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# RESEARCH CONCERNING ANALYSIS OF DYNAMIC PHENOMENA AT DRILLING POLYMERIC BIOCOMPOSITES

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***Abstract:*** *Polymeric biocomposite behavior depends on biomatrix properties, reinforcement element type and structure type. Polymeric biocomposite products are different to drilling than the other polymeric composite, because bioreinforcement element type used has different properties. During drilling defects occur on the surfaced processed and machining tools are different type wear. Therefore, the quality of the drilling surface is highly dependent on material composition and reinforcement element type. The research has the aim to determine the behavior of dynamic phenomena at drilling polymeric biocomposites. This is for complete determination in order to view the developing performances of drilling for the polymeric biocomposites. This paper contains also the principal analysis of dynamic phenomena when drilling polymer biocomposites, using the finite element method.*
***Keywords:*** *Dynamic Phenomena, Drilling, Polymeric Biocomposites, Finite Element Method.*

## 1. INTRODUCTION

Polymeric biocomposite present a real scientific and technical interest, which justifies the development of research in this field, as well as the increase in the production of such materials. The use of natural fibers as reinforcing elements in composite materials presents important advantages, when compared with their synthetic or inorganic counterparts, as: biodegradability, high availability, low cost, low energy consumption, low density, high specific strength and modulus (with fibers possessing an adequate aspect ratio), high sound attenuation and comparatively easy processing ability due to their flexibility and non-abrasive nature. Because of this, polymeric biocomposite have become indispensable for the development of top fields like microelectronics, medical equipment and aerospace constructions [5]. The aim is to optimize the way that these materials are machined. That is to determine, both in theory and in the laboratory, of a global indicator to define and hold all the factors that may influence the machining process. Polymeric biocomposites products are difficult to cutting because of the composite's structure, very soft fibers in a soft matrix. Conventional machining techniques do not work as they do on metals. Using conventional machining techniques the tool wear is greater, producing a significant heat generation, which can be damaging to the polymeric biocomposite. During cutting, defects are introduced into the work piece, and tools have a particular type of wear. [1]

## 2. MECHANICS OF DRILLING POLYMERIC BIOCOMPOSITES

Traditional machining methods such as drilling, turning, sawing, routing and grinding can be applied to polymeric biocomposites using special tool design and operating conditions.
Drilling is the most common composite machining operation, since many holes must be drilled in order to install mechanical fasteners. The thrust and torque applied during drilling operations depend on speed, feed rate, tool geometry and tool wear. Delaminating of the top layer can also be produced by high thermal stresses generated by drilling, but, in that case, no discontinuities are observed in the normal force history.
Delaminating near the exit sides are introduced when the tool acts like a punch separating the thin uncut layer from the remainder of the laminate. This action is associated with an almost instant drop in normal force from its steady value down to zero delaminating can be greatly reduced or eliminated by reducing feed rates near the end

and using backup plates. During drilling torque increases rapidly until the cutting edges of the tool are completely engaged and then increases linearly until a maximum value is reached, followed by a slight drop after hole completion.

As drilling progresses, the tool is in contact with the side over an increasing area so that frictional forces at the interface create increasingly higher resistant torque. After complete penetration has occurred only a small decrease in torque is observed which indicates that friction is the major contribution to total torque. Maximum normal force and maximum torque both increase very significantly with the number of holes drilled.
Drilling is, performed with a rotating cylindrical tool that has two cutting edges on its working end. The tool is called a drill or drill. The rotating drill feeds, parallel to machine axis, into the stationary work part to form a hole whose diameter is determined by the drill diameter. Vertical movement rate is called feed f and is specified in mm/rot. Feed can be converted to feed rate, fr, expressed in mm/min, using equation: [2]

$$f_r = f \times N \tag{1}$$

Rotational speed of the drill N is given in rpm (revolutions per minute). Knowing this speed and the drill diameter D in mm, it is possible to determine the cutting speed vc, which is the surface speed at the outside diameter of the drill in m/min by equation: [2]

$$v_c = \frac{\pi \times D \times N}{1000} \tag{2}$$

One should not forget that in drilling, as the centre of the drill is approached, cutting speed reduces linearly until zero. In drilling, depth of cut is equal to drill radius.There are two measurable components to be considered during drilling: thrust force and torque. Thrust force is the necessary force to maintain a given feed rate into the material. Torque is the amount of tangential force necessary to maintain drill rotational speed. These two forces are affected by cutting parameters like speed, feed, and drill geometry and work part material. From the torque value Mt, in N/m, it is possible to derive the specific cutting energy in N/mm2 by equation: [2]

$$k_c = \frac{4000 \times M_t}{\pi \times f \times D^2} \tag{3}$$

Where f is the feed rate in mm/rot and D the drill diameter in mm.
When feed increases, the chip thickness also increase, the specific cutting energy is lower and tangential force and chip section are greater, causing a torque increase. Chip thickness can also be increased by the use of greater point angles, reducing torque and specific cutting energy.

### 2.1. Damage Induced By Drilling Polymeric Biocomposites

Several types damage are introduced during the drilling operations: matrix cratering and thermal alteration, fiber pullout and fuzzing, interlaminate cracks and delaminating, in addition to geometrical defects commonly found in metal drilling. Drill wear and delaminating are both influenced by the type of drill used. [5] A delaminating factor δ can be defined as the ratio between the maximum diameter of the damage zone and the diameter of the hole: δ reaches an upper limit as the number of holes drilled increases. In figure 1 are presented the defects that occur in drilling polimeric biocomposites. In figure 2 is presented the push-out delaminating at exit and in figure 3 are presented the final result when the fiber is removed. Due to soft fibres , polimeric biocomposites drilling cause high tool wear, leading to the need of frequent tool changes that affect the production cycle. Thermal stress that develops during drilling can also facilitate delamination by matrix softening. Fibre/matrix debonding is observed along the machined hole walls and is characterized by the existence of fibres torn away by the action of drill cutting edges.

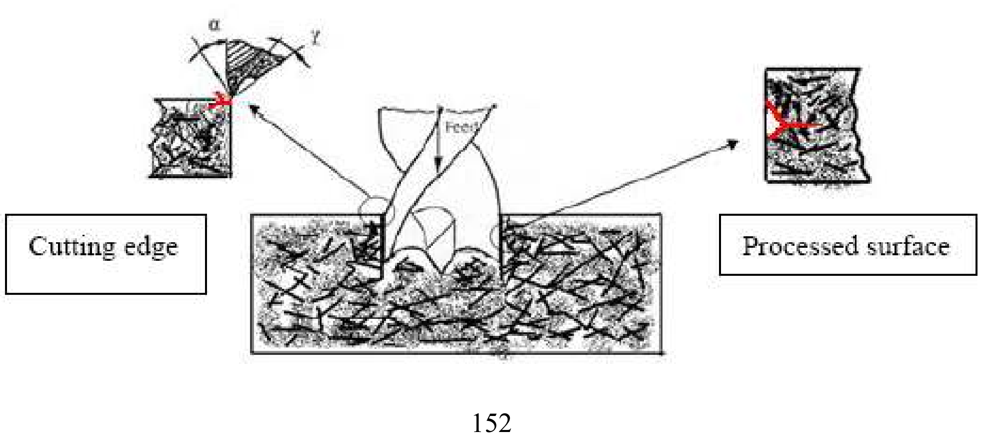

**Figure 1:** Defects that occur in drilling polymeric bicomposites

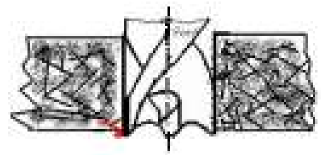

**Figure 2:** Push-out delaminating at exit

Push-out is a consequence of the compressive thrust force that the drill always exerts on the work part.

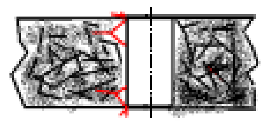

**Figure 3:** The final result when the fiber is removed

Fiber/matrix pull-out is evidenced by fibers pulled out of the matrix, affecting the final value of machined surfaces superficial roughness. This defect is influenced by tool material, anisotropy and the type of loading, that is to say, according to the relative orientation between the fibers and the cutting edge.

### 2.2. Forces At The Tool Face

Because the chip formation in polymeric biocomposites drilling is based on brittle fractures, it not takes place a sliding along the tool face, so that, to be considerate that the overall force on the tool face is perpendicular to the face itself, resulting the followings: [7]

$$F_{hr} = F_{nr} n \cos\gamma \tag{4}$$

$$F_{vr} = -F_{nr} \sin\gamma \tag{5}$$

Where: Fhr and Fvr are the horizontal force respectively vertical force at the tool face; Fnr – overall force at the tool face; γ – rake angle.

From (4) and (5):

$$F_{vr} = -F_{hr} \tan\gamma \tag{6}$$

The vertical force subjects to bending and shear the forming chip, whereas the horizontal force generates compression stresses. Making out the chip as a short beam, clamped at an edge and subjected to compression and shear by action of the forces Fhr and Fvr, respectively, can be calculate the state of stress:

$$\sigma = \frac{F_{hr}}{t} \tag{7}$$

$$\tau = -\frac{F_{hr} \tan\gamma}{t} \tag{8}$$

Where: t represents the depth of cut and it is similarly in length whit the delaminating length l. Using the Thsai-Hill criterion (9), it obtains Fhr (10).

$$\left(\frac{\sigma}{X}\right)^2 + \left(\frac{\tau}{S}\right)^2 = 1 \tag{9}$$

$$F_{hr} = t \times \frac{X \times S}{\sqrt{X^2 \tan^2\gamma + S^2}} \tag{10}$$

Where: X represents the compression strength of unidirectional composite; S – shear strength.
It is seen that, when he rake angle is 00, the chip failure is only due to compression, and when the rake angle increases the chip failure is essentially provoked by shear. It is important to notice that, both the horizontal and vertical force at the tool face is linear dependent on the depth of cut, t.

## 3. MATHEMATICAL MODELATION AT THE FINIT ELEMENT ANALYSIS

Following the usual finite element formulation, the displacement field in any element is assumed to have the form [3]:

$$\{U(X, Y, Z)\}= [N(X, Y, Z)]\{\bar{U}\} \tag{11}$$

Where, [N] is the shape function matrix, and $\{\bar{U}\}$ is the vector of the generalized nodal displacement. The element strain can be expressed as:

$$\{\varepsilon (X,Y,Z)\}= [B(X, Y, Z)] \{\bar{U}\} \tag{12}$$

Where: [B] is the strain function matrix. The appropriate finite element equilibrium equation can be derived by several ways. Using for example, the principle of Virtual Work, it is required that,

$$\int_v \{\varepsilon\}^T \{\sigma\} d - \int_A \{U\}^T \{\bar{X}\} dA = 0 \tag{13}$$

Where: $\{\bar{X}\}$ is the vector of surface tractions. Using equations (11), (12), (13), leads to the following general matrix equilibrium equation:

$$[K]\{\bar{U}\} = \{F\} + \{F^P\} \tag{14}$$

Where,

$$[K] = \int_v [B]^T [D][B] dv \tag{15}$$

$$\{F\} = \int_A [N]^T \{\bar{X}\} dA \tag{16}$$

$$\{F^P\} = \int_v [B]^T [D]\{\varepsilon^P\} dv \tag{17}$$

Here, [K] is the usual elastic stiffness matrix, {F} is the generalised nodal forces vector, and $\{F^P\}$ is the effective plastic load vector. [3]

## 4. ANALYSIS OF DRILIING PROCESS BY FINITE ELEMENT METHOD

The choice of finite element software for drilling analysis is an important factor in determining the quality and scope of analysis that can be performed. The route from initial to ultimate failure of a polymeric biocomposites structure is much more complicate, strategy of analysis of drilling polymeric biocomposites using finite element method is presented in figure 4. [8]

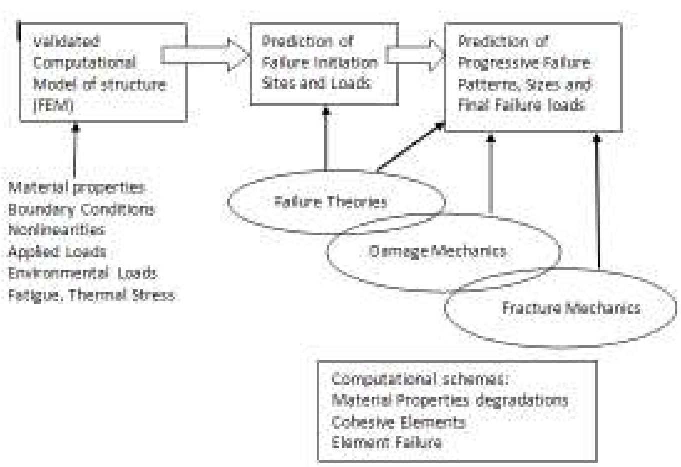

**Figure 4:** Flow chart for finite element method

Fundamental to all finite element analysis is the replacement of a continuum, in which problems variables may be determined exactly, by an assembly of finite elements in which they are only determined at a set number of points, called the nodes of the elements. Values of the variables, or any derived quantity, between the nodes are determined by interpolation. Nodes are the vertices of the elements and an element is divided in a certain number of nodes according to its geometric complexity. As machining is a material removal process, criteria must be included to deal with chip formation, that is to say, the separation of a certain amount of elements from the body to effectively simulate machining conditions. The real issue for a criteria definition is when a connection between elements breaks, by a strain, energy or displacement condition. Finite element method offers an economical and alternative approach to the experimental study of machining processes, that can be expensive and time consuming. In finite element studies, the objective is to derive a computational model predicting the deformations, stresses and strains in the work piece, as well as the loads on the tool working under specific cutting parameters [3]. Finer mesh smoothened variation of cutting force but also lowered its magnitude. That is an expected consequence as stresses depend on the mesh used.
The model for analysis was similar to the one shown in figure 5 – orthogonal cutting.

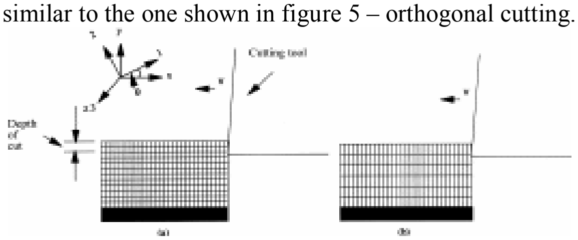


**Figure 5:** Finite element method, mesh and cutting geometry: a) fine mesh; b) coarse mesh [3].

## 5. CONCLUSION

Drilling polymeric biocomposites may indeed produce more damage than desired if not done carefully or correctly. Speed and feeds play a major role in the performance of any cutting tool, especially when working with today's advanced composites.
Drilling is a major process used in most of the parts that are assembled in complex structures for aeronautic, aerospace, automotive, railway, wind turbines and other industries. Parts are joined either by rivets and bolts.

## 6. ACKNOWLEDGEMENT

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