Development of Grade X80 Heavy Gauge Linepipe for Extremely Low Temperature Service

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ABSTRACT

Grade X80 with 29.6mm thick linepipe with excellent low-temperature toughness down to -45 degrees C or less was developed. Good balance of Drop Weight Tear Test (DWTT) properties applicable to the design temperature of -45 degrees C and high Charpy V-Notched (CVN) absorbed energy of approximately 250J were achieved by a microstructure control. DWTT 85% transition temperature of this developed pipe was -65 degrees C or less and CVN absorbed energy at -85 degrees C remained high. In the developed pipe, substantial separation was not formed, although slight separation was observed after DWTT. It can be considered that the excellent properties were obtained due to the suppression of separation. The suppression of separation was achieved by a microstructure control. Fine ferrite-bainite microstructure including few deformed ferrite grains was formed in the developed pipe by the optimized TMCP condition.

KEY WORDS: linepipe; X80; heavy gauge; toughness; DWTT; Charpy V-Notched; separation; ferrite; bainite; TMCP.

INTRODUCTION

The demand for natural gas using LNG (Liquefied Natural Gas) and pipelines to supply the world gas markets is increasing as a substitute for oil and coal. In recent years, gas exploration is actively performed in various places including remote and cold districts such as Russia, Canada, and Alaska. In such regions, long-distance pipelines are required for transporting natural gas from the well to the consumption area or the LNG terminal. Reducing the cost of long distance gas transmission pipelines is becoming increasingly important as the demand for natural gas rises. A high operating pressure helps reduce the cost of gas transportation and construction. The application of high strength line pipes enables the pipeline to withstand such high operating pressure. In particularly, a heavy gauge linepipe with high strength and high toughness can be applied in pipeline projects, such as the Nord Stream, Yamal and Shtokmann projects. Therefore, high strength line pipe steels exceeding American Petroleum Institute (API) 5L X70 or X80 grade with heavy wall thickness have been developed. It is necessary to develop line pipes with optimally-balanced ratios of strength, low temperature toughness, seam weld properties and field weldability. In particular, when developing high strength line pipe with heavy wall thickness, achieving an excellent performance in terms of crack arrestability is vital. It is important to achieve low ductile-to-brittle transition temperature and high absorbed energy of pipe body in order to obtain brittle crack propagation resistance and ductile crack propagation resistance. The Drop Weight Tear Test (DWTT) is one of the major test methods used to evaluate the crack arrestability of a brittle fracture. In the past, ductile-to-brittle transition curves obtained from full-scale burst tests almost coincided with those obtained from DWTT, although the Ductile-to-Brittle Transition Temperature (DBTT) from full-scale burst tests was different from that of Charpy V-Notched (CVN) test (Eiber et al., 1979). In particular, the DWTT evaluates whether a ductile crack is transferred from a brittle fracture after a brittle crack is initiated just under the notch. Previous results (Eiber et al., 1979) indicated that if the crack speed became lower than 450m/s, the crack was arrested during a full-scale burst test, concerning line pipes with a DWTT shear area of more than 40%. Generally, a DWTT shear area of 85% or higher is a required specification for acceptable brittle crack propagation resistance, such as those of the API, because of the DWTT shear area scattering being taken into account in a circumferential direction and longitudinal direction. Conversely, the required CVN absorbed energy for the crack arrestability of running ductile fractures has been proposed (Amano et al., 1986, Maxey et al., 1976, Maxey et al., 1985, Poynton et al., 1974). Ductile crack propagation resistance that is evaluated by the CVN absorbed energy is also an important material property for the high grade linepipes since higher operation pressure increases the driving force for the running ductile fracture. CVN absorbed energy correlated with that of the full-scale burst test results and high CVN absorbed energy is required for the crack arrestability of running ductile fractures. This paper reviews the metallurgical design and introduces production results on grade X80 heavy gauge linepipes for extremely low temperature service. Grade X80 with 29.6mm thick linepipe consisted of fine ferrite-bainite microstructure was developed. Good balance of DWTT properties applicable to the design temperature of -45 degrees C and high CVN absorbed energy of approximately 250J were achieved. In addition, DWTT 85% transition temperature of this developed pipe was -65 degrees C or less and CVN absorbed energy at -65 degrees C remained high.