A Non-Linear Fracture Assessment Procedure for Pipeline Materials with a Yield Plateau

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ABSTRACT
An accurate defect assessment procedure is needed to ensure integrity of girth welded steel pipelines while avoiding unnecessary repairs. An integral part of such a procedure is an estimation scheme for the crack driving force. In a recent paper, a modified reference stress method has been proposed by the authors for the assessment of elastic-plastic pipes with surface breaking defects. For materials with continuous yielding the method has been shown to provide accurate estimates of crack driving force. However, for materials with a yield plateau (Lüders plateau), the description of the evolution of the crack driving force is less accurate. In this work, a method for the estimation of crack driving force (phrased in terms of the $J$-integral) for surface breaking pipeline defects, applicable to materials with a yield plateau, is proposed. The method is validated by comparing the predictions with the results of three-dimensional finite-element analysis of a surface cracked pipe under tension and bending loading.

INTRODUCTION
The reel-lay method is a cost efficient alternative to the S-lay and J-lay methods (Kyriakides and Corona, 2007) for installation of small to medium size steel offshore pipelines (up to approx. 0.5 m in diameter). During reeling a long section of pipe (up to several kilometers in length) is spooled onto a large diameter reel, situated on a vessel while docked at a spoolbase (see Fig. 1). The pipe is installed by unreeling the pipeline once the vessel has arrived at the destination site. In addition to a faster installation process, the quality of the pipeline construction is also enhanced, compared to conventional installation techniques, by the use of on-shore welding and inspection under controlled conditions. However, reeling operations induce plastic strain in the pipeline (up to 2.3% for an 18” (457 mm) diameter pipe). For a pipe of diameter $D$, with a bending radius $R$, the maximum bending strain, $\varepsilon$, (assuming pure bending) is,

$$\varepsilon = \frac{D/2}{R+D/2}$$

(1)

An accurate defect assessment procedure will ensure integrity while avoiding unnecessary repairs. An integral part of such a procedure is a method to calculate the crack driving force, typically phrased in terms of the $J$-integral or crack tip opening displacement.