FATIGUE CRACK EXTENSION MODE OF 18%Ni MARTENSITIC STEEL

Ren Pengxu[1]*, Daisuke Itoh[1 2], and Shigeru Hamada[1]

[1]*Kyushu University, Fukuoka-shi, Fukuoka, JAPAN*
[2]*Nippon Steel Corporation, Kitakyushu-shi, Fukuoka, JAPAN*
** Presenting Author email: ren.pengxu.512@s.kyushu-u.ac.jp*

Abstract

Martensite is applied as the main microstructure of high-strength steel to satisfy the demand for lightweight machines. As the fatigue crack extension life takes almost the whole fatigue life, the complex fatigue extension behavior needs further study. This study is planned to clarify the effect of the hierarchical microstructures and their interfaces on the fatigue extension and the fatigue crack extension mode for the safe and long-lasting use of this material. To achieve the proposal, rotating bending fatigue tests of 18% Ni martensitic steel was carried out. Fatigue crack extension behavior and microstructure near the crack path were observed on the specimen surface. The crack extension was found to be discontinuous and was processed by the sub-crack initiation and coalescence with the main crack. By observing the microstructure around the crack path, the observed sub-crack was found to be the intergranular crack. The proposed reason for the extension process was thought to be the strain localization by the slip along {110} plane and high-angle microstructure interface resistance to dislocation motion. Besides, the crack path included intergranular and transgranular cracks. And the crack extension mode in this material was considered damage accumulation mode.

1. Introduction

The lath martensite microstructure is famous for its hierarchical microstructure, including prior austenite grains, packets, blocks, and lath. The slip behavior and strengthen mechanism were studied deeply under tension loading. The active slip systems in bcc {110} <111> and {211} <111> are classified into in-lath-plane and out-of-lath-plane slip, considering the {110} habit plane in lath geometry. Although the high angle grain boundaries and the high dislocation density would increase the performance in martensite, these cause complex mechanisms in fatigue. The research focused on fatigue crack initiation, and small crack propagation was carried out. However, the crucial interface and mechanism of fatigue crack initiation were still blurry. Therefore, further study about the crack extension evolution affected by the hierarchical microstructure is needed. Much research was carried out on fatigue crack extension on different engineering materials. Two crack extension modes have been defined: “plastic deformation (PD) mode” and “damage accumulation (DA) mode.” The former is caused by alternative slip and deformation involving dislocation emission at the crack tip. The latter is driven by the relation between the crack and damage accumulation ahead of the crack tip caused by the dislocation motion on a single slip plane due to cyclic shear strain.

This study aims to clarify the fatigue crack extension behaviors of martensitic steel. Two issues were focused on: The effect of the hierarchical microstructures and their boundaries on the fatigue crack extension and the fatigue crack extension mode in martensitic steel.

2. Results

The rotating bending fatigue test was performed to conduct the fatigue crack extension behaviors at $R = -1$. The *S-N* curve was obtained to confirm the fatigue property. During the fatigue test, the test was stopped intermittently. Under the no-load condition, the replica method was carried out to observe the specimen surface and to measure the crack extension behavior. After a specified number of load cycles, the test was stopped. An area near the crack path was observed by electron backscatter diffraction (EBSD) and electron channeling contrast imaging (ECCI) to indicate the effect of microstructure and slip behavior on fatigue crack extension. After the specimen failure, the fracture morphologies were observed via scanning electron microscopy (SEM).

From the replica results, the crack extension was found to be discontinuous. Sub-crack would initiate ahead of the main crack and appear at the microstructure interfaces. Afterward, the sub-crack coalesced with the main crack and made the crack extension. The crack initiation site was intergranular and mainly along a block boundary by comparing the results of fracture morphologies and the replica. There was an obvious boundary of the fracture surface, which divided the surface with and without streaks. This difference on the fracture surface was thought to be caused by fatigue crack extension mode transition. Besides, the crack deflection and propagation along {110} plane was observed. And the inter-granular crack path was found on the specimen surface and internal specimen.

3. Conclusions

- Because of the strain localization, the crack extension of 18%Ni martensitic steel was driven by the sub-crack initiation and coalescence.

- Fatigue crack extension mainly along the {110} plane indicates the in-lath slip is active. Therefore, the crack extension mode in this material was DA mode.

Acknowledgments

This work was financially supported by Support for Pioneering Research Initiated by the Next Generation (SPRING) program of Japan Science and Technology Agency (JST) (Grant Number JPMJSP2136).