PLASTIC ENERGY DISSIPATION AND CRITERIA FOR STABLE AND UNSTABLE FRACTURE

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SUMMARY

One drawback of the Griffith-Irwin (G-I) theory is that it can not predict the variation in the Strain-Energy-Release-Rate, with respect to thickness, a variation which is sometimes of the order of 700%. It is important to be able to analyse this, not only from a phenomenological point of view but also for efficient design of structures against fracture.

Bhandari, Int. J. of Fracture 9 (1973) 345, has pointed out that the hypothesis concerning the constancy of the Plastic-Energy-Dissipation-Rate (PEDR) in the G-I theory is not correct even for Small-Scale-Yielding (SSY) situations, since the plastic flow at the crack tip depends on the stress-state and geometrical parameters. The results obtained for an infinite plate with elastic-plastic boundary supposed coincident with the iso-yield-stress contour were presented only to illustrate the model but they do show tendencies observed in fracture experiments. Realising the importance of the plastic flow at the crack tip, an exact elastic-plastic theory would be required to deal with the problem. However, crack solutions are complicated and engineers need a fracture criterion sufficiently accurate from a practical point of view.

During the present investigation we realized a programme to compute an admissible stress-distribution in a ductile material based on total laws of plasticity and the exact 2-D Muskhelishvili solution modified for finitely wide plates. The plastic zones thus obtained for both plane-stress and plane-strain conditions were evidently quite different from what one is habituated to see resulting from asymptotic solutions. These were compared for some cases to the results obtained from a standard finite element programme (NONSAP).

Next, the quantities underlying the general criteria of fracture were calculated. The rate of complementary energy given through the J-integral was evaluated along the plastic zone contour and the PEDR was computed using the idea given in the above mentioned publication. Thus, using the same fundamental approach basic to G-I theory, we come to a relation valid at fracture initiation which is different from G-I theory. It was found that for a given crack, the plastic zone extends rapidly under the increasing load and at some point makes a plastic hinge with the free surface. The fracture at this point is governed by the limit analysis and not the Fracture Mechanics concepts.

The present investigation leads us systematically to the consideration of stable crack growth before instability. This has been done using a very interesting approach by Havner and Glassco, Int. J. of Fracture Mechanics 2 (1966) 506. Using these results, design charts are being prepared which would lay out the zones of safe operation of a cracked plate structure, in terms of its loading and geometrical parameters.

Evidently the above considerations for plane states can be extended to a moderately thick plate. However, a sufficiently accurate 3-D elasto- plastic formulation seems at present to be a difficult task.