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Impact of Mn–C couples on fatigue crack growth in austenitic steels: Is the attractive atomic interaction negative or positive?

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Abstract

In this study, the fatigue crack propagation behavior of Fe-23Mn-0.5C and Fe-18Cr-14Ni austenitic steels was investigated in terms of microstructure and crack propagation paths. Specifically, we carried out rotating bending fatigue tests and subsequent observations of the specimen surface by replica technique, fracture surface by scanning electron microscopy, and detailed microstructure in a vicinity of the fractured part by electron backscatter diffraction observations. Fatigue limits of the Fe-23Mn-0.5C and Fe-18Cr-14Ni steels were 260 MPa and 110 MPa, respectively. The Fe-23Mn-0.5C steel showed a lower fatigue crack propagation rate and higher fatigue limit compared to the Fe-18Cr-14Ni steel because of an attractive Mn-C atomic interaction. The Mn-C interaction has the following effects on the fatigue crack growth behavior: As a negative effect, deformation-induced decomposition of Mn-C couples results in local softening, causing strain localization that cause crack initiation along $\{111\}_{\gamma}$ slip planes. On the other hand, the ease of crack initiation along the slip planes assists crack branching, zigzag crack growth, and subcrack formation. These factors enhance roughness-induced crack closure. In addition, the formation of subcracks brings about stress release at a crack tip. Furthermore, as previously reported, the occurrence of dynamic strain aging arising from Mn-C couples assists fatigue crack non-propagation. These positive effects contribute to enhanced fatigue crack propagation resistance, which results in the lower fatigue crack propagation rate of the Fe-23Mn-0.5C steel compared to that of the Fe-18Cr-14Ni alloy.