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NUMERICAL SIMULATION OF LOW-CYCLE FATIGUE IN PIPING COMPONENTS USING COUPLED PLASTICITY-DAMAGE MODELS

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OUTLINE

The paper discusses the numerical implementation of a coupled cyclic plasticity-damage model, suitable for large-scale structural computations and simulation of ratcheting and low-cycle fatigue damage in metal components. The theoretical formulation of the numerical scheme is based on J2-plasticity theory with combined nonlinear kinematic/isotropic hardening whereas damage is accounted through an isotropic damage function. A nonlinear kinematic hardening rule with multiple back-stresses is considered, for more accurate simulation of ratchetting. To implement this model within a finite element environment, an implicit integration scheme is developed along with its consistent linearization, capable of incorporating a wide range of isotropic damage functions (Chatziioannou, 2020).

AIM OF STUDY

The above numerical scheme is applied for the accurate simulation of physical experiments on large-scale piping elbows subjected to severe cyclic loading that leads to low-cycle fatigue failure. The finite element analyses are conducted using mixed pressure/displacement finite elements, while the damage function is properly regularised within the proposed numerical scheme according to the element's characteristic length to account for size effects (Chatziioannou, K. et al. 2021). Using this formulation, mesh dependency effects are alleviated, and consistent numerical results are obtained using four meshes of different density..

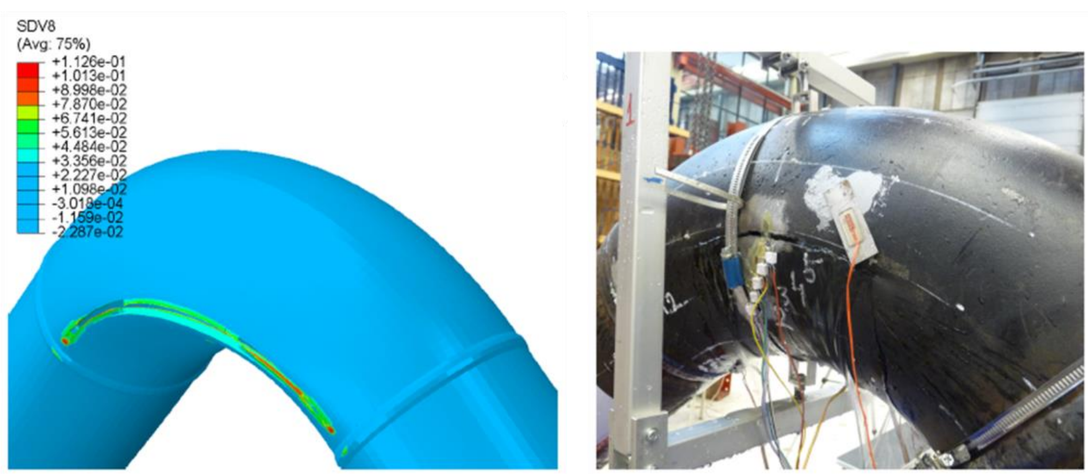

Figure 1. Comparison of present numerical results with experimental data on pipe elbows (Pappa et al. 2012).

CONCLUSIONS

Favourable comparisons between experimental and numerical results are obtained in terms of the structural response, the local strains and the number of cycles to develop through-thickness cracking (Figure 1). This good comparison shows that, upon proper calibration, the coupled model can be used for predicting the response of metal structural components under severe cyclic loading, simulating the gradual material degradation over the loading cycles. Issues related to the type of isotropic damage functions suitable for cyclic loading applications are also discussed.

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