Large strain thermo-visco-plastic model for case-hardening steel

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This work is dedicated to a large strain thermo-visco-plastic material description for case-hardening steel, which is an extension of the small strain model [1]. The alloy is commonly used in machine components due to its favorable mechanical properties. Machine parts are frequently exposed to high temperatures and large temperature differences, hence an important part of modeling is thermo-mechanical coupling. Additionally, around 750 °C the material undergoes phase transformation which affects parameter values. This work includes thermal softening, temperature-dependent parameters and thermo-elastic coupling due to the Gough-Joule effect.

The large strain formulation is based on [2], including a Huber-Mises-type yield function with cold work hardening. Moreover, Perzyna-type visco-plasticity is included. Many parameters are temperature dependent, among others elastic moduli, thermal expansion coefficient, heat capacity, heat conductivity, initial and final yield strength and visco-plasticity related parameters. Some of the parameters are fitted using experimental values from literature.

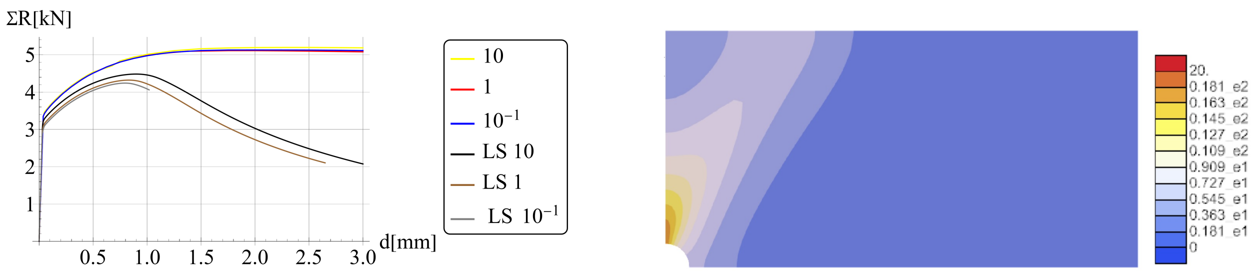

Figure 1: Plate with hole: Sum of reaction forces vs extension for different strain rates (left; strain rate unit in the legend is $1/s$). Diagrams related to Small strain model [1] are depicted with primary colors and results based on the large strain (LS) model with dark colors. Distribution of relative temperature (LS) for $\dot{\varepsilon} = 1/\mathrm{s}$ and d =1mm (right).

Selected numerical examples, including aspects of localization and regularization are computed. Fig. 1 shows a comparison of the diagrams of the sum of reaction forces vs plate extension for different strain rates for the small and large strain models, as well as the distribution of relative temperature for a selected case (large strain, $\dot{\varepsilon} = 1\ \mathrm{s}^{-1}$) and elongation equal to 1 mm. The plate under tension has a rectangular shape and a hole (d) in the middle, [1]. Simulations presented in Fig. 1 are done for initial temperature T_0 equal to 20 °C and 3D model. The computations are performed using AceGen/AceFEM packages of Wolfram Mathematica [3].

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