Rotational bending fatigue property and crack stagnation behavior in nitrocarburized JIS SCM420 steel

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The crack propagation behavior in rotating bending fatigue test of nitrocarburized steel were investigated, focusing on the crack stagnation behavior. Normalized JIS SCM 420 steel was employed for this study after nitrocarburizing treatment. The rotating bending fatigue test was conducted with the specimen with a notch of 1R. The fatigue limit was defined by the maximum stress at which the test could be continued more than 10^7 times. The crack propagation behaviors, in the fatigue test were studied at the number of cycles between 10^5 and 10^7. We found that the crack is clearly stagnated at the length of about 200 µm at the fatigue limit of 400 MPa: the crack stagnation controls the fatigue strength. The calculated stress intensity factor in this process increases with the depth from the notch, implying that the crack stagnation cannot be explained only by the change of the stress intensity factor. Moreover, retained austenite is not existed in the nitrocarburized normalized SCM 420. While a large amount of plastic strain was observed around the tip of the crack by EBSD analysis. Because the stagnated position corresponds to the critical depth between the hardened and unhardened regions formed by nitrocarburizing, it can be easily deformed. Therefore, it is inferred that the crack stagnation in nitrocarburized JIS SCM420 steel can be explained by the plastic-induced closure mechanism.

Keywords: *steel, nitriding, fatigue, crack propagation, EBSD*

1. Introduction

Nitrocarburizing is a heat treatment process for hardening the surface of structural steels and is applied to increase fatigue strength. It has been reported that the rotational bending fatigue strength of carburized steels is controlled by crack stagnation behavior[1)]. The mechanism of stagnation has been considered to be the increase in residual stress by stress-induced or strain-induced transformation of retained austenite to martensite during the fatigue process. Although some reports have examined the fatigue strength and structure of the compound layer formed on the surface of nitrocarburized steels[2,3)], their crack propagation behavior has not been clarified. In this study, the crack propagation behavior of nitrocarburized steel was investigated in a rotating bending fatigue test, focusing on crack stagnation behavior.

2. Experimental procedure

Normalized JIS SCM 420 steel after nitrocarburizing treatment was used in this study. The chemical composition before nitrocarburizing is listed in Table 1. Gas nitrocarburizing was carried out at 570 ℃ for 3 hours with NH3, N2 and CO2 as the treatment gases. A rotating bending fatigue test was conducted with a specimen with a 1R notch. The fatigue limit was defined by the maximum stress at which the test could be continued for more than 10^7 cycles. The crack propagation behavior between 10^5 and 10^7 cycles were studied. Microstructure observation by optical microscopy and EBSD analysis were also carried out.

Table 1 Chemical composition of investigated JIS SCM420 steel (mass%).

	C	Si	Mn	P	S	Cr	Mo
JIS SCM420	0.20	0.21	0.80	0.016	0.018	1.14	0.20

3. Results and Discussion

The change in the crack length during the fatigue test at the fatigue limit of 400 MPa is shown in Fig. 1. The crack has clearly stagnated at a length of about 200 µm at the fatigue limit, which indicates that crack stagnation is controlling for fatigue strength. The calculated stress intensity factor in this process increases with the depth from the notch, implying that crack stagnation cannot be explained only by the change in the stress intensity factor. An EBSD analysis confirmed that retained austenite did not exist in the nitrocarburized normalized SCM 420. Fig. 2 shows an optical micrograph around the crack and the corresponding KAM (Kernel Averaged Misorientation) map. Since a large amount of plastic strain was detected around the crack, it is inferred that crack stagnation in nitrocarburized steel can be explained by a plastic-induced closure mechanism.

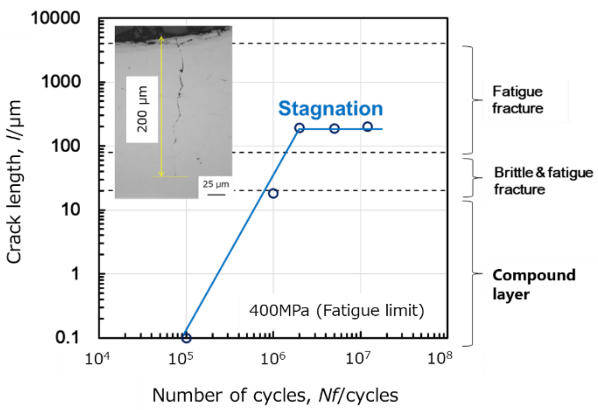

Fig. 1 Change in crack length with number of cycles at fatigue limit in rotating bending fatigue test of nitrocarburized JIS SCM420. An example of a stagnated crack (1.2×107 cycles) is also shown in the figure.

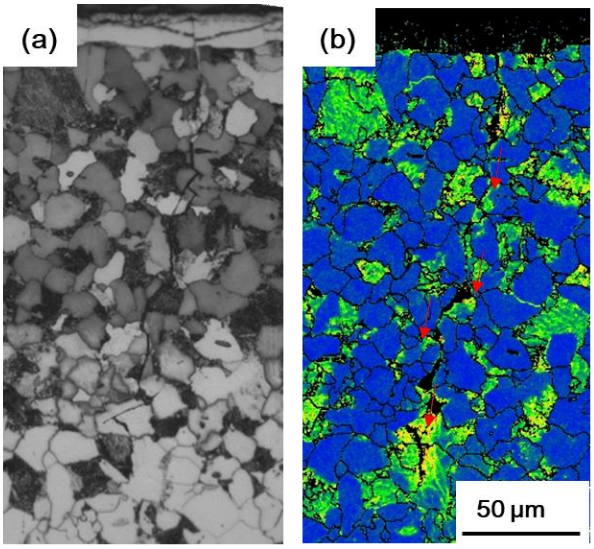

Fig. 2 (a) Optical micrograph and (b) KAM map determined from EBSD analysis of nitrocarburized JIS SCM420 after rotating bending fatigue test.

4. Conclusion

The crack propagation behavior of nitrocarburized JIS SCM 420 was investigated in a rotating bending fatigue test. Crack stagnation occurred and was considered to be controlling for fatigue strength. It is suggested that the fatigue limit is explained by the crack stagnation behavior due to plastic-induced closure.

References

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