Proceedings of the Eighteenth (2008) International Offshore and Polar Engineering Conference
Vancouver, BC, Canada, July 6-11, 2008

ISBN 978-1-880653-70-8 (Set); ISBN 1-880653-68-0 (Set)

Advanced Tensile Behaviour Evaluation of Girth Welds

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ABSTRACT

The knowledge of girth weld tensile behaviour is an essential issue to be considered in the definition of a welding procedure for seamless linepipe, subject to in-plane bending, such as during laying applications. In particular, the evaluation of the behaviour in direction transverse to the welding should be carried out, according to DNV standards.
In this paper, a joined application of experimental testing and Finite Element Analysis is carried out to characterize the tensile behaviour of both weld metal and heat affected zone material, until rupture, that is beyond the onset of plastic collapse, in direction transverse to the weld.

KEY WORDS: Tensile characterization; Joint Girth Weld; Offshore Pipelines; FEM.

INTRODUCTION

Advanced techniques for the assessment of safety of components just like girth welds are nowadays available even for very severe applications. In particular, procedures for the defect tolerance critical assessment, based on the most modern Fracture Mechanics concepts reported in BS 7910 (2005), R6 (2000), SINTAP (1999), API RP 579 (2007), have been developed even for extreme conditions just like reeling installation, where the pipeline and its girth weld are loaded under displacement control, at high values of plastic deformations. Some of the most recognized procedures are presented in the widely recognized standards DNV OS-F101(2007) and DNV RP-F108 (2006) where the calculation route is presented in the form of modifications to the BS 7910 procedure to adapt it to strain-based situations. The evaluation of girth weld tensile behaviour, in direction transverse to the welding, is also recommended by DNV to investigate the actual weld joint load bearing capability, when subjected to in-plane bending, as in the case of reel-laying installation. The use of weld and base material curves, in transverse direction, could provide essential information for possible refinement of defect assessment procedures, especially taking into account the actual plastic deformation pattern associated to the weld-to-base material strength mismatch. In addition, the knowledge of the actual tensile behaviour of weld metal, heat affected zone and base material would facilitate a more accurate modelling of the actual stress-strain field at the tip of the crack. The latter is affected by the closeness of different material zones, so that it is essential to consider the tensile constitutive curve of each material. At this regard, also the knowledge tensile response beyond plastic instability onset point (necking) is a relevant issue, since it is well known that the deformation is highly localized close to the crack tip, and very high strain values are reached.
Standard tensile testing carried out on cross weld specimens can provide important information on the weld joint behaviour, facilitating the verification of the weld metal – to – base material strength over-matching. On the other hand, such testing is not able to evaluate the effective tensile response, in terms of stress – strain constitutive curve of the different materials of the welded joint (weld metal and heat affected zone), which could be useful for a finer evaluation of behaviour of flawed girth welds. In the past, to overcome this lack of information, very small round bar specimens were used, also named "reduced-all-weld metal tensile specimens". Such solution is not completely suited to solve the problem. This can be explained with the following reasons:

- the sample is oriented in welding direction, which is not the actual loading direction of the girth weld during laying and in-service application;
- material anisotropy may be present, hence the actual material response may differ and provides very local information. Generally the weld metal micro-structure is inhomogeneous and its characteristics differ depending on the position examined in the weld.

A demonstration of the influence of the micro-structure on the weld metal tensile behaviour in welding direction has been performed by machining reduced-all-weld metal tensile specimens (Fig. 1) with a diameter of 2.8 mm in the smoothed part. The specimens have been extracted at different radial positions to account for the effect of the microstructure:

- close to the weld cap
- at mid-thickness
- close to the root weld.

A sketch of specimens extraction from the weld is given in Fig. 2 and Fig. 3.

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