Proceedings of the Eighteenth (2008) International Offshore and Polar Engineering Conference
Vancouver, BC, Canada, July 6-11, 2008

ISBN 978-1-880653-70-8 (Set); ISBN 1-880653-68-0 (Set)

Mechanical and Metallurgical Properties of Grade X80 High Strain Linepipe Produced by Heat Treatment On-line Process

Nobuyuki Ishikawa[1)], Mitsuhiro Okatsu[1)], Shigeru Endo[1)], Nobuo Shikanai[1)], Ryuji Muraoka[2)] and Joe Kondo[2)]
[1)] Steel Research Laboratory, JFE Steel Corporation, Kurashiki, Okayama, Japan
[2)] West Japan Works, JFE Steel Corporation, Fukuyama, Hiroshima, Japan

ABSTRACT

Linepipes for high strain application, which used in seismic or permafrost regions, are required to have sufficient deformability in order to prevent buckling or weld fracture caused by compressive, tensile, or bending deformation of the pipe induced by large ground movement. Extensive efforts have been made for developing high strain linepipes which has lower Y/T ratio and higher strain hardenability. Dual phase microstructure control is one of the key technologies for obtaining higher deformability, and high strain linepipe with bainitic microstructure and dispersed MA constituents was developed by applying heat treatment online process (HOP). HOP applied linepipe has superior deformability as well as strength and toughness.

On the other hand, many stringent requirements other than tensile properties are imposed on recent high grade linepipes, such as Charpy energy, DWTT toughness, weldability, and so on. Especially, higher Charpy energy is needed for higher strength linepipe in order to prevent running ductile fracture driven by higher internal pressure. Precise material control is needed to increase Charpy energy of the steels with dual phase microstructure which usually shows lower Charpy energy than single bainitic microstructure. Plate rolling and online heat treatment conditions are also optimized for obtaining higher deformability and sufficient DWTT toughness. In this paper, mechanical properties of Grade X80 high strain linepipe which is produced by applying HOP process were introduced in terms of balancing strength, deformability, Charpy energy, DWTT toughness, and so on. Metallurgical features of this developed linepipe are also presented in comparing to conventional high strain linepipe without applying HOP process.

KEY WORDS: Strain based design, High strength linepipe, High strain, Dual-phase microstructure, Martensite-austenite constituent (MA), Heat treatment On-line Process

INTRODUCTION

There has recently been a growing demand for higher grade linepipes that can help reduce the total cost of long-distance gas pipelines. The application of high-strength linepipes such as API X70 and X80 grades has therefore been increasing in recent years (Masuda et al, 2004; Wang and Pan, 2004). Developments have been continuously conducted for API X100 and X120 linepipes (Glover et al., 2003, 2004; Petersen et al., 2004; Marchesani et al, 2005), and many research and development projects had been carried out in the world. On the other hand, pipeline developments have been expanded toward environmentally severe regions such as permafrost and seismic regions. Especially, East Asia and North America are the regions where severe ground displacement can be expected by earthquake or permafrost movements. Linepipes installed in those regions must have sufficient resistance against the failures caused by bending or compressive deformation of pipes, such as local buckling or weld fractures.

In order to design the pipelines installed in seismic or permafrost regions, new design methodology, so called “strain-based design”, has been developed (Denys et al., 2000; Wang et al., 2002, 2007; Ishikawa et al., 2004; Suzuki et al., 2002, 2004). Limit state of the pipeline under displacement-controlled loads is given as the point where “strain demand”, which is defined by the strain imposed to the pipe body by ground movement or other load, exceeds “strain capacity” of the pipeline. Strain capacity for both compressive and tensile deformation need to be determined for the strain based design. For investigating the compressive strain limit, experimental and analytical studies for pipe buckling were conducted and several formulations for compressive strain limit were proposed. Same as the compressive strain limit, many studies on tensile fracture of pipe girth welds were carried out. In order to simulate the tensile fracture of girth welds, curved wide plate tensile testing with weld flaw was conducted. Analytical study on the curved wide plate test was usually accompanied with the experiment to evaluate the driving force for tensile fracture and the effect of geometrical and material factors. Many studies on both compressive and tensile strain limits revealed that deformability of the pipe materials which is parameterized by yield to tensile ratio (Y/T), strain hardening coefficient (n), or uniform elongation (uEl) is important to improve strain capacity of pipeline. Therefore, using the linepipe with higher deformability is the essential process in the strain based design.

High deformability linepipe was first developed for the application of the gas pipeline installed in seismic area (Endo et al., 2000, 2002). Stress-strain behavior of the linepipe steel was controlled by dual phase microstructure. Higher strain hardenability and lower Y/T ratio was achieved by ferrite-bainite microstructure, and higher resistance against buckling was demonstrated by compression and bending test of the pipe. Ferrite-bainite microstructure can be obtained by applying controlled rolling and accelerated cooling process in plate