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Evaluation of Fatigue Crack Growth Rate Using a New Parameter ΔA

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ABSTRACT

This paper is a study to estimate fatigue crack growth rate using a new parameter ΔA, which was derived experimentally. The cyclic strain distribution ($\Delta\varepsilon_{eq}$) at the local zone near the crack tip was investigated during the process of fatigue, and its results were measured and analyzed using the Computer-Aided Fine Dot Grid Method. It was found that the magnitude of the $\Delta\varepsilon_{eq}$ was varied by cyclic load level and material, but the shape of the $\Delta\varepsilon_{eq}$ was scarcely altered. The cyclic strain distribution could be formulated as $\Delta\varepsilon_{eq} = \Delta A \cdot f(\theta) \cdot r^{-1}$ within the local cyclic strain field. The ΔA here was proposed as a parameter which quantitatively characterized the $\Delta\varepsilon_{eq}$ in the local cyclic strain field near the crack tip, and the ΔA might have been defined as the cyclic strain intensity factor range. This ΔA was applied to estimate fatigue crack growth rate. The fatigue crack growth test was carried out at different stress ratios of R = 0.1, 0.3 and 0.5 for different materials of SNC631-A, SNC631-B, S45C, Al2024-T3 and Al7075- T6. The fatigue crack growth rates (da/dN) at the three stress ratios for the five materials were expressed as a function of the stress intensity factor range (ΔK), the effective stress intensity factor range (ΔK_{eff}) and the cyclic strain intensity factor range (ΔA), respectively. The superiority and usefulness of the parameter ΔA for the stress ratio and the material were verified and its validity was discussed as compared with the ΔK and the ΔK_{eff}. As a result, the relation between the da/dN and the ΔA could be expressed as $da/dN = C(\Delta A)^{2.0}$ regardless of the stress ratio for the five materials. The coefficient C in $da/dN = C(\Delta A)^{2.0}$ was a constant of material which was varied with material. Thus, a method was presented that evaluated the coefficient C using a simple experimental equation including the yield strength (σ_{ys}) and fracture toughness (J_{IC}) of material, which was $C = 2.35 \times 10^{-5}(\sigma_{ys}/J_{IC})^{0.35}$. Therefore, the equation between da/dN and ΔA resulted in $da/dN = 2.35 \times 10^{-5}(\sigma_{ys}/J_{IC})^{0.35} \cdot (\Delta A)^{2.0}$.

INTRODUCTION

Fatigue crack growth is a very local fracture phenomenon. It is a prerequisite to the examination of the fatigue fracture problem of materials that the distribution of stress and strain is grasped clearly within the fracture process zone near the crack tip in fatigue fracture. This fracture process zone is the region in which the immediate crack extension process, such as advanced separations, void growth and coalescence, takes place.

Many studies have been conducted to investigate the distribution of stress and strain at the fracture process zone on the basis of the fracture mechanics theories and the finite element methods (Rice, 1967, 1968; Hutchinson, 1968). However, those are almost theoretical studies. The theoretical studies to find the state of deformation near the crack tip are very difficult for actual materials due to its mathematical complexities, so that those theoretical solutions could be discussed only under simplifying assumptions for material behavior such as homogeneous isotropic elastic or perfect plastic materials.

However, as the deformation behaviors near the crack tip in actual materials is far from such assumptions simplifying real situations, it has been pointed out that the distribution of stress and strain near the crack tip could not be analyzed easily by theoretical analysis. For this reason, it has been argued that experimental examination to investigate the state of the deformation near the crack tip is necessary to solve fatigue fracture problems. Many experimental researches (Shimada, 1990; Furuya, 1986; Kang, 1974; Davidson, 1970) have been made. Nevertheless, it is very difficult to investigate the cyclic strain at the local zone near the

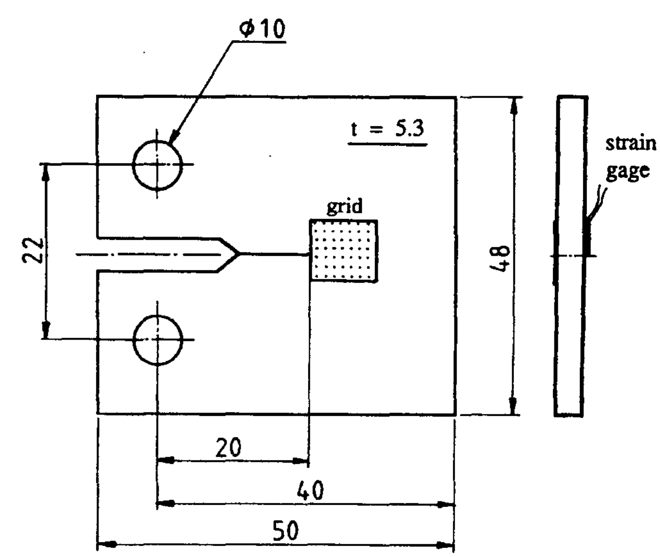

Fig. 1 Specimen geometry and dimensions (mm)

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KEY WORDS: Fracture process zone, computer-aided Fine Dot Grid strain method, cyclic strain distribution, local cyclic strain field, cyclic strain intensity factor range, effective stress intensity factor range.