ABSTRACT

Fatigue crack initiation, short crack growth behaviour and fatigue thresholds of short and long cracks of a few plain carbon steels (0.003%C, 0.14%C, 0.25%C, 0.47%C and 0.62%C steels) have been studied. The phenomena of the formation of small cracks in 0.003%C (single phase) and 0.14%C (multiphase) steels have been studied on dumble-shaped plate type specimens under varied cyclic stress amplitudes at the load ratio of R = 0. Simple experimental techniques have been developed with new specimen configurations to examine short crack growth behaviour vis-à-vis microstructural features of materials and to determine the fatigue thresholds using a rotating bending machine. The fatigue thresholds have been estimated by load drop procedure and each crack profile is recorded together with the associated microstructures during these studies. The microstructures of the investigated steels have been characterized using optical and scanning electron microscopes. The influence of the microstructural features of these steels on the near threshold crack growth has been examined. Conventional mechanical properties like hardness and tensile parameters have been determined following standard procedures.

Studies on crack initiation revealed that ferrite-pearlite interfaces and/or ferrite-ferrite grain boundaries are preferred crack initiation sites in the investigated steels. The lengths of the initiated cracks at ferrite-pearlite interfaces or at grain boundaries are usually larger in size compared to those of grain body cracks. The formation of slip band inside the grain body, slip band impingement at grain boundary and elastic-plastic incompatibility are attributed as the main causes for crack initiation. The formation of irregular voids inside slip bands, initiation and growth of small voids at grain boundaries and subsequent joining of these are some interesting observations for fatigue crack initiation in 0.003%C steel. It is observed here for the first time that the angle between the direction of banding and the loading axis, has pronounced effect on the orientation and on the size of initiated cracks.

Studies on short crack growth have demonstrated that the developed technique (with new specimen configuration) can be used satisfactorily to understand short crack growth behaviour and to determine the transition length from short to long

cracks. The estimated critical crack lengths can be considered as function of the nature of the short cracks. Short crack growth rate decreases or gets arrested with increasing crack length under the same applied crack driving force. The fatigue threshold values obtained from short crack growth experiments are found to lie in a narrow range and are closer to long crack thresholds. The cracks were found to have affinity to grow through interfaces, but the length of a crack passing through a specific phase was found to be approximately proportional to its amount.

The developed technique to determine fatigue thresholds using a rotating bending machine yielded reliable results. The fatigue thresholds of four steels with carbon contents 0.003, 0.25, 0.47 and 0.62% were found to be 3.8, 4.2, 5.8 and 6.0 $MPam^{1/2}$ respectively. The developed procedure is based on the measurement of da/dN with high sensitivity of the order of 10^{-12} m/cycle and the obtained threshold values appear to represent effective fatigue thresholds determined by conventional technique. Analysis of the crack growth behaviour near the notch indicates occurrence of non-propagating cracks only in 0.25%C and 0.47%C steels. The occurrence of non-propagating cracks has been attributed to the presence of some secondary stress field at the crack tip. Fatigue threshold at R = -1 for plain carbon steels increases with increasing carbon content or the harder pearlitic constituent.

A new model for short fatigue crack growth has been proposed to overcome some of the limitations of the earlier models. The model accounts the effect of mixed mode loading and the surface characteristics of a specimen, and describes both short and long crack growth. A series of computations have been carried out to examine the influence of different parameters considered in the model to describe short crack growth rate. The generated experimental results as well as some reported results have been satisfactorily described using the proposed model.