

Development of High Deformability Linepipe with Resistance to Strain-aged Hardening by Heat Treatment On-line Process

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Linepipes installed in permafrost ground or seismic regions, where larger strains can be expected by ground movement, are required to have sufficient deformability in order to prevent local buckling or girth weld fracture. Also required is resistance to strain-aged hardening by external coating heat. High deformability linepipe with high resistance to strain-aged hardening, with a bainite and martensite-austenite constituent (MA) microstructure, has been developed by applying a heat treatment on-line process (HOP). Trial production of X70 to X100 high deformability linepipes was conducted by applying the HOP process. This paper introduces microstructural characteristics and mechanical properties of developed linepipes.

INTRODUCTION

In recent studies, it is indicated there are significant economical advantages to using higher-strength linepipes in constructing long distance pipelines, because it is possible to improve transportation efficiency by increasing internal pressure, and to reduce material costs. By using thinner materials, total tonnage of materials and consumables for girth welding can be reduced. On the other hand, construction of pipelines has been expanded to severe-climate regions, such as a cold region, a seismic region, and a deepwater and sour gas environment. In addition to high strength, various material properties are required, such as high toughness, high deformability and sour resistance property. One of the most challenging fields for pipeline developments can be seismic and permafrost regions. In these, large plastic deformation is expected to be induced to pipes by ground movement.

Recently, new design methodology has been developed, the so-called strain-based design for pipeline engineering for seismic and permafrost regions (Zimmerman, 1995). According to this new concept, higher resistance of linepipes to larger compressive and tensile strains is required. Buckling is a critical failure event in compressive deformation, and enough resistance to buckling is needed for linepipes. Fig. 1 shows the relationship between maximum buckling strain and pipe diameter-to-thickness ratio for conventional pipes (Suzuki, 1999).

Generally buckling behavior depends strongly on pipe dimensions. Buckling strain decreases with an increasing D/t ratio, and thicker pipe needs to be used for a large ground movement field. Further, higher-strength material generally has lower uniform elongation, which means lower deformability. These are opposite trends to take advantage of higher-strength linepipes: A thinner

pipe wall gives material cost benefit. Hence, high strength linepipe with higher deformability, which means higher resistance to buckling, needs to be developed in order to take advantage of higher-strength linepipes in seismic and permafrost regions.

The deformability of steel pipes is improved by increasing the strain hardenability of the steel. It has been indicated that pipes with a higher n -value and a roundhouse-type stress-strain curve have a higher buckling strain (Suzuki, 1999). Strain hardenability is strongly affected by the steel's microstructure; steels with larger strain hardenability can be obtained by dual-phase microstructure, which consists of a softer phase and a harder phase. To clarify the optimum microstructural morphology, an analytical study was conducted (Huper, 1999, Okatsu, 2005). It was suggested that the n -value is increased with increasing the strength difference with a matrix phase and a second phase, which means that steels with a harder second phase have higher deformability.

On the other hand, prevention of corrosion damage is an important issue, because it may cause leakage of gas or a fatal accident. Generally, to protect pipes from corrosion damage, a thicker external coating, such as fusion bond epoxy (FBE), is applied. During the pipe coating process, pipes are heated to the temperature range of melting coating materials. A recent study indicated

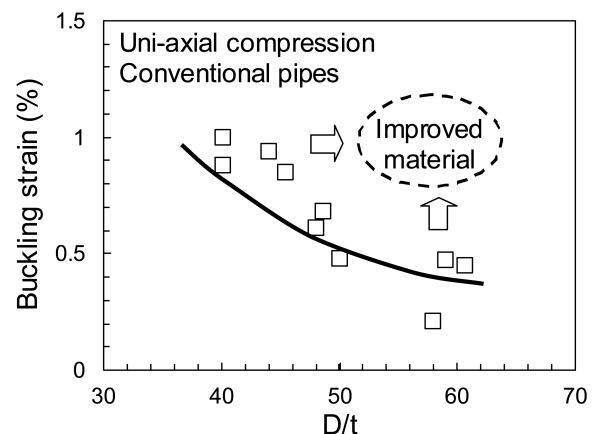


Fig. 1 Relationship between buckling strain by axial compression and pipe diameter-to-thickness ratio (D/t)

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KEY WORDS: High strength linepipe, deformability, dual-phase microstructure, martensite-austenite constituent (MA), external pipe coating, strain-aged hardening, heat treatment on-line process (HOP).