OPTIMIZATION OF INPUT PARAMETERS FOR DRILLING HYBRID AL/GFRP/AL STACK USED IN AERONAUTICAL JOINTS

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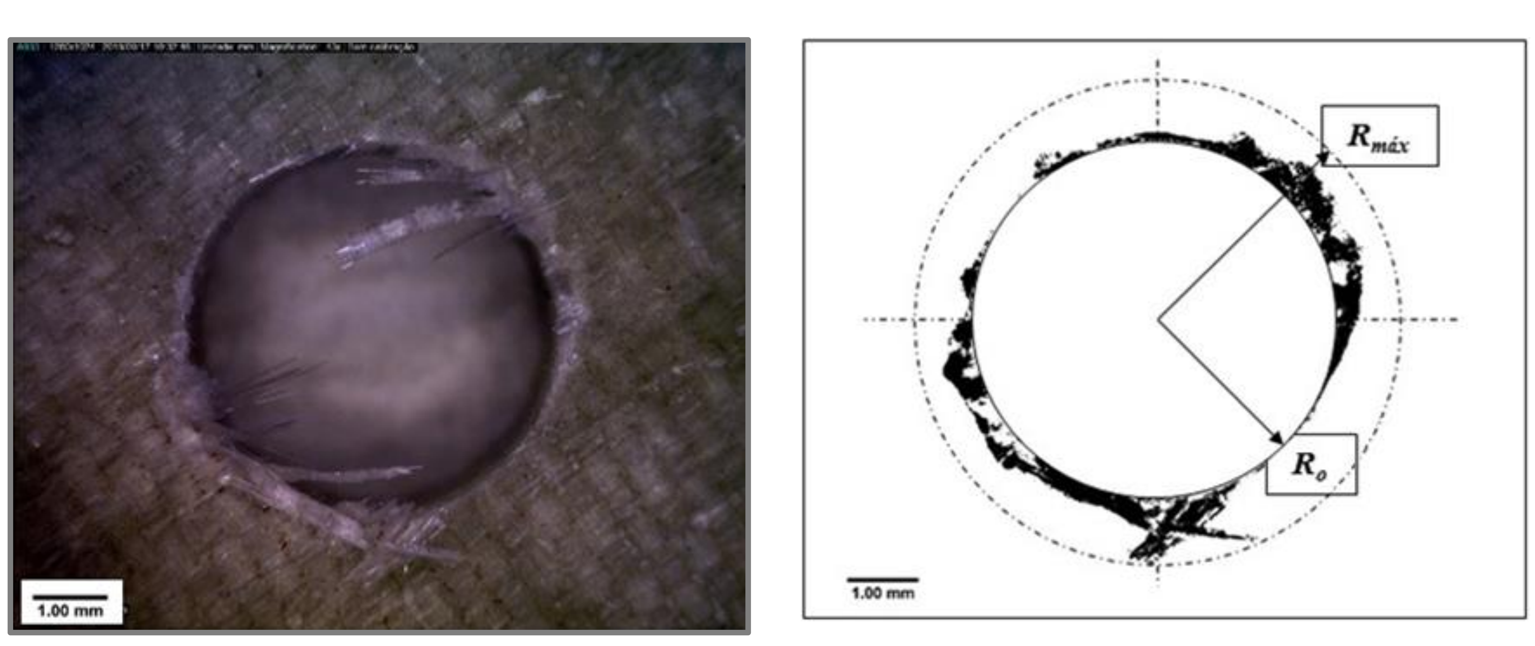
Introduction

The advent of new processing techniques and cutting tools ensures that the composite and hybrid materials been used in several fields of Engineering, especially in aeronautical, aerospace, and automobile industries [1-2]. Fiber-reinforced polymer matrix composites (FRP) are widely used in the aeronautical industry, with carbon (CFRP) and glass (GFRP) fibers being the most used reinforcements and, consequently, the most studied [3-4]. The mechanical properties of CFRP are superior to those of GFRP. However, the machinability of both materials is similar [9]. The drilling of hybrid metal/composite plates is the main challenge due to the phenomenon of fiber delamination, damage to tools [5] and damage to the matrix and fibers due to thermal gradients from metal chips [6], as well as the difficulty in select optimal cutting parameters and tools, such that it is possible to guarantee machining quality and surface integrity for all constituents [4-5]. The delamination of CFRP directly affects the quality of the assembly of structures. The mechanical performance of the parts decreases, especially when subjected to cyclic loads (fatigue), and can be identified in the region of entry and exit of the cutting tool [1]. Damage caused by delamination at the tool exit is higher than that caused at the tool entrance [14]. The delamination at the tool entrance (peel-up) can be considered as a consequence of the contact between drill tip and upper layers of laminate; at the tool exit (push-out), it is caused by the compressive effect exerted by the end of the drill on the upper layers of laminate [15]. Different authors concluded that feed rate is the most influential input parameter of the drilling process in GFRP on the delamination factor and thrust force [18-23]. Other authors have also verified the influence of the drill. Therefore, the objective is to find the optimal combination of drill type, cutting speed, and feed rate to minimize the delamination factor, the thrust force, and burr formation generated during drilling of the hybrid plate AA2024/GFRP/AA2024 using the Box-Behnken Design (BBD) for the project, analysis, and optimization of the experiment.

Materials and methods

The specimen (sandwich Al/GFRP/Al) was prepared in which 16 holes were made for fixing and joining the hybrid plate (Fig. 1a). Pre-tests were also carried out (Fig. 1b). The hole positions have been optimized for maximum use of the plates (the minimum 2,5·D distance between centers was observed) to measure the F_t on the 100 mm dynamometer delimited diameter. After assessing the delamination defects associated with the drilled holes, BBD methodology by Minitab® 19 software was used to analyze the influence of each input delamination parameters (Fda_E and Fda_S) and thrust force (F_t), considering a 95% confidence interval (p-value ≤ 0.05). The evaluation of the burr type on drilling AA2024 with a comparative visual analysis.



(a) (b)

Fig. 1. Output hole 1: (a) Original image. (b) Segmented image for calculation of F_{da}.

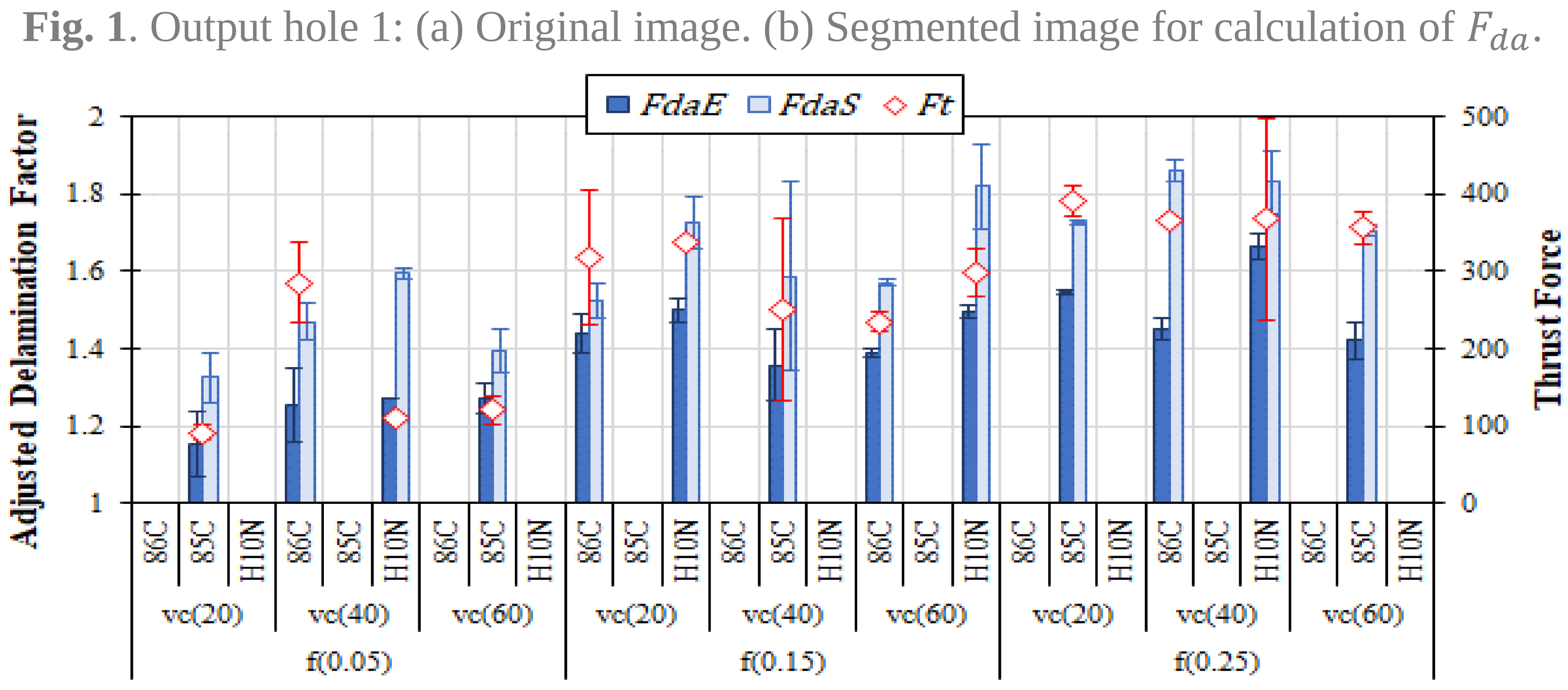


Fig. 2. Adjusted delamination factor in the entrance and exit sides of GFRP, and the thrust force of the hole drilling.

Results and discussion

Delamination factor: Fig. 2 shows an increasing behavior with the increase of F_t, Fda_E, and Fda_S in agreement with the increase of the feed rate (*f*). However, the same behavior does not occur when compared to cutting speed (v_c), evidencing its lesser influence on the results.

Thrust force: Concerning the analysis of the thrust force (F_t) measured along with the experiment. The feed rate was the most significant parameter (56.5%), as mentioned by Zitoune et al. [6]. The drill type (quadratic effect) and its combination with the feed rate (f x $drill$) were partially significant (4.25% and 4.55%, respectively). The R-squared was 74.3%. The surface plots indicate a decreasing trend in F_t with decreasing f and increasing v_c with 85C drill type. This fact can be attributed to the material removed rate. Moreover, the 85C drill contributes to the lowest F_t values since it has modified geometry on the tool-tip, resulting in less damage to the analyzed materials.

Parameter optimization: The multivariate optimization of the control variables was performed through the Box Behnken Design (BBD) in the function of the response variables to minimize delamination (tool entrance and tool exit) and the thrust force simultaneously. Thus, the following input parameters were obtained: drilling with the 85C drill applying v_c = 20m·min^{-1} and f = 0.05 mm·rev^{-1}, with the estimated responses Fda_E = 1.15, Fda_S = 1.36, F_t = 90.6 N.

Conclusions

- The thrust force (F_t) during drilling depends significantly on the feed rate (f).
- Another partially significant factor was the drill type (isolated or combined with f).
- The control variables that significantly influence the adjusted delamination factor at the input (Fda_E) and output (Fda_S) of the GFRP were f and drill.
- The cutting speed (vc) not significantly affected F_t and Fda_S. However, the combination f x vc was significant in Fda_E as well.
- The optimization of the cutting parameters via Box-Behnken Design was able to obtain values close to those estimated for the response variables (Fda_E, Fda_S and F_t). The optimized levels were vc = 20m·min-1, f = 0.05 mm·rev-1, and drill type 85C.
- Regarding the burrs at the hole output of AA2024 using the optimized parameters, the results were unsatisfactory (crown type), justifying a further study on the optimal hybrid stack drilling.

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