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Experimental analysis of the defects of drilling woven CFRP

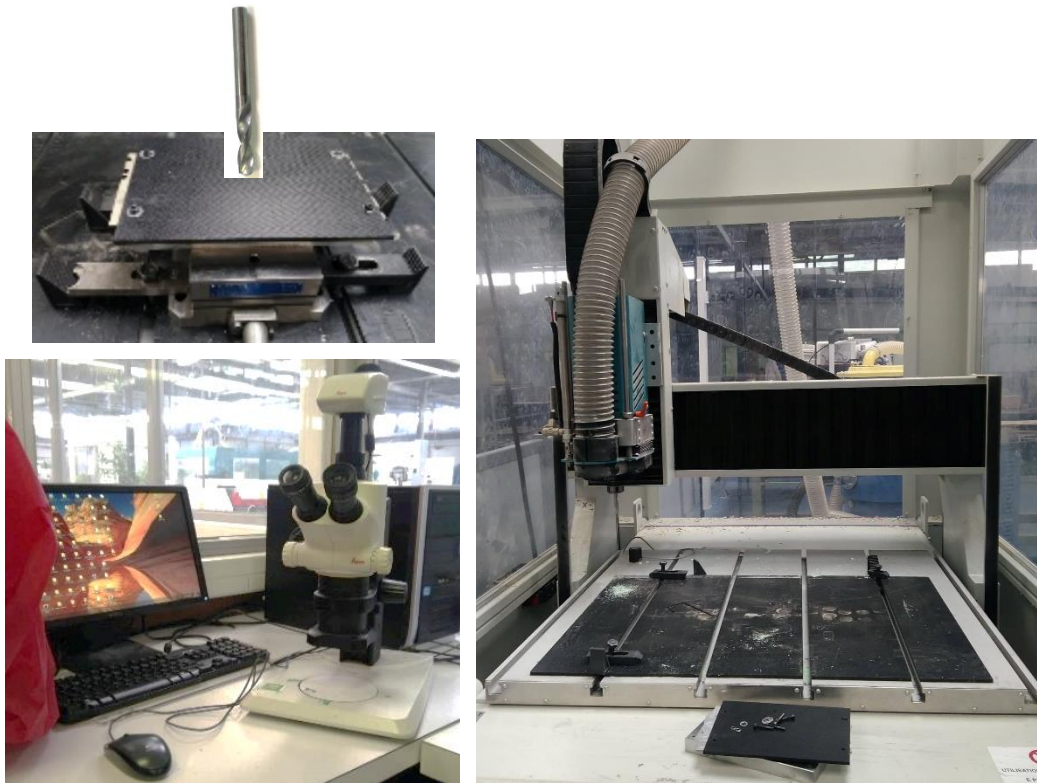
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Abstract: In this paper, experimental analysis has been done to study delamination phenomenon when drilling 4 shaft satin weave carbon fiber and epoxy matrix using twist drill. The composite is exposed to generate damage during processing due to delamination phenomenon. It was found that the increase of the feed rate was related to the apparition of superficial defects. Indeed, this increase gave birth to new types of drilling defects.

Keywords: drilling, delamination, woven CFRP.



Graphical abstract

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1. Introduction

Nowadays, composite materials are more and more used in many fields especially in aeronautic and aerospace industry. It has specific proprieties such as low density, high mechanical characteristics, easy manufacture of composite parts and zero thermal expansion coefficient [1]. Woven carbon fiber reinforced polymer (CFRP) has been used in hot parts of structures such as engines and nacelles in aerospace industry due to its high thermal protection [2]. The study of delamination phenomenon generated by drilling CFRP has a big importance because those types of superficial defects reduce the life of composite components. Indeed, delamination has spread in aeronautical structures during their service life. They are submitted to fatigue phenomenon because of aerodynamic turbulent flow [3]. Several researchers have studied the delamination phenomenon of unidirectional CFRP analytically, numerically and experimentally. Qui et al. [4] have studied the impact of machining parameters and tool structure on delamination phenomenon. They have used a unidirectional CFRP whose plies were in the same direction. Two types of tool geometry were utilized: twist and spur drills. They have noted that the bigger feed rate was applied, the more defects were appeared. The same results were obtained in many other researches works such as Li et al. [5] and Turki et al. [6]. Delamination obtained by the drilling of woven CFRP has been the current theme of research. There are many types of woven CFRP. The most popular one is based on 4 shaft satin weave (AS-4) carbon fiber and epoxy matrix because it is commonly used in aerospace industry. Feito et al. [7] have studied the effect of tool geometry on drilling AS-4 woven CFRP using brad, reamer and stepped drills. They have noted that delamination phenomenon was related to the tool structure. Brad drill caused more drilling defects than the other geometries. From the mentioned study, it appears that the study of delamination of woven CFRP

have been poorly developed. So, it is still a challenge understand this phenomenon. In this paper, we are interested on the study of the defects of drilling AS-4 woven CFRP using twist drill. The delamination at the entrance and the exit of the hole is also evaluated.

2. Experimental work

2.1 Workpiece material and drill

The material studied in this work and shown in the figure 1 is a AS-4 woven CFRP composite based on 4 shaft satin weave carbon fiber and epoxy matrix and composed of 18 plies with the same orientation. It was manufactured by Hexcel composites and it was made in plate of 100 mm x 100 mm x 4.6 mm thick by Zodiac aerospace. Uncoated twist carbide drill was utilized in this study. It has two sides and it was shown in the figure 2. Its nominal diameter is equal to 6.3 mm. It has 150° tip angle, 5° cutting angle, 11° draft angle and 30° helix angle.

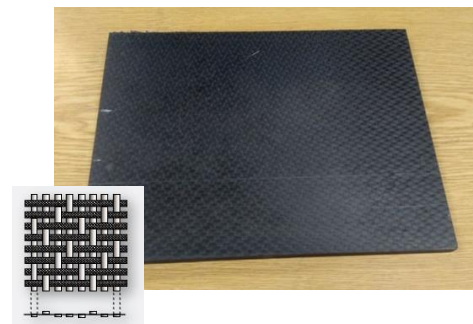


Fig. 1 AS-4 woven CFRP



Fig. 2 Twist carbide drill

2.2 Machining Tests

The drilling operation was performed on a numerical controlled Charlyrobot CPR0705 machine. The used drilling mode in this study was without support and lubrication. So, the use of vacuum cleaner is necessary. Concerning the cutting conditions, the cutting parameters were summarized in table 1.

Macroscopic observations of the drilling holes were made with Leica binocular loupe. The position of the drilling hole related to the textile float may influence the delamination phenomenon. However, Feito et al. [8] have indicated that this influence does not have a remarkable effect.

Table 1 Cutting parameters used in drilling tests

f [mm/rev]	N [rpm]
0.05	2000
0.2	3500
0.35	5000

3. Results and discussion

The hole quality was evaluated in terms of visual observation of delamination phenomenon at the entrance and the exit of the hole. We have noted, using the naked eye, that the increase of the feed rate f increases drilling defects. However, the increase of spindle speed N does not have a remarkable effect. The best quality obtained of the hole corresponds at $f = 0.05$ mm/rev. Figure 3 shows macroscopic observations of the delamination phenomenon in entrance holes at $N = 3500$ rpm using a scale of 2 mm. The effect of N on delamination is presented in the figure 4 at $f = 0.2$ mm/rev using a scale of 2 mm. The use of twist drill causes also damages. We can see uncut fibers, chipping which is a mark made by the drilling operation and spalling which is a delamination accompanied by tearing of a piece of ply. These drilling defects are similar to results obtained in the case of drilling unidirectional CFRP composite [9].

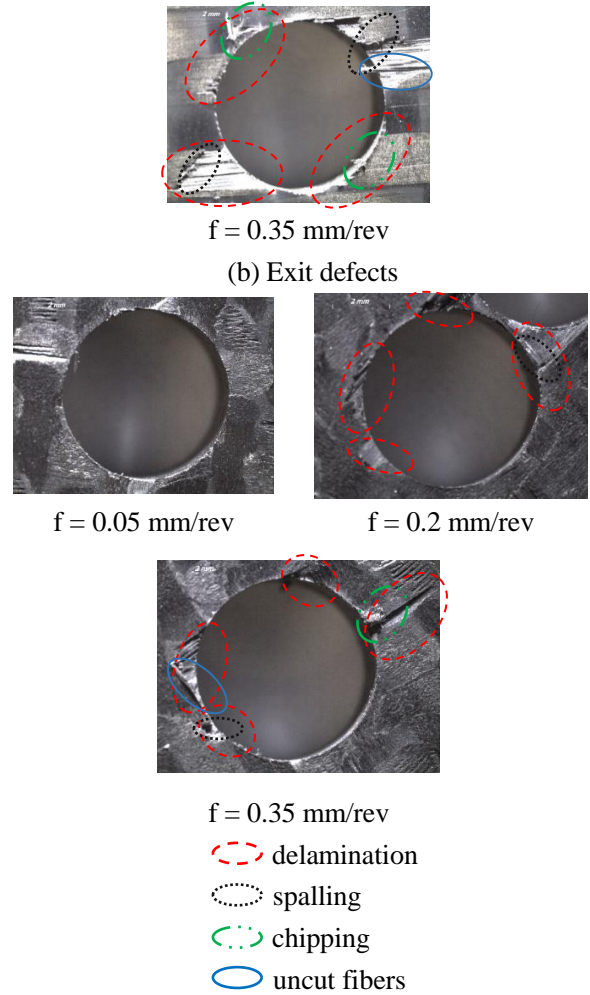
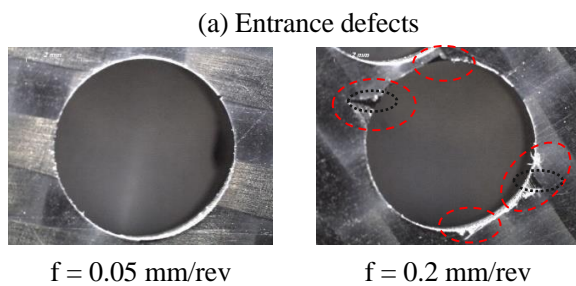
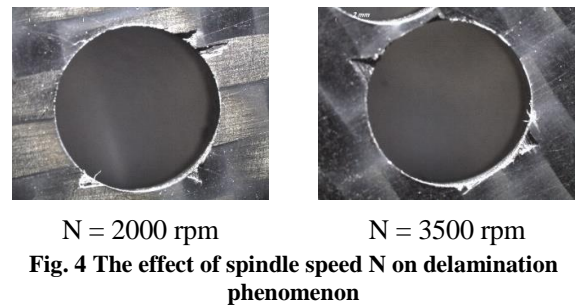


Fig. 3 Macroscopic observations of the delamination phenomenon at $N = 3500$ rpm



6. Conclusions

An experimental analysis of the defects of drilling woven CFRP has been developed in this paper. It has been noted that the feed rate f is the most responsible one of delamination phenomenon. Also, the increase of f has given birth to several types of drilling defects. In further works, it will be important to calculate the

delamination factor and to compare delamination in CFRP and woven CFRP.

Acknowledgments

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