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Author: Dr. Tracie Prater
United Launch Alliance LLC (ULA), United States, tracie.j.prater@gmail.com

FRICTION STIR WELDING OF METAL MATRIX COMPOSITES FOR USE IN AEROSPACE STRUCTURES

Abstract

Friction Stir Welding (FSW) is a relatively nascent solid state joining technique developed at The Welding Institute (TWI) in 1991. The process was first used at NASA to weld the super lightweight external tank for the Space Shuttle. Today FSW is used to join structural components of the Delta IV, Atlas V, and Falcon IX rockets as well as the Orion Crew Exploration Vehicle. A current focus of FSW research is to extend the process to new materials which are difficult to weld using conventional fusion techniques. Metal Matrix Composites (MMCs) consist of an metal alloy reinforced with ceramics and have a very high strength to weight ratio, a property which makes them attractive for use in aerospace and defense applications. MMCs have found use in the space shuttle orbiter's structural tubing, the Hubble Space Telescope's antenna mast, control surfaces and propulsion systems for aircraft, and tank armors. The size of MMC components is severely limited by difficulties encountered in joining these materials using fusion welding. Melting of the material results in formation of an undesirable phase (formed when molten Aluminum reacts with the reinforcement) which leaves a strength depleted region along the joint line. Since Friction Stir Welding occurs below the melting point of the workpiece material, this deleterious phase is absent in FSW-ed MMC joints. FSW of MMCs is, however, plagued by rapid wear of the welding tool, a consequence of the large discrepancy in hardness between the steel tool and the reinforcement material. This work characterizes the effect of process parameters (spindle speed, traverse rate, and length of joint) on the wear process. Based on the results of these experiments, a phenomenological model of the wear process was constructed based on Dr. Art Nunes's (NASA MSFC) rotating plug model of Friction Stir Welding. The effectiveness of harder tool materials (such as Tungsten Carbide, high speed steel, and tools with diamond coatings) to combat abrasive wear is explored. In-process fprce, torque, and vibration signals are analyzed to assess the feasibility of in situ monitoring of tool shape changes as a result of wear (an advancement which would eliminate the need for offline evaluation of tool condition during joining). Monitoring, controlling, and reducing tool wear in FSW of MMCs is essential to implementation of these materials in structures (such as launch vehicles) where they would be of maximum benefit.