A macro scale constitutive model for TRIP steel

H.J.M. Geijselaers†∗, E.S. Perdahcıoğlu‡, A.H. van den Boogaard†

†Universiteit Twente
Enschede, the Netherlands
‡M2i Materials innovation institute
Delft, the Netherlands

Keywords: TRIP, martensitic transformation, mean-field homogenization, constitutive model.

ABSTRACT

The existence of different phases in the micro structure of TRIP steels is a consequence of its chemical composition and the heat treatment during production. Two main constituents are ferrite and austenite. The austenite phase ($\gamma$) can transform into stable martensite ($\alpha'$) during deformation. One of the attractive features of these steels is the fact that with slight changes in the heat treatment and/or chemical composition, a material with significantly different mechanical properties can be obtained [1].

The aim of this study is to build a model that can be used to predict the final mechanical properties based on knowledge about the constituent phases. The model is based on the Mean-Field homogenization technique for computing the stress-strain distribution into different phases [2].

The martensitic transformation is modeled as a stress-driven process [3, 4]. The transformation depends on the stress resolved in the austenite phase and is determined as a function of the mechanical driving force supplied to the material [5, 6]. The martensitic transformation involves a diffusionless change of crystal structure. This is analyzed starting from the postulate of an invariant plane (habit plane) as interface between the martensite and the parent austenite [7]. The result is a set of 24 habit plane normals $n$ and corresponding shear vectors $m$. When a stress $\sigma$ acts, while the transformation evolves, it supplies mechanical driving force $U$ for the transformation.

$$U = \sigma_\gamma : (m \otimes n) = \sigma_\gamma : \frac{1}{2}(m \otimes n + n \otimes m)$$

(1)

Here $\sigma_\gamma$ is the Cauchy stress in the austenite phase. In a polycrystalline material there are always some grains optimally oriented with respect to the local stress to maximize the mechanical driving forces. When this maximum exceeds a critical value $\Delta G^{\text{cr}}$ the transformation will start [3].

$$U^{\text{max}} = \sum \sigma_{\gamma j} \lambda_j > \Delta G^{\text{cr}}$$

(2)

where $\lambda_j$ are the eigenvalues of the transformation deformation tensor in (1) and $\sigma_{\gamma j}$ are the eigenvalues of the local austenite stress tensor, both sorted in ascending order. The values of $\lambda$ are material parameters, which are based on measured data. The amount of martensite formed is a function of $U^{\text{max}}$:

$$f_{\alpha'} = f_{\alpha'}^0 + f_\gamma^0 F(U^{\text{max}} - \Delta G^{\text{cr}})$$

(3)

where $f_{\alpha'}$ and $f_\gamma^0$ are the initial fractions of martensite and retained austenite. An analytical expression for $F(U^{\text{max}} - \Delta G^{\text{cr}})$ is obtained.
The transformation plasticity $d^{TP}$ is calculated as [8]:

$$d^{TP} = \dot{f}\alpha\left(\frac{1}{3}\delta I + \frac{3}{2}T\frac{s_{\gamma}}{\sigma_{\gamma M}}\right)$$

(4)

where $\delta$ is the volume change, $s_{\gamma}$ and $\sigma_{\gamma M}$ are the austenite deviatoric and Von Mises stress, $T$ is the amount of shape change and can be calculated analytically.

In figure 1 results from the model are compared to measurements from [9].

References


