Mechanical Properties and Microstructure of Welding Joint for High Strength-toughness Line Pipe

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ABSTRACT

In recent years, Low carbon line pipes with high strength and toughness have been widely used in the field of petroleum and natural gas transportation over a long distance. Diameters and strength of line pipes have been continuously increased in order to improve the transportation efficiency of line pipes. Weldability is a key factor in the application of high strength line pipes. In present paper, Mechanical properties and microstructure of a high strength-toughness line pipe are investigated. The pipe presented the excellent weldability. The base metal of experimental pipe has high tensile strength with 823MPa and 279J impact toughness at 263K, respectively. Moreover, its heat affected zone (HAZ) also has 210J impact energy at 263K. The outstanding weldability of the pipe is derived from the characteristic microstructure. Microstructure of base metal for the pipe is the ferrite-bainite dual-phase (DP) microstructure. The ferrite of dual-phase microstructure displays polygonal shape with the dislocation substructure at grain boundary. The bainite of dual-phase microstructure is consisted of amount of laths with the width of about 200-300nm, and most laths display parallel arrangement. Microstructure of CGHAZ is consisted of the fine granular bainite and lath-like bainite. General microstructure of CGHAZ is massive substructure and higher dislocation intensity. Fine equiaxed ferrite is the characteristic microstructure of FGHAZ. The microstructure of weld metal displays the fine acicular ferrite. Some spherical particles are observed in the ferrite matrix. A great deal of nanometer precipitates and high intensity dislocation substructure are observed in the microstructure of the pipe.

KEY WORDS: line pipe; Weld metal; HAZ; Microstructure; mechanical property.

INTRODUCTION

Low carbon pipeline steels with high strength and toughness have been used widely to transportation of crude oil and natural gas over a long distance under high pressure (Witek, 2015; Eskandari, 2016; Zhong, 2006). In order to improve the transportation efficiency, the diameter and transportation pressure of line pipe has been continuously increased recent years, and the strength of pipeline steels have also been improved (Zhang, 2010; Shanmugam, 2008; Ghajar, 2015). Large-diameter pipe lines have been a trend of pipeline construction in future (Graf, 2003). Large-diameter line pipes not only require excellent mechanical properties, but also require good resistance to hydrogen-induced blister cracking and stress corrosion cracking resistance in sour service environment (Fallahmohammadi, 2014; Contreras, 2012; Roffey, 2014). Outstanding weldability also is an essential characteristic for high strength pipeline steels owning to the increase of cracking sensitivity of line pipes with the grade of pipeline steels increases (Barsanti, 2001).

Mechanical properties of welding joint for line pipe not only depend on the chemical compositions of line pipe, but also have an import relationship with its matrix microstructure. Line pipes with ferrite and bainite dual-phase (DP) microstructure exhibit high uniform elongation (UEL), larger work hardening exponent and low yield strength (YS)/tensile strength (TS) ratio (Barsanti,2001; Ishikawa, 2015; Zhang, 2013). The DP line pipe has been generally used at Seismic zone or fault zone. However, mechanical properties and microstructural evolution of welding joint have not been adequately investigated for large diameter DP line pipe.

MATERIALS AND METHODS

X100 pipeline steel was produced by special processes to obtain outstanding mechanical properties and special microstructures. The steel was melted in a 240t converter furnace and refined in Ladle furnace to decrease the contents of harmful elements, and then casted continuously into casting slabs. And then the slabs were rolled to plates with 17.8 mm thickness in a hot continuous rolling mill. A special rolling process was used with certain air cooling relaxation time after finish rolling in order to obtain the dual-phase microstructure, and then cooled by the accelerated cooling method. Lastly, the steel plates were used to manufacture φ1219 diameter straight seam welded pipes using proportional-integral-derivative (PID) automatic controlling continuous J-C-O forming technology and double-sided submerged arc welding process. The welding process had the advantages of high speed, low stress distribution and low tolerance of size. The chemical composition