties (see table 1). The workpiece thickness is 10 mm. The tool used is an uncoated metal carbide twist drill made by Guhring with a 100° point angle and 6.35 mm diameter. During the cutting process no coolant was used.

In order to study the thrust force and torque evolution, there have been made tests regarding the influence of the cutting speed and feed. For these tests there were chosen three values for the cutting speed and three values for the feed, as following:

- v_c = 50 m/min, v_c = 100 m/min, v_c = 150 m/min
- f = 0.05 mm/rev, f = 0.10 mm/rev, f = 0.15 mm/rev.

The output experimental data acquisitioned with the used original dynamometer are two radial forces (F_x and F_y), one axial force (F_z), two radial moments (M_x and M_y) and one axial moment (M_z) (Laporte et al. 2004). Drilling experiments were performed on a high speed machining center MIKRON HSM 600U. It is a five axis CNC machining center with ITNC 530 control, with the maximum parameters specified in table 2.

3. EXPERIMENTAL RESULTS

There were performed experimental tests as previously presented and in the following figures 1, 2, 3 and 4 are shown graphically the obtained data.

Figure 1 presents the influence of feed on the thrust force in case cutting speed is 100 m/min. As expected, the increase of feed leads to the increase of thrust force.

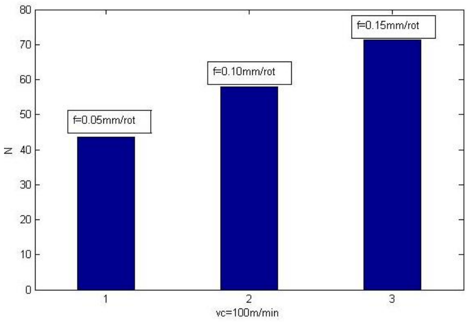

Fig. 1. Influence of feed on the thrust force

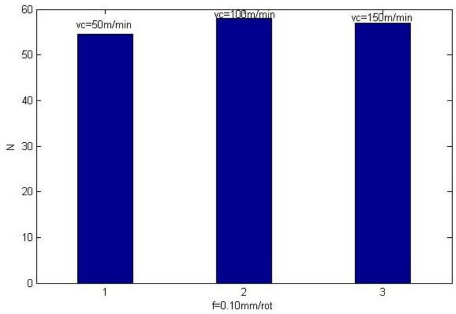

Fig. 2. Influence of cutting speed on the thrust force

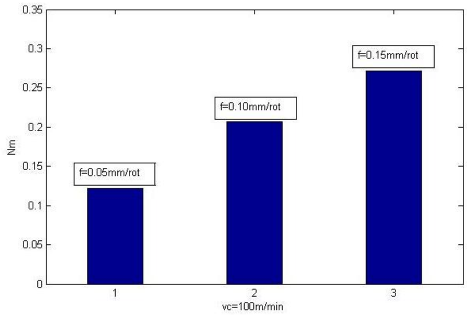

Fig. 3. Influence of feed on the torque

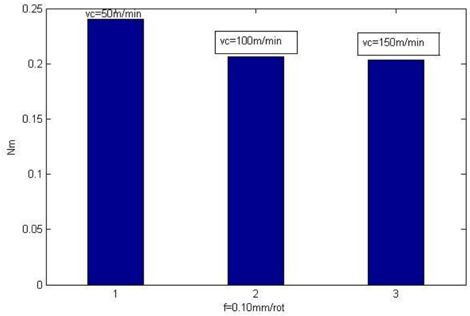

Fig. 4. Influence of cutting speed on the torque

Figure 2 presents the influence of cutting speed on the thrust force in case feed is 0.10 mm/rev. It is interesting to observe that the increase of cutting speed leads to an increase, followed by a decrease of the thrust force. This can be explained by the increase of the cutting temperature influenced by the increase of the cutting speed. This leads to a softening of the plastic material being the matrix of the composite material.

Figures 3 and 4 show a similar behavior of the torque depending on the same cutting speed and feed.

In can be observed the increase of both thrust force and torque depending on the feed is greater than their variation depending on the cutting speed. This means that in Taylor's mathematical model of cutting force and torque the exponent of feed is greater than the exponent of cutting speed.

4. CONCLUSIONS

This paper presents an experimental study on thrust force and torque in drilling glass fiber reinforced material composites. The obtained experimental data show that the cutting regime parameters have an important influence on the values of cutting efforts: thrust force and torque.

This paper is limited to set the initial experimental frame, mathematical models of the cutting efforts and, also, cutting temperature and tool wear will be determined in future.

Keeping the value of the cutting speed constant and increasing the value of the feed speed with 200%, the value of the thrust force increases with 60%.

The same experiment was made, but this time with constant feed, increasing the cutting speed. The value of the thrust force varies slightly, firstly increasing, then decreasing. Under the circumstances it was not measured the cutting temperature the authors presume it to be the reason of this variation. Every plastic material used as matrix in a composite material is softening with the increase of temperature. On the other hand, it was proved the cutting temperature increases with the increase of the cutting speed.

There were performed some experiments regarding the tool wear which the authors did not mentioned in the previous paragraphs, because obtained results were not significant.

For a better understanding of the implied phenomena related to the tool wear another series of tests will be made with another diamond coated tool having different geometry. The tool life will be studied relatively to the cutting efforts and the surface quality.

As drilling is one of the most commonly used machining processes for these types of materials, it is necessary to know and better understand the occurring phenomena. Once these phenomena are understood one can try to issue a mathematical model with results close to reality.

Cutting efforts, tool wear, cutting temperature and other cutting parameters models can be used both in analysis and design. In the design stage, simulation can be used to choose better process parameters.

5. ACKNOWLEDGEMENT

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