Ultra-low-cycle fatigue of pipeline steels

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Abstract:

Pipelines and piping components when subjected to extreme loading conditions (e.g. earthquakes, hurricanes, support settlements, industrial plant shutdown) undergo large plastic deformations, associated with widespread yielding, leading to fracture, either due to monotonic loading or ultra-low-cycle fatigue (ULCF). ULCF is neither satisfactorily understood nor conveniently investigated compared to the monotonic ductile or low-cycle fatigue damage mechanisms. Having in mind the existing gaps in the knowledge about the ULCF, the ULCF European project, coordinated by FEUP, aimed at developing innovative computational methodologies for the simulation of steel material fracture under both monotonic and ultra-low-cycle fatigue, based on a significant experimental program including small and large-scale tests. This presentation makes an overview of the main results of the project, which includes: i) Database of small-scale testing data covering the X52, X60, X65, X70 and X80 piping steel grades. Smooth and special notched specimens were tested under both monotonic and cyclic (LCF & ULCF) loading. Dedicated monotonic tests were performed to assess the anisotropic behaviour of some materials (X70/X80). Combined multiaxial loading conditions were also investigated. ii) Database of full-scale testing results covering same materials also tested under small-scale conditions was generated. Monotonic and ULCF tests of pipe components were performed. ULCF tests included buckled and dented pipes, elbows and straight pipes. iii) New constitutive models for both monotonic and ULCF loading were proposed. Besides the Barcelona model, alternative approaches were investigated. Further constitutive refinements of non-linear monotonic damage and enhanced anisotropic models, were also studied. iv) Developed constitutive models were calibrated and validated using experimentally derived testing data.