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Procedia Materials Science 12 (2016) 24 – 29

Procedia Materials Science

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6th New Methods of Damage and Failure Analysis of Structural Parts [MDFA]

Collapse evaluation of double notched stainless pipes subjected to combined tension and bending

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Abstract

In order to simplify the structural integrity assessment of double cracked stainless steel piping, plastic collapse stress of asymmetric double notched pipes subjected to combined tension and bending was investigated. The experimental plastic collapse stress of the asymmetric double notched pipe is compared with the theoretical plastic collapse stress of the single notched pipe. The experimental plastic collapse points were over the theoretical collapse limit curve. The integrity of asymmetric double cracked stainless steel pipes subjected to combined tension and bending can be evaluated simply and conservatively using the theoretical plastic collapse stress of the single notched pipe.

Selection and peer-review under responsibility of the VŠB - Technical University of Ostrava,Faculty of Metallurgy and Materials Engineering

Keywords: combined load; integrity assessment; plastic collapse; stainless steel; piping

1. Introduction

Stainless steel piping items are widely used in light water nuclear reactor plants and chemical plants. By the end of 2011, approximately 30 percent of nuclear power plants in Japan had been in operation for more than 40 years (IAEA, 2012). Aging of piping in old nuclear power plants is significant concern to the safe operation of old nuclear

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Selection and peer-review under responsibility of the VŠB - Technical University of Ostrava,Faculty of Metallurgy and Materials Engineering
doi:10.1016/j.mspro.2016.03.005

Nomenclature

F	axial tensile force
M	applied bending moment
σ_b	bending stress
σ_m	membrane stress
σ_y	yield stress
θ_1, θ_2	notch angles
α_1, α_2	separation angles
R_m	mean radius of the pipe
t	pipe wall thickness
Y_Z	distance between the gravity center of cross sections of the pipe with and without a notch
β	neutral axis angle
e	distance between the notch tip and the gravity center of cross section of the pipe with notch
Z_e	section modulus
I_Z	moment of inertia of area for Z-Z axis

power plants. In order to safely operate old nuclear power plants, integrity assessment of aging piping is important and maintenance has to be performed as necessary. Structural integrity assessment procedures for reactor equipment are specified by the Japan Society of Mechanical Engineers (JSME, 2008) and the American Society of Mechanical Engineers (ASME, 2011).

The J-integral based criterion is widely used in elastic-plastic fracture mechanics (DUONG, 1996). The J-integral is useful to analyze ductile facture mechanics (Kamaya, 2012). However, the evaluation of the J-integral is difficult. The simple method is used to evaluate the integrity of damaged pipes (Medjo, 2012). The structural integrity evaluation of stainless steel pipes cracked due to aging can be evaluated using simple plastic collapse evaluation method based on the net-stress approach. This is because the large plastic deformation and large work hardening occur in the ligament area of the pipe before the plastic collapse. The plastic collapse point is generally obtained by the double elastic slope (DES) method and the double elastic deformation (DED) method (Saxena, 2006). A cracked pipe is typically subjected to combined tension and bending in structural integrity evaluations. A circumferential crack located in pipe cross section is more detrimental for guillotine break than an axial crack. In many cases, a circumferential cracked pipe can be treated as a single-edge cracked pipe (Izawa, 2007). In this study, the plastic collapse stress of asymmetric double circumferential notched stainless steel pipes subjected to combined tension and bending is investigated experimentally and is compared with the theoretical plastic collapse stress. In addition, the potential is discussed for the simplification of structural integrity evaluation of double cracked piping.

2. Theory

The distributions of the stress along the axial direction in the ligament area of the asymmetric double notched pipe at plastic collapse are shown in Fig. 1. This pipe is subjected to combined tension and bending moment. A thin-

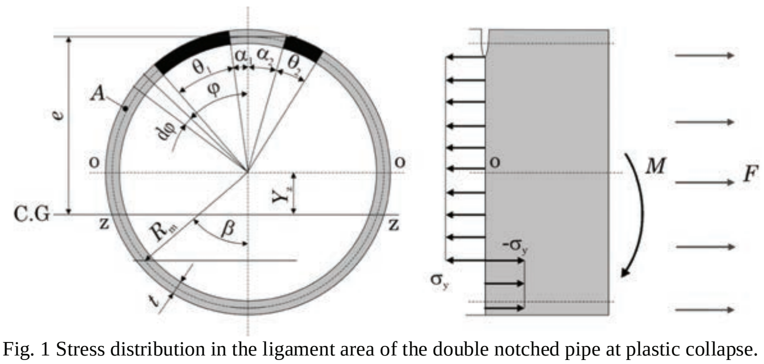

Fig. 1 Stress distribution in the ligament area of the double notched pipe at plastic collapse.