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Effect of Crack Geometry and Tensile Properties on Tensile Strain Limit of X80 Linepipe

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ABSTRACT

Construction of gas transmission pipelines is expanding to severe environmental area such as seismic or permafrost region. This paper presents the preliminary studies performed with curved wide plate test focused on the tensile strain limit of X80 girth welded linepipe which will be used in such regions. Three dimensional elastic-plastic finite element analyses (FEA) are also conducted to obtain the equivalent plastic strain at the notch tip which is used for critical parameter of ductile crack initiation. The critical equivalent plastic strain for ductile crack initiation is obtained from the single edge notched tension test and the FEA.
In this paper, curved wide plate tests of specimens having defects in the heat affected zone (HAZ) of girth welded joints and a parametric study by FEA were carried out, focusing on the tensile strain limit for ductile crack initiation as a early stage of ductile fracture. In particular, the effects of material tensile properties, strength matching, crack dimensions, plate thickness and the width of HAZ on the relationship between the critical equivalent plastic strain at the crack tip for ductile crack initiation and the global strain were investigated by using curved wide plate model.

KEY WORDS: Strain based design, High strength linepipe, Strain limit, Curved wide plate test, Girth weld fracture

INTRODUCTION

Increasing energy demand in recent years, natural gas pipelines are now being constructed in severe environments such as seismic or permafrost region. In these regions, it can be expected that buried pipelines will be subjected to large plastic strain due to ground movement associated with repeated thawing and freezing of the discontinuous permafrost area, earthquakes, and so on (Cayz, 2003).
In recent large-scale projects, use of high strength linepipe of grades X80 or higher has been planned in natural gas pipeline projects in these regions because of increasing transportation efficiency and reducing welding costs (Glover, 2003). It is not possible to apply conventional stress-based design methods or integrity assessment methods in cases where a pipeline is subjected to large plastic strain that greatly exceeds the yield stress of the pipe material. A number of studies have been carried out on developing new design so-called "strain-based design (SBD)" methods and integrity assessment methods for the high strength linepipe is subjected to SBD by the PRCI (Pipeline Research Council International), EPRG (European Pipeline Research Group), and other research groups (Mohr, 2004, 2006, Wang, 2002, 2007, Denys, 2004).
In the case of pipelines subjected to bending large deformation, the important parameters for pipeline design and integrity assessment are local buckling of the pipe body on the compression side of bending, and the tensile fracture at girth welded joint from existing defects on the tension side of that (Suzuki, 2007, Igi, 2007). As for the study of critical tensile strain, uniaxial tensile tests using a curved wide plate (CWP) specimen have been carried out by many researchers including Ghent University because of the difficulty of the tension or bending tests using full pipe specimen with internal pressure applied (Denys, 1990). With the CWP test, the tensile limit strain corresponding to the maximum tensile strength can be obtained comparatively simply using a test specimen cut out from girth welded joint. However, the tensile limit strain is sometimes unclear because the slope of the stress-strain (S-S) curve of the material decreases gradually in the stage where tensile stress approach to ultimate tensile strength and limit strain corresponds to the point when this reaches zero.
Furthermore, CWP test have been mainly conducted using the specimen which a defect is introduced in the center of the welded metal. The effects of defect dimensions and strength matching of the weld metal and base material on the strain capacity of pipeline have to be investigated using the specimen which a defect is introduced in HAZ where toughness and strain concentration are of greatest concern.
Based on this background, in this paper, CWP tests of specimens having defects in the HAZ of girth welded joints and a parametric study by FEA were carried out, focusing on the tensile strain limit for ductile crack initiation as a early stage in ductile fracture. In particular, the effects of material tensile properties, strength matching, crack dimensions, plate thickness and the width of HAZ on the relationship between the critical equivalent plastic strain at the crack tip for ductile crack initiation and the global strain were investigated by using curved wide plate model.