Abstract

The fracture resistance behaviour of SA 333 Gr 6 steel has been studied, as a part of the assessment of the structural integrity of the primary heat transfer piping of nuclear power plants. The microstructure of the steel and its relevant mechanical properties such as hardness, tensile and impact properties have been characterized. A series of tensile tests and a few strain rate change tests have been carried in the temperature range of 28° to 300°C. Monotonic *J-R* curves of the material have been determined in the temperature range of 28-300°C, whereas cyclic crack growth resistance curves have been determined at the stress ratios of $R = 0$, -0.5, -0.8, -1.0 and –1.2, and for three plastic displacement levels 0.5, 0.3 and 0.15mm at the ambient temperature. Fractographic studies and examinations of crack tip profiles of specimens interrupted during monotonic and cyclic *J* tests have been carried out

Microstructural characterization of the steel revealed banded ferrite-pearlite structure along both the longitudinal and transverse directions with high degree of cleanliness. The material exhibited dynamic strain ageing behaviour in the strain rate range 1.2×10^{-3} to $1.2 \times 10^{-5} s^{-1}$ and in the temperature range 200° to 300°C. The occurrence of dynamic strain ageing in the material between 200-300°C has been confirmed by strain rate change test. The results of fracture studies under monotonic loading infer: (a) the material exhibits high fracture resistance at room temperature; this has been attributed to its high degree of cleanliness, (b) the fracture resistance of the steel deteriorates in the temperature range 200-250°C; the deterioration in the fracture properties has been attributed to dynamic strain ageing behaviour operative in this temperature range, (c) the fracture initiation toughness and the crack propagation resistance are inferior along CL plane in comparison to LC plane; this has been attributed to the presence of elongated inclusions in CL crack plane and (d) the stretch zone in the investigated steel is of unconventional type and is intermixed with ductile tearing.

The results and their analysis of the cyclic fracture behaviour of the steel lead to the following conclusions (a) cyclic *J-R* curves are similar for positive stress ratio, (b) The cyclic *J-R* curves, the fracture initiation toughness and the resistance to crack propagation of the steel were found to degrade with (i) decrease in stress ratio from 0 to -1.0 and /or (ii) decrease in plastic displacement associated with these tests. The degradation in the fracture initiation toughness and the resistance to crack propagation of the steel for $R < 0$ occurs due to re-sharpening of the crack tip during compressive loading. The fractographic studies and examination of crack tip profiles have revealed that the crack propagation mechanism in monotonic and cyclic loading is different. An empirical relation has been proposed to estimate cyclic fracture toughness from its monotonic fracture toughness.