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Weld Metal Mechanical Properties in Hyperbaric GTAW of X70 Pipeline

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In the present investigation, 2 different wires for hyperbaric (underwater) GTA (gas tungsten arc) welding of X70 pipelines have been tested with respect to their weld metal mechanical properties. Welding of full coupons at different pressures (seawater depths of 16, 75 and 200 msw) was done with subsequent weld metal chemical analyses, hardness measurements, tensile testing and Charpy V notch testing as well as microstructure characterization. It is shown that both wires satisfied strength requirements set to X70 grade, representing a weld metal overmatch situation. Both wires gave sufficient impact toughness, but the toughness of the Ni-Mo containing weld was reduced with increasing seawater depth. This observation was strongly linked to the positioning of the Charpy V notch, and crack growth in a brittle, partially transformed region as a consequence of reheating by subsequent stringer beads. The embrittling microstructure consisted of high carbon MA (martensite-austenite constituents islands) decorating prior austenite grain boundaries. This microstructure was less pronounced when welding with the high Ni wire, which may explain why no similar toughness drop was found.

INTRODUCTION

Up to now, subsea pipelines of grades X60 and X65 have mainly been used in the Norwegian continental shelf installations. These are 10 to 42 in outer diam and their wall thickness ranges from 14 mm to 40 mm. Offshore tie-ins using qualified welding procedures have been made at 40 to 218 msw (meter sea water). X70 has been used only in one case, the Europipe (Aune et al., 2005). Forthcoming installations will include several X70 pipelines. One example is the Langeled pipeline, which will be the longest subsea pipeline in the world and will transport gas from Nyhamna on the West Coast of Norway via Sleipner in the North Sea to Easington in the U.K. Prior to subsea installations of pipelines, a test programme on welding consumables is required. The present investigation was then done to evaluate 2 different wires for welding of X70 pipes, both representing an overmatching situation with respect to weld metal strength (weld metal strength > base metal strength). The experimental programme consisted of hyperbaric welding at pressures corresponding to 16, 75 and 200 msw with subsequent mechanical testing (tensile and Charpy V notch toughness) and microstructure characterisation.

MATERIALS AND EXPERIMENTAL PROCEDURE

Pipe Material

The pipe materials used for testing the different welding consumables were of steel grade X70 with chemical compositions as outlined in Table 1. The outer diam of these pipes was 310 mm. For the shallow water depth of 16 msw, pipe 1 with 27.2-mm wall thickness (WT) was used, while for larger depths (75 and 200 msw) pipe 2 with 29.8-mm WT was used. The latter pipe had a higher P_{cm} value due to higher Mn content. The concentration of impurity elements was low in both steels.

Pipe 1, 27.2 mm							
	C	Si	Mn	P	S	Nb	Ti
	0.075	0.279	1.49	0.012	0.001	0.036	0.022
	V	Al	Cu	Ni	Cr	Mo	Pcm
	0.004	0.031	0.013	0.021	0.026	0.175	0.176
Pipe 2, 29.8 mm							
	C	Si	Mn	P	S	Nb	Ti
	0.08	0.26	1.65	0.011	0.001	0.04	0.00
	V	Al	Cu	Ni	Cr	Mo	Pcm
	0.07	0.03	0.03	0.05	0.08	0.01	0.190

Table 1 Pipe material chemical composition (wt%)

Welding Consumables

Table 2 shows the chemical composition of the 2 wires. As shown, 2 different alloying philosophies are used, i.e.:

- Wire 1 is a nickel-molybdenum alloyed wire, 1.6 mm in diam
- Wire 2 is a nickel alloyed wire, 1.6 mm in diam

Welding Procedures

The test welding was performed at different pressures, corresponding to 16, 75 and 200 msw. Table 3 reports the heat input employed in the various hyperbaric welding procedures.

Fig. 1 illustrates the groove geometry and dimensions, the groove being a specially designed narrow gap based on years of experience. The chamber gas was Heliox; the shielding gas, a

Wire 1[1]	C	Si	Mn	P	S	Ni	Mo
	0.08	<0.10	1.32	0.005	0.006	1.01	0.55
	Cr	Cu	Al	V	Nb	Ti	O
	0.03	0.18	n.a.3	<100	<100	<100	80
Wire 2[2]	C	Si	Mn	P	S	Ni	Mo
	0.09	0.44	1.06	0.007	0.013	2.3	0.01
	Cr	Cu	Al	V	Nb	Ti	O
	0.03	0.17	<100	<100	<100	<100	200

[1] With 0.005% N; [2] With 0.008% N; 3 n.a.: not analysed

Table 2 Wire composition (in wt%, Al, V, Nb, Ti and O given in ppm)

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