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Application of adaptive method in thermomechanical modeling and simulation of extrusion of aluminum alloys

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ABSTRACT

The purpose of this work is modeling and simulation of aluminum alloys during extrusion, cooling and further forming processes. Such individual steps are often combined into integrated multi-stage processes in order to optimize the production process as a whole.

The advantages of aluminum and its alloys include high ductility (due to its fcc crystal structure), making it particularly suitable for complex extrusion processes. Additionally, the ideal ratio of the Young's modulus to density of Al makes it ideal for a wide range of application in automotive and aircraft manufacturing, as well as for lightweight construction in general. Here attention is focused on aluminum alloys of the 6000 series (Al-Mg-Si) and 7000 series (Al-Zn-Mg). Alloys of the 6000 series are especially designed to provide maximum ductility, whereas members of the 7000 series are less ductile but show better hardness properties.

In particular, since aluminum has a relatively high stacking fault energy, dislocation cross slip is energetically-favored over recrystallization. Therefore the material behavior of these alloys at high temperature during extrusion is governed mainly by dynamic recovery and subgrain evolution. Whereas static recrystallization is dominant during the following cooling process. Experimental results regarding the developing microstructure (e.g., texture, dislocation structures, etc.) provide information on how the process conditions such as extrusion rate, temperature and ram velocity affect its development.

The current material model is based on the role of energy stored in the material during deformation as the driving force for microstructural development which is offered by Sellars and Zhu [1]. The concept of internal variables is used to describe state quantities such as dislocation density, average grain size and average grain orientation. Constitutive equations for these quantities are formulated in a thermodynamically-consistent fashion as part of a thermo-elastic, visco-plastic model with heat conduction.

In this work, a number of aspects of the structural simulation as well as that of extrusion as a thermomechanical process are considered. These aspects include contact and adaptive mesh refinement, heat transfer inside the billet, heat transfer between the workpiece and the container, frictional dissipation,

mechanical energy and surface radiation. An efficient and robust numerical simulation of the very large deformations occurring during extrusion requires the use of mesh-refinement and remeshing methods. In this case python scripting drives the numerical simulation in the commercial finite-element program ABAQUS and the mesh refinement with an external remeshing software.

REFERENCES

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