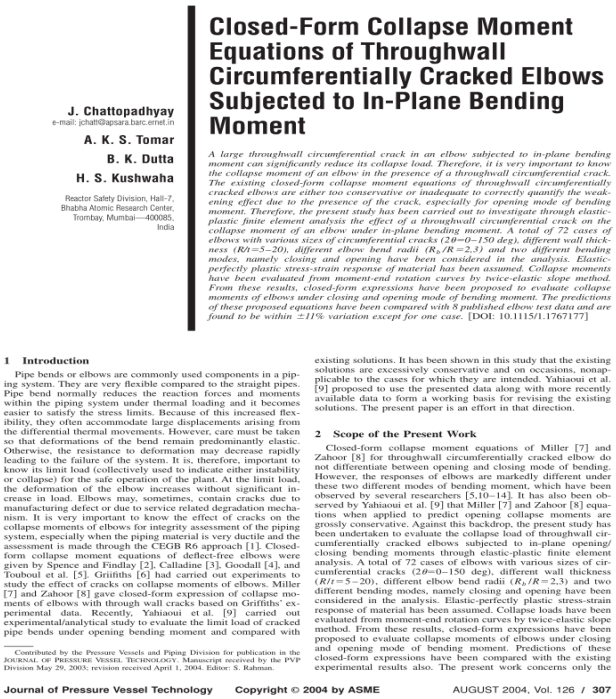
Dynamic Fracture Mechanics For The 1990s: Presented At The 1989 ASME Pressure Vessels And Piping Con



Closed-Form Collapse Moment Equations of Throughwall Circumferentially Cracked Elbows Subjected to In-Plane Bending Moment

J. Chattopadhyay
e-mail: jchatt@apsara.barc.ernet.in
A. K. S. Tomar
B. K. Dutta
H. S. Kushwaha

Reactor Safety Division, Hall-7,
Bhabha Atomic Research Center,
Trombay, Mumbai—400085,
India

A large throughwall circumferential crack in an elbow subjected to in-plane bending moment can significantly reduce its collapse load. Therefore, it is very important to know the collapse moment of an elbow in the presence of a throughwall circumferential crack. The existing closed-form collapse moment equations of throughwall circumferentially cracked elbows are either too conservative or inadequate to correctly quantify the weakening effect due to the presence of the crack, especially for opening mode of bending moment. Therefore, the present study has been carried out to investigate through elastic-plastic finite element analysis the effect of a throughwall circumferential crack on the collapse moment of an elbow under in-plane bending moment. A total of 72 cases of elbows with various sizes of circumferential cracks (2θ=0–150 deg), different wall thickness (Rt=5–20), different elbow bend radii ($R_b/R=2,3$) and two different bending modes, namely closing and opening have been considered in the analysis. Elastic-perfectly plastic stress-strain response of material has been assumed. Collapse moments have been evaluated from moment-end rotation curves by twice-elastic slope method. From these results, closed-form expressions have been proposed to evaluate collapse moments of elbows under closing and opening mode of bending moment. The predictions of these proposed equations have been compared with 8 published elbow test data and are found to be within ±11% variation except for one case. [DOI: 10.1115/1.1767177]

1 Introduction

Pipe bends or elbows are commonly used components in a piping system. They are very flexible compared to the straight pipes. Pipe bend normally reduces the reaction forces and moments within the piping system under thermal loading and it becomes easier to satisfy the stress limits. Because of this increased flexibility, they often accommodate large displacements arising from the differential thermal movements. However, care must be taken so that deformations of the bend remain predominantly elastic. Otherwise, the resistance to deformation may decrease rapidly leading to the failure of the system. It is, therefore, important to know its limit load (collectively used to indicate either instability or collapse) for the safe operation of the plant. At the limit load, the deformation of the elbow increases without significant increase in load. Elbows may, sometimes, contain cracks due to manufacturing defect or due to service related degradation mechanism. It is very important to know the effect of cracks on the collapse moments of elbows for integrity assessment of the piping system, especially when the piping material is very ductile and the assessment is made through the CEGB R6 approach [1]. Closed-form collapse moment equations of deflect-free elbows were given by Spence and Findlay [2], Calladine [3], Goodall [4], and Touboul et al. [5]. Griffiths [6] had carried out experiments to study the effect of cracks on collapse moments of elbows. Miller [7] and Zahoor [8] gave closed-form expression of collapse moments of elbows with through wall cracks based on Griffiths' experimental data. Recently, Yahiaoui et al. [9] carried out experimental/analytical study to evaluate the limit load of cracked pipe bends under opening bending moment and compared with existing solutions. It has been shown in this study that the existing solutions are excessively conservative and on occasions, nonapplicable to the cases for which they are intended. Yahiaoui et al. [9] proposed to use the presented data along with more recently available data to form a working basis for revising the existing solutions. The present paper is an effort in that direction.

2 Scope of the Present Work

Closed-form collapse moment equations of Miller [7] and Zahoor [8] for throughwall circumferentially cracked elbow do not differentiate between opening and closing mode of bending. However, the responses of elbows are markedly different under these two different modes of bending moment, which have been observed by several researchers [5,10–14]. It has also been observed by Yahiaoui et al. [9] that Miller [7] and Zahoor [8] equations when applied to predict opening collapse moments are grossly conservative. Against this backdrop, the present study has been undertaken to evaluate the collapse load of throughwall circumferentially cracked elbows subjected to in-plane opening/closing bending moments through elastic-plastic finite element analysis. A total of 72 cases of elbows with various sizes of circumferential cracks (2θ=0–150 deg), different wall thickness ($Rt=5-20$), different elbow bend radii ($R_b/R=2,3$) and two different bending modes, namely closing and opening have been considered in the analysis. Elastic-perfectly plastic stress-strain response of material has been assumed. Collapse loads have been evaluated from moment-end rotation curves by twice-elastic slope method. From these results, closed-form expressions have been proposed to evaluate collapse moments of elbows under closing and opening mode of bending moment. Predictions of these closed-form expressions have been compared with the existing experimental results also. The present work concerns only the

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