Heat Transfer Interface Guided Design for an Instrument to Measure the Heat Transfer Coefficient in Friction Stir Welding

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Friction stir welding (FSW) is a solid-state joining process that offers superior weld quality compared to traditional fusion welding. Important process parameters (e.g. translational velocity, rotation rate, and downward force) affect the temperature fields and thus weld quality within the welded material. Important parameters that cannot be directly controlled include the friction coefficient and heat transfer coefficient. Current literature presents the heat transfer coefficient within a range of three orders of magnitude, within which the weld quality varies greatly. Because of the complex nature of FSW processes and the uncertainty of parameters, fine-tuning procedures have typically been limited to trial-and-error methods.

The present research develops and validates an instrument design to directly measure the heat transfer coefficient during FSW processes, allowing more rapid fine-tuning. The device uses the frequency domain thermoreflectance (FDTR) technique to probe thermal interface properties (e.g. the heat transfer coefficient) between a transducer and welded material. The novel transducer design withstands the intense forces of FSW while being sensitive to the heat transfer coefficient. A curve-fitting process can fit the device's measurements to an analytic expression.

COMSOL was used to perform an initial validation of the device's design, after which a sensitivity analysis was done. This analysis was used to design an optimal design for the transducer that functions within the geometrical and structural constraints of FSW processes. COMSOL was then used as further validation that the analytic expression properly models the transducer.