Study of Parameters Elasto-Plastic Stable Crack Growth

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INTRODUCTION

During the process from the initiation to failure there must be a stable carack growth for the widely used materials with high toughness and low strength in engineering. This problem has been paid to much attention for the past twenty years. As far as applications in engineering are concerned we want to know whether some parameters exist which can be used as a criterion in stable crack growth. These parameters should satisfy the following requirments: independent of specimen geometry, computational model-used and stable crack extension; prediction of crack initiation and crack instability; siutable for full plastic situations; saving in computation and easy to be measured. So far some parameters have been proposed by researchers (Kanninen et al, 1980, Shih et al, 1980, Paris et al, 1980, Hutchinson et al, 1980). Paris (Paris et al, 1977) proposed J-integral and variation rate of J-integral. De Knoing (De Knoing, 1975) used crack tip opening angle CTOA. Green (Green et al, 1975) employed average crack opening angle COA which has the definite physical meaning and reflects crack growth and gives the possibility to be directly measured as well. Later on generalized energy released rate G was given as a parameter which is insensitive to specimen geometry and element mesh. Crack tip constrained force F_c was also proposed which keeps constant during crack growth. The objective of this paper is to study the variations of the above parameters with crack extension during stable crack growth.

COMPUTATIONAL METHOD AND COMPUTER PROGRAM

In finite element analysis of stable crack growth the key problems is how to simulate the stable crack growth. Kobayashi (Kobayashi et al, 1973) De Knoing (De Knoing, 1975) Light (Light et al, 1975) proposed node relaxation technique in which nodal coupled constrained force at crack tip is replaced by two fores equal in magnitude and opposite in direction acting separately on two opposite crack surfaces at the same node. The force is gradually released up to zero. Anderson (Anderson, 1974, Anderson, 1975) Newman (Newman et al, 1974) proposed another procedure to simulate stable crack growth by gradually reducing the stiffness of the coupled node at crack tip. The above two procedures are essentially the same. During the node release from one node to the another the number of node release has much effect on the accuracy and the efficiency. In this paper the release of nodal constrained force at crack tip was performed by three steps. In this way a suitable accuracy can be reached with reasonable cost in computation. In the analysis of stable crack growth the following two situations are involved: one is the Generation Phase analysis i.e. load and crack extension relation obtained by experiments has been simulated in the finite element analysis and then the variations of some parameters with crack extension are obtained. The other is Application Phase Analysis in which crack extension against load can be predicted by choosing a suitable parameter as a criterion. A computer program for elasto-plastic stable crack growth is developed. Its flow diagram is given in Fig. 1.

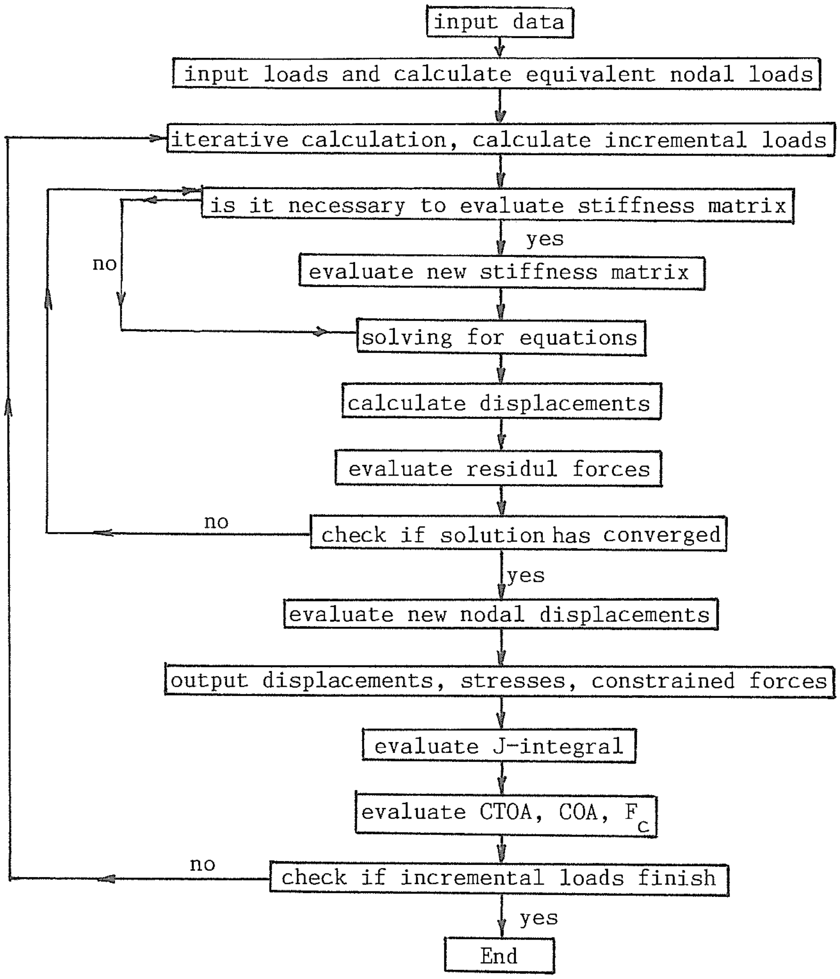
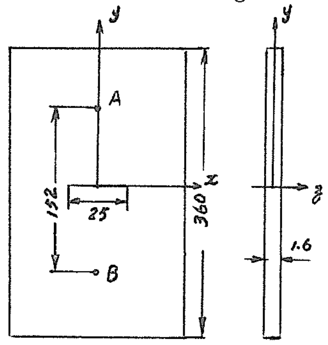


Fig. 1 Flow diagram

The main characteristics of this program are described as follows:
A. Applicable to plane stress, plane strain and three-dimensional axisymmetric problems.
B. Four yielding criteria can be chosen: Tresca criterion, Von Mises criterion, Drucker criterion and More-Coulomb Criterion.
C. The isotropic hardening of materials is considered.
D. To offer more efficient solution procedures for nonlinear equations, such as tangential stiffness scheme, initial stiffness scheme, secant Newton method, modified secant Newton method and quasi-Newton method.
E. The following parameters can be calculated including J-integral, the variation rate of J-integral, average crack opening angle, crack tip opening angle CTOA and the constrained force at crack tip F_c.

NUMERICAL ANALYSIS

The experiment of stable crack growth was carried out by Bleackley. (Bleackly et al, 1983) for the Aluminum alloy plate with central crack under uniform tension. The geometry of the plate is shown in Fig. 2. From the above experiment the curve of the relative displacement between points A and B against crack length was given in Fig. 3. Due to the symmetry only one quarter of the plate was modelled by the finite element mesh shown in Fig. 4. It contains 112 four-node isoparametric elements. Stress-strain relation for the material is given in Fig. 5. Using the above computer program and experimental results the generation phase analysis was performed. Numerical results from the crack growth simulation are shown in Fig. 6-9.



yield stress σ_y=0.312 KN/mm²

elastic modulus E=73.0 KN/mm²

poisson's ratio ν =0.33

Fig. 2 The geometry of the plate

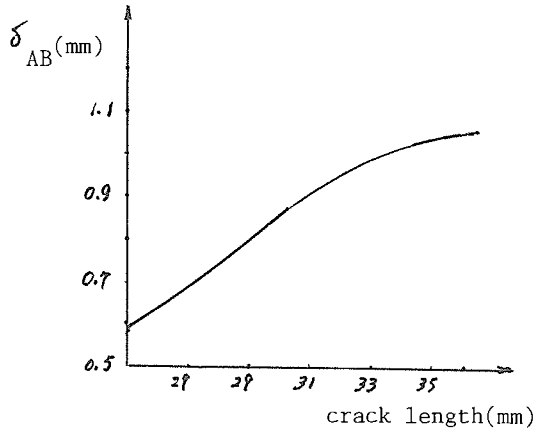


Fig. 3 Curve of the relative displacement $_{AB}$ against crack length

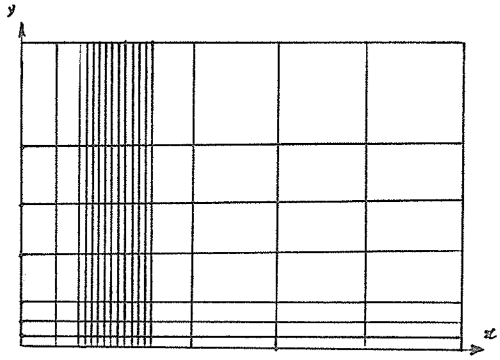


Fig. 4 Finite element mesh

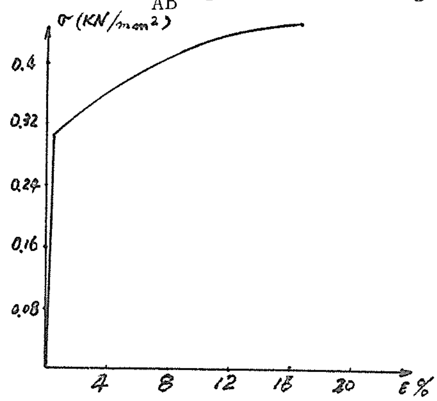


Fig. 5 Stress-strain relation for the material

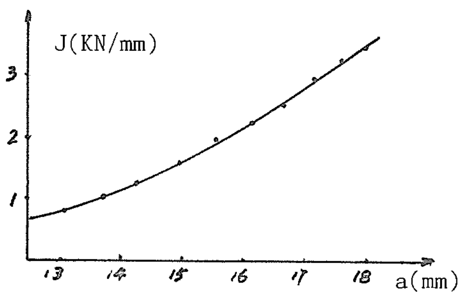


Fig. 6 Variation of J-integral with crack extension

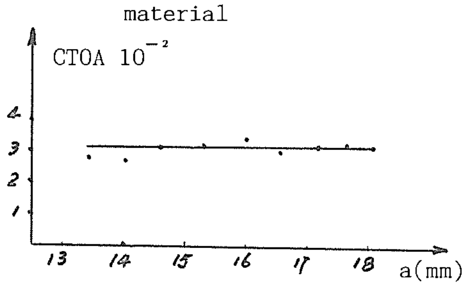


Fig. 7 Variation of CTOA with crack extension

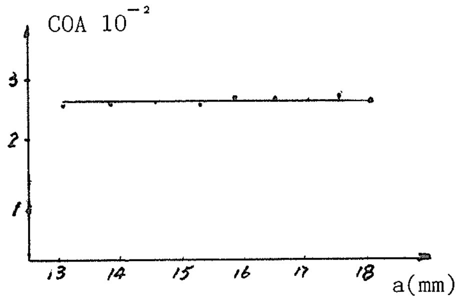


Fig. 8 Variation of COA with crack extension

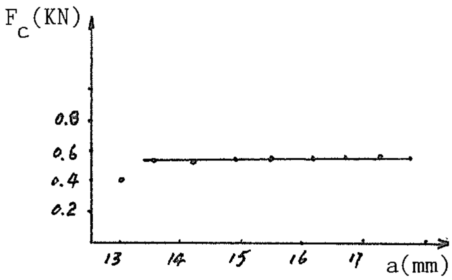


Fig. 9 Variation of F_c with crack extension

CONCLOSIONS

1. The crack opening angle COA approximates constant during stable crack growth.
2. J- integral almost varies linearly with crack extension at the initial stage of stable crack growth.
3. The crack tip opening angle CTOA oscillates at the initial stage of stable crack growth and nearly maintain constant at the late stage.
4. The curve of the crack tip constrained force F_c against crack extension approximates constant during the stable crack growth except at the beginning.

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