

Measurement of defects in carbon fiber reinforced polymer drilled

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Abstract. Increasingly, fiber-reinforced materials are more widely used because of their good mechanical properties. It is usual to join pieces of these materials through screws and rivets, for which it is necessary to make a hole in the piece, usually by drilling. One of the problems of use CFRP resides in the appearance of defects due to the machining. The main defect to be taken into account is the delamination. Delamination implies poor tolerance when assembling parts, reducing the structural integrity of the part, and areas with high wear, as a series of stresses arise when mounting the screws. Much has been published about delamination and the factors that influence its appearance, so we are not going to focus on it. The present study aims to quantify and measure the defects associated with the drilling of compounds reinforced with carbon fibers, in relation to the cutting parameters used in each case. For this purpose, an optical measurement system and a posterior digital image processing will be used through Deltec Vision software.

1 Introduction

The union of pieces made with the materials of the type carbon fiber reinforced polymer (CFRP) is made mainly by screws and rivets, for which it is necessary to drill a hole in these pieces. It is of vital importance to study how these drills are made and what their quality and final geometries are, because the tolerances of the assembly process and the structural integrity of the assembly will depend on the appearance of possible stresses in the joining areas, the screws or the rivets [1].

2 Experimental Procedure

For the development of the study, a carbon fiber reinforced polymer plate was used, similar to the material used in the aeronautical industry. The plate consists of three layers of fabric, of the taffeta type, with fibers at 45° between the different layers. The last layer has a special treatment to reduce the delamination at the exit (push-out), reason why in this study we will focus on the delamination to the entrance (peel-up). Holes were practiced in that plate, using three drills: two of them were equal, and the other one was different. All three were of the Gühring brand, 6 mm in diameter and were HSS cobalt-coated. The difference between them resided in the geometry: the angles of the points were 118° and 130° respectively [2]. The

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commercial references of these drills are HSCO5524 and HSCO1261. These tools were not specific to drilling carbon fiber, but were used to observe the results obtained, and to be able to study if their use is profitable, because the cost is five times inferior to a specific one for carbon fiber.

The machine used to perform the machining was a numerical control mill, Nicolás Correa brand, model A-16, equipped with a control Heidenhain brand, model TC 355 [3].

To simulate the working conditions, the drills were made at a minimum distance from each other of twice the diameter, as is the case in the aeronautical industry. With this, we avoid the influence of some holes on others. The sequence of drills carried out was as follows: keeping constant the speed of rotation of the spindle, five holes were realized with an intermediate feed speed. Subsequently, five more holes were drilled with a feed speed 50% higher, and finally, five more holes were drilled with a feed speed 50% lower than the first one. The sequence was repeated twice with each drill. That is, with each drill used, thirty drills were made, in series of five and with three different feed speeds. The cutting conditions were taken based on previous experiences, because the tools were not specific to mechanize this type of materials [4].

Table 1. Cutting conditions.

Parameter	HSCO5524	HSCO5524	HSCO1261
Diameter (mm)	6	6	6
Tip angle (°)	118	118	130
Cutting speed (m/min)	61,07	16,30	16,30
Spindle speed (rpm)	3240	865	865
Feed rate (mm/min)	300	80	80
Feed rate (mm/rev)	0,092	0,092	0,092

As for the measurement of the diameters and the affected areas, they were realized by means of an optical microscope, coupled to a computer to process the image through the software Deltec Vision and its utilities to determine longitudinal magnitudes. Each diameter was determined by taking 10 points, and the software itself implemented its algorithm to determine the diameter by least squares, as well as the roundness error. The delamination factor (F_d) was defined as the quotient of the maximum diameter of the zone affected by the drill (D_{max}) between the nominal diameter of the hole drilled (D_o), that is, the diameter of the bit, as indicated by equation 1 [5].

$$F_d = D_{max} / D_o \quad (1)$$

We only focused on the peel-up delamination, that is, the one produced when the tool was inserted in the material, because as we mentioned, the plate was treated to avoid push-out delamination (at the exit) [6].

3 Results

In figures 1, 2 and 3 we represent the values obtained for the delamination factor in the initial and final bores of each of the two series performed for the three feed ratios used, that is, we have four data in each line represented in each graph.

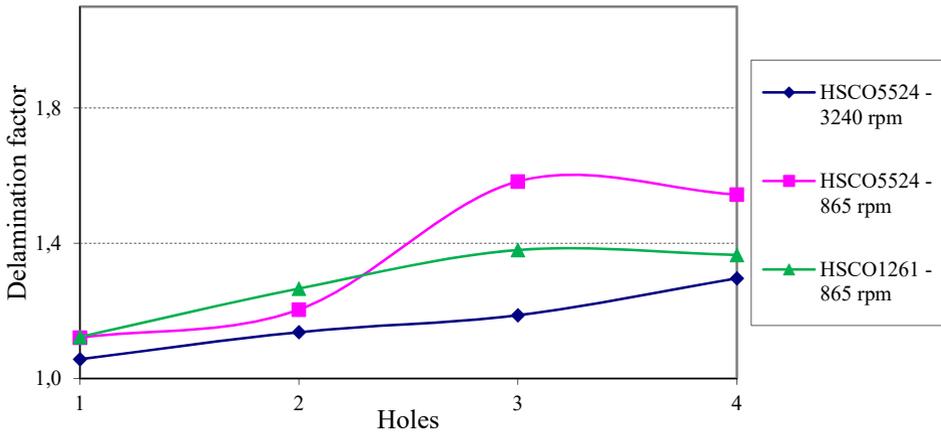


Fig. 1. Drills performed at 0,10 mm/rev.

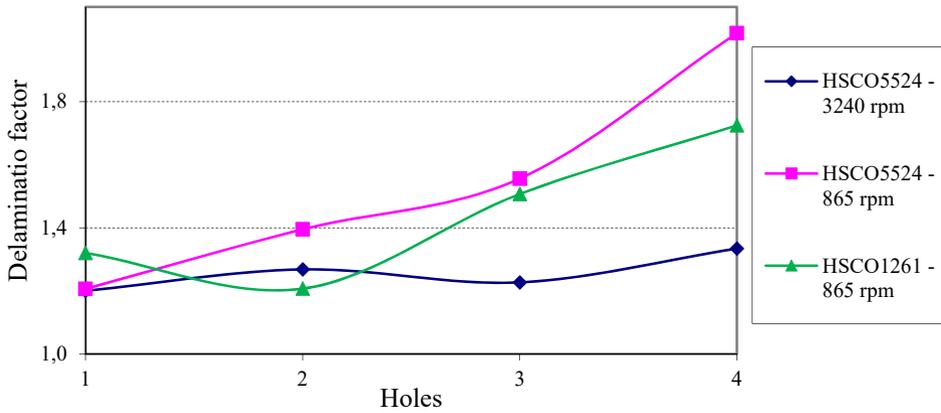


Fig. 2. Drills performed at 0,15 mm/rev.

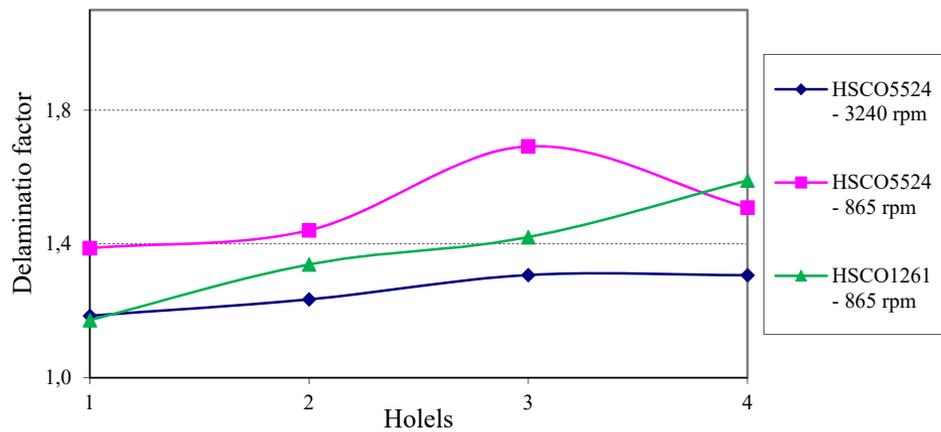


Fig. 3. Drills performed at 0,05 mm/rev.

In figure 4 we can see how the delamination factor evolves as the holes were produced with each drill. The wear of the tool was appearing, in some cases more progressively than in others.

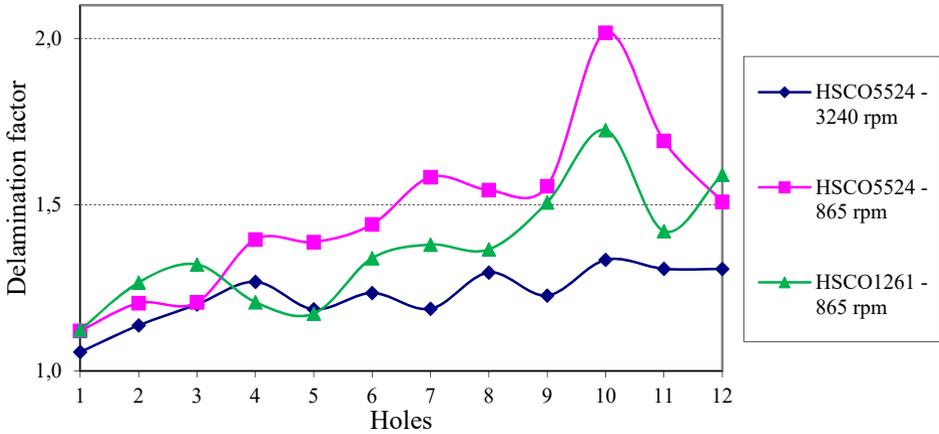


Fig. 4. Delamination in successive holes.

The different qualities obtained for the drills practiced are visible in the following images (see figures 5 and 6), corresponding to the first bore of a series and to the last, respectively. It can be seen how the wear of the tool has repercussions in obtaining a drill of poor quality only having made 30 holes with that tool.

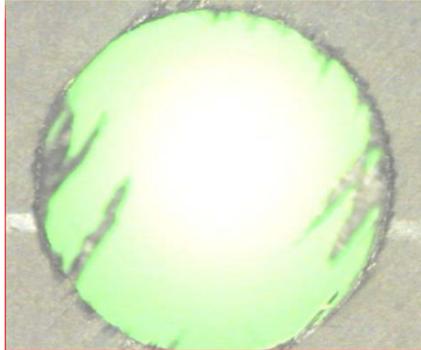


Fig. 5. First hole in a series.

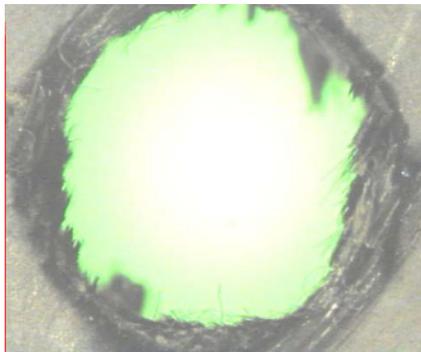


Fig. 6. Last hole in a series.

4 Conclusions

If we focused on the HSCO5524 drill bit, we could clearly see that the tool wears obtained for 3240 rpm were much lower than those obtained for 865 rpm, as well as the delamination data were also lower for the higher cutting speed.

If we focus on the cutting speed (16 m/min), we obtained better results with the HSCO1261 drill, probably due to the more progressive wear suffered by this tool. Both drills followed a similar behavior, but the delamination values obtained for HSCO1261, for the same cutting conditions, were generally lower than those obtained for HSCO5524.

We can say that the tool tip angle has great influence when machining carbon fiber, because under equal conditions, we obtain smaller delamination defects with the 130° bit.

The lower delamination obtained at high cutting speeds may be due to the increase in the temperature in the plate, which would reduce its resistance to machining. On the contrary, internal damages could have been generated that we cannot observe through these techniques.

In the HSCO5524 drill bit at 3240 rpm, it is observed that, in the last drills performed, the delamination factor remains almost constant, due to the lesser wear suffered by the tool.

When we worked with low feeds ratios and the tools already worn, we did not obtain higher values of delamination, reason why, at lower feed speeds, less delamination, although the tool wear was greater.

It is worth noting the excessive wear suffered by the tools in all cases, so it will not be profitable to mechanize these materials with tools of this type if we want to obtain a minimum of quality.

He would fail to do the experiment with a HSCO1261 drill at 3240 rpm, where it would be expected to obtain lower delamination factors.

References

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