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Short and Long Crack Growth Behavior in Ferrite Bainite Dual Phase Steels

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Abstract : There is growing awareness to design steels against fatigue damage Ferrite martensite dual-phase steels are known to exhibit favourable mechanical properties like good strength, ductility, toughness, continuous yielding, and high work hardening rate. However, dual-phase steels containing bainite as second phase are potential alternatives for ferrite martensite steels for certain applications where good fatigue property is required. Fatigue properties of dual phase steels are popularly assessed by the nature of variation of crack growth rate (da/dN) with stress intensity factor range (ΔK), and the magnitude of fatigue threshold (ΔKth) for long cracks. There exists an increased emphasis to understand not only the long crack fatigue behavior but also short crack growth behavior of ferrite bainite dual phase steels. The major objective of this report is to examine the influence of microstructures on the short and long crack growth behavior of a series of developed dual-phase steels with varying amounts of bainite and. Three low carbon steels containing Nb, Cr and Mo as microalloying elements steels were selected for making ferrite-bainite dual-phase microstructures by suitable heat treatments. The heat treatment consisted of austenitizing the steel at 1100°C for 20 min, cooling at different rates in air prior to soaking these in a salt bath at 500°C for one hour, and finally quenching in water. Tensile tests were carried out on 25 mm gauge length specimens with 5 mm diameter using nominal strain rate $0.6x10^{-3}$ s^{-1} at room temperature. Fatigue crack growth studies were made on a recently developed specimen configuration using a rotating bending machine. The crack growth was monitored by interrupting the test and observing the specimens under an optical microscope connected to an Image analyzer. The estimated crack lengths (a) at varying number of cycles (N) in different fatigue experiments were analyzed to obtain log da/dN vs. log °ΔK curves for determining ΔKthsc. The microstructural features of these steels have been characterized and their influence on the near threshold crack growth has been examined. This investigation, in brief, involves (i) the estimation of ΔKthsc and (ii) the examination of the influence of microstructure on short and long crack fatigue threshold. The maximum fatigue threshold values obtained from short crack growth experiments on various specimens of dual-phase steels containing different amounts of bainite are found to increase with increasing bainite content in all the investigated steels. The variations of fatigue behavior of the selected steel samples have been explained with the consideration of varying amounts of the constituent phases and their interactions with the generated microstructures during cyclic loading. Quantitative estimation of the different types of fatigue crack paths indicates that the propensity of a crack to pass through the interfaces depends on the relative amount of the microstructural constituents. The fatigue crack path is found to be predominantly intra-granular except for the ones containing > 70% bainite in which it is predominantly inter-granular.

Keywords : bainite, dual phase steel, fatigue crack growth rate, long crack fatigue threshold, short crack fatigue threshold
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