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ULCF AND CYCLIC ELASTOPLASTIC BEHAVIOUR OF LINEPIPE STEEL GRADES

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Severe actions applied to pipelines, such as those resulting from accidental loads, soil settlements and landslides, earthquakes, fluctuations of permafrost layers, reeling of pipelines, may induce large plastic deformations, with widespread yielding in the pipelines which may promote monotonic or fatigue failures, for a very low number of load fluctuations ($N_f \leq 100$ cycles). Even though progresses have been made to understand and to model monotonic ductile damage and low-cycle fatigue (LCF), the fatigue damage for very high plastic strain ranges leading to failures for a very low number of cycles is neither sufficiently investigated nor understood. The latter damage mechanism has been called in the literature as ultra-low cycle fatigue (ULCF) or extreme low-cycle fatigue (ELCF) to distinguish it from the LCF or monotonic damage mechanisms.

The characterization of the monotonic and cyclic behaviour under LCF and ULCF regimes of three linepipe steels, namely the X52, X60 and X65 API steels is presented in this paper using small-scale smooth and notched specimens. Usual smooth geometries may show instability under ULCF tension/compression loading even using an anti-buckling set-up. Tension-compression tests of notched specimens and cyclic bending tests of smooth/notched specimens arise as an alternative approach to investigate the ULCF behaviour of these materials. The experimental program was carried out supported with 2D digital image correlation to provide full-field measurements.

Cyclic elastoplastic constitutive models were calibrated for the linepipe materials. The J2 plasticity model with non-linear isotropic/kinematic hardening was calibrated using experimental data, the DIC data being very important for this purpose. Several uncoupled damage models were assessed concerning the LCF and ULCF prediction. In particular, the classical Coffin-Manson relation, the Xue model and the cyclic void growth model (CVGM) proposed by Kanvinde and Deierlein, were assessed. These models were applied to predict the experimental fatigue data. Some model improvements were proposed in order to correct some predictions.