

Numerical Simulation of Buckling Resistance for UOE Line Pipes with Orthogonal Anisotropic Hardening Behavior

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ϵ_{comp} : compressive strain

ϵ_{limit} : compressive strain limit

θ : angle of inclination at pipe end, rad

ABSTRACT

Strain capacity is required for buried line pipes to endure ground movement. A constitutive model with anisotropic strain-hardening behavior is proposed in order to analyze the deformation behaviors of UOE pipes accurately. Finite element analysis (FEA) of the pipes using the developed constitutive model has revealed that the aspect of strain-hardening behavior in the circumferential direction significantly affects the buckling resistance of a pipe subjected to bending moment in high internal pressure and high diameter/thickness (D/t) pipes.

KEYWORDS: line pipe; UOE pipe; buckling; strain limit; thermal aging; work hardening; anisotropy; yield function

NOMENCLATURE

C: circumferential

D: pipe diameter, mm

D_A : average diameter, mm

D_B : minimum diameter, mm

D_C : maximum diameter, mm

L: pipe length, mm

L: longitudinal

P_i : internal pressure, MPa

SMIP: specified minimum internal yield pressure

S-S: stress-strain

t: wall thickness, mm

TS: tensile strength, MPa

uEL: uniform elongation

YPE: yield point elongation

YS: yield strength, MPa

Y/T: YS/TS

α : geometric imperfection

INTRODUCTION

Pipelines buried in discontinuous permafrost are subjected to repeated bending load under internal pressure, caused by frost heave and subsidence. Seismically, ground movement generates the excessively high bending and axial loading beyond the yield strength of the pipe body. In such fields, a pipeline design method, so-called strain-based design (SBD), allows for the plastic deformation of the pipe bodies (Glover, 2004, Barbas, 2007).

The buckling resistance and the joint integrity of the girth weld should be required for the line pipes used in SBD. The buckling resistance under the bending is often represented by the compressive strain limit calculated from the angle of inclination at the peak moment. On the other hand, the tensile strain limit of the girth weld is evaluated using the remote strain on the strain demand in the pipeline design.

In order to determine these strain limits, the full size pipe bending test and the curved wide plate tests were performed (Gioielli, 2007, Fairchild, 2007, Wang, 2007). Finally, the numerical simulations using finite element analysis (FEA) are utilized for specifying the effective mechanical properties in the pipes, checking the predicted values against the experimental results.

Recently, the detailed mechanical properties of UOE line pipes in practical use have been discussed for investigating the high reliability of SBD. Firstly, the pipe strengths are changed by heating during the anti-corrosion coating process (Timms, 2005). These studies describe the high yield strength to tensile strength ratio (Y/T) and the yield point elongation (YPE) after heating can degrade the strain capacity of the line pipe. Secondly, the strengths in UOE pipes are distributed by the plastic strain developed in the pipe forming process, so the strain capacity under the bending moment is dependent on the loading orientation (Shinohara, 2005, Tsuru, 2007). Thirdly, the strength is different between the longitudinal (L-) direction and the circumferential