ULTIMATE CAPACITY OF CYCLICALLY-LOADED STEEL PIPES FOR OFFSHORE PIPELINE APPLICATIONS

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ABSTRACT

Thick-walled steel pipes during their installation in deep-water are subjected to combined loading of external pressure and bending, which may lead to pipe collapse due to excessive pipe ovalization with catastrophic effects [1]. In particular, the reeling installation method, a popular installation process, induces strong cyclic strain in the pipe material, well into the inelastic regime, resulting in residual stresses and deformations, which undermine the structural capacity of the pipe. The present study, using advanced material tools, examines the effect of reeling on the structural response and resistance of seamless steel pipes during the reeling installation process.

The constitutive model under consideration adopts an enhanced form of the nonlinear kinematic hardening rule, initially proposed in [2]. Assuming von Mises plasticity, the yield surface is:

$$F = \frac{1}{2}(\mathbf{s}-\mathbf{a})\cdot(\mathbf{s}-\mathbf{a}) - \frac{k^2}{3} = 0$$

where $\mathbf{s}$ is the deviatoric stress tensor, $\mathbf{a}$ is the “back stress” tensor and k is the size of the yield surface. The value of k is a function of equivalent plastic strain ε_q representing material hardening, so that $k = k(\varepsilon_q)$, and the evolution of back stress tensor is:

$$\dot{\mathbf{a}} = C\dot{\boldsymbol{\varepsilon}}^p - \gamma \mathbf{a}\dot{\varepsilon}_q$$

where $\dot{\boldsymbol{\varepsilon}}^p$ is the plastic strain rate tensor, and C, γ are parameters calibrated from cyclic test data. In the present formulation to account for the smooth transition from elastic to plastic response (Bauschinger effect), C is assumed a function of equivalent plastic strain ε_q' accumulated at each plastic loading step, so that $C = C(\varepsilon_q')$. Moreover, adopting a modification of the original model, as proposed in [3], it is possible to describe the plastic plateau of the stress-strain steel material curve, as well as the Bauschinger effect, in an accurate and efficient manner. The constitutive model has been implemented in a material user-subroutine (UMAT) for ABAQUS/Standard, using an “elastic predictor – plastic corrector” Euler- backward numerical integration scheme.

Using the finite element models, an extensive parametric analysis is conducted, with emphasis on the effects of reeling process on the ultimate capacity of the pipe under combined loading of external pressure and bending. The numerical results show that reeling-induce strains may have a decisive role in both external pressure capacity and bending deformation capacity of the pipe.

REFERENCES

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