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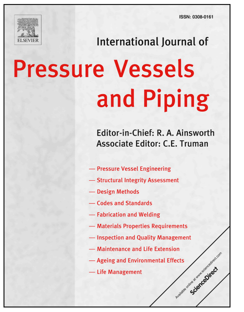

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A Probabilistic Model Including Constraint and Plastic Strain Effects for Fracture Toughness Predictions in a Pressure Vessel Steel

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Abstract

This work describes a probabilistic model based upon a local failure criterion incorporating the potential effects of plastic strain on cleavage fracture coupled with the statistics of microcracks. A central objective is to explore and further extend application of a multiscale methodology incorporating the influence of plastic strain on cleavage fracture phrased in terms of a modified Weibull stress ($\tilde{\sigma}_w$) to correct fracture toughness for effects of geometry and constraint loss. Fracture toughness testing conducted on an ASTM A285 Gr C pressure vessel steel provides the cleavage fracture resistance data needed to assess specimen geometry effects on experimentally measured J_c-values. Non-linear finite element analyses for 3-D models of fracture specimens with varying geometries provide the relationship between $\tilde{\sigma}_w$ and J from which the variation of fracture toughness across different crack configurations is predicted. This study shows that the modified Weibull stress methodology effectively removes the geometry dependence of fracture toughness values.

Keywords: Cleavage Fracture, Local Approach, Weibull Stress, Plastic Strain, Probabilistic Fracture Mechanics

1 Introduction

Fracture assessment procedures for pressurized components play a key role in design, fabrication and fitness-for-service(FFS) methodologies (such as, for example, repair decisions and life-extension programs) for pressure vessels, piping systems and storage tanks. Several cases of considerable interest include conventional pressure vessels, boilers and storage tanks designed to operate at intermediate temperature ranges (from 0°C to about 425°C), which are commonly made of low-carbon, moderate strength steels [1]. In particular, hydrocarbon-processing industry (HPI) pressure vessels which are exposed to low-temperature conditions, either as part of normal operation, emergency, equipment failure or an unplanned maintenance event, can be depressurized rapidly thereby causing auto-refrigeration of the component with increased risk for brittle failure [2, 3]. For components and process vessels typically made of carbon and low-alloy steels, unstable fracture by transgranular cleavage at temperatures in the ductile-to-brittle transition (DBT) region represents one the most serious failure modes as catastrophic structural failure may occur at low applied stresses with little plastic deformation.

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