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Effects of ε-martensitic Transformation on Crack Tip Deformation, Plastic Damage Accumulation, and Slip Plane Cracking Associated with Low-cycle Fatigue Crack Growth

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Abstract

Fatigue crack propagation behavior and associated plastic strain evolution in the vicinity of crack planes were investigated at different crack lengths for Fe-30Mn-6Al, Fe-30Mn-4Si-2Al, and Fe-30Mn-6Si alloys. In particular, fractographic analyses and electron backscatter diffraction measurements underneath the fracture surfaces were carried out. It was found that austenite of the Fe-30Mn-6Al alloy was completely stable at ambient temperature, and the Fe-30Mn-6Si and Fe-30Mn-4Si-2Al alloys showed deformation-induced ε-martensitic transformation. Both the Fe-30Mn-4Si-2Al and Fe-30Mn-6Si alloys showed γ/ε interface cracking. However, ductile cracking was observed in the former, while the latter showed brittle-like cracking. Additionally, both the Fe-30Mn-4Si-2Al and Fe-30Mn-6Al alloys showed ductile fatigue striation when the cracks became long, but the critical crack length to induce the striations in the Fe-30Mn-4Si-2Al alloy was longer than that in the Fe-30Mn-6Al. In contrast, the Fe-30Mn-6Si alloy did not show striation, not even just before failure. These observations are all related to ε-martensite transformation. In terms of the crack tip deformation, the key roles of ε-martensitic transformation are (1) brittle-like cracking along the γ/ε interface, (2) inhibition of fatigue damage accumulation, and (3) geometrical constraint of ε-martensite crystallographic structure at a fatigue crack tip. When ε-martensite is ductile, such as in the case of the Fe-30Mn-4Si-2Al alloy, the brittle-like cracking does not occur. Because of the roles (2) and (3) mentioned above, the Fe-30Mn-4Si-2Al alloy showed the lowest fatigue crack growth compared to the other tested alloys. This paper presents the proposed ε-martensite-related crack growth mechanism in detail.

Keywords: Martensite transformation; Fatigue crack growth; Austenitic steel; Low cycle fatigue; Fractography