THE MULTIDISCIPLINARY APPROACH TO THROUGH PROCESS MODELLING OF HOT FORMING COUPLED WITH MICROSTRUCTURE TRANSFORMATION

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ABSTRACT

The formability of the metals as well as the service properties of manufactured parts significantly depend on the microstructure. During the series of hot forming technological operations when manufacturing critical parts made of high strength alloys the microstructure variation can be significant. Thus modelling of microstructure development through the whole process is becoming a very important issue in FEM simulation. However the attempts of using the physical models of microstructure transformation along with FEM code very often lead to unsatisfactory results. The main reason for this is the nature of many microstructural models. Being basically obtained from the almost isothermal experiments with constant strain-rate, they are normally well suitable either for steady deformation processes or for describing of some instantaneous relations. At the same time the main peculiarity of the real technological processes is highly inhomogeneous deformation, possibility of slowly or fast changing of temperature and strain-rate. This makes real situation to be far from a steady one. As the result, microstructure developed at each stage of the forming depends not only on the instantaneous conditions but also on the whole thermo-mechanical history of deformation. This means that the model used for the description of microstructure transformation must have functional (history-dependent) nature and to be valid and stable in wide range of main process parameters such as temperature and strain-rate. History dependence is a critical issue for selection of the constitutive model as well as for formulation of the boundary-value problem.

Another specific feature of the hot forming processes is the high sensitivity of the mechanical properties of the material to its microstructural state. Any variation of microstructure causes change of mechanical behaviour of the material, e.g. coarsening of the grains normally leads to the hardening while refinement causes softening. This can significantly change the metal flow pattern. For proper description of the deformation of the material, concomitant microstructure transformation has to be taken into account by constitutive

model included in FEM simulation. It means the necessity of solving of a thermo-mechanical problem of large plastic deformation coupled with microstructural model.

The proposed work presents the constitutive model of active microstructure transformation coupled with large plastic deformation that meets all above mentioned requirements. . The model has been developed using programming facilities of QForm 7 FE metal forming simulation code. The possibility of practical applicability of the model is illustrated by examples of manufacturing of complex shape parts made of Ti-6AL-4V. The comparison between the results obtained by using a coupled model and traditional metal forming simulation is made. The basic trends of material flow and microstructure formation depending on the initial structural state of the material are analyzed. The outline of the further prospects of the model development is given.

SUGGESTED THEMES

Multidisciplinary modelling, large plastic deformation, microstructure transformation, hot working, constitutive model, FEM analysis, coupled problems.