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# JOINING LAPPED LOW-MELT POLYARYLETHERKETONE CARBON FIBER REINFORCED THERMOPLASTIC LAMINATE VIA FRICTION STIR WELDING

**Abstract**

Implementation of lightweight structures in spacecraft and on-board instruments directly relates to increased cargo capacity and scientific capability, matching IAC's Technology category and enabling Artemis crewed Moon missions. Carbon fiber reinforced thermoplastics (CFRTP) have growing attention due to their superior shelf life, impact resistance, specific strength, modulus, adaptability to complex shapes, and weldability. Ultrasonic and laser welding can efficiently provide adequate joint strength in welded CFRTP but are often geometrically limited. Recently, friction stir welding (FSW) has been adapted to join polymers and short strand carbon fiber reinforced thermoplastics (SCFRTP) to similar and dissimilar materials. However, there is lack of study pertaining to FSW of weaved CFRTP laminates, which presents additional challenges over SCFRTP since fully plunging into the laminate sheet disturbs the carbon fiber weave. In this study, 4-ply low-melt polyaryletherketone (LMPAEK) CFRTP sheet is joined in lapped configuration via continuous FSW. The continuous FSW on a weaved CFRTP laminate and FSW of LMPAEK polymer makes this study unique and original in the FSW field. A three-level full-factorial design of experiments varying tool rotation speed and traverse speed was used to find the optimum welding parameters to achieve maximum lap shear strength and include nonlinear parameter effects. The welded specimens undergo mechanical testing to determine their lap shear strength and Rockwell hardness. Weld zones and fracture surfaces are observed using scanning electron microscopy (SEM) and optical microscopy (OM). The results indicate nonlinear relationships between lap shear strength in response to tool rotation speed and traverse speed. These parameters ensure enough interaction between the tool and top sheet to melt the LMPAEK at the interface between the two sheets without degrading the polymer. OM images indicate distinct zones within the welded region, with the thermomechanical affected zone (TMAZ) limited to the tool contact area and the heat affected zone (HAZ) encompassing the welded region between the two sheets. Rockwell hardness of the HAZ and TMAZ differ of that from the base material due to the change in crystallinity. SEM micrographs indicate delamination between the polymer and fibers in fractured specimens. Successful FSW LMPAEK CFRTP joints in this study expand the versatility of CFRTP in lightweight spacecraft materials used internationally in payload fairings, interstage adapters, heat shields, and type IV pressure vessels. Compared to carbon fiber reinforced thermosets, CFRTP are recyclable, ensuring sustainable space exploration in the future for all. Future study will focus on FSW CFRTP laminates to dissimilar materials.