FRACTURE MODELLING AND ANALYSIS OF PLATES WITH MULTIPLE SITE CRACKS UNDER LATERAL PRESSURE

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Abstract: Results of experimental and finite element study on fracture behavior of damaged thin plate specimens subjected to lateral pressure are presented. Plate specimens with a single crack or an array of collinear cracks were tested applying lateral pressure load by using a specially designed experimental setup. The elastic plastic fracture mechanics concept (EPFM) was employed in FE analyses, as large scale yielding occurred in ligaments of fractured specimens. The critical *J*-integral and crack tip opening displacement (CTOD) values associated with fracture onset were inferred from finite element simulation results. Assessed critical pressure loads for considered plate specimens were compared with experimentally obtained results and a good agreement was observed.

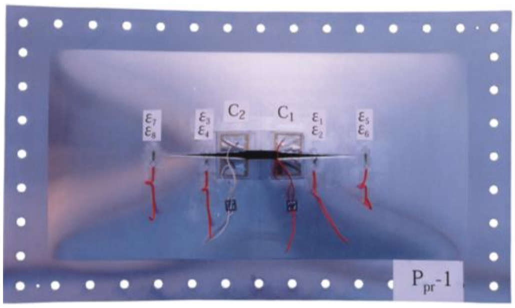
Keywords: stiffened panel, fracture, multiple site cracks, J-integral, CTOD

1. Introduction

In aircraft or ship structures a crack may initiate at a stress concentration site, and further propagate under service loading conditions by fatigue mechanism. Fatigue cracks may grow to a critical crack size, which can eventually lead to an instantaneous failure of the structure under an extreme service load condition [3]. When cracks develop at several adjacent structural members multiple site damage (MSD) is created. In the present study, investigations are made for the fracture mechanisms of thin plates damaged by a single crack or multiple site cracks subjected to lateral pressure, by fracture experiments and the corresponding numerical simulation.

2. Experimental and FE fracture analysis

Plate specimens were made of aluminum plate of thickness t = 2 mm, (AlMg1.5). Along the edges a specimen was fixed to the pressurized tank by bolts. Under loading the pressurized specimen undergoes large deformations and consequently membrane strains occur. Large scale plastic yielding appeared in all specimens. In specimens with a single crack the rapid crack propagation lasted until the driving force (oil pressure) was exhausted. For specimens with three cracks after stable fracture, instantaneous fracture occurs and cracks collide. Specimens after pressurized tests are shown in Fig. 1.

a) 

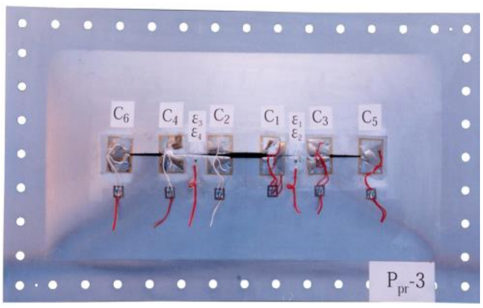
b) 

Fig. 1. Specimens after pressurized test: a) PPR-1; b) PPR-3.

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The elastic plastic fracture mechanics concept (EPFM) was employed in numerical analyses of fracture in pressurized specimens, as large scale yielding occurred in ligaments. Material plasticity behavior was taken into account in all simulations. The multi-linear isotropic hardening model, based on von Mises yield criteria coupled with an isotropic work hardening assumption was used. The *J*-integral introduced by Rice [1] is defined as a path independent integral,

$$J = \int_{\Gamma} \left(W\mathrm{d}y - T_{\mathrm{i}} \frac{\partial \mathrm{u}_{\mathrm{i}}}{\partial x} \mathrm{d}s \right) \tag{1}$$

where W is the strain energy, Γ is a path surrounding the crack tip, **T** is the traction vector defined according to the outward normal along Γ, $T_i = \sigma_{ij} n_j$, **u** is the displacement vector and ds is a line element along Γ. The crack tip opening displacement (CTOD), δ_t is a measure of crack tip blunting and is usually defined as the distance between the intercepts of two 45° lines with the deformed crack profile. The *J*-integral and CTOD values with respect to applied pressure were inferred from finite element simulation results [2]. In Fig. 2 are shown the von Mises stress distribution in plate specimens for a pressure load of 600 kPa. Results for the estimated critical pressures based on J_c and δ_{tc} are given in Table 1.

a) b)

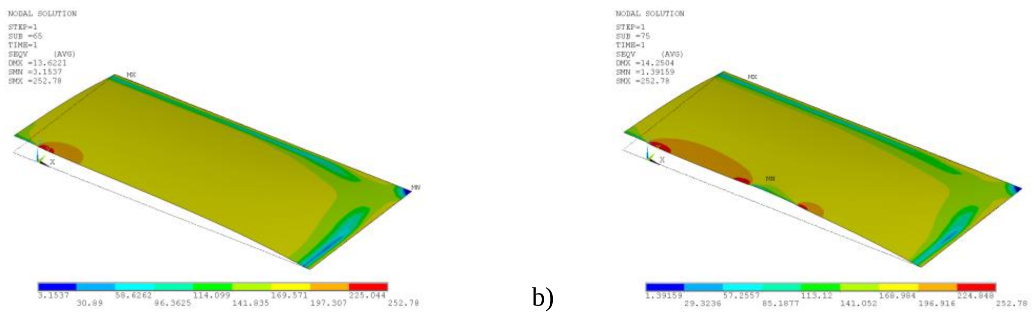

Fig. 2. σ_{eqv} for the pressure p = 600 kPa for specimens: a) PPR-1; b) PPR-3.

Table 1. Assessed critical pressures compared with experimental results.

Specimen	PPR-1	PPR-3
Critical pressure – experiment, kPa	900	750
Critical pressure based upon J_c, kPa	810	725
Critical pressure based upon δ_{tc}, kPa	810	745

3. Conclusions

Fracture mechanisms of plates, damaged by a single and multiple cracks, subjected to lateral pressure have been analyzed. In the finite element models an elastic-plastic fracture mechanics concept (EPFM) was implemented and critical pressures associated with fracture onset in the specimens were assessed based on the critical J_c and δ_c parameters. Numerical results of fracture analyses of plate specimens were compared with experimental results and a reasonably good agreement was observed.

References

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