Coupled Thermo-mechanical Analysis for Frictional Stir Welding Processes

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ABSTRACT

This work describes the formulation adopted for the numerical simulation of the Frictional Stir Welding (FSW) process. FSW is a solid-state joining process (the metal is not melted during the process) and is used for applications where the original metallurgical characteristics must be retained. This process is primarily used on aluminum alloys, and most often on large pieces which cannot be easily heat treated to recover temper characteristics.

On one hand, heat is induced by the friction between the tool shoulder and the material of the work pieces. On the other hand, the heat is generated by the mechanical mixing (stirring) process without reaching the melting point (solid-state process).

To simulate this kind of welding process, a fully coupled thermo-mechanical solution is adopted. A sliding mesh rotating with the pin and the stirring material around it is used to avoid the extremely large deformation of the material around the tool (ALE formulation) while the rest of the mesh of the working piece is kept fix (Eulerian formulation). The material behavior is characterized by Norton-Hoff and Sheppard-Wright rigid thermoplastic constitutive models. A stabilized mixed formulation (within the framework of multiscale methods) is assumed to deal with the incompressible behavior of the material. This allows for equal linear approximations of velocity and pressure fields.

Both the frictional heating due to the contact interaction between the surfaces of the tool and the sheet and the heat induced by the visco-plastic dissipation of the stirring material have been taken into account. Heat convection and heat radiation models are used to dissipate the heat through the boundaries. Both SUPG and OSS stabilization terms have been implemented to deal with the convective term in the balance of momentum equation.

Thermo-mechanical results are presented in terms of temperature evolution and residual stresses, and compared with experimental data.