Computation Of Stress Intensity Factor Esatjournals

Topics covered in this title include: the fracturing and damage of composite materials; ceramics; metals; and concretes and rocks at different scales in both monotonic and cyclic loading.

Computation of Stress Intensity Factors

An SBIR Phase I feasibility study has been conducted on a novel method of calculating cracktip stress intensity factors for cracked metal structures under rapid thermal pulse loadings. The work couples a Green's function integration technique for transient thermal stresses with the well- known influence function approach for calculating stress intensity factors. A preliminary version of a computer program implementing the methodology designated AF-CRACK, was developed and delivered with the Phase I project report. Operable on an IBM-pc or compatible, the program demonstrates the ability to accurately calculate stress intensity factors, with very short turnaround times, and immediate graphics visualization of the results. Keywords: Stress Intensity Factors, Fracture Mechanics, Rapid Thermal Pulses, Crack Growth, Analysis.

A robust method for calculating a generalized stress intensity factor for a V-notched anisotropic body under symmetric and/or anti-symmetric deformation is derived for plane stress or plane strain. The compact formulation for the generalized stress intensity factors is derived based on Stroh formalism. A path-independent line integral together with an auxiliary field solution, called the interaction M-integral, is utilized to solve for these generalized stress intensity factors. Through numeric evaluation of the interaction M-integral using a finite element solution, the generalized stress intensity factors can be found. These generalized stress intensity factors can be used to predict the failure conditions without the need for a detailed notch-tip field solution. Since the interaction M-integral is path-independent, the calculation can be carried out in the region away from the notch tip where a conventional finite element solution is sufficient to perform this analysis. Numeric results for the generalized stress intensity factors are given for a thin rectangular plate with double edge notches. The specimen geometry used follows that in the ASTM standard D 5379/D 5379M-93 for shear property testing of fiber-reinforced composite materials. The method is first verified for three example problems. Then, the generalized stress intensity factors are given for a wide range of notch depths and angles for isotropic and anisotropic material property cases. Two in-plane fiber orientations of a unidirectional fiber-reinforced graphite/epoxy composite are considered. Two loading cases are given to produce symmetric and anti-symmetric deformation. The generalized stress intensity factor results given here for anti-symmetric deformation are unprecedented.

An essential part of describing the damage state and predicting the damage growth in a multicracked plate is the accurate calculation of stress intensity factors (SIF's). Here, a methodology and rigorous solution formulation for SIF's of a multicracked plate, with fully interacting cracks, subjected to a far-field arbitrary stress state is presented. The fundamental perturbation problem is derived, and the steps needed to formulate the system of singular integral equations whose solution gives rise to the evaluation of the SIF's are identified. This analytical derivation and numerical solution are obtained by using intelligent application of symbolic computations and automatic FORTRAN generation capabilities (described in the second part of this paper). As a result, a symbolic/FORTRAN package, named SYMFRAC, that is capable of providing accurate SIF's at each crack tip was developed and validated. Binienda, W. K. and Arnold, S. M. and Tan, H. Q. Glenn Research Center NASA-TM-105766, E-7183, NAS 1.15:105766 RTOP 510-01-50...

A simple technique was developed using conventional finite element analysis to determine stress intensity factors (K1 and K2) for interface cracks under mixed-mode loading. This technique involves the calculation of crack-tip stresses using nonsingular finite elements. These stresses are then combined and used in a linear regression procedure to calculate K1 and K2. The technique was demonstrated by calculating K1 and K2 for three different bimaterial combinations.

One of the difficulties in using fracture mechanics is in determining stress intensity factors of cracked structural and mechanical components. The cracks are often subjected to complex stress fields induced by external loads and residual stresses resulting from the surface treatment. Both stress fields are characterized by non-uniform distributions, and handbook stress intensity factor solutions are seldom available in such cases. The method presented below is based on the generalized weight function technique enabling the stress intensity factors to be calculated for any Mode I loading applied to a planar semi-elliptical surface crack. The stress intensity factor can be determined at any point on the crack tip contour by using the general weight function. The calculation is carried out by integrating the product of the stress field and the weight function over the crack area.

Analytical derivations of stress intensity factors (SIF's) of a multicracked plate can be complex and tedious. Recent advances, however, in intelligent application of symbolic computation can overcome these difficulties and provide the means to rigorously and efficiently analyze this class of problems. Here, the symbolic algorithm required to implement the methodology described in Part 1 is presented. The special problem-oriented symbolic functions to derive the fundamental kernels are described, and the associated automatically generated FORTRAN subroutines are given. As a result, a symbolic/FORTRAN package named SYMFRAC, capable of providing accurate SIF's at each crack tip, was developed and validated. Simple illustrative examples using SYMFRAC show the potential of the present approach for predicting the macrocrack propagation path due to existing microcracks in the vicinity of a macrocrack tip, when the influence of the microcrack's location, orientation, size, and interaction are taken into account. Arnold, S. M. and Binienda, W. K. and Tan, H. Q. and Xu, M. H. Glenn Research Center RTOP 510-01-50...

A computer program, surf3d, that uses the 3D finite-element method to calculate the stress-intensity factors for surface, corner, and embedded cracks in finite-thickness plates with and without circular holes, was developed. The cracks are assumed to be either elliptic or part eliptic in shape. The computer program uses eight-noded hexahedral elements to model the solid. The program uses a skyline storage and solver. The stress-intensity factors are evaluated using the force method, the crack-opening displacement method, and the 3-D virtual crack closure methods. In the manual the input to and the output of the surf3d program are described. This manual also demonstrates the use of the program and describes the calculation of the stress-intensity factors. Several examples with sample data files are included with the manual. To facilitate modeling of the user's crack configuration and loading, a companion program (a preprocessor program) that generates the data for the surf3d called gensurf was also developed. The gensurf program is a three dimensional mesh generator program that requires minimal input and that builds a complete data file for surf3d. The program surf3d is operational on Unix machines such as CRAY Y-MP, CRAY-2, and Convex C-220. Raju, I. S. and Newman, J. C., Jr. Langley Research Center COMPUTER PROGRAMS; CRACK OPENING DISPLACEMENT; FINITE ELEMENT METHOD; STRESS CONCENTRATION; SURFACE CRACKS; COMPUTATIONAL GRIDS; CRACK CLOSURE; CRAY COMPUTERS; HOLES (MECHANICS); SHAPES; STRESS INTENSITY FACTORS; UNIX (OPERATING SYSTEM)...

The performance characteristics of the generalized influence function method for the approximate computation of the amplitudes of the eigenfunctions of the equations of plane elasticity in the vicinity of sharp reentrant corners were evaluated. The eigenfunctions satisfy the equations of equilibrium, compatibility and stress-strain laws and the free-free boundary conditions at reentrant corners. The amplitudes of the eigenfunctions are called the generalized stress intensity factors. It is concluded that the generalized stress intensity factors can be computed to within one percent relative error with small computational effort. Therefore the essential characteristics of the elastic stress field in the neighborhood of reentrant corners can be determined with great precision. This computational technology is essential for the development of theories of crack initiation in metals and composites. Additional keywords: fracture(mechanics); eigenvalues; linearity. (Author).

A method is presented for the calculation of mixed-mode stress-intensity factors for three dimensional crack fronts. The method uses the nodal forces for the calculation. The strength of this approach is the accuracy of nodal force calculations and the avoidance of the assumption of plane strain. The methodology is described for general crack fronts. The special case of a straight crack front is presented in detail. An example problem is solved with a reference solution. The results of the present method agree to within 3% of the reference value.

Part-through-the-thickness flaws are the most common type of flaw occurring in metal structure. Accurate prediction of their growth is vital to ensure adequate life. The majority of stress intensity factor solutions for these flaws are developed through finite-element analyses, iterative techniques, or less accurate superposition of simple solutions. Recently the authors have developed and extended a slice synthesis technique for computation of stress intensity factors for part-through flaws. This technique is far less expensive than finite-element methods, yet provides excellent accuracy. This paper presents the derivation of the method and recently obtained solutions for surface flaws, corner cracks at holes, and corner cracks at the edge of plates in tension and bending. Simple analytical expressions have been fit to these solutions which can be incorporated into computer routines for crack growth prediction.

The existence for a plane or axisymmetric cracked body of an influence or Green's function, depending on the geometry of the body, allows calculation by means of a simple integral of the stress intensity factor. In this way the respective influence of geometry and load in K calculation are separated. The relationship between this function and the compliance for a concentrated force applied on the crack is shown.

An approximate method for the calculation of stress intensity factors of cracks under cladding from stress distributions in the uncracked wall is described. The calculation procedure is calibrated using finite element results for several cases and verified on finite element results for other cases.

To predict crack growth and fracture strengths of riveted joints subjected to widespread fatigue damage, accurate stress and fracture analyses of corner and surface cracks at a rivet hole are needed. The results presented in this report focus on the computation of stress-intensity factor solutions for rivet holes with cracks. The stress-intensity factor solutions for surface and corner cracks at countersunk rivet holes in a plate were obtained using the finite-element-alternating technique. A range of crack shapes, crack sizes, and crack locations under remote tension were considered.

The functional stress intensity factor approach which combines the finite element, thermal simulation and weight function methods developed for the computation of stress intensity factors for multiple-radial cracks at the inner surface of a partially autofrettaged cylinder is applied in this report to external cracks. Numerical results of stress intensity factors are obtained for a cylinder with outer diameter twice the inner diameter. A slight increase in the degree of autofrettage will increase stress intensity factors of inner cracks slightly but will decrease stress intensity factors of external cracks considerably. As in the inner crack case, the cylinder with two diametrically opposed external cracks is in general the weakest configuration and for more than two cracks, the stress intensity factor decreases as the number of external cracks increases. (Author).

These two volumes of proceedings contain 9 invited keynote papers and 126 contributed papers to be presented at the Second International Conference on Advances in Steel Structures held on 15-17 December 1999 in Hong Kong. The conference is a sequel to the International Conference on Advances in Steel Structures held in Hong Kong in December 1996. The conference will provide a forum for discussion and dissemination by researchers and designers of recent advances in the analysis, behaviour, design and construction of steel structures. The papers to be presented at the conference cover a wide spectrum of topics and were contributed from over 15 countries around the world. They report the current state-of-the art and point to future directions of structural steel research.

Fatigue cracks in shot-peened and case-hardened notched machine components are subjected to stress fields induced by the external load and residual stresses resulting from the surface treatment. Both stress fields are characterized by nonuniform distributions, and handbook stress intensity factor solutions are in such cases unavailable, especially in the case of planar nonelliptical cracks. The method presented here is based on the generalized weight function technique enabling the stress intensity factors to be calculated for any Mode I loading applied to arbitrary planar convex and embedded crack. The stress intensity factor can be determined at any point on the crack contour by using one general weight function discussed in the paper. The weight function, mA, can be sufficiently well described by two quantities, i.e., the distance, ?, from the load point, P(x, y), on the crack surface to the point, A, on the crack front where the stress intensity is to be calculated and the length, ?c, of the inverted crack contour. The stress intensity factors are calculated by integrating the product of the stress field and the weight function over the entire crack area.

In this book the authors describe methods for the calculation of weight functions. In the first part they discuss the accuracy and convergence behaviour of methods for one- and two-dimensional cracks, while in the second part they provide solutions for cracks subjected to mode-I and mode-II loading.

The results of a program of research involving application of the hybrid finite element method to fracture mechanics analyses of several typical aircraft structural details are presented. The performance properties of the specialized finite element building blocks are reviewed. Capabilities of the computer analysis codes are discussed with regard to valid parameter ranges, core storage requirements and execution times. Numerical results obtained from extended parameter studies are presented in the form of handbook charts. Suggestions are offered for future improvements and comments are made about the limits of applicability of the data base to airframe damage tolerance analysis.