ABSTRACT

Ferrite-bainite steels are considered as potential alternatives for ferrite-martensite dual-phase steels for certain applications, where good fatigue property is required. The primary aim of the present investigation is to develop and to understand the fatigue crack growth behaviour in ferrite-bainite dual-phase steels. Three low carbon steels containing Nb, Nb and Cr and Nb, Cr and Mo as microalloying elements have been selected for this investigation. The steels are coded as S1, S2 and S3 and these have been suitably heat treated to achieve ferrite-bainite microstructures. The microstructural constituents have been characterized by optical microscopy, SEM, XRD, TEM and EDX analyses. Macrohardness of the developed structures and microhardness of the constituent phases of the differently heat-treated steels have been determined using suitable loads. Tensile tests have been carried out using an universal testing machine. Fatigue behaviour of the developed steels have been studied, using a developed specimen configuration, with the help of a rotating bending fatigue testing machine at a frequency of 50 Hz and using compact tension specimen in INSTRON machine at a frequency of 25 Hz. The optical microscopic examination of the crack profiles and their associated microstructures as obtained on samples tested by rotating bending machine have been carried out using an image analyzer. The experimental results indicate that the strength and elongation of the developed ferrite bainite dual phase steel (FBDP) ranges from 540-1230 MPa and 9.5-22% respectively depending on different compositions and microstructures. The investigated FBDP steels indicate better ductility at the expense of strength, when compared with the tensile properties of the ferrite-martensite dual-phase steels (FMDP) steels, prepared from the same stock having similar volume fraction of martensite. For example the strength of an S1FBDP steel with 90.3 percent bainite is 47 % lower while its elongation is 165% higher compared with S1FMDP steel with 90% of martensite.

The short and long crack behaviour of all the developed FBDP steels have been analyzed with an emphasis on their fatigue threshold and microstructural interaction on crack path. Fatigue thresholds (ΔK_{th}) values have been determined from crack growth rate (da/dN) versus stress intensity factor range (ΔK) plots, obtained from the analyses of the data of the estimated crack lengths (a) versus number of cycles (N). The fatigue threshold values of the FBDP steels are found as 5.81-7.16 (Nb micoalloyed), 6.4-6.57 (Nb and Cr micoalloyed) and 7.10-7.37 (Nb, Cr and Mo micoalloyed) MPa $m^{1/2}$. These obtained fatigue threshold values are higher than the reported values of FMDP steels having similar composition. Studies on short crack growth revealed that the maximum value of the short crack fatigue threshold increases marginally with increasing amount of bainite and lies with in the range of 5.2-5.8 MPa $m^{1/2}$ for Nb micoalloyed, 5.5-6.3 MPa $m^{1/2}$ for Nb and Cr micoalloyed, and 5.95-6.9 MPa $m^{1/2}$ for Nb, Cr and Mo micoalloyed steels. The fatigue crack path in S1-steel is found to be predominantly intra-granular except for the one containing around 70% bainite in which it is predominantly inter-granular.

Key Words: Bainite; Dual-phase steel; Fatigue; Volume fraction; Strain hardening; Fatigue crack growth rate; Micro-crack initiation; Grain-boundary; Inter-granular fracture; Intra-granular fracture; Short crack fatigue threshold; Long crack fatigue threshold.