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FINITE ELEMENT ALALYSIS ON THE INFLUENCE OF OVERLOAD INDUCED RESIDUAL STRESS FIELD ON FATIGUE CRACK GROWTH IN ALUMINUM ALLOY

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ABSTRACT

In this study, a finite element analysis was used to simulate the crack-growth retardation due to the single-peak overload under cyclic loadings. The objective of simulation is to predict the crack-growth retardation due to the influence of overload in Aluminum Alloy with a center-cracked specimen. Compressive residual stress at crack-tip after the overload is the major factor causing retardation. Residual stresses are produced when one region of a part experiences permanent plastic deformation while other regions of the same part remain elastic. The overload introduces a large plastic zone (permanent plastic deformation). Upon unloading, the surrounding elastic material attempts to resume its original size (the plastic zone is permanently deformed) and by doing so, exerts compressive stresses on the plastically deformed material at the crack tip.

A model (Fig.2) in plane stress is presented by running a nonlinear analysis with ANSYS 5.7. A bilinear inelastic isotropic hardening (an elastic perfect-plastic model) is considered as an element material behavior. The crack growth simulation was based on the stress-strain curve of the node point near crack-tip. The stress-strain curve was investigated during cyclic loadings. In this study, 8node PLANE82 was used as an element type with the plane stress option. Nonlinear analysis was performed with elastic-plastic material model under the action of cyclic loadings when a single high peak overload was introduced (Fig.1). The mechanical properties of specimen (Aluminum) are shown in Table 1. To advance the crack, the crack tip advance scheme involving node release after maximum load on each cycle is the preferred technique. But, in this work, the node near the crack tip will be employed to determine the crack growth or displacement. The stress-strain curve and the time-total strain near the crack tip will be recorded. The mesh refinement study was also conducted to determine the size of element length (Le) required along the crack plane. The parameter selected for rating mesh size was the ratio of the element length (Le) to the plastic zone size (r_p). The equation of the plastic zone radius given by Irwin's expression assuming plane stress condition is

$$r_p = \frac{1}{2\pi}\left(\frac{K_I}{\sigma_y}\right)$$

(Irwin's(1960) estimate of the plastic zone radius) The value of K (Stress Intensity Factor) was chosen as 35[N/mm]. To avoid the discontinuity between the crack stress and strain, element size less than Le / r_p = 0.1 are required to appropriately capture the crack plasticity effects. The element length size could be obtained as 0.5mm. Symmetry boundary conditions are adopted. By defining subsequent substep, load increments are controlled. For the cycling loading steps, 5 substeps were specified, with a maximum of 25 and a minimum of 3 substeps. For the overload step, 10 substeps were specified.

In order to investigate the effect of residual stresses in fatigue crack growth, it is necessary to know (1) the magnitude and shape of the residual stress field, (2) the combined effect of the residual stress and applied stresses on the fatigue crack growth rate. The crack tip stress-strain curve at the same node was plotted. The strain was obtained by adding elastic and plastic strain. The results showed that the strain was decreased due to the residual stress which was induced by overload. This compressive residual stress will decrease the crack growth rate. Overloads ratio, strain hardening, node release technique, various loading conditions should be conducted later on. In Fig.3 strain became negative after overloading due to the residual compressive stress. This result might be considered as crack growth retardation. This graph shows us the effect of crack growth retardation due to overloading near crack tip. The two overloads conditions were also carried out (Fig.4). The graph shows second decreased strain after second overloading.

FIGURES AND TABLES

Table 1. Mechanical properties of Aluminum Alloy

Elastic modulus (E)	Poisson Ratio (ν)	Yield Stress (σ_{yp})	Temperature (T)	Tangent modulus (H)
700000 [N/mm]	0.33	200 [N/mm]	20 [°c]	0 [N/mm]

Fig.1 Applied cyclic loading conditions with an overload.

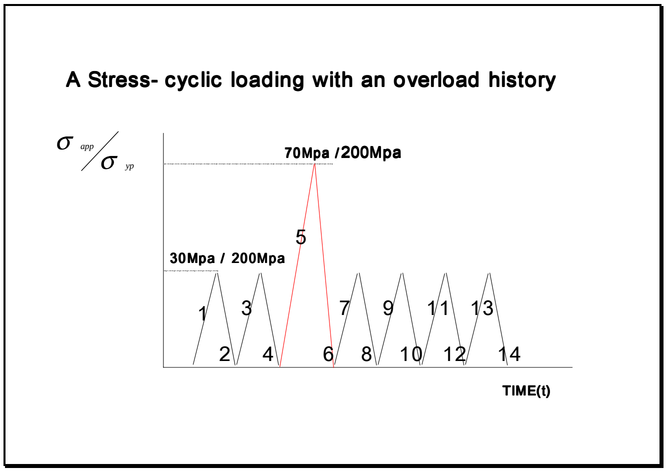


Fig. 2 Geometry and dimensions of a specimen

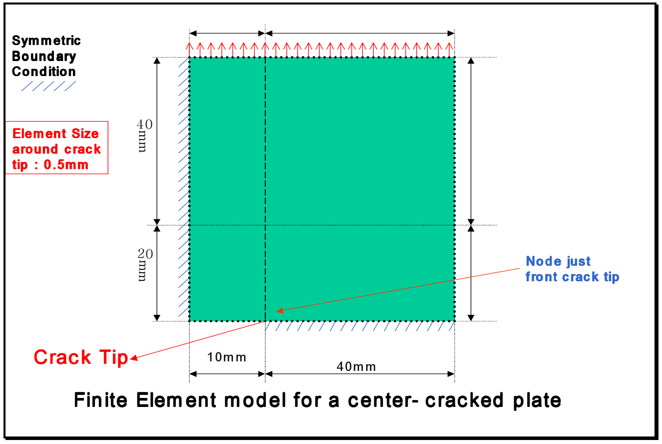


Fig. 3 Time-Total Strain of the node just front crack tip

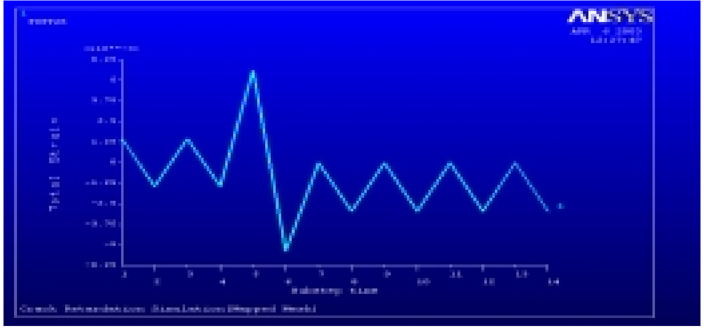
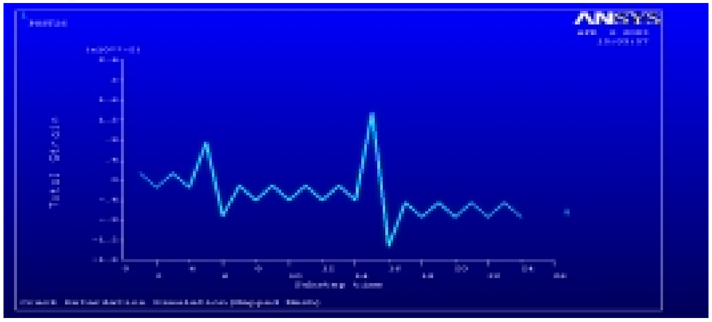


Fig.4 Time-Total Strain graph of the node just front crack tip with two overloads condition (80Mpa-100Mpa).



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