Discontinuity Formation and Detection during Friction Stir Welding of Aluminum Alloys

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Internal discontinuities resulting from the friction stir welding (FSW) process can have a negative effect on the weld quality. Ideally, discontinuity formation would be avoided through careful process planning, or detected by analysis of measurable process signals (e.g., forces, torques, temperatures). To achieve these goals, we must first understand when and why discontinuities are formed. After a brief introduction to prior work on correlating process forces to discontinuity formation and size, the latest results and understanding of when and why discontinuities form as well as how they can be correlated to measurable process signals will be presented. A combination of experimental observations and numerical simulations will be presented, with a focus on the interaction between the friction stir tool probe and the underlying material. This includes a high-fidelity Finite Element Analysis (FEA) simulation of the FSW process and on the correlation of numerically obtained process force signals with the corresponding void structures. This correlation is obtained in the phase-space relating in-plane reaction forces on the tool to the tool rotation angle. The interactions of the tool geometry and tool motion with the surrounding material undergoing plastic deformation provides novel insights into various correlations of tool motion and void formation. Through this approach, it is possible to identify tool-related process conditions that can be optimized to minimize void formation and demonstrate a potential in-situ force-based void monitoring method that links to the underlying plastic flow and defect structures during the FSW process.

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