ABSTRACT

The aerospace industry is undergoing rapid transformation, continually pushing the boundaries of material science and engineering. Within this dynamic context, two materials have emerged as frontrunners in aircraft component construction: Carbon Fiber Reinforced Polymer (CFRP) and Ti-6Al-4V alloy. These materials have attracted substantial interest because of their remarkable combination of strength relative to weight and impressive resistance to corrosion. These materials have extensive applications in critical structural elements, including airframes and engine components. Typically, these materials are assembled using a conventional approach involving precision hole drilling and riveting. However, the conventional drilling process presents formidable challenges, particularly when working with CFRP/Ti-6Al-4V stacks.

Furthermore, drilling multi-stack configurations introduces complexities that include the elevated thrust forces and torque induced by drilling, delamination and subsurface damages of CFRP, and the intricate task of evacuating Ti-6Al-4V chips while addressing burr formation. Adding to these challenges is the relentless issue of rapid tool wear and the associated poor tool life when working with multi-stack materials. This further compounds the intricacies of the entire process. In light of these significant challenges, there is an urgent need to explore innovative techniques to overcome these issues effectively. This machinability study primarily focuses on address the above mentioned challenges associated with drilling hybrid CFRP/Ti multi-stacks.

Initial stage of this study, optimization of machining conditions for drilling CFRP/Titanium hybrid stacks to produce high-quality holes were

carried. Experimental investigations were conducted using Taguchi L16 design of experiments with Ø-6mm tungsten carbide drills. An improved compromise ranking method, VIKOR-(VIseKriterijumska Optimizacija I Kompromisno Resenje), is applied to determine the optimal machining parameters. Key attributes measured from experimental trials include delamination in CFRP, burr height in titanium alloy, thrust force, roughness, roundness, and hole diameter-errors for both CFRP and titanium alloy. Through rigorous experimentation, the ideal machining parameters in trial 13 were identified, featuring a speed-30m/min and a feed-0.025mm/rev. This configuration allowed for drilling multi-stacks without any trade-off in quality. Confirmation tests substantiated the effectiveness of these optimal parameters, ensuring consistent and judicious decision-making in the machining multi stacks.

In the second phase, the EDM technique was utilised to incorporate the chip-breaker-groove on the rake face of the standard Ø-6mm twist drill. Further, the comprehensive performance evaluation of this modified drill was evaluated by a comprehensive experimental investigation on drilling of CFRP/Ti stacks with unmodified standard drill under MQL-(Minimum Quantity Lubrication) conditions. Overall, grooved drills outperformed standard drills particularly at a speed range of 25m/min and 30 m/min. Furthermore, laser-based micro-texturing on the drill's flank and rake faces is incorporated in the third phase of this study to facilitate micro-pool lubrication between the tool and multi-stacks during drilling. Comparative drilling experimentations were carried under MQL conditions, assessing force, drill entry and exit delamination factors and circularity of the drilled holes. Considering the flank face micro-grooved drill, consistently lower thrust forces were observed across all range of cutting speeds and feeds, achieving reductions of up to 17 to 20%.

In the final stage of this study, a comparative tool wear analysis were performed on the standard and flank face micro-textured tools. This analysis reveals a substantial 26% enhancement in tool life with the flank face grooved drill, emphasizing its significant advantages for enhanced machining performance in CFRP/Ti stack drilling.

This study has successfully identified optimal machining conditions for drilling CFRP/Titanium hybrid stacks, ensuring high-quality hole production. Furthermore, the incorporation of a chip breaker groove and micro-level grooves on the various regions of the drill tool has demonstrated significant benefits, including reduced cutting forces, minimized delamination, and decreased burr formation. Notably, the utilization of chip breakers and micro-grooved drills in drilling CFRP/Ti stacks represents a novel approach that has not been attempted earlier, showcasing the potential for future advancements in aerospace manufacturing processes.