On the Numerical Simulation of 3D Friction Stir Welding Processes

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ABSTRACT

This work deals with the computational modeling and numerical simulation of material flow in 3D Friction Stir Welding (FSW) processes. Flow of the material around a FSW tool is characterized by a Reynolds number which is much smaller than 1. Then inertial forces can be neglected and a quasi-static analysis can be performed. The deformation of the material around the tool is extremely high and the computational modeling of the material flow will be performed using Eulerian or Arbitrary Lagrangian-Eulerian (ALE) formulations. The Peclet number for a FSW process typically ranges from 1.0E+01 to 1.0E+03 and the convective term arising in the spatial formulation of the energy balance equation cannot be neglected. Norton-Hoff and Sheppard-Wright rigid thermoplastic material models are considered. Different frictional conditions at the shoulder interface, from fully slip to fully stick, have been considered.

Mixed stabilized velocity/pressure/temperature formulations have been developed within the framework of the subgrid scales stabilization methods. P1/P1/P1 and P2/P1/P2 finite element discretizations are considered. It is shown that classical SUPG method can be recovered as a particular case of the subgrid scale stabilization method. If a P1/P1/P1 formulation is used, then the classical GLS method can be also recovered as a particular case of the subgrid scale stabilization method.

The resulting coupled thermomechanical problem has been solved suing a staggered solution algorithm. Computational flow visualization techniques using tracers have been implemented to be able to get the pattern of the material flow around the tool.

The computational models developed have been used in the numerical simulation of 2D and 3D FSW processes. Results obtained in the numerical simulations have been compared with other numerical or experimental results available.

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