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Strain Capacity of 48"-OD X80 Pipeline in Pressurized Full-scale Bending Test

Satoshi Igi, Takahiro Sakimoto, Hisakazu Tajika, Seishi Tsuyama and Shigeru Endo
Steel Research Laboratory, JFE Steel Corporation Chiba, Chiba, Japan

Ryuji Muraoka
West Japan Works, JFE Steel Corporation Fukuyama, Hiroshima, Japan

Nobuhisa Suzuki
JFE Techno-Research Corporation Kawasaki, Kanagawa, Japan

This paper presents the results of experimental studies focused on the strain capacity of X80 linepipe. A full-scale bending test of X80 grade, girth-welded 48" high-strain linepipe pressurized to 60% SMYS was conducted to investigate the compressive strain limit and tensile strain limit. The compressive strain limit focused on the critical strain at the formation of local buckling on the compression side of bending. One large developed wrinkle and some small wrinkles on the pipe surface during bending deformation were captured relatively well from observation and strain distribution measurement. The tensile strain limit is discussed from the viewpoint of competition of two fracture phenomena: ductile crack initiation/propagation from an artificial notch at the HAZ of the girth weld, and strain concentration and rupture in the base material at the tension (opposite) side of the local buckling position. A curved wide plate (CWP) test and full-pipe tension test were also conducted to investigate the tensile strain capacity of the girth-welded joint under tensile load using relatively small diameter X80 pipeline. Crack initiation and propagation behavior was clarified satisfactorily by sectional observation of the surface notch at the HAZ of the welded joint. Tensile fracture limits related to the maximum load are discussed from the viewpoint of the effect of internal pressure by comparing the CWP and full-pipe tension test results.

INTRODUCTION

There has recently been growing demand for higher grade linepipe that can help reduce the total cost of long-distance gas pipelines. As a result, use of high-strength linepipe, such as API X70 and X80 grades, has been increasing in recent years (Masuda et al., 2004; Wang and Pan, 2004). API X100 and X120 linepipes have been the object of continuing development (Glover et al., 2003, 2004; Petersen et al., 2004), and many research and development projects have been carried out around the world. On the other hand, pipeline projects have expanded into environmentally severe regions such as permafrost and seismic regions. In particular, East Asia and North America are regions where large ground displacement can be induced by earthquake or permafrost movements. Linepipe constructed in those regions must have sufficient resistance against failures caused by bending or compressive deformation of pipes, such as local buckling or weld fractures. Because the conventional stress-based design method cannot be applied when strain greatly exceeds the yield stress of the material, application of strain-based design (SBD) is under active study. Assuming bending deformation of the pipeline, the key parameters for SBD of pipelines are local buckling of the pipe itself on the compression side of bending and the critical strain for fracture from defects, particularly in girth welds, on the tension side of bending. The tensile strain capacity of a pipeline is usually characterized using uniaxial tests such as the curved wide plate (CWP) test (Denys et al., 2004). Accordingly, the most critical fracture mode in pipelines is considered to be ductile fracture originating from defects in girth welds. A method of predicting ductile crack initiation in the CWP test has been proposed using the critical equivalent plastic strain at the notch tip obtained from SENT tests (Sadasue et al., 2004). The tensile strain capacity for ductile crack initiation decreases as the Y/T ratio of the base metal increases (Igi and Suzuki, 2007).

There is also increasing demand for high pressure operation to improve gas transportation efficiency. However, CWP tests cannot consider the effect of internal pressure in strain capacity evaluations. Therefore, it is important to investigate the effect of internal pressure on ductile fracture behavior. Full-scale pressurized and unpressurized tensile tests using X65 ERW pipe and welds have been conducted to investigate the influence of internal pressure on the tensile strain capacity of pipelines (Gioielli et al., 2007; Minnaar et al., 2007). Full-scale pressurized tensile tests using X80 high-strain pipe with girth welds have been conducted to investigate the influence of internal pressure on the tensile strain capacity of pipelines by comparison with CWP test results (Igi et al., 2010). These tests indicated that internal pressure does not seem to affect the ductile tearing resistance curve. However, the tensile strain capacity is reduced due to the influence of internal pressure.

Against this background, this paper presents the results of experimental studies focused on the strain capacity of X80 linepipe. A full-scale bending test of X80 grade, girth-welded 48" high-strain linepipe pressurized to 60% SMYS was conducted to investigate the compressive strain limit and tensile strain limit.

STRAIN CAPACITY OF GIRTH WELDED JOINT OF X80 LINEPIPE UNDER BENDING DEFORMATION

Full-scale Bending Test Rig

A large-scale bending rig was developed in order to verify the bending capacity of high-strength linepipes up to 48 inches

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