Modeling of Simultaneous Heat Transfer and Deformation in Friction Stir Welding

John A.Roubidoux[1], Patricio F. Mendez[1], Thomas J.Lienert[2]
[1]Colorado School of Mines, [2]Los Alamos National Laboratory

Advanced scaling techniques are employed to analyze the coupled thermal and plasticity phenomena during Friction Stir Welding (FSW). Different regimes of operation are identified and their corresponding scaling laws are obtained with good agreement with experiments. These laws can be used to extrapolate successful processing conditions across different families of metals, for example, from aluminum to titanium, thus shortening dramatically the empirical surveying of the parameter space. Also, by estimating key processing parameters, these laws are helpful for the design of high temperature tooling. In this novel approach for FSW, both thermal and plasticity phenomena are considered simultaneously using an ordering analysis inspired in the boundary layer analysis in fluid mechanics. The model presented helps understand the advancing force, torque, temperatures, and deformation history of the material near the rotating pin and on the base plate, but it does not address the mechanical mixing occurring behind the pin.

Modeling FSW is a complex process, since it happens entirely in the solid state. The two main challenges of FSW are: First, material properties are not well known at the temperatures, strain rates, and strains involved in the process. Secondly, the process is coupled (Heat and Deformation). The system being considered is shown below in Figure 1. The model presented provides scaling laws for the two regions, the HDAZ (Heat and Deformation affected zone) and the substrate. The scaling laws estimate the deformation in the HDAZ, heat in the HDAZ, and heat in the substrate. The scaling laws depend only on process parameters.

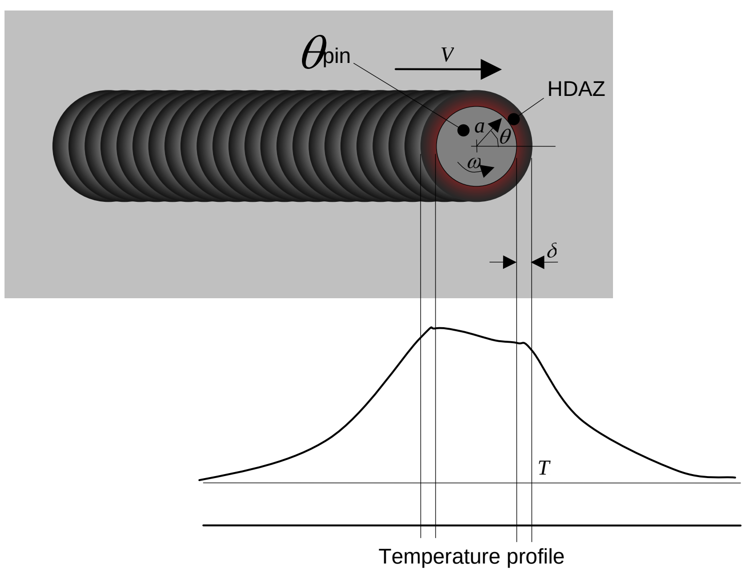

Figure1: Schematic Diagram of FSW considered.