Investigation of failure behavior of ferritic–austenitic type of dissimilar steel welded joints

M.K. Samal, M. Seidenfuss, E. Roos, K. Balani

Reactor Safety Division, Bhabha Atomic Research Centre, Mumbai 400 085, India
Institut für Material Prüfung Werkstoffkunde und Festigkeitslehre, Universität Stuttgart D–70569, Germany
Department of Materials Science and Engineering, Indian Institute of Technology, Kanpur, Kanpur 208 016, India

Abstract

Dissimilar metal welded joints are integral parts of modern-day power and process plant equipments. Among the various types of material combinations, welded joints of ferritic grade carbon–manganese steel and austenitic stainless steels are very common in nuclear and chemical industries. Due to the difference in coefficients of thermal expansion, mechanical strength and fracture properties between the two materials, suitable welding electrodes for buttering and weld regions are selected in order to avoid a drastic gradient in the above properties across the welded region and hence, to avoid significant welding distortions. The weld joint is therefore a complex combination of different materials with presence of heat affected and carbon depleted zones due to the welding process. Investigation of fracture behavior of these types of joints is very important from point of view of design and safety analysis. In this work, the fracture behavior of a dissimilar metal welded joint has been studied through testing of single-edged notched bend type of specimens with initial cracks machined at different locations. The behavior of crack propagation and crack path are investigated and the critical location of the joint is identified through scanning electron microscope investigation. The fracture resistance behavior is also predicted using finite element analysis which incorporates the Gurson–Tvergaard–Needleman’s constitutive model and the simulation results are compared with those of experiment and available data from literature.

1. Introduction

Dissimilar metal welds impose a challenge to the engineers concerned with the structural integrity assessment of these joints. This is because of the highly inhomogeneous nature of these joints in terms of their microstructure, mechanical, thermal and fracture properties. In general, dissimilar metal welds are used in nuclear power plants and in oil refineries at locations where two different types of materials, e.g., ferritic grade carbon–manganese steel and austenitic stainless steel or nickel-base alloys need to be joined together. Nickel-base weld metals are used throughout the light water reactors (LWRs) to join the low alloy steel pressure vessel, the pressurizer and the steam generator nozzles to wrought nickel-base alloy and austenitic stainless steel components. The nickel-base alloy dissimilar metal welds are typically made of alloy 182 and alloy 82. Recently, alloy 52 has been used both in new constructions as well as in repair-welding in pressurized water reactors (PWRs), while in boiling water reactors (BWRs), alloy 82 is still considered to be the best choice [1,2]. The recent interest in the use of alloys with higher content of chromium is driven by the need to address the issue of cracking which is observed...