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Additive Friction Stir Manufacturing Process: Interest in Understanding Thermal Phenomena and Numerical Modeling of the Temperature Rise Phase

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Abstract : Additive Friction Stir Manufacturing (AFSM) is a new industrial process that follows the emergence of friction-based processes. The AFSM process is a solid-state additive process using the energy produced by the friction at the interface between a rotating non-consumable tool and a substrate. Friction depends on various parameters like axial force, rotation speed or friction coefficient. The feeder material is a metallic rod that flows through a hole in the tool. Unlike in Friction Stir Welding (FSW) where abundant literature exists and addresses many aspects going from process implementation to characterization and modeling, there are still few research works focusing on AFSM. Therefore, there is still a lack of understanding of the physical phenomena taking place during the process. This research work aims at a better AFSM process understanding and implementation, thanks to numerical simulation and experimental validation performed on a prototype effector. Such an approach is considered a promising way for studying the influence of the process parameters and to finally identify a process window that seems relevant. The deposition of material through the AFSM process takes place in several phases. In chronological order these phases are the docking phase, the dwell time phase, the deposition phase, and the removal phase. The present work focuses on the dwell time phase that enables the temperature rise of the system composed of the tool, the filler material, and the substrate and due to pure friction. Analytic modeling of heat generation based on friction considers as main parameters the rotational speed and the contact pressure. Another parameter considered influential is the friction coefficient assumed to be variable due to the self-lubrication of the system with the rise in temperature or the materials in contact roughness smoothing over time. This study proposes, through numerical modeling followed by experimental validation, to question the influence of the various input parameters on the dwell time phase. Rotation speed, temperature, spindle torque, and axial force are the main monitored parameters during experimentations and serve as reference data for the calibration of the numerical model. This research shows that the geometry of the tool as well as fluctuations of the input parameters like axial force and rotational speed are very influential on the temperature reached and/or the time required to reach the targeted temperature. The main outcome is the prediction of a process window which is a key result for a more efficient process implementation.

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