CRACK PROPAGATION RATE DEPENDING ON STRUCTURE OF MODELING COMPOSITE MATERIALS

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ABSTRACT

It is said that the remarkable progress of Japanese automobiles depends on the development of dual phase steel. Our martensite-ferrite dual phase steel that is three dimensionally composed of martensite in hard phase and ferrite in soft phase is the model material for composite materials. Fatigue crack propagation behavior resulting from different structure sizes is different. The reason is investigated in the study of fracture mechanism by using microstructural method. This dual phase steel has a remarkable difference in strength, and its deformation behavior is applied for construction materials. The fatigue crack propagation behavior in the region of stage II is not only dependent on the striation formation mechanism, but also the microstructure such as grain size of the soft phase, the volume fraction of the hard phase and its distribution state.

1 INTRODUCTION

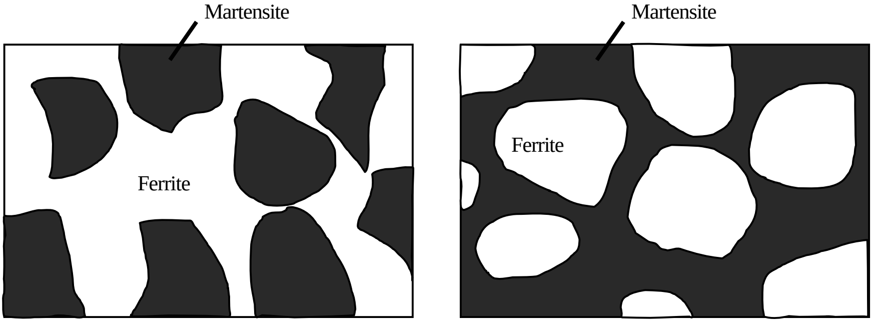
It has been recognized that the fatigue crack propagation behavior in the region of stage II is not only dependent on striation formation mechanism, but also the microstructure such as the grain size of the soft phase, the volume fraction of the hard phase and its distribution state. Thus, it is presumed that the fatigue crack propagation in the region of stage II is also affected by the microstructure according to the Paris Law.

To characterize the fatigue crack propagation behavior in dual phase steel, it is necessary to evaluate the micro-fracture mechanisms of the microstructure.

In this study, martensite-ferrite dual phase steel composed of the martensite in hard phase and the ferrite in soft phase is prepared. The fatigue crack propagation behavior for the variation of the ferrite grain size is investigated in the study of fracture mechanism by using microstructural method.

2 BODY OF PAPER

Figure 1 shows a typical figure of the microstructures of specimens. The microstructural characteristics for specimens are tabulated in Table 1 and the mechanical properties are given in Table 2. The ferrite grain size of specimen A is greater than specimen B, and that is the only principal difference between these two microstructures. In all other respects they are quite similar.



(a) Specimen A (b) Specimen B

Figure 1: Schematic drawing of typical microstructures of dual phase steel

Table 1: Metallurgical properties

Specimen	Ferrite Grain Size D (μm)	Volume Fraction V_m (%)	Connectivity C_t (%)	Hardness (25g)		Hardness Ratio
				Martensite	Ferrite	
A	140	45	93	661	155	4.2
B	70	46	93	668	163	4.1

Table 2: Mechanical properties of materials

Specimen	0.2 % Proof Stress	Tensile Stress	Nominal Breaking Strain
	(kgf/mm^2)	(kgf/mm^2)	(%)
A	74	98	3.1
B	75	99	12.3

The fatigue crack propagation rate *da/dN* as a function of stress intensity factor range ΔK are shown in Figure 2 and 3. Figure 4 shows the linear relation between *da/dN* and ΔK obtained by fitting data points for materials A and B, and their relations are given by the eqns (1) and (2) respectively.

$$\text{Material A: } da/dN = 4.26\times10^{-13}(\Delta K)^{4.28} \tag{1}$$

$$\text{Material B: } da/dN = 4.90\times10^{-14}(\Delta K)^{4.73} \tag{2}$$

It is observed from Figure 2 that the crack propagation rate of the material A of larger ferrite than the material B is greater at low ΔK. However, this difference of the crack propagation rate between the two materials disappears as ΔK increases. In particular, it is found the crack propagation rate of the material A is nearly equal to material B despite the ferrite size when ΔK exceeds 130 kgf/mm^2.

The calibration curve of crack length was obtained by using the notched specimen machined by saw-cutter and then the curve was compared to the real crack length. The stress intensity factor range, $\Delta K = K_{max} - K_{min}$, is calculated according to the eqn (3),

$$\Delta K = \frac{\Delta P(2+\alpha)}{B\sqrt{W}(1-\alpha)^{3/2}}\left(0.886 + 4.64\alpha - 13.32\alpha^2 + 14.72\alpha^3 - 5.6\alpha^4\right) \tag{3}$$

where $\alpha = a/W$, ΔP is the applied load range, B is the specimen thickness, a is the crack length, and W is the specimen width.

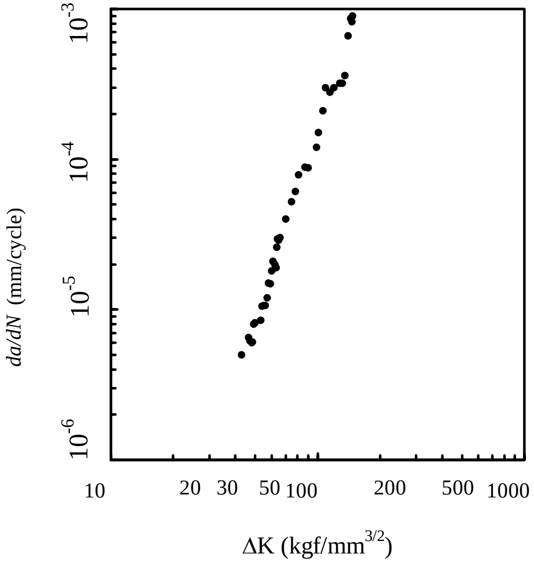


Figure 2 : Fatigue crack propagation rate vs. stress intensity factor range of specimen A (ferrite grain size = 140 μm)

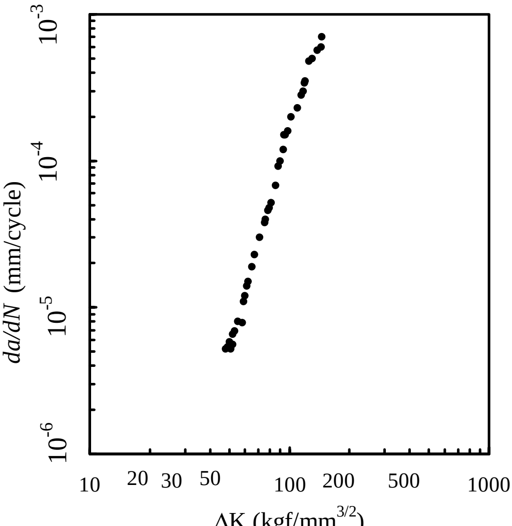


Figure 3 : Fatigue crack propagation rate vs. stress intensity factor range of specimen B (ferrite grain size = 70 μm)

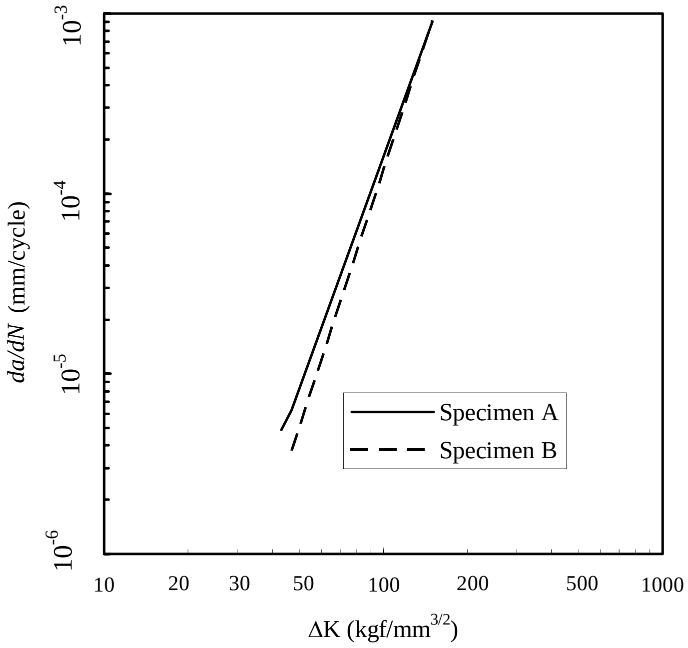


Figure 4 : Effect of grain size on crack propagation rate

3 CONCLUSION

The effect of the microstructure on the fatigue crack propagation rate and its resistance by using two kinds of the martensite-ferrite dual phase steel composed of the martensite in hard phase and the ferrite in soft phase was evaluated. The conclusions were as follows:

1) The fatigue crack propagation rate was influenced by the ferrite grain size. In other words, at low stress intensity factor range ΔK, the fatigue crack propagation rate resulted from the structural size decreases as stress intensity factor range ΔK increases.
2) The above conclusion is explained by the degree of the crack arrest effect of the martensite phase for the fatigue crack propagation depending on the ratio of the reversed plastic zone site to the ferrite grain size.

4 REFERENCES

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