A micromechanical model for the austenite-martensite transformation in hot stamping of automotive steel sheets

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Hot stamping is a process widely used in the automotive industry to produce safety parts of a car body in white, supposed to ensure the vehicle interior integrity [1]. Aluminised sheets are first austenitised, then formed and quenched within a single step, which simultaneously produces the final geometry and the martensitic structure. The description of such a process requires thermal, mechanical and metallurgical aspects. This work presents a hot stamping model with a micromechanical description of the austenite-martensite transformation. It has been implemented into a finite element simulation, as it is a tool able to encompass many different fields. The model is based upon an additive decomposition of the global strain [2,3]:

$$\Delta\varepsilon_{ij} = \Delta\varepsilon_{ij}^{el} + \Delta\varepsilon_{ij}^{th} + \Delta\varepsilon_{ij}^{pl} + \Delta\varepsilon_{ij}^{iso} + \Delta\varepsilon_{ij}^{pt}$$

The first three increments represent elastic strain, thermal dilatation and plastic strain respectively. They are macroscopic increments, built upon multiple homogenisation schemes that include elastic and plastic properties for each phase. The two others are induced by the phase transformation and accounts for a spherical isotropic volume expansion $\Delta\varepsilon_{ij}^{iso}$ and a deviatoric transformation plasticity $\Delta\varepsilon_{ij}^{pt}$ [4]. Within this work, the thermomechanical behaviour simulation is performed by a predictor-corrector algorithm. Temperature and strain increments are given to the algorithm that then returns plastic strain and stress increments, regarding homogenised material properties such as the yield stress. A linear elastic prediction is performed prior to a plastic correction with respect to transformation plasticity.

After implementation into a Fortran UMAT Abaqus subroutine, this algorithm is able to predict the thermal, mechanical and metallurgical states of any part after hot-stamping. Different geometries have been experimentally considered, from mere geometries to industrial cases, and a correlation with temperature measurements (also witnessing the phase transition) has been performed.

Keywords: hot stamping; transformation plasticity; finite element modelling

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