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► **To cite this version:**

Anne Collaine, Jean-Marie Freyburger, Catherine Jordan, Michel Turlonias. Influence of cutting parameters on vibrations in trimming of a Glass Fiber Reinforced Polymer Composite plate. A3M 2021 : International conférence on advanced matériaux mechanics and manufacturing, Mar 2021, En ligne, France. hal-03553685

HAL Id: hal-03553685

<https://hal.science/hal-03553685v1>

Submitted on 2 Feb 2022

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Influence of cutting parameters on vibrations in trimming of a Glass Fiber Reinforced Polymer Composite plate

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Abstract – Many parameters -such as tool geometry, composite constitution, cutting parameters, lubrication- have an influence on milling of composites. These parameters may affect cutting forces, vibrations and tools wear and consequently tools lifetime and quality of the composite. In this paper, we focus on the influence of three cutting parameters (cutting speed, feed per tooth and radial engagement) on vibrations during the trimming of Glass Fiber Reinforced Polymer plates. For five different values of these three parameters, we record the acceleration with an accelerometer and calculate the Root Mean Square value of acceleration. The experiments show that the most influent parameter is the cutting speed, V_c : the RMS value of acceleration increases with the cutting speed. Varying the radial engagement gives similar trends, except that the RMS reaches a threshold for high levels of radial engagement. The feed per tooth variations does not affect significantly RMS value of acceleration, maybe due to the small range of variation of the feed per tooth.

Key words: GFRP / Vibrations / Milling / Cutting parameters.

1 Introduction

Nowadays composite materials are used as effective solutions among others to lighten mechanisms. As a matter of facts, manufacturing of composite parts often need finishing steps. The goal is whether to obtain the final dimensions of the parts or to add forms such as pockets or holes... Among finishing operations, machining, and more particularly milling, is one of the processes that is used to finish composite parts. These finishing steps have to be performed in terms of productivity and quality. On the one hand, time-saving and increase of tool life improve productivity, on the other hand, quality is impacted by delamination defects, uncut fibers at part edge, bad surface roughness... Finishing steps by milling of composite parts are fastidious and complex because of the heterogeneity and the anisotropy of composites. Optimization of many parameters in the finishing process is necessary to reach the required level of productivity and quality. It is well-known that damages derived from milling are linked to the intrinsic properties of both the reinforcement and the matrix. In the same way, geometry and material of the tool, cutting parameters, lubrication during machining have a great influence on the final cut surface. In terms of cutting parameters, previous studies have shown that the feed per tooth is the most influent parameter. However, cutting speed or depth of cut also influence the surface quality [1][2][3][4][5]. Bad cutting parameters enhance cutting forces [4][6][7] and vibrations during machining. Therefore, surface quality is impacted and tool life decreases. These phenomena are well-known in the case of metallic materials, and have been studied for many years [8][9][10][11]. However, very few studies are dedicated to vibrations during composite materials machining and even less during milling of GFRP (Glass Fiber Reinforced Polymer). A detailed study shows that during boring process of GFRP, vibrations increase with depth of cut and cutting speed because of the increase of cutting forces [12]. Our study focuses on trimming of composites GFRP through the analysis of vibrations due to machining and interactions between the composite part and the tool. More particularly, we present in this paper the influence between vibrations and some cutting parameters in order to see if the influence of cutting parameters on vibrations is in relation with quality or cutting forces.

2 Composites plates and experiments

The composites plates are made of a polyepoxide matrix reinforced with UD-glass fibers. In this study, a specific solid carbide mill dedicated to composite materials milling is chosen (cutting diameter 6 mm – 4 teeth). A sample carrier is set up on the milling machine. The composite plate, whose thickness is

constant and equal to 3 mm, is clamped with a constant overhang (called L_{paf}). One accelerometer is implemented on the top side of the plate to measure the vibrations of the composite part (Figure 1).

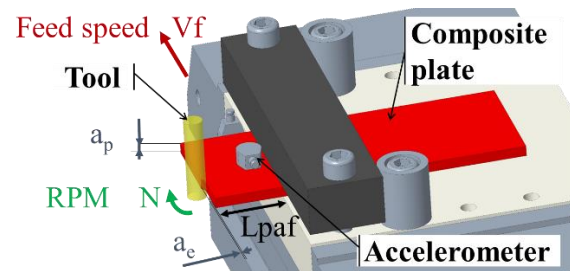


Figure 1. Experimental devices

During the machining test, acceleration values are recorded for the accelerometer described before. With these acceleration values, we can study the shape of temporal signals of vibrations and compute the RMS (Root Mean Square) (1) values in order to compare different experiments.

$$RMS = \sqrt{\frac{\sum_n \text{acceleration}^2}{n}} \quad (1)$$

3 Measurements and results

3.1. Settings of cutting parameters

Basic settings of cutting parameters (feed per tooth, f_z , cutting speed, V_c , and radial engagement, a_e) are chosen in accordance with experimental conditions and with tool manufacturer recommendations (Values in bold in Table 1). The depth of cut (a_p) corresponds to the whole thickness of the composite plate whatever the experiment. The influence of the three chosen cutting parameters is investigated by varying each of them separately. Four different levels for each parameter are spread on the both sides of the basic setting.

Table 1. Values of cutting parameters

V_c (m.min ⁻¹)	120 – 135 – 150 – 165 – 180
a_e (mm)	0,3 – 0,5 – 0,75 – 1 – 1,25
f_z (mm.thooth ⁻¹)	0,043 – 0,0455 – 0,048 – 0,0505 – 0,053

3.2. Results

After checking the reproducibility of the experiments, vibrations according to the thickness direction of the composite plate are studied. Vibrations are due to the contact between each tooth of the mill and the machined surface, during tool motion.

First, by considering cutting speed, V_c , we show that RMS values increase with cutting speed (Figure 2). Because of the increase of cutting speed, i.e. the spindle rotation, each tooth of the mill engages the part with a higher speed i.e. a higher energy level.

That induces a higher level of vibrations of the composite plate. The radial engagement, a_e , also influences sample vibrations.

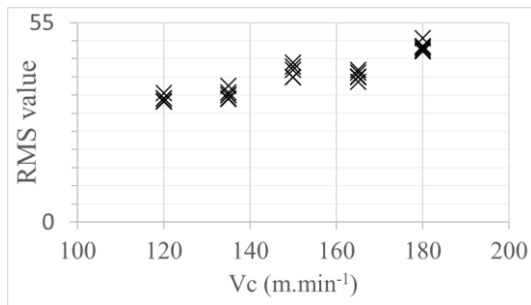


Figure 2. Influence of Vc on RMS value

As for the cutting speed, Vc, an increase of the radial engagement increases the RMS value. However, when radial engagement becomes high, RMS value levels off. The threshold can be explained by a modification of the contact between the tool and the sample (surface in contact). Indeed, during the machining, the number of teeth in contact with the composite part changes: between 0 and 1 for low radial engagement and more than 1 for higher radial engagement. When this value is greater than 1, there is always one tooth in contact with the part. That phenomenon reduces the influence of the contact of the following tooth with the composite part. Finally, the feed per tooth, fz, has also been studied but no obvious influence is observed. The RMS values seem to be similar whatever the value of feed per tooth. Yet, the chosen experimental range is small, our observations could be different if a larger range of values was investigated.

4 Conclusion and prospects

This work shows that radial engagement and cutting speed are the most relevant cutting parameters of vibrations level during trimming of a GFRP plate. The influence of the feed per tooth should be tested in a largest range of values in order to conclude. We also will have to focus on the link between vibratory level and surface roughness of the plate and more widely on the quality of the cut surface, where fibers remain uncut.

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6 Acknowledgments

The authors want to thank the internship students who worked on this subject.