IDENTIFICATION DES MODELES DE RUPTURE DUCTILE TENANT COMPTE DE L'ETAT DE CONTRAINTE, DE LA VITESSE DE DEFORMATION ET DE LA TEMPERATURE

Dirk Mohr[a], Christian Roth[a], Vincent Grolleau[a,b], Kedar Pandya[a], Xueyang Li[a]

[a]Chair of Computational Modeling of Materials. ETH Zurich, Switzerland, dmohr@ethz.ch
[b]Univ. Bretagne Sud, FRE CNRS 3744, IRDL, F-56100 Lorient, France

Mots clés : Ductile fracture, thermo-visco-plasticity, machine-learning

Résumé

This lecture discusses recent progress on the experimental characterization and modeling of the effects of temperature and strain rate on the plasticity and fracture response of metals. In particular, a recently developed specimen for characterizing the in-plane shear fracture response of sheet metal is used to examine the response of a dual phase steel DP780. Low (0.001/s) and intermediate (~1/s) strain rate experiments are performed on a hydraulic universal testing machine, while high strain rate tests (~1000/s) are carried out on a modified split Hopkinson pressure bar system. Planar digital image correlation as well as (high speed) infrared imaging is used to access the surface strain and temperature fields. An induction system (Fig. 1) is employed to perform temperature experiments ranging from 25°to 1000°C at different strain rates in an attempt to shed some light on the material response under these conditions.

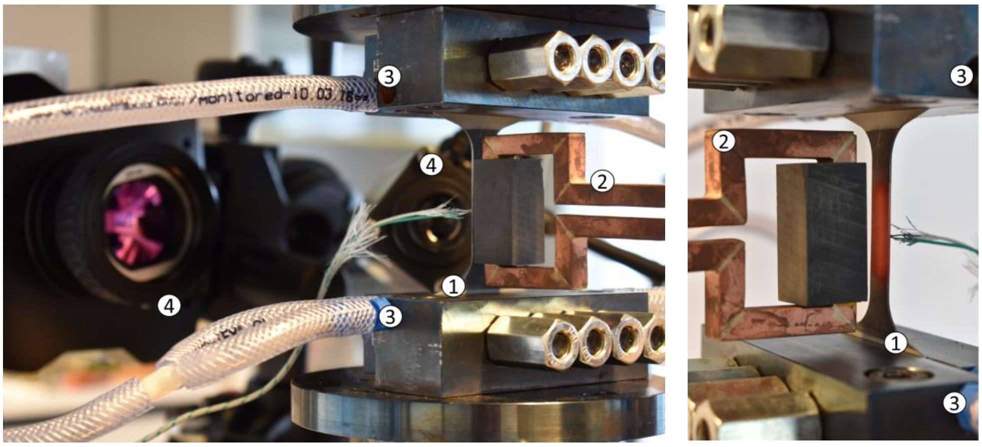

Figure 1. *Experimental setup for high temperature experiments at low and intermediate strain rates on the Instron 8801 hydraulic testing system. ① UT specimen in high pressure clamps, ② inductor for UT specimens, ③ water-cooled clamping system, ④ pyrometer, ⑤ high speed infrared camera/optical camera.*

The material microstructure is examined post-mortem with electron backscatter diffraction (EBSD) microscopy to provide insight into the effect of the strain rate and the temperature on the shear localization at the microscale. In addition to investigating the shear fracture response, an automated testing system (Fig. 2) is used to characterize the material response of DP780 steel at low strain rates. Uniaxial tension tests are carried out for seven different material orientations as well as fracture

experiments along the rolling, diagonal and transversal direction using specimens with different notched cut-outs and a central hole.

Figure 2. *Battery of specimens (left) testing on a custom-made automatic testing system (right)*

A new machine-learning based hardening law is presented which accounts for the non-monotonic effects of temperature and strain rate on the hardening of dual phase steel (Fig. 3). Additional experiments are performed using V-bending and mini-punch specimens to identify and validate the Hosford-Coulomb fracture initiation model for a wide range of stress states. Furthermore, an extension of the fracture initiation model is presented to account for the combined effects of strain rate and temperature on the fracture response. The above experimental program is repeated (up to 500°C) for a 7000-series aluminum alloy. Also the same machine-learning approach is taken to describe the constitutive response of the aluminum alloy.

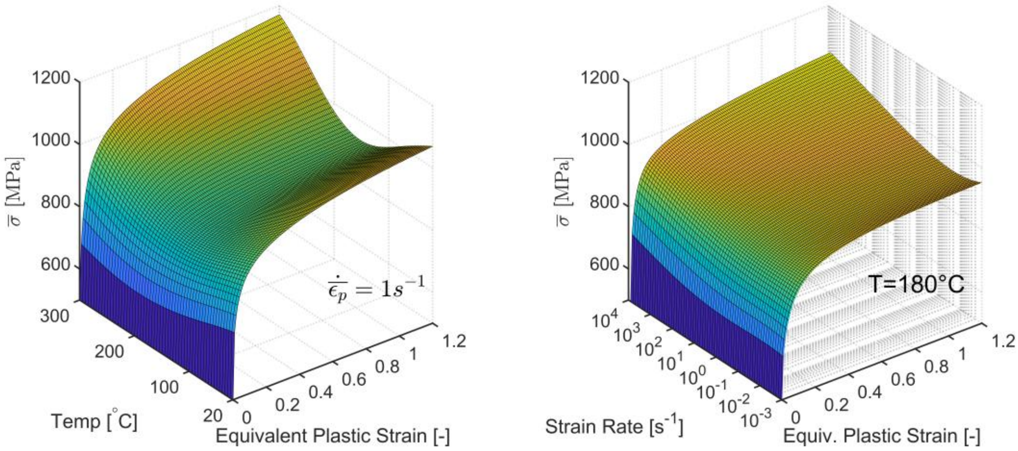

Figure 3. *Visualization of the machine-learning based temperature- and strain-rate dependent hardening law for DP780 steel*

Références

[1] CC Roth, D Mohr, Determining the Strain to Fracture for Simple Shear for a Wide Range of Sheet Metals, International Journal of Mechanical Sciences

[2] Roth C.C., Mohr D. (2014). Effect of strain rate on ductile fracture initiation in advanced high strength steel sheets: Experiments and modeling, International Journal of Plasticity.

[3] X Li, C Roth, D. Mohr, A Machine-Learning Based Modified Johnson-Cook Plasticity Model for Dual Phase Steel.
[4] V Grolleau, CC Roth, V Lafilé, B Galpin, D Mohr, Loading of Mini-Nakazima Specimens with a Dihedral Punch: Determining the Strain to Fracture for Plane Strain Tension through Stretch-bending, International Journal of Mechanical Sciences (under revision).