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Qualification of Reeled Mechanically Lined Pipes for Fatigue Service

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To meet an increasing demand for conveying corrosive fluids in the subsea oil and gas sector, the authors have proposed a design of mechanically lined pipe (MLP) that enables reel-lay installation under atmospheric pressure without the risk of wrinkling of the corrosion resistant alloy (CRA) lining. The novel design was qualified for reeling and subsequent service life in accordance with DNV-RP-A203. To provide further evidence that a high fatigue performance can be achieved before a carbon steel backing pipe is exposed to corrosive constituents, a qualification programme, detailed in this paper, was undertaken. In addition, a 3D finite element (FE) study was performed on MLPs with interface flaws between the liner and clad overlay weld, and recommendations for the fatigue assessment of MLPs with interface flaws were made.

INTRODUCTION

An increasing demand for the transport of corrosive constituents in the subsea oil and gas sector is creating a growing demand for high-strength pipelines with enhanced corrosion resistance such as bimetal pipes. These include hot roll bonded (HRB) clad pipes and mechanically lined pipes (MLPs). The latter are made of a corrosion resistant alloy (CRA) liner adhering to a backing carbon steel pipe by means of an interference fit. MLPs are generally more readily available and cheaper than both solid stainless steel and HRB clad pipes.

Reel-lay is a highly effective installation method, which is an alternative to S-lay and J-lay, for the installation of small to medium-sized subsea pipelines. Reeled pipes are subjected to plastic straining during installation. Although it has been suggested that such plastic straining may reduce the fatigue performance of reeled pipes, no detrimental effect was found in recent works, e.g., Gray et al. (2009). However, plastic straining of the MLP during reeling may trigger wrinkling of the CRA liner if reeling is not properly managed.

Technip has developed and patented a design of the MLP with an increased liner thickness that enables reel-lay installation at atmospheric pressure without the risk of liner wrinkling, thus combining an economically attractive MLP product with a very efficient reel-lay method (Pepin and Tkaczyk, 2011). In accordance with the guidance provided in DNV-RP-A203 (2011), the novel design was qualified for reeling and a subsequent static service in 2011 (Tkaczyk et al., 2011; Pepin et al., 2011). Subsequently, six API 5L X65 (API 5L, 2007) carbon steel pipes lined with alloy 625 with a nominal outer diameter $D = 10.75"$ (273.1 mm) and a total wall thickness $t = 26.5$ mm were qualified for fatigue service (Tkaczyk et al., 2012a). Clad overlay and girth welding were carried out through the use of alloy 625 (ERNiCrMo-3) consumables. Overlay cladding was internally machined, whereas girth weld caps were ground flush. The test strings were subjected to two bending cycles in one plane followed by two bending cycles in a perpendicular plane to simulate perpendicular reeling. Visual inspection carried out on completion of the bending trials confirmed no signs of damage to the liner. Subsequently, the test strings were fatigue tested at positive stress ratios until failure (loss of internal pressure) occurred or until the run-out condition (the DNV class C target curve) was achieved. Fatigue cracks were initiated from lack of fusion flaws, similar to that shown in Fig. 1, in three test pipes. The lack of fusion flaws were approximately 1 mm in height. The post-mortem examination of fracture faces suggested that the anti-corrosion barrier was not breached until after the crack had reached the carbon steel outer surface. The fourth failure initiated from a blemish at the outer surface of the pipe. Specimens tested at the lowest stress range reached the run-out condition without failure. Overall, the fatigue life was above the DNV class D target curve (DNV-RP-C203, 2011). Following this study, DNV endorsed the design of MLPs reeled at atmospheric pressure for dynamic service.

Toguyeni and Banse (2012) tested three API 5L X65 carbon steel pipes lined with alloy 625 to qualify MLPs reeled under internal pressure for steel catenary riser (SCR) service. The MLPs had a nominal outer diameter $D = 8.625"$ (219.1 mm) and a total wall thickness $t = 21.3$ mm. Each test string had 50-mm-long machined clad overlay welds on either side of a central CRA girth weld. Girth weld caps were ground flush. Clad overlay and girth welding were carried out through the use of alloy 625 consumables. The test strings were internally pressurised to 30 bar and subjected to bending to simulate pressurised reeling. Subsequently, the pipes were fatigue tested at positive stress ratios until the DNV class F1 target curve (DNV-RP-C203, 2011) was

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KEY WORDS: Mechanically lined pipe, reel-lay installation, steel catenary riser, fatigue strength, stress intensity factor.