Numerical simulation of transient temperature and plastic dissipation in Friction Stir Welding

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ABSTRACT

This work presents a fully coupled thermo-mechanical formulation in an Arbitrary Lagrangian Eulerian (ALE) framework for the numerical simulation of Friction Stir Welding (FSW). FSW is a solid state joining technology in which no gross melting of the welded material during the joining process takes place. In this technique, a tool is inserted into the welding line between two pieces and rotates with high speed while moving through the welding line. Heat is generated by friction between the tool and the work-piece and by the plastic deformation of the material.

In the numerical model proposed, both heat generation via the viscous dissipation and frictional heating due to contact are taken into account. The material behavior is characterized by two alternative rigid thermo-viscoplastic constitutive models: Norton-Hoff and Sheppard-Wright. Numerical difficulties associated to the material behavior modeling are discussed.

The welding plates are modeled in the Eulerian framework, while ALE is used for the inner part (material around the tool). The reason for this is the fluid motion cannot be handled with a classical updated Lagrangian scheme, since it would lead to mesh degradation. At the same time, a purely Eulerian scheme is not satisfying, since it cannot provide enough precision for the tracking of the free surfaces evolution.

A pressure stabilized mixed linear velocity/linear pressure finite element interpolation for the mechanical problem and convection stabilized linear temperature interpolation formulation for the thermal problem (convection-diffusion) is considered.

The resulting system of equations is solved in a staggered manner in which the mechanical and thermal parts are solved sequentially.

The proposed thermo-mechanical formulation is validated by simulating several benchmarks and comparing the results with the experimental data.