Construction of Probabilistic Model on Interior Crack Nucleation and Propagation in Very High Cycle Fatigue of High Strength Steels

Tatsuo Sakai[a], Yuki Nakamura[b], Akiyoshi Nakagawa[c], Noriyasu Oguma[d]

[a] *Research Organization of Science and Technology, Ritsumeikan University, sakai@se.ritsumei.ac.jp*

[b] *Dept. of Mech. Engineering, National Institute of Technology, Toyota College, nakamura@toyota-ct.ac.jp*

[c] *Machinery Systems Division, Hitachi Industrial Products, Ltd., akiyoshi.nakagawa.ue@hitachi.com*

[d] *Faculty of Engineering, University of Toyama, oguma@eng.u-toyama.ac.jp*

Introduction

In very high cycle regime, the fatigue crack of high strength steels tends to occur around the interior inclusion, and fine granular area (FGA) is formed around the inclusion. The fatigue crack growth rate in the FGA is less than the Bergur's vector and lattice constant of the steel. How can we interpret such a low rate of the fatigue crack growth? This question is the fundamental motivation of the present study.

Fractography of fatigue crack growth inside the material and its probabilistic model

The authors have carried out fatigue tests for the bearing steel (SUJ2) in rotating bending toward the very high cycle regime of 10^9 cycles. Fig.1 indicates the SEM observation of the fracture surface around inclusion, in which a clear FGA is found around the inclusion[1]. Fig2(a) represents the FGA replaced by a number of fine cells, whereas Fig.2(b) indicates the definition of the crack length *a* (radius of penny-shape crack).

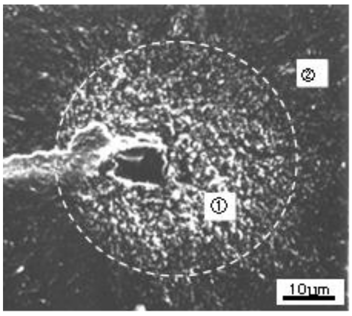
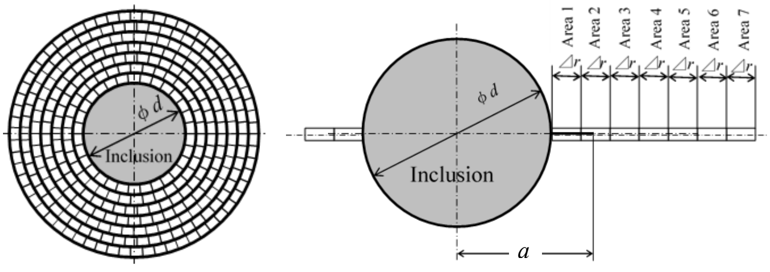


Fig.1 FGA formed around inclusion



(a) Cell division (b) Definition of virtual crack length within FGA

Fig.2 Cell division and definition of crack length within fine granular area (FGA)

Then, the crack length is given as follows;

$$a = \frac{d}{2} + 7\Delta r \frac{n_c}{n_t} = \frac{d}{2} + 7\Delta r P(N) \qquad (1)$$

where n_t is total number of cells inside the FGA, n_c is the number of debonded cells and *P(N)* denotes the debonding probability, respectively. Thus, we obtain the crack growth rate by Eq.(2).

$$\frac{da}{dN} = 7\Delta r \frac{dP(N)}{dN} \qquad (2)$$

Accepting the intermittent and discrete cell debonding together with an appropriate function as *P(N)*, the crack growth law indicated by thick line in Fig.3 is obtained through numerical analysis. The analytical result is in good agreement with the experimental results by some researchers.

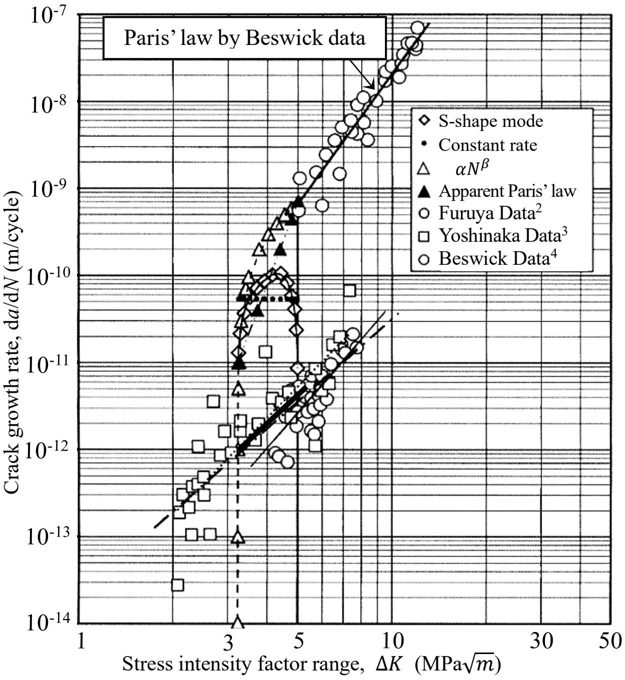


Fig.3 Relationship between da/dN and ΔK [52]

Conclusion

The crack growth behavior within FGA is well interpreted by introducing the intermittent and discrete debonding model combined with an appropriate function of *P(N)*.

1) N. Oguma et al., *Trans. of the JSME*, Vol.88, No.907, **2022**, p.22-00021. 2) Y. Furuya, *Mater Sci Eng, A*, Vol.678, **2016**, p.260. 3) F. Yoshinaka et al., *J Soc Mat Sci, Japan*, Vol.66, **2017**, p.928. 4) J. M. Beswick, *Metal. Trans.*, Vol.20A, **1989**, p.1961.