11th. World Congress on Computational Mechanics (WCCM XI)
5th. European Conference on Computational Mechanics (ECCM V)
6th. European Conference on Computational Fluid Dynamics (ECFD VI)
July 20 - 25, 2014, Barcelona, Spain

STUDY ON HOMOGENIZATION METHODS FOR HARDENING AND FAILURE OF ULTRA HIGH STRENGTH STEEL WITH TAILORED MATERIAL PROPERTIES

Stefan Golling[1*], Mats Oldenburg[2]

[1] Division of Mechanics of Solid Materials, LuleåUniversity of Technology, 971 87 Luleå, stefan.golling@ltu.se, www.ltu.se

[2] Division of Mechanics of Solid Materials, LuleåUniversity of Technology, 971 87 Luleå, mats.oldenburg@ltu.se, www.ltu.se

Key words: *Press Hardening, Homogenization, Damage, Fracture.*

Over recent years the demand of press hardened ultra-high strength steel for safety structures in automobiles has increased and continuation of this trend is expected. Components with tailored properties can be manufactured using a thermo mechanical process with heated and cooled areas in a tool. In industry the cooling rate of the blank is controlled this utilizes the formation of different microstructures with varying mechanical properties within a single component. The structural response in a crash situation can be altered by the design of the component with formation of different material grades based on the microstructure designated areas of the component. Material models used in finite element analysis are required by the automotive industry and its suppliers. These models contribute to the improvement and quality of press hardened components.

For this study a set of tensile test specimens with different volume fractions of phases were produced. The samples were cut out of a sheet in as delivered conditions perpendicular to the rolling direction. As material is the boron steel 22MnB5 chosen which is a common material used in press hardening due to its good hardenability. The precut specimens are austenitized at 950°C for five minutes before starting a heat treatment at different temperatures and holding times. In total eleven different microstructures are produced. The produced samples consist of ferrite-bainite, ferrite-martensite and bainite-martensite with different volume fractions, additionally a microstructure consisting of three phases, ferrite-bainite and martensite, is available. The ferrite formation is achieved under isothermal conditions at 650°C, the holding time is varied to form different amounts of ferrite. Bainite for the ferrite-bainite samples was formed isothermaly at 430°C and the holding time was chosen in way that all retaining austenite transforms. For the three phase sample the holding time for bainite was shortened, this left some austenite remain which could be transformed into martensite by quenching.

The phase composition of the samples produced are estimated using the austenite decomposition model proposed by Kirkaldy [1]. The basic model of Kirkaldy is designed for isothermal phase transformations, for temperature histories with continuous cooling the additive rule is used to predict formed volume fractions, for this study both prediction tools are implemented in Matlab. The model of continuous cooling is comparable to the implementation in the commercially available finite element code LS-Dyna based on the work of [2] and [3], to get results in agreement with experimental observations parameters need to be adjusted depending on initial conditions.

Using measured mechanical properties of pure phases and the volume fraction of formed phases different homogenization methods are compared in their ability to represent the mechanical response of mixed microstructures. The homogenization methods account for elastic deformation and the hardening of the material. The onset of necking is seen as the last valid point for all homogenization methods. After this point a localization and damage function for the prediction of softening and fracture is applied. Strain localization and fracture are mesh dependent, therefore an analysis length scale is introduced to account for different element sizes, see [4]. The determination of parameters for the damage model is described in [5]. A weakest link criterion is used for fracture. Failure of the composite is assumed to occur if one phase fails. The material model for homogenization of mixed mircostrucutres including damage is implemented in the commercial finite element code LS-Dyna and validated by comparison to experimental results.

REFERENCES

[1] J.S. Kirkaldy, Phase Transformations in Ferrous Alloys, AIME New York, 1983.

[2] P. Åkerström, M. Oldenburg, Austenite decomposition during press hardening of a boron steel - computer simulation and test, Journal of Materials Processing Technology, 2006, 174, pp. 399-406

[3] P. Åkerström, G. Bergman and M. Oldenburg, Numerical implementation of a constitutive model for simulation of hot stamping, Modelling Simul. Mater. Sci. Eng., 2007, 15, pp. 105-119

[4] H.-Å. Häggblad, Daniel Berglund, K-G Sundin and Mats Oldenburg, Formulation of a finite element model for localization and crack initiation in components of ultra high strength steels. Hot sheet metal forming of high performance steel, June 15-17 2009. Luleå: Verlag Wissenschaftliche Scripten, 2009, pp. 229-237.

[5] R. Östlund, M. Oldenburg, H-Å. Häggblad and D. Berglund, Evaluation of localization and failure of boron alloyed steels with different microstructure compositions, Journal of Materials Processing Technology, 2013