Investigation of the unique staircase type strain hardening behavior in a medium Mn steel

Achintya Kumar Patra[a], Zoltan Hegedues[b], Norbert Schell[c], Heinz-Günter Brokmeier[d], Sumantra Mandal[e], K.C Hari Kumar[a], V. Subramanya Sarma[a*]

[a]*Department of Metallurgical and Materials Engineering, Indian Institute of Technology Madras, Chennai, India.*
[b]*Deutsches Elektronen-Synchrotron (DESY), Hamburg, Germany*
[c]*Helmholtz-Zentrum Hereon, Geesthacht, Germany*
[d]*Institute for Materials Science and Engineering, Technical University of Clausthal, Clausthal-Zellerfeld, Lower Saxony, Germany*
[e]*Department of Metallurgical and Materials Engineering, Indian Institute of Technology Kharagpur, Kharagpur, India.*
**Corresponding Author- vsarma@iitm.ac.in*

Medium Mn steels are among the most promising candidates among the third-generation AHSS for automotive applications, owing to their enhanced strength and ductility. The superior mechanical properties can be attributed to their extended strain hardening behavior. In the current work, we have designed and developed a medium Mn steel using the CALPHAD approach to optimize parameters such as austenite stability and stacking fault energy [1]. The developed steel shows excellent uniaxial tensile properties with UTS of ~1350 MPa and uniform elongation of ~26%. One of the interesting observations is the presence of a unique staircase-like feature and fine serrations throughout the plastic regime of the stress-strain curve (Figure 1). The staircase-like feature consists of a plateau with negligible strain hardening followed by an abrupt rise in the flow stress. The quantitative characterization of the microstructure evolution during the tensile deformation is of great importance to understanding the strain-hardening behavior [2]. Hence, we have used an in-situ tensile study coupled with high-energy synchrotron X-Ray diffraction to gain better insight regarding the microstructure, defect density, and phase evolution during the uniaxial deformation. Preliminary analysis shows a direct correlation between the austenite/martensite volume fraction and the strain hardening behavior, with the staircase-like feature marked by a dip in austenite fraction, indicating a significant role of the TRIP effect.

Keywords: Medium Mn steels, Alloy design, Strain hardening behavior, Synchrotron X-ray diffraction, TRIP effect

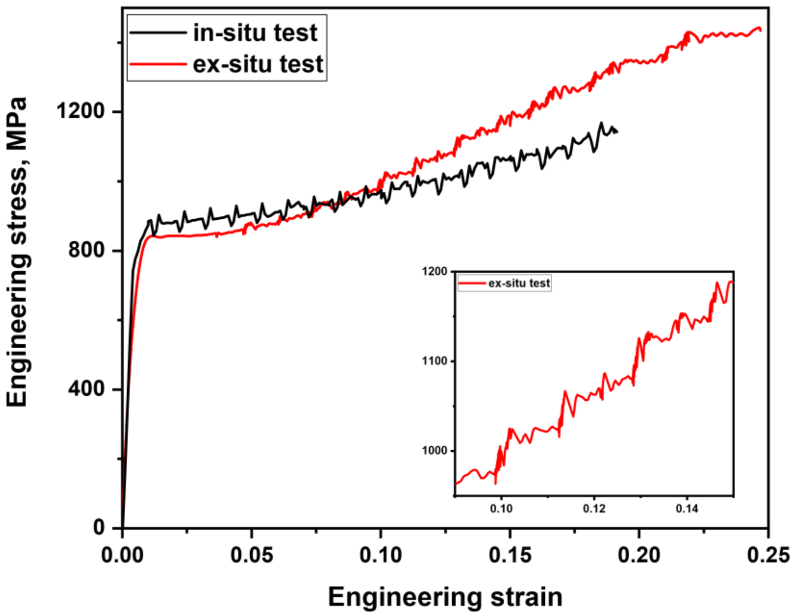

Figure 1: Engineering stress – engineering strain plot of the medium Mn steel sample highlighting the staircase-like features and the fine serrations in the plastic region during the ex-situ test and the in-situ test results at the same crosshead velocity (0.1 mm/s) with the jerks corresponding to the periodic interruptions done to capture the diffractograms.

References:

[1] A.K. Patra, C.N. Athreya, S. Mandal, K.C. Hari Kumar, V. Subramanya Sarma, High strength-high ductility medium Mn steel obtained through CALPHAD based alloy design and thermomechanical processing, Mater. Sci. Eng. A. 810 (2021) 140756. https://doi.org/10.1016/j.msea.2021.140756.

[2] P. Barriobero-Vila, R. Jerez-Mesa, A. Guitar, O. Gavalda-Diaz, J.A. Travieso-Rodríguez, A. Stark, N. Schell, J. Llumà, G. Fargas, A. Mateo, J.J. Roa, Deformation kinetics of a TRIP steel determined by in situ high-energy synchrotron X-ray diffraction, Materialia. 20 (2021) 101251. https://doi.org/10.1016/j.mtla.2021.101251.