Prediction and optimization of the total yield strength in Al-alloys for non-uniform (local) heat treatments by coupling different software packages

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ABSTRACT

Local heat treatment is widely used in steels but it is very limited applied in case of aluminum alloys. This is primarily due to the facts that aluminum alloys do show a change of the crystal structure and that these materials exhibit a high thermal conductivity. Despite these restrictions, local thermal cycles can be realized which might affect the dislocation density and the precipitation state. Aim of this work is to study the possibilities of local thermal treatment of aluminum components by means of numerical simulation.

The prediction of the yield strength of aluminum alloys can be performed by using different software packages. However, the available software tools rely on the averaged-field approach. This hypothesis relies on a uniform heat treatment and cannot predict the yield strength spatially in 3D reliably. As a consequence, a local treatment in 3D requires more complex models that accounts for the locally different thermal history for prediction of the yield strength. That leads to the necessity to calculate how locally different thermal cycles influence the contributions of the various strengthening mechanisms, e.g. solid solution strengthening or precipitation strengthening.

Furthermore, local heat treatment induces temperature gradients that lead to thermal stresses. Based on the fact that during the process the yield strength decreases or increases due to the material transformation. If the thermal stresses reach the yield strength, plastic straining of the material occurs which may affect its hardness and precipitation behavior. In order to avoid plastic straining the local heat input has to be limited. In addition, the maximum temperature has to be constraint in order to ensure that the solidus temperature of the material is not exceeded.

The fact that the local heat treatment due to a regional heat input and the thermal treatment time change the yield strength, an optimization procedure was applied to calculate the optimal parameters for the heat input flux and the duration of local thermal treatment. Furthermore, the optimization framework allows one to define further object functions such as minimizing the energy cost of the heat treatment which can be coupled with the varying quantities or other object functions.

In order to achieve fast local heat treatment simulations, a new technique was developed to simplify the coupled system related to the thermal stresses and the yield strength calculation within the simulation framework. The automatic multi criteria optimization is then coupled to this framework for adjusting the parameters in order to fulfil the object functions while taking care about restrictions to the varying quantities. The coupling procedure and the results of the automatic optimized local heat treatment are discussed in this paper.

Coupling of the prediction and optimization of the total yield strength in Al-alloys for non-uniform (local) heat treatments

Prediction of the total yield strength in Al-alloys for non-uniform (local) heat treatments that is coupled to an optimization framework

Coupling an optimization framework to vary quantities in order to predict the total yield strength in Al-alloys for non-uniform (local) heat treatments while minimizing defined object functions