Material Tensile Properties for Strain-Based Design of Clad Pipelines

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ABSTRACT

As design temperatures increase and steel strength increases, the limits on yield strength of the nickel-alloy weld consumables make it more difficult to achieve overmatched weld areas, increasing the difficulty of a strain-based design assessment. Testing of Alloy 625 girth welds in X65 pipe clad with Alloy 825 found that the welds were approximately matching in yield strength to the steel in circumferential direction tests. Cross-weld tests at 20°C and 150°C found localized yielding up to 15% strain in the weld cap area followed by distribution of strain into the steel and failure in the steel.

KEY WORDS
Pipe; clad; steel; nickel; weld; strain; localization.

INTRODUCTION

The use of clad pipes for offshore oil and gas production has been worldwide, with multiple methods of pipe laying considered (Hval et al. 2014) (Jones et al. 2011). Assessments of the allowable flaw sizes in these girth welds generally indicate that there is value in increasing the strength of the girth welded area toward overmatching of both the yield and ultimate strength of the girth weld compared to the base metal, particularly in cases with cyclic plastic strain (Yang et al. 2009) (Tronskar et al. 2015) (Tkaczyk et al. 2015) (Carlucci et al. 2014).

There has been a desire to continue to use a single electrode for the entire girth weld to advance strength, but also provide internal corrosion resistance. Some patented methods are available for increasing the strength of girth welds, while retaining other desirable properties (Ayer et al. 2013) (Ayer et al. 2014). These methods have not widely entered welding practice, as users have primarily worked with Alloy 625 and Alloy 688 consumables.

Under these circumstances one way of improving the assessment of the allowable flaw size for strain-based design conditions would be to include a better understanding of the yielding behavior and strain aging capability of both the steel and the weld metal into models describing their behavior during reeling, installation, and service.

OBJECTIVES

Assess the tensile behaviors of Alloy 625 girth welds in clad pipe steel both at room temperature and a reasonable maximum design temperature, with particular attention to the initial stage of plastic deformation.

EXPERIMENTAL PROCEDURE

Two girth-welded pipe sections were provided by a welding contractor. These were numbered 1322 and 1323, indicating consecutive girth welds. The dimensions were 9.625 in. (244.5 mm) diameter by 0.827 in. (21.0 mm) thick and 11.8 in. (300 mm) long. The X65 pipe sections were clad with Alloy 825 that were 0.118 in. (3 mm) thick. The welds were automatic using Alloy 625 weld metal. The caps of the girth welds had been ground flush with the pipe surface. The pipe segments had long seam welds which had been performed by arc welding that were used as reference points.

EWI performed ultrasonic phased-array inspection of the girth weld areas as confirmation and did not detect imperfections that would be rejectable to normal offshore criteria.

After inspection, the pipe segments were heat treated in air at 250°C for one hour to exceed the thermal cycle of external coating. This strain aging treatment is also commonly performed for materials undergoing weld qualification.

Metallographic photos were taken after etching designed for the steel (2% nital) and after etching designed for the weld metal (electrolytic with 10% oxalic and 10% acetic acid alternating). This allows for two different views of the fusion line region.

Vickers microhardness testing with a 500 gm load was performed in the weld metal at the centerline at five positions and at five positions 1 mm from the fusion line after etching.