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Tensile Properties and Microstructure of Girth Welds for High-Strength Linepipe

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This study was conducted to confirm that the tensile and Charpy impact properties of weld metal produced using commercial welding consumables could achieve high yield strength of 830 MPa or more with Charpy impact energy of 50 J or more at −50°C. Mechanized pulsed gas metal arc welding (P-GMAW) using a single wire with narrow groove weld geometry is basically applied to girth welding. A single wire-single torch (single torch) and a single wire-dual torch (dual torch) processes were applied to produce X100 joints. A series of 4 experimental girth welds was produced using 3 kinds of commercial welding wires classified ER90S-G, ER100S-G and ER110S-G. Tensile properties, hardness distributions and microstructures of weld metal were evaluated. It was confirmed that the girth weld metal produced by using the dual torch process using commercial welding wire could achieve high yield strength of 851 MPa with Charpy impact energy of 50 J or more at −50°C.

INTRODUCTION

To maximize economic advantages, the use of high-strength steels (X80 and over) in pipeline systems has been investigated. X80 and X100 grade steels have been developed and utilized for gas pipelines (Zhou et al., 2008). Welding of these high-strength pipes posed challenges because of their sensitivity to variations of welding conditions. Thus several kinds of investigations have been conducted to characterize the properties of X80 and X100 welds under specific conditions (Hammond et al., 2002; Gianetto et al., 2006; Gianetto et al., 2008; Fiore et al., 2008). From these investigations it has been confirmed that weld metal can match the X80 and X100 grade pipes using commercially available welding consumables under the developed welding procedures. On the other hand, the necessity of strain-based design in pipeline systems is discussed more seriously with spreading applications of pipes of strength greater than X80. and there is a great focus on overmatching criteria for pipeline girth welds. One of the proposed criteria of weld overmatching is that the yield strength of weld metal must be greater than that of the actual pipe rather than the specified minimum yield strength. This criterion led the minimum yield strength requirement for the girth weld metal to be around 830 MPa (120 ksi) for X100 pipes.

This study was conducted to confirm that the tensile and Charpy impact properties of weld metal produced using commercial welding consumables could achieve high yield strength of 830 MPa or more with adequate impact energy of 50 J or more at −50°C.

EXPERIMENTAL PROCEDURES

An X100 double submerged arc welding (DSAW) pipe with a 914-mm diameter and a 19-mm wall thickness was used as a mother pipe. The chemical composition of base metal of the DSAW pipe is shown in Table 1.

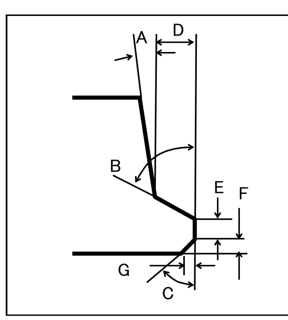
The pipe ends were prepared by machining with a bevel angle of 5°, a hot pass bevel angle of 45° and an offset distance of 2.8 mm. A root pass bevel angle was 37.5°; root pass bevel depth and root face were both 1.3 mm. A schematic diagram of the bevel preparation is in Fig. 1.

A series of 4 experimental girth welds was produced using a mechanized P-GMAW of RMS Welding System. The welds were produced using 3 kinds of commercial welding wires of ER90S-G (Bohler NiMo 1-IG, 1.0 mm diameter), ER100S-G (ESAB Autrod 13.25, 1.0 mm diameter) and ER110S-G (Bohler X 70-IG, 1.0 mm diameter) combined with an $85\%Ar + 15\%CO_2$ shielding gas. A dual torch process with a 100-mm torch distance was applied for this study. In the case of ER100S-G welding wire, a single torch process was also applied to compare the dual torch process. Welding conditions are shown in Table 2. The preheating and interpass temperatures were controlled from 50°C to 125°C in all cases.

Round bar all-weld tensile specimens and Charpy V-notch specimens were taken from each weld section. The round bar specimens with 4.0-mm diameter and 25-mm gauge length were taken at the mid-wall thickness within the weld metal. Charpy V-notch specimens were also taken at the mid-wall thickness and the notch

C	Si	Mn	Others	Pcm	Ceq(IIW)
0.064	0.1	1.78	Cu, Ni, Mo, Nb, Ti	0.198	0.473

Table 1 Chemical composition of base metal of DSAW pipe (mass %)



Steel	X100
OD (mm)	914
WT (mm)	19
A (deg.)	5
B (deg.)	45
C (deg.)	37.5
D (mm)	2.8
E (mm)	1.3
F (mm)	1.3
G (mm)	1

Fig. 1 Schematic diagram of pipe joint preparation

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KEY WORDS: X100, girth welds, acicular ferrite, carbon content, pulsed gas metal arc welding.