

## Analysis of the Retardation in Fatigue Crack Propagation Considering the Redistribution of Residual Stress Induced by Overload

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### ABSTRACT

For the assessment of the retardation of fatigue crack propagation behavior by overload, the retardation model of fatigue crack propagation based on the finite element analysis considering the redistribution of compressive residual stress near crack tip was proposed in this paper. The compressive residual stress distribution near crack tip was evaluated by elasto-plastic analysis. The amount of residual stress redistribution was assessed by subsequent elasto-plastic analysis. In the analysis of the retardation in fatigue crack propagation, the applied Stress Intensity factor (SIF) range was evaluated by equations in ASTM E647, and the effect of residual stresses on crack propagation was considered using the effective SIF concept. The test results of the retardation in fatigue crack propagation were compared with the predicted data obtained by the analysis.

**KEY WORDS:** overload, residual stress, elasto-plastic analysis, redistribution of residual stress, retardation of fatigue crack propagation, effective stress intensity factor

### INTRODUCTION

Recently, the ship structure becomes larger in size and lighter in weight and the bigger load is applied in the parts of stress concentration such as welded joints. In order to apply damage-tolerance design (DTD) which is one of recent fatigue design methods, the effect of ship structure due to propagated crack has to be assessed during design life. Practically, because fluctuating environmental loads act on ship structure, the effect of fluctuating environmental loads on fatigue crack propagation needs to be precisely assessed. Especially, the retardation of fatigue crack propagation due to overload should be evaluated.

Elber(1971) considered the crack closure which is induced by compressible residual stress in the fatigue crack surface. He proposed effective stress intensity factor. Wheeler(1972) suggested the retardation model of crack propagation that considered the size of plastic zone near crack tip induced by overload. Kim et.al. (2003)

measured the size of plastic zone using ESPI system. ESPI system which uses optical equipment can measure the large field strain distribution on the surface of structure which has a complex shape. They proposed a retardation model considering crack growth length and size of plastic zone. In these studies, the retardation model was proposed as Eq. 1.

$$\left(\frac{da}{dN}\right)_{OL} = C_p \left(\frac{da}{dN}\right)_{CA} \quad (1)$$

Where  $da/dN$  is crack growth rate,  $OL$  and  $CA$  are the states of overload and constant amplitude load.  $C_p$  is the retardation factor, which is the function of the sizes of plastic zone in  $OL$  and  $CA$ . (Eq. 2)

$$C_p = \left(\frac{r_p}{\alpha \times r_{OP}}\right)^P \quad (2)$$

Where  $r_p$  and  $r_{OP}$  is the sizes of plastic zone in  $CA$  and  $OL$ .  $\alpha$  and  $P$  are experimental constants.

Jang, et.al.(2002) developed the simulation method of the redistribution of residual stress due to crack propagation. They analyzed fatigue crack propagation considering the redistribution of residual stress.

In this study, for the assessment of the retardation of fatigue crack propagation behavior by overload, the new retardation model of fatigue crack propagation considering the redistribution of residual stress based on FE analysis was proposed. The test results of the retardation in fatigue crack propagation were compared with the predicted data obtained by the analysis.

### Fatigue Crack Propagation Test

In order to assess the retardation of fatigue crack propagation due to overload, fatigue crack propagation test is performed. CT (compact