Fracture Assessment of Elastic-Plastic Steel Pipelines Subject to Multi-cycle Bending

Tomasz Tkaczyk∗
Offshore Engineering Division
Technip
Westhill, Aberdeenshire, UK

Noel P. O’Dowd
Department of Mechanical and Aeronautical Engineering
University of Limerick
Limerick, Ireland

Kamran Nikbin
Department of Mechanical Engineering
Imperial College London
London, UK

Brett P. Howard
Offshore Engineering Division
Technip
Westhill, Aberdeenshire, UK

ABSTRACT
In this work a large scale bending test, representative of conditions experienced under reeling of steel pipelines, is discussed. The pipeline material is an X65 steel and the pipe has a diameter of 273.1 mm (10.75”) wall thickness of 14.3 mm. The pipe was subject to multi-cycle reverse bending in a four-point bending rig. The crack driving force in terms of crack tip opening displacement (CTOD) was measured and compared with the results from three-dimensional finite-element analysis of the notched pipe. A number of existing estimation schemes for crack driving force, in addition to a novel estimation scheme developed by the authors, have also been evaluated. An important feature of the latter scheme is the ability to account for a yield plateau in the deformation response of the material. It has been seen that the measured CTOD-strain relationships for multi-cycle bending are closely predicted by the new estimation scheme. The first cycle, in particular, provides a robust validation of the procedure as the material response in this case is strongly affected by the existence of a yield plateau in the material tensile response.

1 INTRODUCTION
The reel-lay method, illustrated in Fig. 1, 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). The quality of the pipeline construction is enhanced by on-shore welding and inspection under controlled conditions. However, reeled pipelines are subject to at least two plastic strain cycles during installation. The maximum bending strain, , which can be calculated from geometrical considerations, is given by

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

(1)

where D and R are the pipe outer diameter and the bending radius, respectively.

Figure 2 shows a plot of the bending moment, M, applied to a given section of the pipeline versus the pipe curvature, , at this location during reeling. Numbers from ‘1’ to ‘7’ in Fig. 2 indicate the sequence of loading. First, the pipeline is bent to the curvature , dictated by the reel radius and the pipe diameter. After the vessel arrives at the field, the pipeline undergoes reverse plastic

∗Address all correspondence to this author.