Fracture Toughness Testing Approach for Engineering Critical Assessment of Triple-Point Flaws in Mechanically Lined Pipes

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ABSTRACT
Mechanically lined pipes (MLP) are increasingly being used for subsea pipelines to transport corrosive wellbore fluids due to their cost-effectiveness. However, the reel-lay installation method requires an engineering critical assessment (ECA) of flaws at the interface between the liner and weld overlay. The authors previously proposed an ECA approach that involves complex segment testing to estimate ductile tearing associated with each fracture event. This paper suggests a streamlined ECA process that replaces segment testing with more conventional fracture testing to obtain a toughness resistance curve. This curve can be used in a classical ductile tearing analysis.

KEY WORDS: Mechanically lined pipe; bimetallic pipe; subsea pipeline; reel-lay installation; ECA; fracture toughness; triple-point interface.

INTRODUCTION
The demand for subsea transportation of wellbore fluids through pipelines resistant to corrosion, such as stainless steel or bimetallic pipes, has been increasing for years. In the pursuit of cost reduction for subsea field development, MLP pipelines have been qualified for installation using the reel-lay method. In this method, the pipeline up to 18" (457.2 mm) in diameter is fabricated onshore and spooled onto a large diameter reel, onboard an installation vessel, see Fig. 1. After the vessel arrives at the subsea field location, the pipe is spooled off the reel, straightened in a free span between the reel and aligner, bent over the aligner, reverse bent in the straightener, and finally lowered onto the seabed. A standard reeling operation involves two reverse plastic bending cycles (Kyriakides and Corona, 2007).

A typical 40 ft (12 m) MLP joint, illustrated in Fig. 2, is manufactured by inserting a corrosion resistant alloy (CRA) liner into a carbon steel host pipe and expanding it plastically so that contact with the host pipe occurs (American Petroleum Institute, 2015a; Det Norske Veritas, 2021). Expansion pressure is increased until the host pipe achieves a predefined level of expansion. Once pressure is released, the CRA layer, often 3/32-5/16" (2.5-8 mm) in thickness and made of alloy UNS S31603 (316L), N06625 (625) or N08825 (825) (American Petroleum Institute, 2015b) is held inside the host pipe by interference fit. To prevent moisture ingress and allow automatic ultrasonic testing (AUT) of girth welds during the pipeline fabrication, the liner is metallurgically bonded to the host pipe at the MLP ends by overlay welding, commonly deposited using alloy 625 consumable.

Fig. 1 Illustration of the reel-lay process (Kyriakides and Corona, 2007)

Fig. 2 Mechanically lined pipe

An ECA is commonly performed to determine the acceptance criteria for girth weld fabrication flaws in subsea pipelines. This assessment includes a series of fracture and fatigue evaluations, typically following...