3ω Contact Resistance Measurement at Pressure

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Friction stir welding (FSW) is a solid-state welding process that takes place below the melting point of the materials to be joined, and the quality of the resulting weld is based on the material's temperature. When modeling FSW, there are two key factors that have yet to be experimentally measured: the friction coefficient (μ) and the heat transfer coefficient (h) at the tool/workpiece interface. The current practice is to tune μ after selecting h values based on two often cited papers from 2003, but the original authors specify multiple times that the values they obtain are very approximate. This value has yet to be experimentally measured. Experimentally determining this value is challenging because of the heat, pressure, vibration, and rotation associated with the FSW process. We present an experimental method to determine the heat transfer coefficient (h) by integrating a 3ω sensor into the shoulder of the FSW tool. An intermediary step before measuring during a weld was to statically measure the heat transfer coefficient over a range of pressures. A 3ω sensor on a silicon substrate was compressed against aluminum at different pressures to vary the h coefficient at the interface. The measurements were fit to an analytical 1D heat transfer model to solve for h and compared to a semi-empirical result that calculated h from knowing material properties, contact pressure, and surface characterization using the YIGC (Integral gap conductance) model. Results indicated that phase temperature measurements from the sensor decrease as pressure increases, indicating that h increases with pressure. These results are a step towards accurately interpreting sensor data from a weld and the ability to calculate the h coefficients between the tool and the workpiece during a friction stir weld. Having the ability to experimentally determine heat transfer coefficients will allow future studies to more accurately model the FSW process, with the end goal of producing a fully predictive model.