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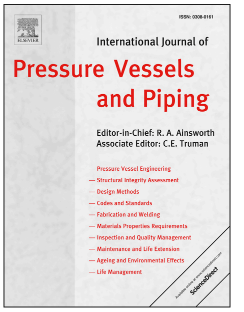

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Application of Failure Assessment Diagram Methods to Cracked Straight Pipes and Elbows

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Abstract

This paper reports fracture assessments of large-scale straight pipes and elbows of various pipe diameters and crack sizes. The assessments estimate the load for ductile fracture initiation using the failure assessment diagram method. Recent solutions in the literature for stress intensity factor and limit load provide the analysis inputs. An assessment of constraint effects is also performed using recent solutions for elastic T-stress. It is found that predictions of initiation load are close to the experimental values for straight pipes under pure bending. For elbows, there is generally increased conservatism in the sense that the experimental loads are greater than those predicted. The effects of constraint are found not to be a major contributor to the initiation fracture assessments but may have some influence on the ductile crack extension.

Keywords: Pipe, elbow, crack, failure assessment diagram, fracture

1 Introduction

In a wide range of industries, the structural integrity assessment of piping components containing defects is required to demonstrate safe and reliable operation. For example, leak-before-break (LBB) assessments of primary piping systems of some nuclear power plant assume the presence of cracks and demonstrate that such cracks lead to detectable leakage before pipe burst. There have been many studies addressing the defect tolerance of piping components, some addressing the influence of defects on the collapse load, others addressing fracture using linear and non-linear fracture mechanics. This has led to the inclusion of procedures for assessment of piping components within more general fracture assessment approaches such as R6 [1], BS7910 [2], API 579 [3], RSE-M [4] and others.

Large-scale experimental validation of the methods for assessment of piping components is available. For example, recently Zhu and Leis [5] examined the burst pressure prediction of over 100 uncracked pipes while Bedairi et al. [6] examined the influence of corrosion defects on fracture. Another study involved a large number of large-scale tests on straight pipes and elbows of various pipe sizes and crack configurations subjected to different loading conditions, as summarised by Chattopadhyay et al. [7, 8] and assessed recently in [9].

Although analyses of pipes and elbows have been available for some years, the major closed form inputs into fitness-for-service assessments, such as limit load and stress intensity factor solutions for pipes and elbows, are still being improved. The limit load solution for defective pipes, despite decades of research, are still being refined. For example, solutions have recently been developed for thick-walled cylinders with circumferential surface defects under any combination of axial force, global bending moment and internal pressure [10, 11].

The pipe geometry is relatively simple and can be solved semi-analytically. However, the elbow geometry brings additional challenges. For instance, there is a lack of accurate solutions for elastic stress distributions in defect-free elbows loaded by internal pressure or in-plane bending moment and research is being continued in this area [12, 13]. Usually the elbow cross-section is considered to be circular with uniform wall thickness. In practice, according to [14, 15, 16, 17] the elbow cross-section