ABSTRACT

The fracture and fatigue characteristics of two varieties of Cu-strengthened HSLA steels, designated HSLA-80 and HSLA-100, differing essentially in their Cu and Ni contents, have been studied as part of assessment of their structural integrity for marine applications. The microstructures of the steels have been characterized using optical and scanning electron microscopes. Conventional mechanical properties like hardness, tensile parameters and impact toughness have been determined as per standard ASTM procedures. The tensile behaviour of the HSLA steels has been examined in detail for various prestrained conditions with emphasis on understanding their yielding and hardening behaviour. The fracture toughness of the steels has been evaluated using the elastic-plastic J-integral parameter. The effects of specimen thickness and application of prestrains on the fracture toughness of the materials have been investigated. The blunting behaviour of cracks and the formation of stretch zones during the process of ductile fracture has been studied. The resistance of the HSLA steels to the growth of fatigue cracks in them has been evaluated in air and 3.5% NaCl solution. The effects of specimen thickness, R-ratio and frequency on fatigue crack growth rates have been examined. The crack closure behaviour during fatigue crack growth has been quantified for the various test conditions. Attempt has been made to understand the micromechanism of crack propagation through extensive fractgraphic examinations.

Microstructural characterization revealed that HSLA-80 steel is primarily ferritic and HSLA-100 steel is predominantly bainitic in structure. Both of them possessed a fine prior austenitic grain size, and exhibited high degree of cleanliness. The conventional mechanical properties of the two steels conformed to the specifications based on which they were produced.

Studies on the tensile behaviour highlighted that the yield and post yield deformations in the two HSLA steels were substantially different due to difference in their microstructures. The hardening response in both the steels consisted of multiple regimes, each of which could be characterized with a strain hardening exponent. The multiple regimes of hardening, alongwith a regime of inhomogeneous deformation for the HSLA-80 steel, resulted in discrepancy between the strain hardening exponent and true uniform

elongation. The difference in the hardening behaviour in the two steels was also responsible for the nature of variation of tensile parameters with prestraining.

With the maximum thickness of 15mm used in fracture toughness specimens, validity criteria for plane strain measurements could not be met. It was observed that the apparent fracture toughness of the HSLA-80 steel was higher than that of HSLA-100. The blunting line slope for *J-R* curve of HSLA-80 steel showed substantial deviation from theoretical predictions. This could be attributed to the formation of secondary cracks within the stretch zone during the process of crack blunting. It was observed that variation of specimen thickness did not affect the blunting line slope, but altered the fracture toughness of both the steels. Application of prestrains resulted in retention of fracture toughness upto 2% prestrain, and rapid deterioration thereafter. A model for predicting the fracture toughness of prestrained material from tensile property data has been proposed.

The fatigue crack growth resistance of the two HSLA steels was found to be similar in air. But in 3.5% NaCl environment HSLA-80 was observed to be superior in comparison to HSLA-100. The effect of specimen thickness and *R*-ratio in air, and the effect of *R*-ratio in NaCl solution could largely be explained from considerations of fatigue crack closure. The effect of frequency in 3.5% NaCl solution was found to be primarily due to changes in the micromechanism of fatigue crack growth, as observed by a study of fatigue fracture surfaces. A methodology for accelerating "decreasing ΔK fatigue crack growth rate test" was formulated and validated. This was employed for the corrosion fatigue crack growth tests at lower frequencies.