Development of A High Strength Steel Line Pipe for Strain-based Design Applications

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ABSTRACT.
A strain-based design has been widely discussed in recent years, particularly for the use of high strength steel line pipes. Line pipes for strain-based design applications are required to have not only good toughness and weldability but also high deformability such as low yield to tensile strength (Y/T) ratio, high work hardening rate (n-value) and high uniform elongation (U.El).

We studied how to simultaneously improve toughness and deformability in high strength steel line pipes through laboratory research. In addition, we considered the means to control change in the mechanical properties by thermal aging during anti-corrosion coating treatment.

Basic study in a laboratory indicated that a dual phase microstructure, which consists of bainite and fine polygonal ferrite, was effective for simultaneously improving deformability and toughness instead of bainite single microstructure. We confirmed the optimized volume fraction and grain size of polygonal ferrite to achieve excellent elongation, Y/T ratio and DWTT property to line pipes for a strain-based design application. Moreover, the basic study revealed that the accelerated cooling condition in hot rolling absolutely correlated with thermal aging during the coating treatment and that reduction in the solute carbon content in steel was the most effective way to suppress strain aging.

Based on the experimental results, we experimentally manufactured X80 UOE pipes for strain-based design applications, which had a low Y/T ratio, high uniform elongation, good Charpy impact and DWTT properties, in a commercial mill.

KEYWORDS: line pipe; UOE pipe; high strength steel; deformability; toughness; thermal aging

INTRODUCTION
A strain-based design has been discussed for pipeline construction in discontinuous permafrost areas (Glover, 2002). A strain-based design aims to prevent any fracture of the pipe for its plastic deformation due to ground movement. For strain-based design, we need to consider the tensile strain limit and the compressive strain limit. The relation between the pipe and the girth weld properties is important for the tensile limit. We need to estimate the allowable defect size and required toughness (Denys, 1994) and then control the yield strength (YS) and stress-strain (S-S) curve shape to achieve an overmatch of the girth weld strength.

The compressive strain limit is affected by many factors such as operation conditions, pipe size and mechanical properties in the longitudinal direction of a pipe (Glover, 2004). The Y/T ratio, U.El and stress-strain (S-S) curve shape affect the compressive strain limit and thus it is important to control these properties.

A line pipe is normally coated for corrosion protection. The use of a fusion bonding epoxy (FBE) type has increased while there are many types of coating treatment methods. In the case of an FBE coating application, a pipe is heated at 200°C and higher. The coating treatment causes thermal aging because of cold pipe forming (Shinohara, 2005; Timms, 2005). The mechanical properties such as Y/T ratio, YS, FS at lower strain and S-S curve shape also change due to thermal aging.

In this paper, we studied how to simultaneously improve toughness and deformability in high strength steel line pipes through laboratory research. In addition, we considered the means to control change in mechanical properties due to thermal aging during anti-corrosion coating treatment.

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