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Development and Mechanical Properties of X120 Linepipe

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ABSTRACT

To enable the development of remote gas sources, X120-grade UOE linepipe has been developed. Low carbon-low Pcm and Mn-Ni-Mo-Nb-V-B bearing steel with a microstructure of fine ausformed martensite and bainite has excellent combinations of strength and toughness. With respect to longitudinal seam welding, the X120 pipe exhibits good heat-affected-zone (HAZ) cracking resistance due to a low Pcm. Deformation behaviors of the X120 linepipe were investigated using field bending and hydrostatic burst tests. The results verify that the overmatched seam weld in the X120 is sufficient to enable burst strength consistent with this grade of pipe. Sufficient deformability of the X120 for field bending was demonstrated using existing pipeline construction equipment.

INTRODUCTION

To maximize economic advantages, the use of higher-strength steels (X80 and over) in linepipe systems has been investigated (Sanderson et al., 1999). X80-grade steels have been developed and utilized for gas linepipes. Regarding X100, this steel has been developed, and the characterization of prototype pipes has been extensively studied by pipe manufacturers (Hashimoto et al., 1988; Kawabata, 1995) and by a joint industry project of major oil companies (Hammond and Millwood, 2000). In the case of X120-grade steel, ExxonMobil has developed a basic concept for manufacturing and applying the steel to high-pressure gas linepipes. In 1996, ExxonMobil and Sumitomo Metals started a cooperative research and development effort on ultra high-strength linepipe steels (Fairchild et al., 2002). The joint project was initiated to develop and commercialize X120-grade steel by conducting both laboratory tests of candidate plates and full-scale tests of prototype pipes. This paper will discuss the metallurgical concept of X120-grade linepipes, the characteristics of prototype pipes, the deformation behavior during hydrostatic burst tests, and the results of field bending tests.

Tables 1 and 2 summarize the target properties established at the beginning of the joint development. Because API5L has not set specific tensile properties for X120 linepipe, the targets were established by correlation with the minimum specified yield strength (SMYS) and tensile strength (SMTS) of X70 and X80. For the application of high-strength steel to gas pipelines, the subject of crack arrest must be addressed. Fracture control methodologies including both intrinsic and extrinsic arrest (i.e., crack arrestors) were considered (Papka et al., 2003). The Charpy impact energy target for the base metal was calculated for X120 using the Battelle 2-curve approach and a 1.4 multiplier (Papka et al., 2003). The Charpy target for the heat-affected zone (HAZ) (fusion line) and weld metal of the longitudinal seam weld were derived by extrapolation using the DnV Offshore Standard for Submarine Pipeline Systems: Table 6-3. The CTOD target was calculated using BS 7910 and a surface-breaking flaw 2 mm deep and 100 mm long. The pipe geometry for this calculation was 16 mm (0.63 in) in thickness and 914 mm (36 in) in outer diameter.

Tensile property		Charpy impact property		DWTT
YS	TS	$vE_{-30°C}$	vTrs	$SA_{-20°C}$
827 MPa	931 MPa	231 J	−50°C	75%

Table 1 Target mechanical properties (base metal)

Tensile property	Charpy impact		Fracture toughness	
Welded joint	HAZ	WM	HAZ	WM
TS 931 MPa	$vE_{-30°C}$ 84 J	$vE_{-30°C}$ 84 J	$CTOD_{-20°C}$ 0.08 mm	$CTOD_{-20°C}$ 0.08 mm

Table 2 Target mechanical properties (welded joint)

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KEY WORDS: Linepipe, X120, TMCP, bainite, boron, burst test, field bending.