Numerical framework for high accuracy simulation of the FSW process

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Abstract: The numerical simulation of the FSW process is tackled by means of an apropos kinematic framework. Hence, the computational domain is split into three different zones: the work-piece is defined by a visco-plastic law (e.g. piece-wise linear Norton-Hoff model) in the Eulerian framework (the material flows while the mesh is kept fix); the pin rotates only, and is assumed to be rigid within a Lagrangian framework (the material is attached to the mesh) and the stir-zone is solved through an Arbitrary Lagrangian Eulerian (ALE) formulation allowing for an independent movement of the material and the mesh. As a result, the mesh is not distorted and re-meshing of any kind is not necessary to analyse complex non-cylindrical pin-tools [1,2].

A fully coupled thermo-mechanical model is introduced considering the heat fluxes generated by the plastic dissipation in the stir-zone as well as the frictional dissipation at the contact interface between the tool and the work-piece through a modified Norton frictional contact model [3]. This friction model has been calibrated to account for the tool tilt angle too [4].

A novel finite element technology based on a three-field mixed formulation is exploited [5]. The Variational Multi Scale (VMS) method is used to circumvent the LBB stability condition allowing for the use of linear piece-wise interpolations for displacement, strain-rate and pressure fields, respectively. The result is an enhanced stress/strain field approximation which enables for stress-accurate results in non-linear computational mechanics [6,7]. The use of an independent nodal variable for the pressure field allows for an ad-hoc treatment of the incompressibility constraint. This is a mandatory requirement due to the isochoric nature of the plastic flow in FSW processes.

Finally, a tracing technique has been implemented to show the material flow around the pin leading to a better understanding of the welding mechanism, [8] defect prediction [9] as well as to follow the evolution of the metallurgy [10].

Numerical results are compared with the experimental evidence provided by Hydro (SAPA).

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