ARTICLE IN PRESS

Engineering Fracture Mechanics xxx (2017) xxx–xxx

Contents lists available at ScienceDirect

Engineering Fracture Mechanics

journal homepage: www.elsevier.com/locate/engfracmech

A modified hybrid method to estimate fracture resistance curve for pipes with a circumferential surface crack

Neha Parool, Xudong Qian *, C.G. Koh

Department of Civil and Environmental Engineering, Centre for Offshore Research and Engineering, National University of Singapore, 1 Engineering Drive 2, Singapore 117576, Singapore

ARTICLE INFO

Article history:
Received 7 March 2017
Received in revised form 3 May 2017
Accepted 29 May 2017
Available online xxxx

Keywords:
Fracture resistance
Energy release rate
Surface cracked pipe
Hybrid method
J-R curve
Single edge notch tension specimen

ABSTRACT

This study presents a modified hybrid method to estimate the fracture resistance curve for pipes with a circumferential surface crack. The hybrid method combines a single experimental specimen with an extending crack and several numerical models with a stationary crack of different sizes, to calculate the fracture resistance directly from the pipe specimen. The strain energy used in estimating the fracture resistance derives from the load and crack-mouth opening displacement curve. The proposed method leads to good agreement in the estimated fracture resistance curves with those based on the unloading-compliance eta-approach, for both fracture specimens and for circumferentially surface-cracked pipes.
© 2017 Elsevier Ltd. All rights reserved.

1. Introduction

The fracture failure in welded pipes often involves ductile extensions of pre-existing crack-like defects caused by complex cyclic loadings and corrosion attacks [1]. The fracture or failure assessment of such pipe structures relies on the detailed measurement of the material fracture resistance, from either a standard fracture specimen [2,3] or a modified fracture specimen with comparable load-induced or geometry-induced crack-front constraints as that anticipated by a crack in a pipe [4]. The crack-front materials in a welded pipe experience substantial constraint losses, which lead to severe stress redistributions near the crack tip and consequently much higher fracture resistance, measured by the *J-R* curve, than that measured in the high-constraint, standard fracture specimens [5,6]. Integrity assessments [7] based on the *J-R* curves from standard fracture specimens thus lock in considerable conservatism in the pipe design. Such over-conservatism inspires tremendous research efforts in quantifying the constraint effect [8–10] and sourcing for a feasible fracture specimen to replicate the fracture resistance in a pipe [2,11]. Moving beyond the small-scale fracture test, simple and reliable methods to measure the *J-R* curve directly from a cracked pipe provide an enhanced basis for the engineering critical assessment of such welded pipes.

Experimental methods to measure the material *J-R* curve separate into two broad categories: (1) the multiple specimen method; and (2) the unloading-compliance single specimen approach. Begley and Landes [12] have pioneered the experimental measurement of the energy release rate, *J*-value, deploying a number of standard fracture specimens each with a

* Corresponding author.
E-mail address: qianxudong@nus.edu.sg (X. Qian).

http://dx.doi.org/10.1016/j.engfracmech.2017.05.046
0013-7944/© 2017 Elsevier Ltd. All rights reserved.

Please cite this article in press as: Parool N et al. A modified hybrid method to estimate fracture resistance curve for pipes with a circumferential surface crack. Engng Fract Mech (2017), http://dx.doi.org/10.1016/j.engfracmech.2017.05.046

Nomenclature

A_{crack}	crack area
B	specimen thickness
B_N	net specimen thickness excluding side grooves
B_L	length of the entire crack front for a surface crack
C	compliance of the specimen
C_i	coefficients ($i = 1, 2, 3\ldots$.) in the polynomial fit for the specimen-specific CMOD versus crack depth relationship
E	Young's modulus
H	distance between the clamped ends of SE(T) specimen
J	energy release rate
P	applied load
S	span length of SE(B) specimen
U	total strain energy
W	width of the fracture specimen
a	crack depth of the specimen
a_0	crack depth at the end of fatigue pre-crack
a_f	crack depth at the end of ductile crack extension
a_i	crack depth in i^{th} model
Δa	crack growth
c	half crack length of a surface crack in a pipe
d_0	outer diameter of the pipe
t	thickness of the pipe
δ	load-line displacement
δ_{CTOD}	crack tip opening displacement
δ_{CMOD}	crack mouth opening displacement
$\delta_{CMOD,i}$	crack mouth opening displacement at i^{th} unloading-reloading cycle
ε	true strain
η	dimensionless factor
σ	true stress
σ_y	yield strength

different crack size. Some material testing standards [13,14] have adopted this method in the material fracture test. Rice et al. [15] have proposed the η method to measure the energy release rate for standard fracture specimens. Andrew et al. [16] have coupled the unloading-compliance method with the η approach to measure the $J - \Delta a$ curve using a single specimen with an extending crack. The η approach estimates the J-value using the area below the experimentally measured load-displacement curve, while the increasing compliance recorded in each unloading and reloading cycle allows an indirect sizing of the growing crack.

Direct application of the material J-R curve measured from standard fracture specimens in engineering critical assessments of pipes mandates a constraint scaling [17–22] to quantify the effect of the constraint loss experienced by the crack or crack-like defect in a pipe. Zhou [23] has proposed and validated the constraint corrections on the J-R curves measured from single-edge notched bend, SE(B) specimens, to estimate the J-R curve in SE(T) specimens, using three different constraint parameters, i.e., the T-stress, Q-stress and A_2. Research evidences [23–28] have revealed that the single-edge-notched tension, SE(T) specimen, represents more closely the constraint condition in cracked pipes than do the standard fracture specimens. Thaulow et al. [29] have presented the application of constraint correction for high strength steel and its weldments by conducting tests on deep and shallow notched SE(B) along with shallow notched SE(T) specimens.

Recent efforts on experimental fracture mechanics have extended the J-R curve measurement beyond the standard fracture specimens. Qian and Li [30] have reported the $J - \Delta a$ curves measured from flat plates with a center surface crack under four-point bending. Other researchers have presented fracture tests on full-scale pipe specimens to quantify $J - \Delta a$ curves from pipes with a through-wall crack [31–34], as well as damage-mechanics based numerical analyses for cracked or damaged pipes [35,36]. Recently, Parool et al. [37] have extended the η-unloading compliance method to measure the J-R curve from surface-cracked pipes.

The current study proposes a modified hybrid method to measure the J-R curve for surface-cracked pipes. The hybrid method combines the experimentally measured load-displacement data from a single surface-cracked pipe and the numerically computed load-displacement data from a number of FE pipe models with varying crack sizes. The validation study compares the J-R curve estimated from the proposed method and that from the unloading-compliance approach, for the SE(B) and SE(T) specimens, as well as pipe specimens with a circumferential surface crack.

The next section of the paper introduces the multiple specimen method, which illustrates the basic principles behind the hybrid method. The subsequent section presents the hybrid method for standard fracture specimens and the modified hybrid

Please cite this article in press as: Parool N et al. A modified hybrid method to estimate fracture resistance curve for pipes with a circumferential surface crack. Engng Fract Mech (2017), http://dx.doi.org/10.1016/j.engfracmech.2017.05.046

Download English Version:

https://daneshyari.com/en/article/7169184

Download Persian Version:

https://daneshyari.com/article/7169184

Daneshyari.com