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Root Bead Profiles in Hyperbaric GTAW of X70 Pipeline

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This investigation began with the goal of studying the root bead penetration profiles in hyperbaric GTAW welding of X70 pipelines. Such profiles may vary substantially depending on the wire and base metal chemical composition. Root beads were deposited with a pressure corresponding to 75-m seawater depth, and with a systematic increase of 10 A in the pulse current until burnthrough took place. The results obtained showed that the penetration profiles were different between the 2 wires included in the welding program. The largest penetration width was found for wire B with the highest sulphur content (0.013% S), with a maximum width of about 8-mm width on the pipe inside for 160 A. At pulse current levels of 120 to 170 A, the difference between the 2 wires was about 1 mm. With current beyond 180 A, the profiles approached similar values, followed by burnthroughs for both wires at 190 A. However, the welding parameters were already too hot at 180 A. These results are probably caused by a Marangoni convection in the weld pool. A high content of surface active elements (e.g., sulphur) is known to shift the flow pattern, providing deeper penetration. In practice, small variations in the bead penetration profile may have large consequences during offshore tie-in welding. Cost-increasing repair operations may be required if nondestructive inspection later reveals poor root bead quality. Such actions require mobilisation of huge resources.

INTRODUCTION

During hyperbaric welding of subsea pipelines on the Norwegian continental shelf, the robustness of the selected steel and consumables must be sufficiently high to avoid welding-related problems, since this may cause a substantial cost increase due to the required onsite repair. In this connection, one of the most critical parts is the deposition of the root bead, where insufficient penetration (too-cold welding parameters) or burnthrough (too-hot parameters) may occur. Such defects will not come to light before the full weld is completed, thus causing major delay in the welding operation due to the subsequent weld removal and repair welding. Hence, factors that influence weld bead penetration must be kept under strict control. The present investigation addressed root bead penetration under hyperbaric conditions, using new high-strength wires applicable to welding of X70 pipelines. The wires' manufacture is based on different alloying practice. With relevance to bead penetration, the wires also contained different sulphur levels.

MATERIALS AND EXPERIMENTAL PROCEDURE

Materials

The pipe materials used for testing the different welding consumables were of steel grade X70 quality with their chemical composition as outlined in Table 1. The wall thickness was 33.3 mm. The base metal is a typical low carbon Mn steel containing low alloying and impurity content. The P_{cm} value is as low as 0.18.

Coupons with the following fit-ups were used:

- Root face: 2.75 mm
- High/low: 0 mm
- Root gap: 0 mm

C	Si	Mn	P	S	Nb	Ti
0.08	0.29	1.66	0.009	0.001	0.05	0.02
V	Al	Cu	Ni	Cr	Mo	Pcm
0	0.03	0.02	0.03	0.04	0.01	0.18

Table 1 Pipe material chemical composition (wt%)

The scanning tests were carried out with a systematic increase of 10 A in pulse current every 70 s in root bead welding to examine the robustness of the wires for making sound welds, including no lack of penetration and no burnthrough. The arc voltage and base current were kept constant at 19 V and 60 A, respectively. The chamber gas was Heliox; shielding gas, 70 He–30 Ar. The weld appearance is inspected visually, with macros prepared for measuring penetration width.

In order to examine the robustness of the root bead deposition, 2 wires were included. Table 2 gives their chemical composition. The wires differ as regards to the alloying elements. Wire A is Ni-Mo alloyed (1% Ni–0.5% Mo), while wire B contains high Ni content (2.3%). Their sulphur content is also different, i.e., one with low sulphur content (0.006%, wire A) and one with high sulphur content (0.013%, wire B). Both wires were supplied with 1.6-mm diam.

RESULTS AND DISCUSSION

Bead Penetration Width

Visual inspection. The weld appearance is inspected visually, with macros prepared for measuring penetration width (P_W) on

Wire	C	Si	Mn	P	S	Ni	Mo
Wire A[1]	0.08	<0.10	1.32	0.005	0.006	1.01	0.55
Wire B[1]	0.09	0.44	1.06	0.007	0.013	2.3	0.01

[1] Both wires contain 0.03% Cr and 0.18% Cu

Table 2 Chemical composition of wires (wt%)

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KEY WORDS: Hyperbaric (underwater) welding, subsea pipelines, X70 steel, mechanized GTAW, root bead penetration, surface active elements, Marangoni convection.