ABSTRACT

Application of high-strength line pipe is beneficial for the reduction of the cost of gas transmission pipelines by enabling high-pressure operation. Long-distance gas transmission pipelines from remote areas sometimes pass through discontinuous permafrost, seismic and land slide and are subject to ground movement by repeated thaw subsidence and frost heave. For such a case, highly deformable line pipe is required for strain-based design. Therefore, to meet these requirements, high-deformable line pipe is required for strain-based design. Nippon Steel Corporation has also developed highly deformable, high-strength line pipe material from X60 to X100 line pipes suitable for strain-based designs. Material design for highly deformable line pipe and the development of X60 and X100 highly deformable line pipe has been described. (Terada, 2003; Terada, 1997; Terada, 2004; Shinohara, 2005; Shinohara, 2006; Shinohara, 2008)

KEY WORDS: strain-based design, line pipe, thermal aging, mechanical properties, deformability, arrestability

INTRODUCTION

The demand for natural gas using pipelines and LNG to supply global gas markets is increasing as a substitute for oil and coal. The use of high-strength line pipe steel reduces the cost of gas transmission pipelines by enabling high-pressure transmission of gas in bulk. Long-distance gas transmission pipelines from remote areas sometimes traverse discontinuous permafrost, seismic and land slide and are subject to ground movement by repeated thaw subsidence and frost heave. For such a case, strain-based design has been applied. Therefore, highly deformable line pipe is required to prevent pipelines from fracturing (Glover, 2002; Denys, 1994; Denys, 2004; Glover, 2004; Hillenbrand, 2002; Liessem, 2004; Al-Sharif, 1996). There are two critical strain limits for strain-based designs. One is the tensile strain limit; the other is that of compressive strain limit. For the tensile strain limit, a critical strain to prevent the line pipe from buckling is required when the pipeline is exposed to bending pressure. Generally, a tensile strain limit is required considering the defect size and misalignment of the girth weld portion. The girth welds matching the base metal in a longitudinal direction is effective for achieving a high tensile strain limit. It is well known that yield strength increases by thermal aging during pipe coating. Therefore, a narrow range of base metal strength before and after thermal aging is required. On the other hand, for the compressive strain limit, a critical strain to prevent the line pipe from buckling is required when the pipeline is exposed to bending. The compressive strain limit correlates with the work-hardening ratio (n value), the yield-to-tensile ratio (Y/T), and the uniform elongation (U.I) of the base metal. With this in mind, a high n value, a low yield-to-tensile ratio, and a high uniform elongation for the base metal are required to obtain a high compressive strain limit. Therefore, to meet these requirements, high-deformable line pipe is required for strain-based design. Nippon Steel Corporation has also developed highly deformable, high-strength line pipe material from X60 to X100 line pipes suitable for strain-based designs. Material design for highly deformable line pipe and the development of X60 and X100 highly deformable line pipe has been described. (Terada, 2003; Terada, 1997; Terada, 2004; Shinohara, 2005; Shinohara, 2006; Shinohara, 2008)

In recent years, API grade, X60-to-X70 line pipe are required for the Far East pipeline project, the Myanmar project, the Papua New Guinea project, and the Arkutun Dagi project. As mentioned above, Nippon Steel Corporation has been developing API grade, X60-to-X70 highly deformable line pipe suitable for strain-based design. In order to obtain enough deformability, dual-phase material is important, while the optimization of the volume fraction of the soft and hard phase is also important. For example, high work-hardening is obtained with increasing volume fractions of ferrite and M-A (martensite-austenite constituent). In case of API grade, X60-to-X70 line pipe, ferrite is easy to form because small amounts of alloying elements are added, compared with API grade X80 or higher. As a result, the banded structure is also easy to form. It is also reported that the banded structure deteriorates low temperature toughness. The banded structure is defined that soft phase and hard phase transformed from deformed austenite was formed as lamellar in the parallel rolling plane. In this study, deformability, crack initiation resistance and crack arrestability of X60-to-X70 line pipe with banded structure and with fine dual phase microstructure was compared respectively.

METALLURGICAL DESIGN OF HIGHLY DEFORMABLE, HIGH-STRENGTH LINE PIPE

General specification of highly deformable, high-strength line pipe