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ZIP3D - AN ELASTIC AND ELASTIC-PLASTIC FINITE-ELEMENT ANALYSIS PROGRAM FOR CRACKED BODIES

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CONTENTS OF MANUAL

CONTENTS OF MANUAL (cont.)

ZIP3D
An Elastic-Plastic Finite-Element
Program for Cracked Bodies

I. SUMMARY

ZIP3D is an elastic and an elastic-plastic finite-element program to analyze cracks in three-dimensional solids. The program may also be used to analyze uncracked bodies. For crack problems, the program has several unique features including the calculation of mixed-mode strain energy release rates using the three-dimensional virtual crack closure technique, the calculation of the J-integral using the equivalent domain integral method, the capability to extend the crack front under monotonic or cyclic loading, and the capability to close or open the crack surfaces during cyclic loading. This report includes three sections: a theoretical section, a user manual section, and two example problems (with input and output files). The theories behind the various aspects of the program are explained briefly in the theoretical section. Line-by-line data preparation is presented in the user manual. Input data and results for an elastic analysis of a surface crack in a plate and for an elastic-plastic analysis of a single-edge-crack-tension specimen are presented in the example section.

II. THEORETICAL MANUAL

INTRODUCTION

ZIP3D is an advanced finite-element code developed to analyze cracks in elastic or elastic-plastic bodies. The stress-intensity factor (or strain-energy-release rate) for elastic materials and the J-integral for elastic-plastic materials are important parameters for damage tolerant design of structures. For simple configurations and loading conditions, closed-form analytical techniques can be used to calculate the fracture mechanics parameters. However, for general structural configurations and loading conditions, and non-linear material behavior, the finite-element (FE) method is the best alternative. A large number of FE codes for both linear and nonlinear stress analyses of two- and three-dimensional bodies are available in the public domain and also through private companies. These codes are suitable for general engineering applications to calculate the usual quantities like stress, strain, displacements, forces, buckling loads or post buckling responses. Very few codes have the capability to calculate fracture mechanics parameters and those that are available are restricted to 2-D (plane) problems or for evaluating only total strain-energy-release rates for three-dimensional (3-D) problems.

The purpose of this report is to document a 3-D elastic-plastic finite-element program developed at the NASA Langley Research Center that calculates mixed-mode fracture mechanics parameters in cracked solids. However, bodies without cracks may also be analyzed to obtain stresses, strains and displacement fields. In this code, eight-node isoparametric elements and small-strain deformation theory are used. A special reduced-shear integration scheme [1] is provided for bending dominant problems. The elastic-plastic analysis is based on the incremental plasticity theory using the von Mises yield criterion, isotropic hardening, and Drucker's flow rule. The initial-stress algorithm [2,3] is used in the analysis. Three types of material stress-strain curves may be modeled: elastic-perfectly plastic, Ramberg-Osgood, and multilinear representations. Some unique features of the code are the computation of mixed-mode strain-energy release rates (G) for elastic solids using a 3D virtual-crack-closure technique (VCCT) [4], the calculation of the J-integral for elastic-plastic materials using the equivalent domain integral (EDI) method [5-7], the capability to extend the crack under monotonic or cyclic loading, and the capability to close or open the crack faces during cyclic loading [8,9].

ELEMENT FORMULATION

This section presents the element definition, which will be useful in data preparation, and the reduced-shear integration scheme [1] that is used to improve the bending performance of eight-noded elements.

Isoparametric element formulation, given in many standard books (for example [2]), is used to define the shape functions and generate the element stiffness matrix. Figure 1 shows a 2-unit cube mapped into a general hexahedron element in the Cartesian coordinate system. The element shape function is determined for the cube and then transformed to any general element shape through coordinate transformation. Consider a local coordinate system ξ, η, ζ for the cube as shown in Figure 1. The displacement or the coordinate at any point within the cube is defined by eight unknown α's corresponding to the eight nodes as

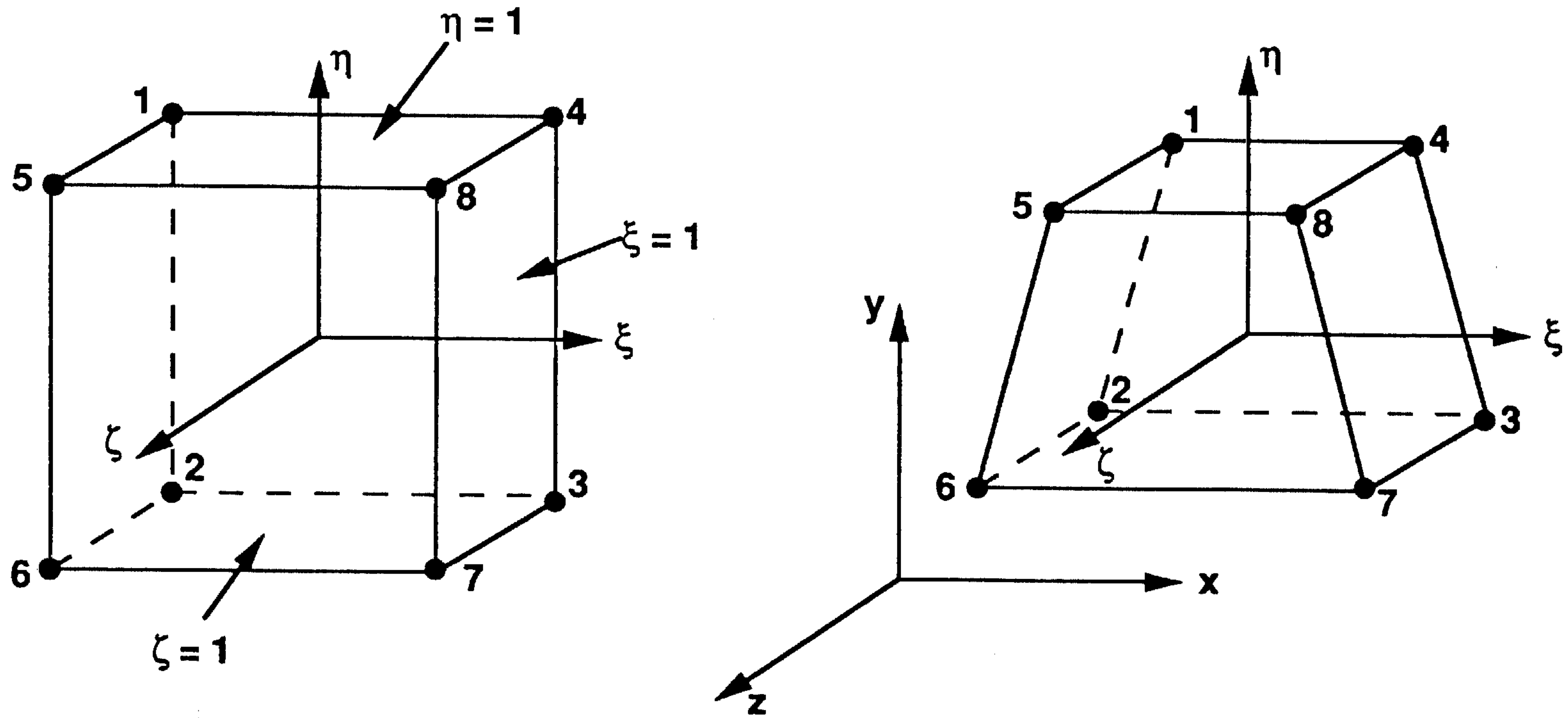
$$\phi = \alpha_1 + \alpha_2\xi + \alpha_3\eta + \alpha_4\zeta + \alpha_5\xi\eta + \alpha_6\eta\zeta + \alpha_7\zeta\xi + \alpha_8\xi\eta\zeta \quad (1)$$

Applying Equation 1 at all nodal points, a relation between the nodal coordinate values and α_i is written in a matrix equation as

$$\phi^e = C\,\alpha \quad (2)$$

where the transpose of ϕ^e and α matrices are defined as

$$\{\phi^e\}^T = \{\phi_1, \phi_2, \ldots, \phi_8\}$$



(a) Basic cube of side 2 units

(b) Typical element and local coordinate system

Figure 1.- Typical eight-node hexahedral element with local coordinate system

$$\{\alpha\}^T = \{\alpha_1, \alpha_2, \ . \ . \ . \ , \alpha_8\}$$

and C is a 8 by 8 square matrix consisting of coordinates (-1 or 1) of the eight nodes in the cube. Equation 2 is rewritten as

$$\alpha = C^{-1} \phi^e \tag{3}$$

Substituting Equation 3 into Equation 1 gives

$$\phi = L \alpha = L C^{-1} \phi^e \tag{4}$$

where

$$L = [1, \xi, \eta, \zeta, \xi\eta, \eta\zeta, \zeta\xi, \xi\eta\zeta]$$

Thus, the element shape functions are defined by

$$\phi = N \phi^e = [N_1, N_2, \ . \ . \ . \ , N_8] \phi^e \tag{5}$$

where

$$N = L C^{-1} \tag{6}$$

The element stiffness and consistent load vector evaluation follow the same procedures as given in Reference 1. In the element local coordinate system, the first two node numbers (1,2) in the element connectivity define the η-axis and the second and third nodes (2,3) define the ξ-axis in the parent cell (cube). The coordinate system follows the right-hand rule. Therefore, the element face definition for surface loading (uniform pressure or stress) and corresponding program variable (IEFAC) is

Face No.	Planes	Program Variable
1	$\xi = -1$	IEFAC(1)
2	$\xi = +1$	IEFAC(2)
3	$\eta = -1$	IEFAC(3)
4	$\eta = +1$	IEFAC(4)
5	$\zeta = -1$	IEFAC(5)
6	$\zeta = +1$	IEFAC(6)

As reported in References 1 and 2, the bending deformations of a linear element can be improved by performing reduced integration on shear strains. The procedure is straight forward for 2-D problems. However, for 3-D problems, a special procedure is needed to restrain rigid body deformation modes. The procedure outlined in Reference 1 is used in this program and is presented here for a two-point Gauss quadrature integration scheme. Each of the three shear strains ($\epsilon_{\xi\eta}$, $\epsilon_{\eta\zeta}$ and $\epsilon_{\xi\zeta}$) are evaluated at two integration points as given in the following table, instead of at all eight Gauss points.

SHEAR STRAIN INTEGRATION POINTS		
$\epsilon_{\xi\eta}$	$\epsilon_{\eta\zeta}$	$\epsilon_{\zeta\xi}$
$\xi = \eta = 0$	$\eta = \zeta = 0$	$\xi = \zeta = 0$
$\zeta = -1/\sqrt{3}$	$\xi = -1/\sqrt{3}$	$\eta = -1/\sqrt{3}$
$\zeta = +1/\sqrt{3}$	$\xi = +1/\sqrt{3}$	$\eta = +1/\sqrt{3}$

The integration points in the above table refer to the local coordinate system in the parent cube (or brick type) element. Care must be taken to avoid using highly skewed elements, especially when the reduced integration scheme is used.

ELASTIC AND ELASTIC-PLASTIC ANALYSIS

The analysis in the ZIP3D code consists of two parts. First, an elastic analysis is performed. Stresses, strains, nodal displacments, nodal forces and fracture parameters (G,J) are printed out as requested by the user. The program terminates if only an elastic analysis is requested.

If an elastic-plastic analysis is requested, the stresses, strains, nodal displacements and nodal forces for the previous elastic analysis are scaled to the incipient yield condition (that is, the highest stressed point is scaled to match the specified elastic limit of the material) and an incremental plasticity analysis is performed (see section on Solution Method). The selection of the elastic limit is not crucial in the analysis because the stress and strain state will always follow the input stress-strain curve (within a user specified tolerance). The elastic limit is used to establish the incipient yield condition and to obtain the incremental load (or incremental displacement) value. The finite-element formulations for the elastic and elastic-plastic analyses used in this program are given in Reference 1 and 2. An isoparametric finite-element formulation [2] was used to calculate the element stiffness matrix and consistent load vector due to distributed loads acting on the element faces. Element stiffness matrixes are assembled in a variable-band width stiffness matrix. A variable-band width linear equation solver given in Reference 8, based on Choleski's decomposition technique, is used to solve for the unknown nodal displacements. The solution algorithm and element stiffness generations are formulated differently from standard procedures to increase the vector lengths so that computations will be faster on vector processing computers.

Figure 2 shows a flow chart for the elastic analysis in ZIP3D. The program has the option to impose symmetry boundary conditions on six different planes, as requested by the user. On the x = 0 and x = WIDTH planes, the displacement u = 0; on y = 0 and y = HEIGHT planes, the displacement v = 0; and on z = 0 and z = THICK planes, w = 0 can be specified. Also, nodes on the uncracked region of the crack plane are automatically restrained for FE models where the crack plane is on y = 0

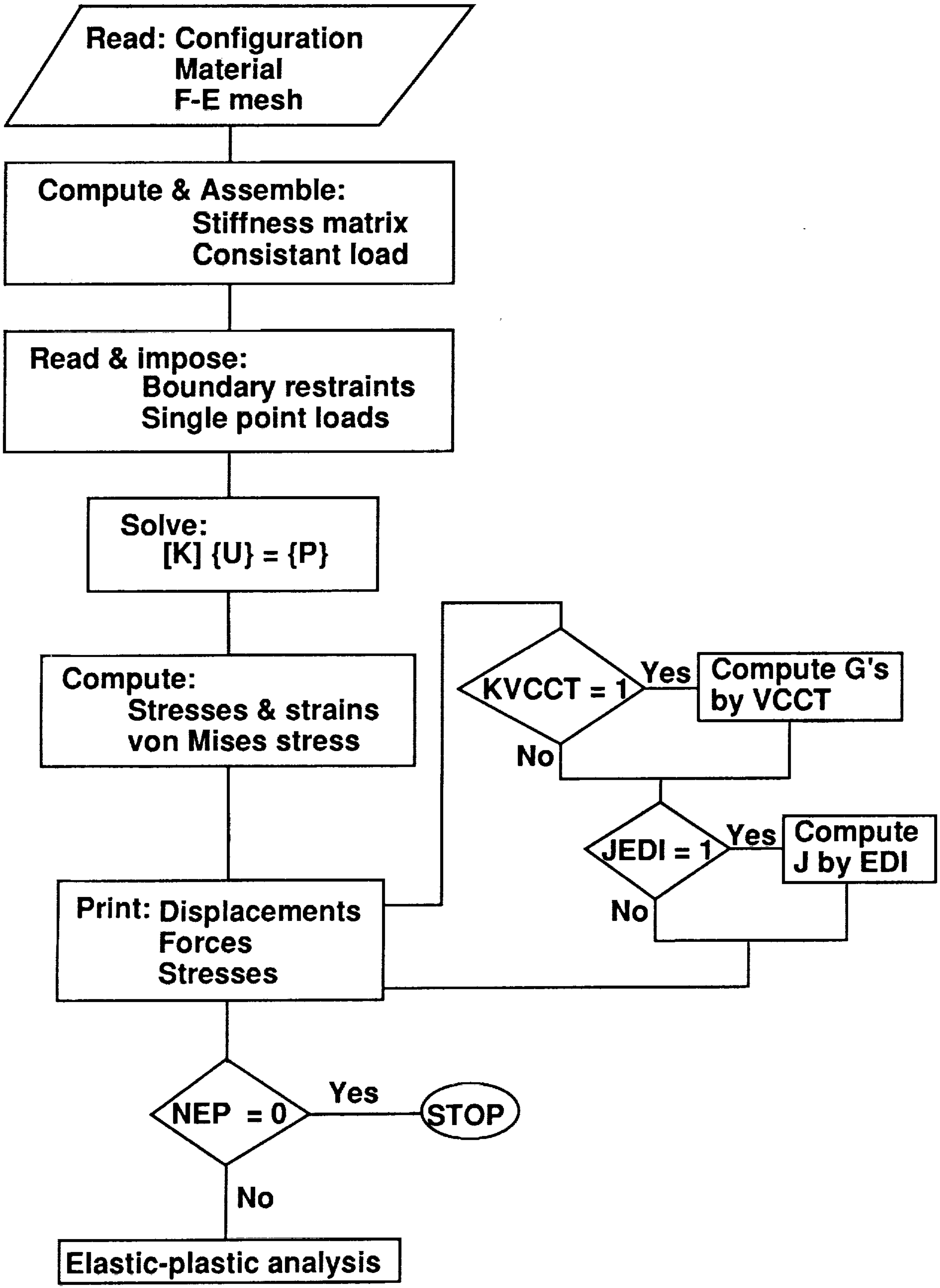


Figure 2.- Flow chart for elastic analysis

plane and the crack front is straight and normal to the x-axis, otherwise, the user must restrain the appropriate nodes to model the uncracked region.

The parameter which controls whether an elastic or elastic-plastic analysis is performed is NEP (specifying NEP = 0 performs only an elastic analysis or NEP = n a positive number (n) performs an elastic-plastic analysis. During a plastic analysis, stresses, strains, displacements and nodal forces, as specified by the user, are printed out after every NEP (n^{th}) load or displacement steps.

The elastic-plastic analysis is based on incremental plasticity theory using the von Mises yield criterion, isotropic hardening, and Drucker's flow rule. The initial-stress algorithm developed by Zienkiewicz et.al. [3] is used in the analysis to satisfy the equations of equilibrium and the stress-strain relation. The von Mises yield criterion for a 3-D stress state is defined by:

$$F(\sigma) = \sigma_{eff} - \bar{\sigma} \tag{7}$$

where

$$\sigma_{eff} = \{[(\sigma_{xx} - \sigma_{yy})^2 + (\sigma_{yy} - \sigma_{zz})^2 + (\sigma_{zz} - \sigma_{xx})^2 + 6\sigma_{xy}^2 + 6\sigma_{yz}^2 + 6\sigma_{zx}^2]/2\}^{1/2}.$$

The stresses σ_{ij} represent the 3-D stress components at any Gauss point and $\bar{\sigma}$ is the current flow stress at the same Gauss point. If $F(\sigma) \leq 0$, the material is in an elastic stress state and if $F(\sigma) > 0$, the material is in a plastic state. A radial-return technique [10] is used to bring the stress field to yield surface, $F(\sigma) = 0$. The difference between the total incremental stress and the true incremental stress gives the residual stresses which contribute to the plastic load vector Q. A flow chart for the step-by-step procedures in the elastic-plastic analysis is presented in the Figure 3. Convergence of the solution is defined by

$$(\sigma_{eff} - \bar{\sigma})/\bar{\sigma} \leq \text{ERIT} \tag{8}$$

where ERIT is the user specified accuracy. The elastic-plastic analysis is continued by applying incremental load (or displacement) steps, as specified in the input data by PCT, until the desired load (or displacement) is reached. PCT is a percentage of the load (or displacement) that causes incipient yielding on the highest stressed element. At the end of a specified number of load steps (NEP), stresses, strains, displacements, forces, and J-integrals are calculated and printed out.

Three types of material stress-strain curves can be used in this analysis: elastic-perfectly plastic, Ramberg-Osgood, and multilinear representations. These three types of stress-strain representations are shown in Figure 4.

The ZIP3D program can be used to analyze stationary cracks as well as growing cracks. In stationary crack problems, the analysis can be continued for any type of loading and unloading cycles by inserting a series of load factor (ratio of maximum load to initial applied load) input lines. The program stops when it encounters "HALT" in columns 12-15 in the load-factor input line.

SOLUTION METHOD

The application of the finite-element method to problems involving linearly elastic materials is straightforward because the material properties are constant and only one solution is required to obtain

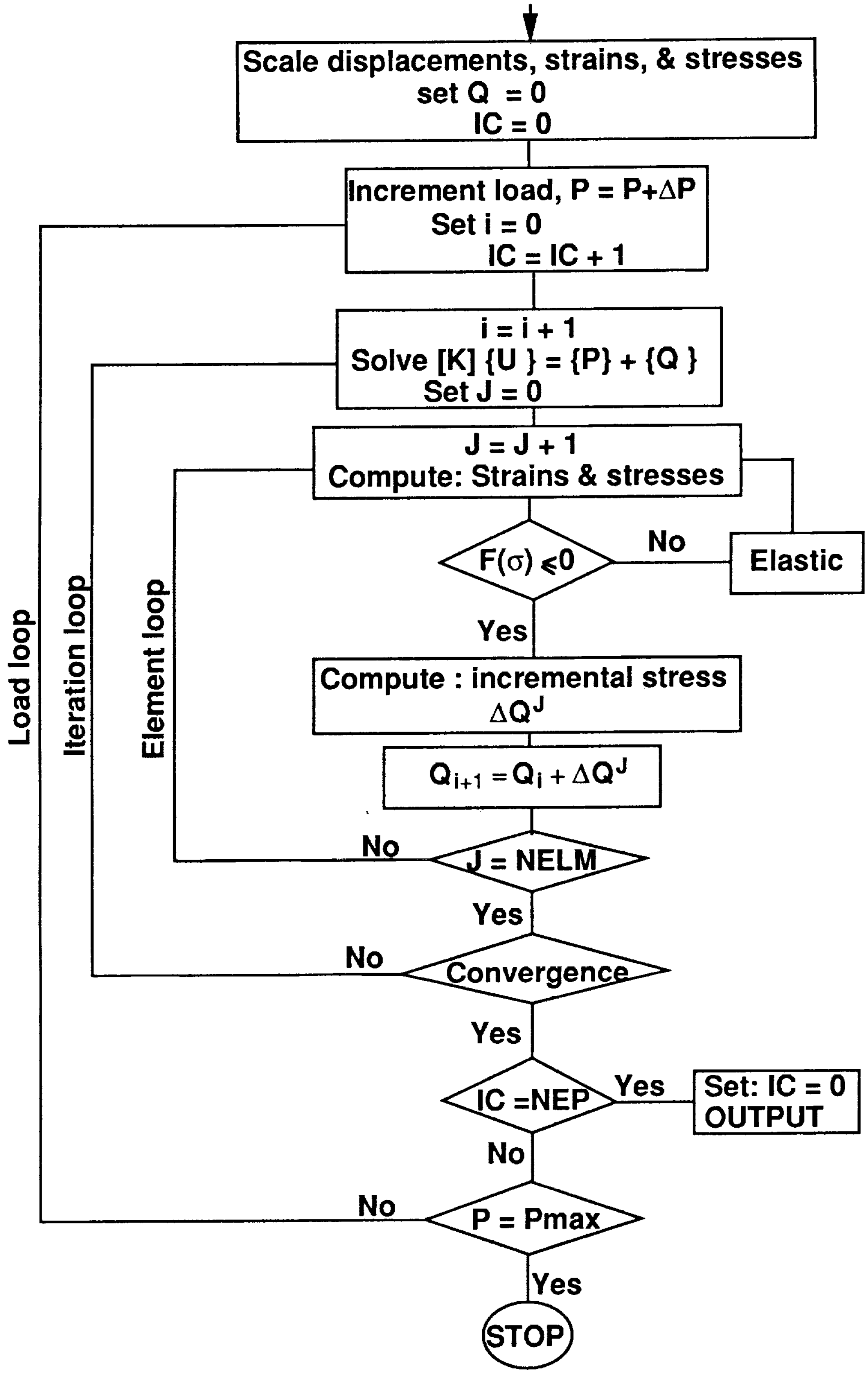


Figure 3.- Flow chart for elastic-plastic analysis

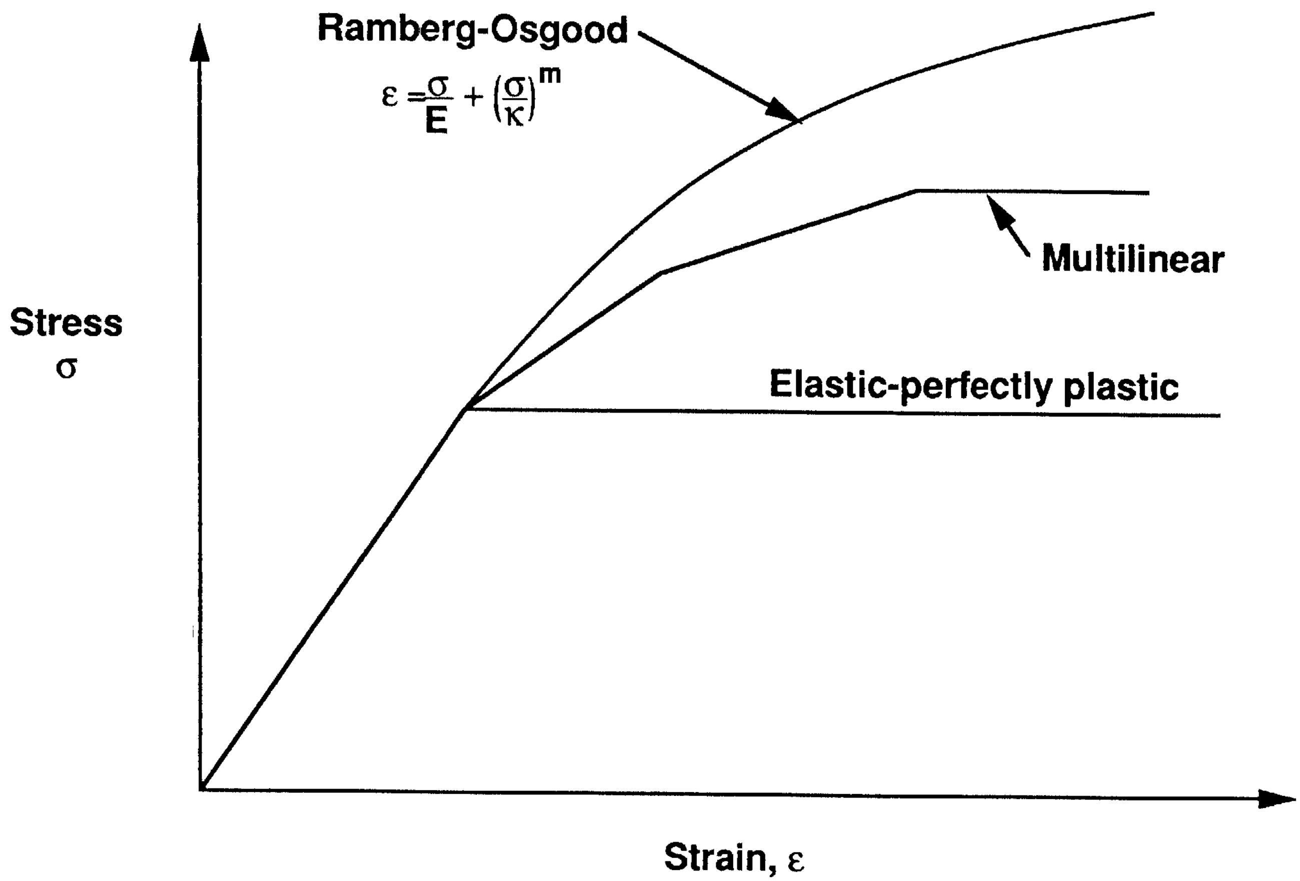


Figure 4.- Schematic of stress-strain modelling

displacements for the elastic structure. However, for elastic-plastic structures the coefficients in the stiffness matrix are functions of loading. Thus, the displacements usually are obtained by applying small load increments to the structure and either updating the coefficients of the stiffness matrix or applying an "effective" plastic-load vector after each load increment (initial-stress method). The latter technique was used in the ZIP3D code.

In general, the matrix equation which governs the response of a discretized structure under loads which cause plastic deformations is

$$[K_e] \{U\}_I^i = \{P\}^i + \{Q\}_{I-1}^{i-1} \tag{9}$$

where $[K_e]$ is the elastic stiffness matrix, {U} is the generalized nodal displacement vector, {P} is the applied load vector, and {Q} is the plastic load vector. The superscript i in Equation 9 denotes the current load increment, and i-1 denotes the preceding increment. After each load increment an iterative process is required to stabilize the plastic-load vector. The subscript I in Equation 9 denotes the current iteration, and I-1 denotes the preceding iteration. The elastic element stiffness matrixes are assembled in a variable-band width storage routine. A variable-band width linear equation solver given in Reference 8, based on Choleski's decomposition technique, is used for the solution. The solution algorithm and element stiffness generations are formulated differently from standard procedures to increase the vector lengths so that the computations will be faster on vector processing computers. In the initial-stress method, the solution to an elastic-plastic problem is obtained by applying a series of small load increments to the structure until the desired load is reached, $\{P\}^{i} = \{P\}^{i-1} + \{dP\}$. The incremental load vector {dP} is chosen as a percentage of the applied load (or applied displacement) that causes the highest stressed element to yield. During the i^{th} load increment a purely elastic problem is solved, and the increments in total strain $\{d\epsilon\}$ and corresponding elastic stress $\{d\sigma_e\}$ are computed from the displacements for every element. Because of material nonlinearity the stress increments are not, in general, correct. If the correct stress increment for the corresponding strain increment is $\{d\sigma\}$, then a set of body forces or plastic-load increment {dQ} caused by the "initial" stress $\{d\sigma^{\circ}\}$ $(= \{d\sigma_e\} - \{d\sigma\})$ is required to maintain the stress components on the yield surface. The plastic-load increments on each element are computed from

$$\{dQ\} = \int [B]^{T} \{d\sigma^{\circ}\}\, dV \qquad (10)$$

where [B] is the strain-displacement matrix and V is the volume of the element. For elements which are in an elastic state or unloading from a plastic state, {dQ} = 0. The total plastic-load vector is computed as

$$\{Q\}_{I}^{i} = \{Q\}_{I-1}^{i-1} + \{dQ\} \qquad (11)$$

The new force system $\{Q\}_{I}^{i}$ is added to the applied load vector in Equation (9) and a new set of displacements is obtained. The iteration process is repeated until the stress state is sufficiently close to the stress-strain curve of the material (see Eqn. 8). Usually, 5 to 15 iterations are required to stabilize the plastic-load vector. However, for configurations which have large strain gradients, more iterations are required. In order to reduce the number of iterations, a relaxation technique [2] was incorporated into the plastic analysis program by using

$$\{Q\}_I^i = \{Q\}_{I-1}^{i-1} + g\ \{dQ\} \qquad (12)$$

where g is the relaxation parameter (RP). Because the displacements from the preceding increment or iteration are used to compute the plastic-load increment, the plastic-load vector is underestimated. Thus, the relaxation parameter is used to increase the plastic-load vector and, consequently, increase the rate of convergence. A value of RP = 1.5 has been found to give accurate solutions in about two-thirds of the CPU time as that for RP = 1. Higher values of RP are not recommended.

CRACK EXTENSION METHODS

Two types of crack extension criteria are used to simulate crack front movement. They are the critical crack-tip-opening-displacement criterion and a specified load criterion. In the first criterion, the crack is extended when the crack-tip opening (v) displacement (CTOD) at the node immediately behind the crack-tip node exceeds a specified value (SCRIT). In the critical CTOD approach, the CTOD value will depend upon element size. Therefore, the element size and pattern around the crack front must be the same for other crack sizes or other crack configurations. In the second criterion, when the applied load equals or exceeds a specified input value the crack is extended.

The program has the option to extend the crack either to create a new crack surface during loading or to close and open the crack surfaces during cyclic loading. Crack extension is restricted to symmetric problems, where the crack plane lies on the $y = 0$ plane and the crack front is straight. Symmetry boundary conditions on the $y = 0$ plane are enforced by using "rigid" springs on the uncracked region (springs with a very large stiffness). The spring stiffness, K_s, is added to the diagonal stiffness coefficient in $[K_e]$. During crack extension, the crack front extends by one element size and the crack front remains straight after extension. FE models multilayered in the z-direction, such as that shown in Figure 5(a), are recommended for crack extension analyses. The crack extension process is shown in Figure 5(b). The program identifies nodes on the crack plane and those in the immediate region around the crack front. To extend the crack, the transverse (y-direction) restraint at each of the nodes on the crack front is replaced by a nodal force {F} acting in the y-direction; the factorized stiffness matrix is modified to account for the change in the boundary condition associated with each of the separated crack front nodes. This keeps the new crack faces closed and the stresses and displacements in the body are identical to the previous solution. The equations of equilibrium are then given by

$$[K_e'] \{U\}_I^i = \{P\}^i + \{Q\}_{I-1}^{i-1} + \{F\} \qquad (13)$$

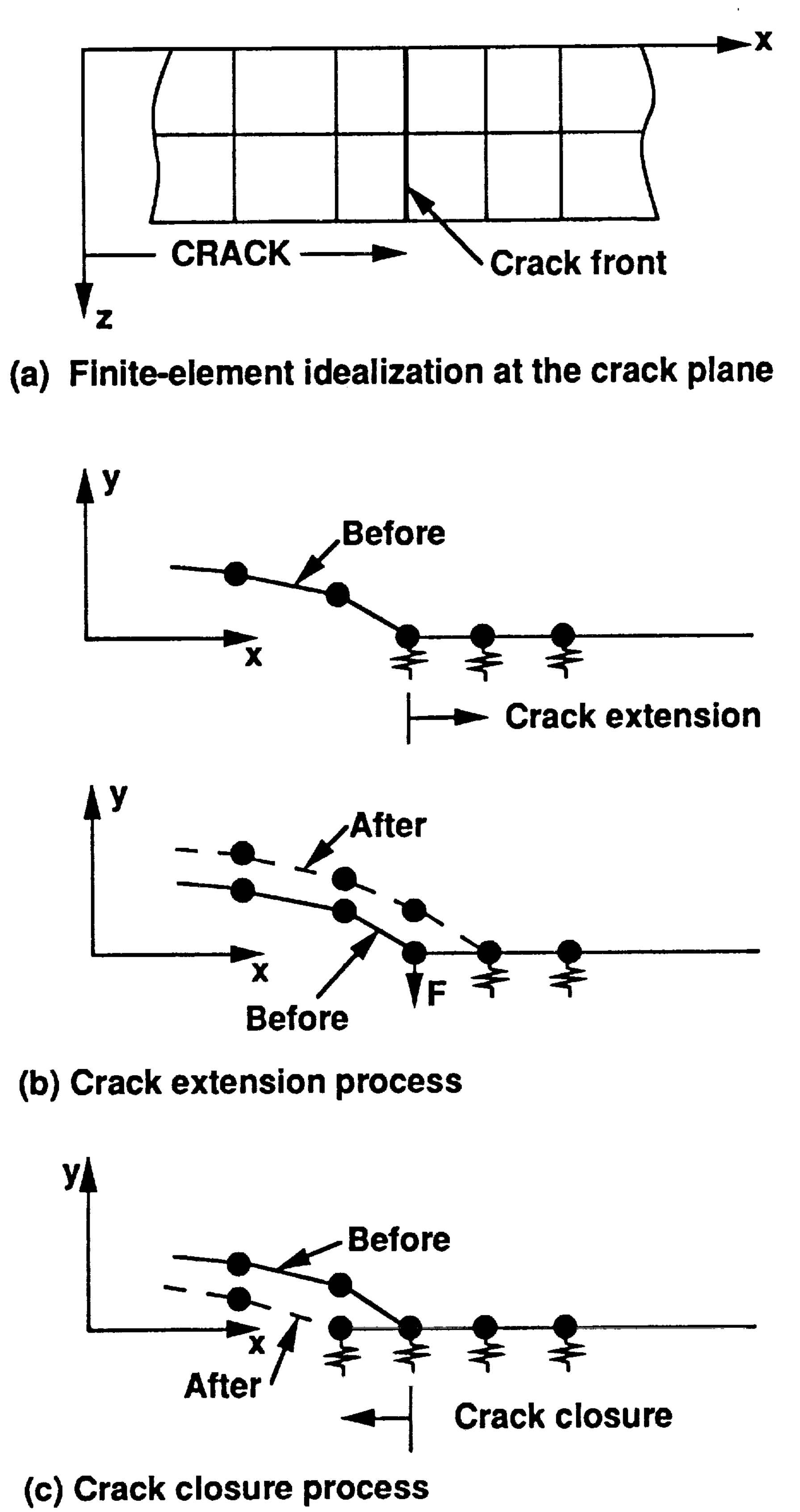


Figure 5.- Crack extension and closure process for a straight crack front problem

where $[K_e']$ = $[K_e]$ + $[K_s]$. $[K_s]$ is the diagonal matrix for intact springs. The change in boundary conditions associated with crack advance is achieved by replacing the rigid spring with a zero-stiffness spring. See Reference 8 for details on modifing the Cholesky factors in the stiffness matrix. The crack-front nodal forces {F} are now released incrementally in steps (usually 4 to 5 steps, a value NLM specified by the user in the input data). After each incremental nodal-force {dF} change, a plasticity analysis is performed. When the nodal forces on the crack-front nodes become zero ({F} = 0 in Eqn. 13), a new crack surface equivalent to one-element length is created and the crack front has advanced by the same amount. In this process, residul plasticity deformations are left behind as the crack advances.

To model crack closure during unloading, the crack-surface nodal displacements are monitored and if any nodes come in contact or overlap, a rigid spring is inserted to carry the compressive loads (see Fig. 5(c)). The equations of equilibrium are

$$[K_e''] \{U\}_I^i = \{P\}^i + \{Q\}_{I-1}^{i-1} \tag{14}$$

where $[K_e''] = [K_e'] + [K_s]$.

The crack opening and closure operations are performed in subroutines BREAK and CONTACT, respectively. Although the program is specialized for straight crack fronts, the program can be modified to analyze extension of curved crack fronts. However, the growth criterion would have to be modified and would now be a function of location through the plate thickness.

EVALUATION OF FRACTURE PARAMETERS

The most commonly used fracture parameters are the stress-intensity factor and strain-energy-release rate for linear-elastic fracture mechanics and the J-integral for nonlinear fracture mechanics. Two methods of evaluating these parameters for cracks in solids are presented: the virtual-crack-closure technique (VCCT) [4] and the equivalent-domain-integral (EDI) method [5-7]. The VCCT is used for elastic mixed-mode fracture problems and the EDI method is used for both elastic and elastic-plastic fracture problems. The EDI method used here calculates only the total J-integral and not its components for mixed-mode crack problems. The two methods are described in the following sections.

Strain-Energy-Release Rates and Stress-Intensity Factors

The three-dimensional virtual-crack-closure technique [4] used here is an extension of the 2-D technique of Rybicki and Kanninen [11]. The present method accounts for the variation of the stress-strain field along the crack front. The method calculates the energy required to close the crack surfaces on a segment of the crack front. Figure 6 shows the cross-section and plan view of a FE idealization near the crack front. The crack front is divided into several segments as shown in Figure 6. A segment is the thickness of an element. Consider the i^{th} segment along the crack front defined by nodes p and q. The Cartesian coordinate system (x, y, and z) and the corresponding displacements (u, v, and w) are defined as shown. The local crack front coordinate system is represented by x_1, x_2, and x_3. The FE idealization around the crack front should be nearly orthogonal and the element pattern and sizes immediately behind and ahead of the crack front

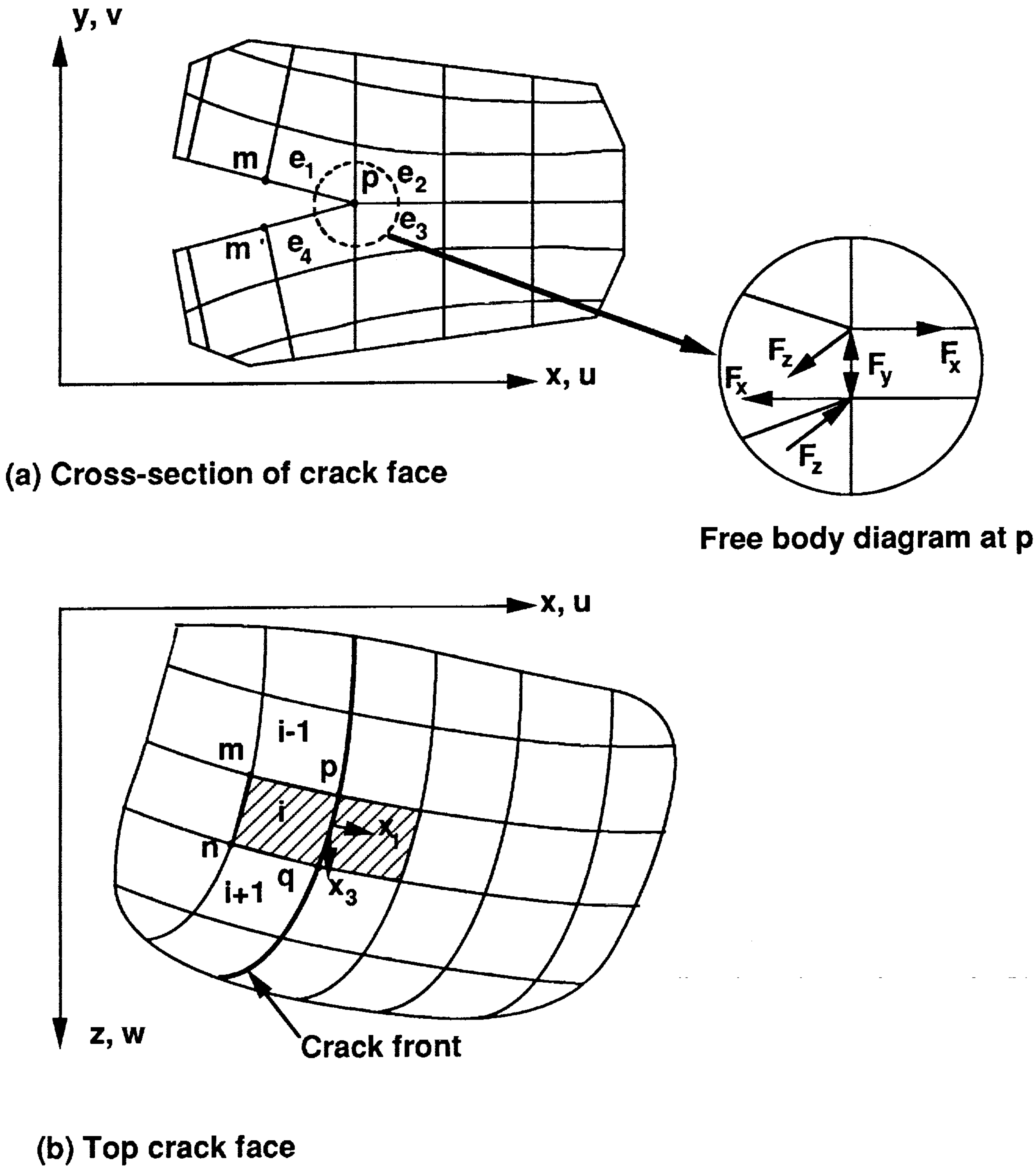


Figure 6.- Finite-element idealization at a segment of the crack front

should be nearly identical. The elements, for example, e_1, e_2, e_3, and e_4, surround the crack front. Nodes p and q are on the crack front. Nodes m and n are behind the crack front on the top face; and nodes m′ and n′ are on the bottom crack face. At each of the crack-front nodes there is a self-equilibriating force system as shown in the insert in Figure 6. If the element size around the crack front is small compared to the crack length (ratio less than or equal to 1/10), the total strain-energy-release rate (G_T) is given by

$$\begin{aligned} G_T = [&F_{xp} (u_m - u_{m'}) + F_{yp} (v_m - v_{m'}) \\ &+ F_{zp} (w_m - w_{m'}) + F_{xq} (u_n - u_{n'}) \\ &+ F_{yq} (v_n - v_{n'}) + F_{zq} (w_n - w_{n'})]/(2\Delta_1\Delta_3) \end{aligned} \quad (15)$$

where u, v, and w are displacements in x, y, and z directions, respectively. F_{xj}, F_{yj}, and F_{zj} refer to nodal forces acting in the x, y, and z directions respectively. The subscript j refers to nodes p and q. Lengths Δ_1 and Δ_3 are the length and width of the crack front element in the x_1 and x_3 directions, respectively. G_T calculated by the Equation 15 is an average value over the crack front segment (p to q) and, hence, it is assumed to be valid at the mid-point of the segment.

Components of strain-energy-release rates in the opening (G_I), shearing (G_{II}), and tearing (G_{III}) modes can be evaluated by resolving the nodal forces and displacements into components in the local coordinate system (x_1, x_2, and x_3). Applying the virtual crack closure principles to components of forces and displacements for opening, shearing, and tearing modes, the G_I, G_{II}, and G_{III} equations are written as

$$G_I = \{F_{2p}\,(v_{2m} - v_{2m'}) + F_{2q}\,(v_{2n} - v_{2n'})\}/(2\Delta_1\Delta_3) \tag{16}$$

$$G_{II} = \{F_{1p}\,(u_{2m} - u_{2m}) + F_{1q}\,(u_{2n} - u_{2n'})\}/(2\Delta_1\Delta_3) \tag{17}$$

$$G_{III} = \{F_{3p}\,(w_{2m} - w_{2m'}) + F_{3q}\,(w_{2n} - w_{2n'})\}/(2\Delta_1\Delta_3) \tag{18}$$

Corresponding stress-intensity factors in modes I, II, and III are given by

$$K_I = \sqrt{G_I E^*} \tag{19}$$

$$K_{II} = \sqrt{G_{II} E^*} \tag{20}$$

$$K_{III} = \sqrt{G_{III} E/(1 + \nu)} \tag{21}$$

where

$E^* = E/(1-\nu^2)$ for plane-strain condition

$E^* = E$ for plane-stress condition

E = Young's modulus

ν = Poisson's ratio

J-Integrals

The Equivalent Domain Integral (EDI) method is used in ZIP3D to obtain the total J-integral for cracked elastic and elastic-plastic bodies. The total J-integral at any point along the crack front in a 3D cracked body is defined as an integral over a closed surface around the crack front [12] (the tube represented by the broken line in Fig. 7) as

$$J = \lim_{\substack{r/\Delta \to 0 \\ \Delta \to 0}} \frac{1}{\Delta} \int_{A_r + O_1 + O_2} [\tilde{w} n_1 - \sigma_{ij} \partial u_i/\partial x_1 n_j] dA \qquad (22)$$

where $\tilde{w}$ is the stress-work density, defined as

$$\tilde{w} = \int_0^{\epsilon_{ij}} \sigma_{ij} d\epsilon_{ij} \qquad (23)$$

In Equation 22, σ_{ij} and ϵ_{ij} are stress and strain tensors on the surface of the tube, u_i is the displacement vector, n_j is the j^{th} component of the unit normal vector on the surface, Δ is the projected length of the crack front along the x_3 axis, and r is the radius of the tube over which the integral is evaluated. The indices i and j take the values 1, 2, and 3. Recently, the surface integral in Equation 22 was modified to a volume integral, called the equivalent domain integral [5-7], for ease of implementation in a finite-element analysis and accurate evaluation of the integral. This was done using Green's divergence theorem and de Lorenzi's s-function [13]. For traction-free crack faces, Equation 22 is written as a volume integral between the inner tube A_r (broken line) and any other closed tube (solid line) enclosing A_r (see Fig. 7) as

$$J = -\frac{1}{f} \left\{ \int [\tilde{w}\, \partial s/\partial x_1 - \sigma_{ij}\, \partial u_1/\partial x_1\, \partial s/\partial x_j]\, dv + \int [\, \partial\tilde{w}/\partial x_1 - \sigma_{ij}\, \partial\epsilon_{ij}/\partial x_1\,]\, s\, dv \right\} \qquad (24)$$

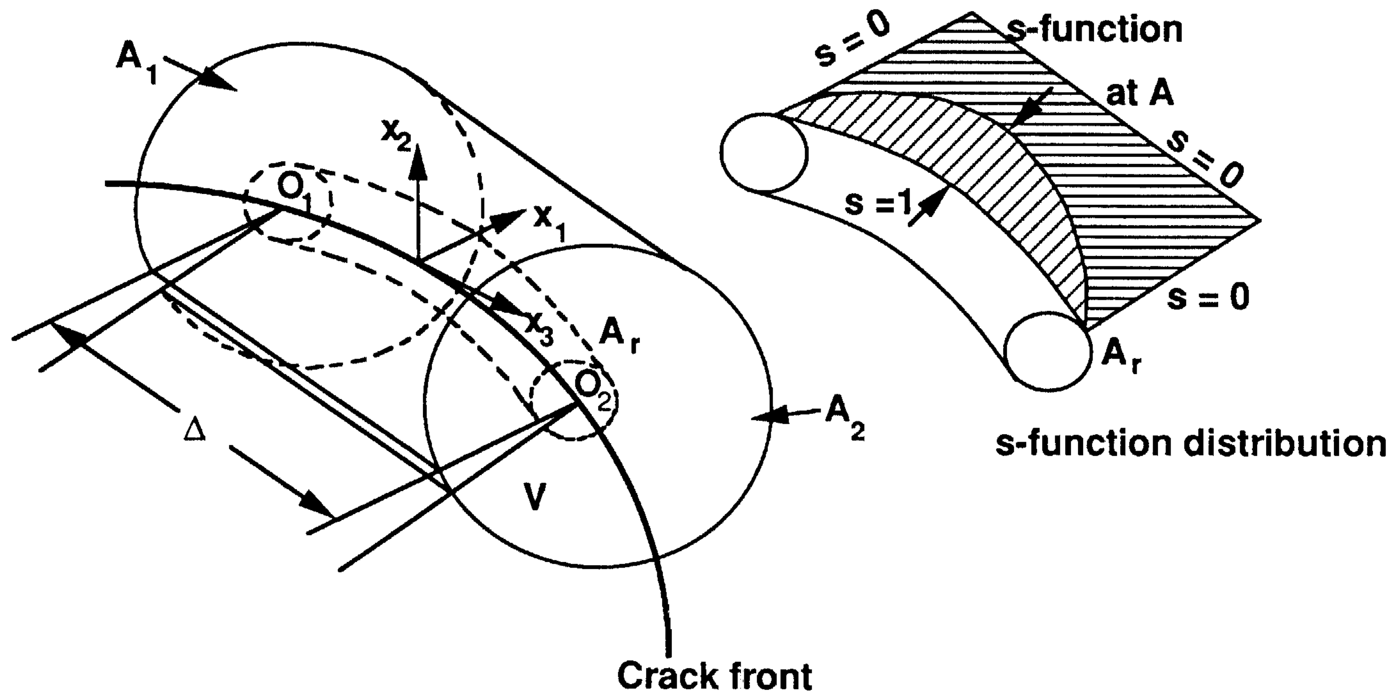


Figure 7.- Domain around the crack front

where s is any arbitrary but continuous function with a characteristic value of one on the inner tube and zero on all outer surfaces, and f is the integrated value of s along the x_3- axis. Equation 24 can be used for isotropic or anisotropic as well as linear or nonlinear materials. In the present incremental elastic-plastic analysis, the stress-work density, stresses, and strains were evaluated at each load step. Then, the J-integral was evaluated at specified load steps from the accumulated stress-work density, stress, total strain, and displacement fields.

In the ZIP3D code, the user inputs only the element numbers within a selected domain (between A and A_r surfaces and within the volume V) and the node numbers on the "inner" surface A_r at which s = 1. The program calculates s-values for all other nodes and automatically sets up the appropriate s-functions and f-integrals (Eqn. 24) for each domain specified. Because the 8-node hexahedral element is a linear displacement element, only linear s-functions are used. Details of general s-functions are given in References 5 and 7.

The selection of the domains for evaluating the J-integrals depends upon several factors for 3-D crack configurations. The important factors are the gradient of the strength of the singularity along the crack front, radii of the inner and outer surfaces of the domain, and the finite-element modeling in the crack front region. Some simple guidelines are stated here. Further details are given in Reference 7. The crack front need not to be modelled with singularity elements and the FE idealization at the crack front can be either rectilinear or polar. The radius of the inner surface of the domain should be small (less than 1/10 of the crack length) or zero. The radius of the outer surface of the domain should be less than 1/5 of the crack length. Because the amount of input data increases with the number of elements in the domain, it is convenient to use one or two rings of elements around the crack front. If the FE mesh around the crack front is a polar mesh, the first ring of elements should give an accurate solution. However, for rectilinear meshes the second ring of elements is recommended. For an elastic-plastic analysis the second ring of elements is recommended.

NOMENCLATURE

a	surface crack depth
B	plate thickness
[B]	strain-displacement relation
c	crack length
{dP}	incremental applied load vector
{dQ}	incremental plastic-load vector
$\{d\epsilon\}$	incremental strains
$\{d\sigma_e\}$	incremental elastic stress increments
$\{d\sigma^\circ\}$	incremental initial stress
E	Young's modulus
{F}	crack front nodal force vector
$F(\sigma)$	von Mises yield criterion
f	area under s-function curve
G, G_T	strain-energy release rate
G_i	mode i strain-energy release rate (i = I, II, III)
g	relaxation parameter
H	plate height
J	J-integral
K_i	mode i stress-intensity factor (i = I, II, III)
$[K_e]$	elastic stiffness matrix
$[K'_e]$	modified elastic stiffness matrix
$[K_s]$	spring stiffness diagonal matrix
m	Ramberg-Osgood stress-strain curve power
{P}	applied load vector

{Q}	plastic-load vector
S	applied stress
s	deLorenzi's s-function
W	plate width
$\tilde{W}$	stress-work density
{U}	generalized displacements
u,v,w	displacements in x-,y- and z-directions, respectively
V	element volume
x,y,z	Cartesian (global) coordinate system
x_1,x_2,x_3	local crack front coordinate system
α_i	constants used in defining element shape function
Δ	element length along crack front
ϕ	element shape function
ϵ_{ij}	strain tensor
κ	Ramberg-Osgood stress-strain coefficient
ν	Poisson's ratio
σ_{ij}	stress tensor
$\bar{\sigma}$	flow stress
σ_{eff}	effective stress
σ_0	elastic (proportional) limit stress
ξ,η,ζ	element local coordinate system

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III. USER MANUAL FOR ZIP3D

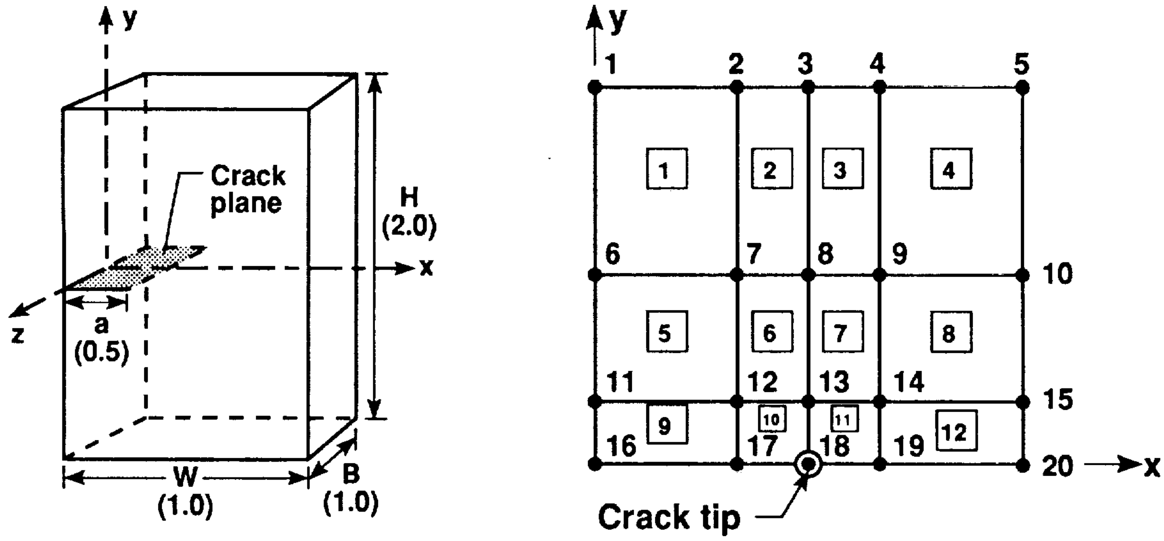
INTRODUCTION

A line-by-line explanation of the input data for the ZIP3D code is presented herein. Each of the parameters used in the input data file is defined and explained. Input data preparation is explained with reference to a single-edge-crack-tension specimen, for the purpose of clarity. Because the finite-element (FE) idealization used in this model is coarse, the user is urged to use this data only as a guideline and not for producing an accurate solution.

Figure 8(a) shows a single-edge-crack-tension specimen with crack length a, width W, thickness B, and height H. For symmetric loading, only one-fourth of the specimen is modeled in the FE analysis. Figure 8(b) shows the FE idealization at z = 0 plane and Figure 8(c) shows the 3-D idealization. The overall size of the FE model is defined by the WIDTH, THICK, HEIGHT parameter, see Fig. 8(c). The finite-element idealization at the crack plane and around the crack front are shown in Figures 8(d) and 8(e), respectively.

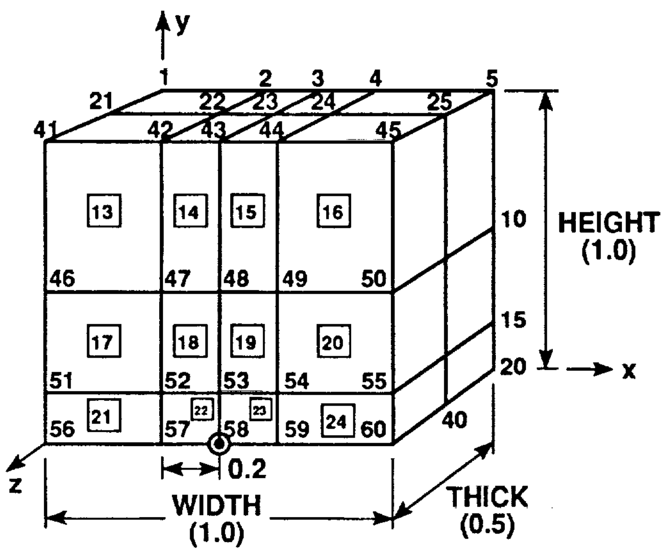
For ease of handling, the input data is specified in two files: an analysis file and a mesh file. The analysis file consists of the geometric definition of the cracked body, number of nodes and elements in the finite-element idealization, material data, boundary conditions, loading, G and J calculation data, plastic analysis data, and output specifications. Free format read statements are used in the program, except as noted.

The mesh file consists of nodal coordinates (x, y, and z), element connectivity, and information on pressure loadings on each of the element faces. An option for reduced-shear integration or full integration for each of the elements is specified by the variable INDXEL. Because it is



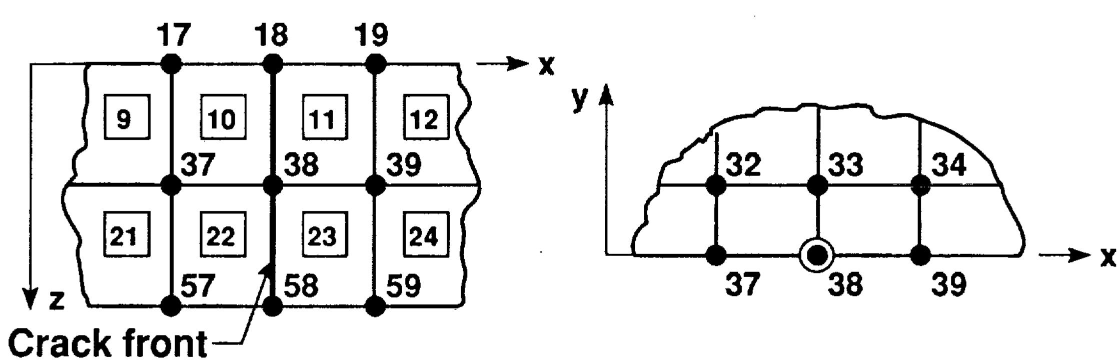
(a) Single-edge-crack tension specimen

(b) Mesh at z = 0 plane



Face	ISYMPL
x = 0	1
y = 0	2
z = 0	3
x = WIDTH	4
y = HEIGHT	5
z = THICK	6

(c) Three-dimensional idealization with element and node numbers



(d) Crack plane idealization

(e) F-E idealization at the mid-plane

Figure 8. Example problem and finite-element idealization.

useful to keep the original node numbers as they are input and also to print out the results in the original numbering scheme, an option to input an optimized nodal numbering scheme is provided. The user must provide the optimized nodal numbering scheme. Several optimizing codes are available in the literature and are not discussed here. An optimized numbering scheme will reduce the storage and solution time. However, output data will be printed out in the original nodal numbering scheme. A line-by-line description of analysis and mesh files are presented in the following sections.

PROGRAM SIZE CONTROL

The code was written in ANSI standard Fortran 77 language for vector processing computers. The code was originally developed for the Cyber 205 super-computer and has been converted to CRAY2 computers. The program utilizes several CRAY2 intrinsic functions to speed up the computation. The program can be implemented on any other super-computer or workstation by appropriately changing the intrinsic functions. The complete program is written using variable dimensions and parameter statements as

```
PARAMETER (LNSTIF = 11000000)
PARAMETER (MXNOD = 6000, MXNEL = 5000, MXBND = 3*MXNOD)
PARAMETER (MXPNOD = 2000, MXBCND = 975, MXNL1 = 10, MXMAT = 3)
```

The program size is controlled by the eight variables defined in these parameter statements. They are:

LNSTIF - maximum profile length of stiffness matrix (11,000,000)

MXNOD - maximum number of nodes (6000)

MXNEL - maximum number of elements (5000)

MXBND - maximum bandwidth of assembled stiffness matrix (3*MXNOD)

MXPNOD - maximum number of loaded nodes (2000)

MXBCND - maximum number of restrained nodes or maximum number of specified displacement degrees-of-freedom (975)

MXNLI - maximum number of layers in thickness (z-direction) + 1 (10)
(only used in crack-extension analysis)

MXMAT - maximum number of materials (3)

The numbers within the parenthesis represent the initial values set in the program. Whenever the input data exceeds any of these specified values, the program flags the exceeded variable and stops. The program size can be increased by changing the value of any variable in all parameter statements in the program.

ANALYSIS (INPUT DATA) FILE

Line No.	Parameter	Format
1.	TITLE - Analysis Title (80-characters)	20A4
2.	MFILE - Mesh Filename	A10
3.	CRACK, WIDTH, THICK, HEIGHT, DAX, SCALE, PRSUR	

CRACK - crack length, applicable for problems with crack plane on the y = 0 plane and the crack front is normal to the global x-axis of the specimen, see Fig. 8(c). (set to zero for uncracked body)

WIDTH - width of the FE model, measured parallel to the global x-direction

THICK - thickness of the FE model measured parallel to the global z-direction

HEIGHT - height of the FE model, measured parallel to the global y-direction

DAX - element length in x-direction at crack front, applicable for crack extension analyses only

SCALE - scale factor, globally scales model to desired size

PRSUR - intensity of pressure applied on any element face specified in the mesh file

PRINT AND PROGRAM OPTIONS

4. LPRIT, NNODE, NELM, NLAYER, NEP, IOPTON, KVCCT, JEDI

LPRIT = 0 - short output
= 1 - detailed output

NNODE - number of nodes in the model

NELM - number of elements in the model

NLAYER - number of layers in z-direction, layers must be repetitions of first layer, see example in Figure 8. (used only for controlling output)

NEP -number of load increments between output of results in the plastic analysis.

NEP = 0 - elastic analysis of cracked body, with crack plane on y = 0 plane and the crack front is normal to the x-axis

NEP = -1 - elastic analysis of general solid with or without a crack (crack plane not on y = 0 plane)

NEP = n - elastic-plastic analysis of cracked body with output at every n^{th}-load increment (crack plane on y = 0 plane)

NEP = -n - elastic-plastic analysis of an uncracked body or crack plane is not on y = 0 plane with output at every (n-1) load increments

IOPTON = 0 - stress output at element centroid

IOPTON = 1 - stress output at Gauss points

IOPTON = 2 - stress output at nodal points

KVCCT = 1/0 - Yes/No calculate G using the 3D VCCT method

JEDI = 1/0 - Yes/No calculate J using the 3D EDI method

MATERIAL PROPERTY DATA

5. NMAT - number of material types

6. YOUNG, POIS, SIGYS, AM, ROM

YOUNG - elastic modulus

POIS - Poisson's ratio

SIGYS - elastic (proportional) limit stress

AM - specifies type of material stress-strain representation

AM = 0 - elastic-perfectly plastic

AM > 0 - Ramberg-Osgood exponent

AM = -1 - piecewise linear representation

ROM - Ramberg-Osgood constant as defined in the stress-strain equation

$$\epsilon = \frac{\sigma}{YOUNG} + \left(\frac{\sigma}{ROM} \right)^{AM}$$

If AM = -1 continue, otherwise go to 9.

7. NSEGMT - number of piecewise linear segments in stress-strain curve description

8. YSTRS(i), YSTRN(i) - stress and total strain at end of segment i on the stress-strain curve (see Fig. 4)

[Repeat line 8 NSEGMT times]

9. NSET, (NBEGIN(i), NEND(i), NINC(i), i = 1 to NSET)

   NSET - number of sets of elements having material properties specified on lines 6-8.

   NBEGIN(i), NEND(i), and NINC(i) - Beginning, ending, and increment in element number for material property set i

[Repeat lines 6 to 9 NMAT times]

SYMMETRY BOUNDARY CONDITIONS

10. NSYMPL - number of symmetric conditions (only used when all nodes on a plane are to be restrained; otherwise set NSYMPL = 0)

11. (ISYMPL(i), i = 1, NSYMPL) (skip if NSYMPL = 0)
    - plane numbers (see Fig. 8(c))
    = 1 x = 0
    = 2 y = 0

= 3 z = 0
= 4 x = WIDTH
= 5 y = HEIGHT
= 6 z = THICK

FIXED, DISPLACED AND LOADED NODES

12. NFIX, NLOAD, NSPD

NFIX - number of restrained nodes

NLOAD - number of nodes with specified loads

NSPD - number of nodes with specified displacements

13. JFIX, MU, MV, MW (If NFIX > 0 continue, otherwise go to 14)

JFIX - restrained node number

MU = 1/0 - restrained/unrestrained in x-direction

MV = 1/0 - restrained/unrestrained in y-direction

MW = 1/0 - restrained/unrestrained in z-direction

[Repeat line 13 NFIX times]

14. NODS, K, DISP (If NSPD > 0 continue, otherwise go to 15)

NODS - node number of the specified displacement

K = 1 - displacement in x-direction

K = 2 - displacement in y-direction

K = 3 - displacement in z-direction

DISP - specified displacement

[Repeat line 14 NSPD times]

15. NODLOD, PX, PY, PZ (If NLOAD > 0 continue, otherwise go to 16)

NODLOD - node number

PX - load in x-direction

PY - load in y-direction

PZ - load in z-direction

[Repeat line 15 NLOAD times]

CRACK EXTENSION OPTIONS

16. NTYP, NLM, SCRIT, RP, ACURCY

NTYP - specifies crack extension criteria

NTYP = 0 - crack extension at specified load (see line 30)

NTYP = 1 - crack extension at specified CTOD

NLM - number of steps to release crack-tip force (see Eqn. 13)

SCRIT - critical value of CTOD for crack extension

RP - relaxation parameter to accelerate convergence of elastic-plastic analysis: specify value of RP between 1 and 2 (RP = 1 is normal analysis without acceleration.)

ACURCY - tolerance between SCRIT and calculated crack-tip opening displacement to extend crack

NOTE: NTYP, NLM, SCRIT, and ACURCY are required only for crack extension analysis (use dummy values for other analyses)

PLASTICITY OPTIONS AND NODAL/ELEMENT OUTPUT INFORMATION

17. PCT, ERIT, MAXIT, NODE1, NODE2, NELE1, NELE2

PCT - increment load as percentage of yield load (ΔP = PCT * load at elastic limit)

ERIT - allowable error for stress convergence criteria (terminates plastic-load vector iterations), see Eqn. 8.

MAXIT - maximum number of iterations allowed (stops divergent solutions)

NODE1 and NODE2 - beginning and ending node numbers for output of nodal displacements and forces. Nodal stresses are also output if IOPTON = 2.

Set NODE1 = NODE2 = 0 to print out only fracture mechanics parameters (nodal displacements, forces and stresses will not be printed)

NELE1 and NELE2 - beginning and ending element numbers for stress output (IOPTON = 0 or 1). If NLAYER > 1, NELE1 and NELE2 correspond to element numbers of the first layer. Stress output for corresponding elements in other layers is automatic.

G-CALCULATION BY VCCT

If KVCCT = 0 Skip lines 18 through 21

18. NGCAL - number of crack front segments were G is desired (a segment is the width of an element)

19. JSYM - symmetry on/off switch

JSYM = 0 - general unsymmetric crack problem

JSYM = 1 - crack plane coincides with x = 0 plane of the model

JSYM = 2 - crack plane coincides with y = 0 plane of the model

JSYM = 3 - crack plane coincides with z = 0 plane of the model

20. NGEL, (LEG(i), i = 1 to NGEL)

NGEL - number of elements around crack front; top half of model for symmetric problems and all elements around the crack front for unsymmetric problems

LEG(i) - element number

21. (NGV(j), j = 1 to NODV), NGF(1), NGF(2)

NGV(j) - node numbers for nodes behind crack front segment. For symmetric problems, use the two nodes on the top crack surface (NODV = 2) and for unsymmetric problems, use both top and bottom crack surface nodes (NODV = 4) in the same order as specified in Figure 6 (m-n and m′-n′).

NGF(k) - node number on the crack front segment (see Fig. 6, nodes p-q; k=1 for node p and k=2 for node q).

[Repeat lines 20 to 21 NGCAL times]

J-CALCULATION BY EDI METHOD

If JEDI = 0 Skip lines 22 through 29

22. NEDIS - number of domains for EDI calculation of J-integral

23. IROTYP - definition of local crack front coordinate system

IROTYP = 0 - Cartesian coordinate system defined by three points

IROTYP = 1 - polar coordinate system, where crack plane is on x-y plane and the angle (THETA) is measured from the x-axis.

24. x_0, y_0, z_0, x_1, y_1, z_1, x_2, y_2, z_2, if IROTYP = 0

coordinates of the three points 0, 1, and 2 (see Fig. 9(a)). Point 0 is on the crack front where J is evaluated. Point 1 is on the crack plane and the vector from points 0 to 1 is normal to the crack front. Point 2 is on a plane normal to the crack plane and the vector from points 0 to 2 is normal to the vector from points 0 to 1.

24. THETA, if IROTYP = 1

angle between the x-axis and a vector drawn normal to the crack front, measured on the crack plane, from a point at which the J-integral is required (see Fig. 9(b)).

25. NELEDI, LAYER

NELEDI - number of elements in the domain

LAYER - number of crack front segments in the domain

26. (ELNEDI(i), i = 1 to NELEDI)

ELNEDI(i) - element numbers for all elements within domain

27. NODEDI - number of nodes in the domain with s = 1 (s-function)

28. (SNODS(i), i = 1 to NODEDI)

SNODS - node numbers with s = 1 in the domain

29. [SNODX(i), i = 1 to (LAYER + 1)]

SNODX - node numbers on the crack front element within a domain

APPLIED LOAD/DISPLACEMENT FACTOR AND TERMINATION OPTION

30. P, WORD F10.4,1X,H4

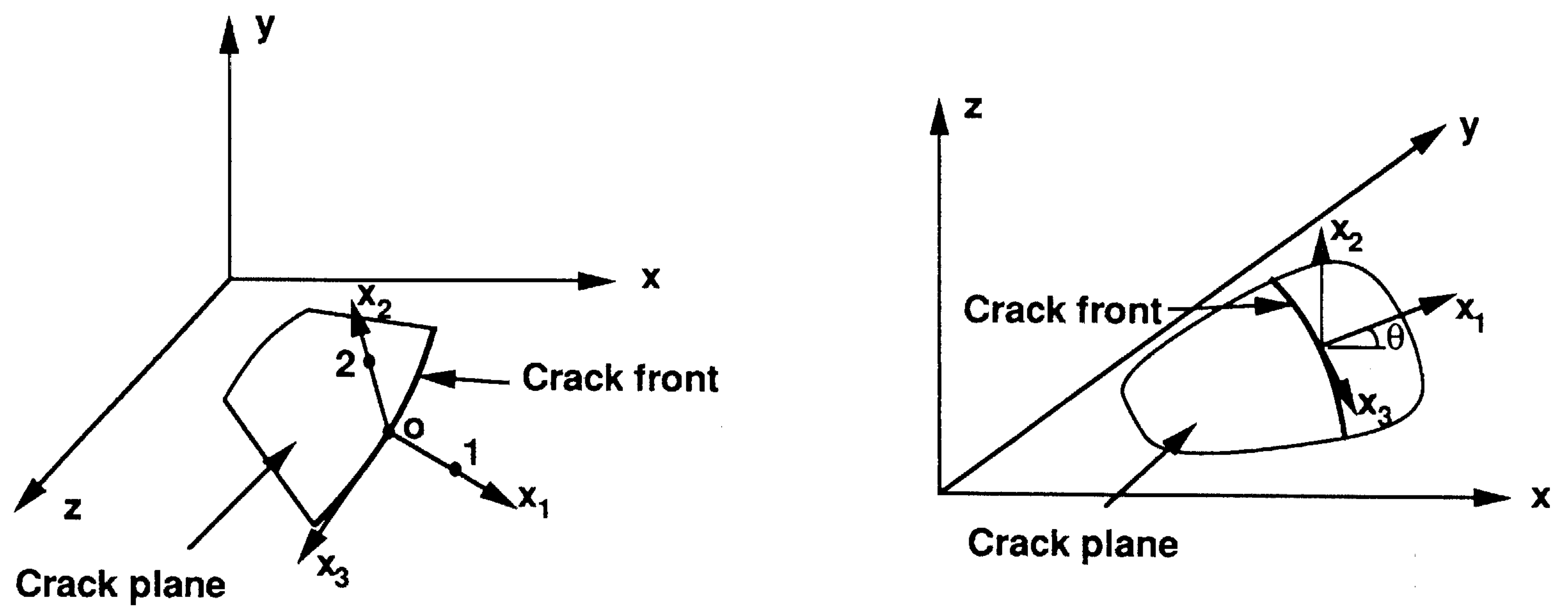
P - desired load factor

WORD = GROW - extend crack at P
= "blank space" - contines analysis with no crack growth

[Repeat line 30 to describe monotonic or cyclic load-factor history; such as P_1, P_2, P_3 and etc.]

31. WORD 11X,H4

WORD = HALT - terminates the analysis



(a) Three-point definition (IROTYP = 0)

(b) IROTYP = 1 definition

Figure 9.- Definitions of local coordinate system at any point on the crack front

FINITE-ELEMENT MESH FILE

Line No.	Parameter	Format
1.	JRENUM	
	JRENUM = 0 - original node numbering scheme is used in the analysis	
	JRENUM = 1 - renumbering string for mesh optimization is provided	
2.	(JNEW(i), i = 1 to NNODE) if JRENUM = 1	
	JNEW(i) - string of optimized node numbers	
3.	NODE, x, y, z	
	NODE - node number	
	x, y, z - Cartesian coordinates of the node NODE	

[Repeat line 3 NNODE times]

Line No.	Parameter	Format
4.	IE, [MODE(IE,j), j=1 to 8], INDXEL, [IFACE(j), j=1 to 6]	16I5
	IE - element number	
	MODE - nodal connectivity defined in a counter-clockwise direction using the right-hand rule (1, 2, 3, 4, 5, 6, 7, 8 as shown in Fig. 1)	
	INDXEL = 0 - reduced shear integration, select this option for bending dominant problems	
	INDXEL = 1 - full integration, select this option for tension dominant problems	
	IFACE(j) = 0 - jth face is not pressure loaded	
	IFACE(j) = 1 - jth face is uniformly loaded with a pressure of intensity PRSUR (Line #3 in Analysis File). Element face numbers are defined in Figure 1 with reference to the local coordinate system.	

[Repeat line 4 NELM times]

EXAMPLE DATA FILES

The following analysis and mesh files are for an elastic analysis of a single-edge-crack-tension specimen subjected to uniform stress at the ends of the specimen. Only one-fourth of the specimen is idealized by 8-node elements. The specimen configuration and details of the finite-element mesh are shown in Figure 8. This example is for a coarse mesh, hence it should be used as a guideline only, not for generating accurate solutions.

ANALYSIS FILE

```
EXAMPLE DATA FOR ELASTIC ANALYSIS OF SINGLE-EDGE-CRACK-TENSION SPECIMEN
MESHFILE
.5, 1., .5, 1., .2, 1.
0, 60, 24, 2, 0, 1, 1
1
1., .3, .5, -1., 0.0
3
0.5, 0.5
0.7, 0.75
0.7, 1.00
1, 1, 24, 1
1                             $ number of symmetric planes
3                             $ z = 0 plane
1, 0, 0, 1.0
1, 1, 0, 0                    $ node 1 u=0
0, 1, 1., 1., 0.99            $ not applicable for elastic analysis
1., .01, 100, 1, 60, 1, 12    $ two layer analysis
2                      $ G by VCCT method at 2 crack front segments
0
2, 10, 11                     $ set # 1
17, 37, 18, 38
2, 22, 23                     $ set # 2
37, 57, 38, 58
3                      $ J by EDI method at 3 locations on the crack front
0                             $ set # 1 at z=0
0., 0., 0., 1., 0., 0., 0., 1., 0.
2, 1
10, 11
1
18
18, 38
0                             $ set #2 at z= THICK/2
0., 0., 0., 1., 0., 0., 0., 1., 0.
4, 2
10, 11, 22, 23
1
38
```

```
18, 38, 58
0                                   $ set #3 at z=THICK
0.,0.,0., 1.,0.,0., 0.,1.,0.
2, 1
22, 23
1
58
38, 58
1.0        HALT         $ required only for elastic-plastic analysis
```

MESHFILE

```
1  0.  1.  0.                $ x, y and z coordinates of nodes
2  .3  1.  0.
3  .5  1.  0.
4  .7  1.  0.
5  1.  1.  0.

--- (continue)

56  0.  0.  1.
57  .3  0.  1.
58  .5  0.  1.
59  .7  0.  1.
60  1.  0.  1.

    1   1   6   7   2  21  26  27  22   1   0   0   0   1
    2   2   7   8   3  22  27  28  23   1   0   0   0   1
    3   3   8   9   4  23  28  29  24   1   0   0   0   1
    4   4   9  10   5  24  29  30  25   1   0   0   0   1
    5   6  11  12   7  26  31  32  27   1
    6   7  12  13   8  27  32  33  28   1
    7   8  13  14   9  28  33  34  29   1
    8   9  14  15  10  29  34  35  30   1
    9  11  16  17  12  31  36  37  32   1
   10  12  17  18  13  32  37  38  33   1
   11  13  18  19  14  33  38  39  34   1
   12  14  19  20  15  34  39  40  35   1
   13  21  26  27  22  41  46  47  42   1
   14  22  27  28  23  42  47  48  43   1
   15  23  28  29  24  43  48  49  44   1
   16  24  29  30  25  44  49  50  45   1
   17  26  31  32  27  46  51  52  47   1
   18  27  32  33  28  47  52  53  48   1
   19  28  33  34  29  48  53  54  49   1
   20  29  34  35  30  49  54  55  50   1
   21  31  36  37  32  51  56  57  52   1
   22  32  37  38  33  52  57  58  53   1
   23  33  38  39  34  53  58  59  54   1
   24  34  39  40  35  54  59  60  55   1
```

ERROR MESSAGES

The program gives two types of error messages. One is related to the problem size and the other is related to the finite-element (FE) modelling. In both cases the program STOPS normally and the error is flagged. The first type of error is easy to correct. Simply replace the dimension of the variable flagged with the new dimension value. This correction should be made in all of the parameter statements where that particular variable appears. These errors will pertain to the eight variables listed in the section Program Size Control. The second type of error is corrected by checking the FE model and the plastic analysis strategy. The three error messages and the probable corrections (remedies) are given below:

1. ELEMENT ie HAD NONPOSITIVE DIAGONAL STIFFNESS MATRIX; ELEMENT CONNECTIVITY: i,j,k,l,m,n,p,q.

   Check element "ie" connectivity which must follow the right-hand screw rule.

2. IERR=1, NONPOSITIVE DEFINITE MATRIX

   Check boundary conditions to suppress all six rigid body modes of deformations. Impose restraints such that the three translations and the three rotations about x, y, and z axes are suppressed.

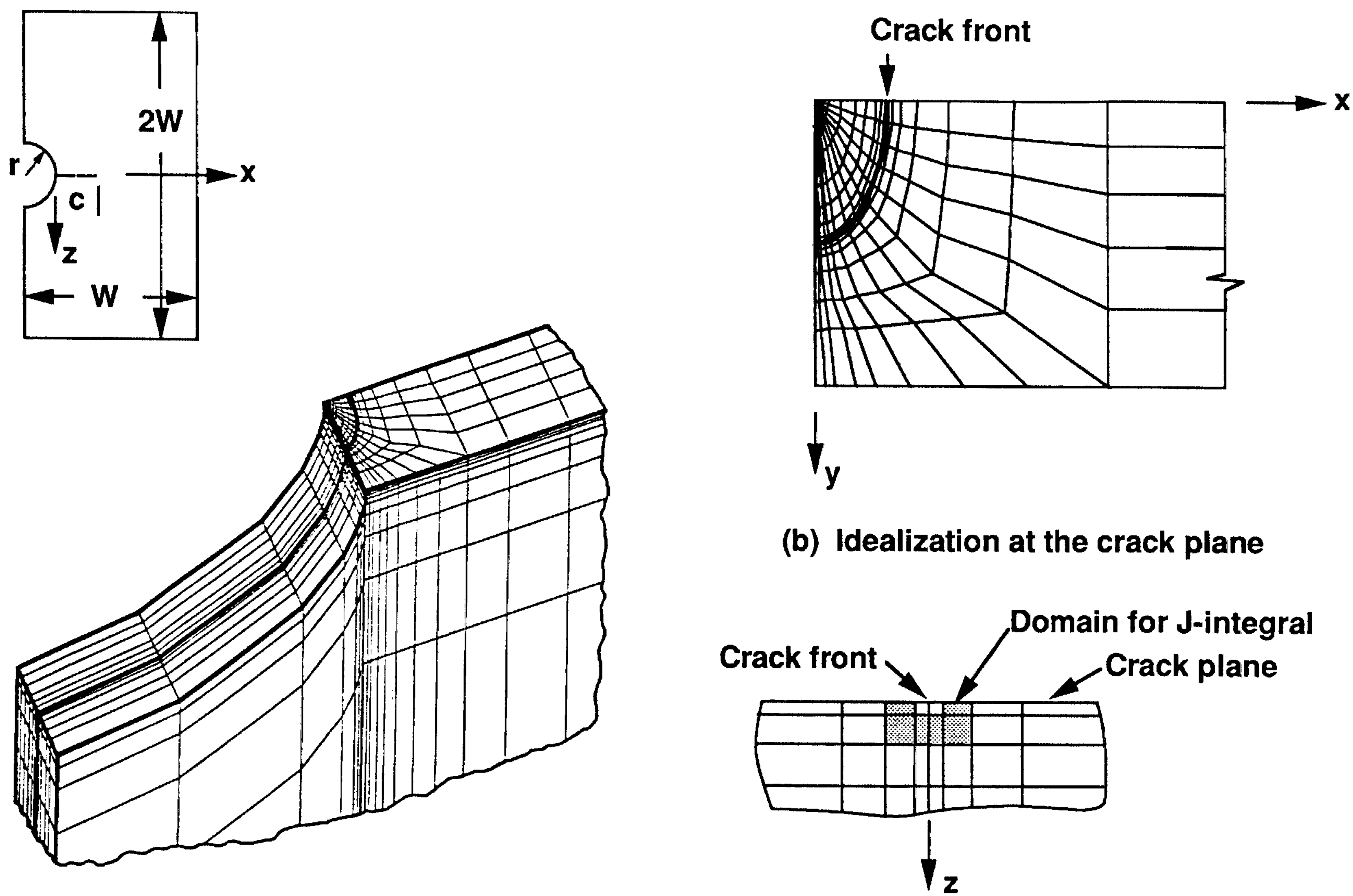
3. NO CONVERGENCE AFTER 100 ITERATIONS

   This is the most difficult error to diagnosis and correct, but use the following guidelines. Increase the value of MAXIT, decrease the load-increment size, or increase the allowable error (ERIT) for stress convergence. Also, do not use a fine mesh (small elements) at a point load. If a fine mesh is used, then make the element immediately under the point load elastic.

IV. EXAMPLE PROBLEMS

ELASTIC ANALYSIS OF SURFACE CRACK IN A PLATE

A semi-elliptical surface crack emanating from the root of a single-edge-notched plate subjected to remote stress (S = 1) was analyzed. The plate width was W = 45t, notch radius was r = 3t, and the thickness was t = 1.0. The aspect ratio of the crack was a/c = 2.0, and the ratio of a/t = 0.8. Because of symmetry, only one-quarter of the plate was modelled using 8-node isoparametric elements. The model had 5380 nodes and 4375 elements. The FE idealization near the notch root is shown in the Figure 10(a) and the FE idealization at the crack plane is shown in the Figure 10(b). The crack front is divided into thirteen segments with larger segment lengths near the x-axis. The mesh is nearly orthogonal at the deep section of the crack front and skewed towards the free surface (intersection of the crack front and the notch root). The domain used for the J-integral is shown in the Figure 10(c). The elastic modulus and Poisson's ratio were 1.0 and 0.3, respectively. In this analysis, NODE1 was specified to be zero to eliminate printout of nodal displacements, forces and stresses. Fracture mechanics parameters G and J are calculated along the crack front from the midplane to the free surface. Although the mesh is not exactly orthogonal, both G calculated from the virtual-crack-closure technique (VCCT) and J calculated from the equivalent-domain integral (EDI) method agree well. The J-integral is not calculated where the crack front intersects the free surface (y-axis) for reasons explained in Reference 14. Three files, namely, surac2.dat (analysis file), SURAC2M (mesh file - only a partial listing), and the output file (surac2.res) are listed separately. All three files are provided along with the program file.



(a) Finite-element idealization

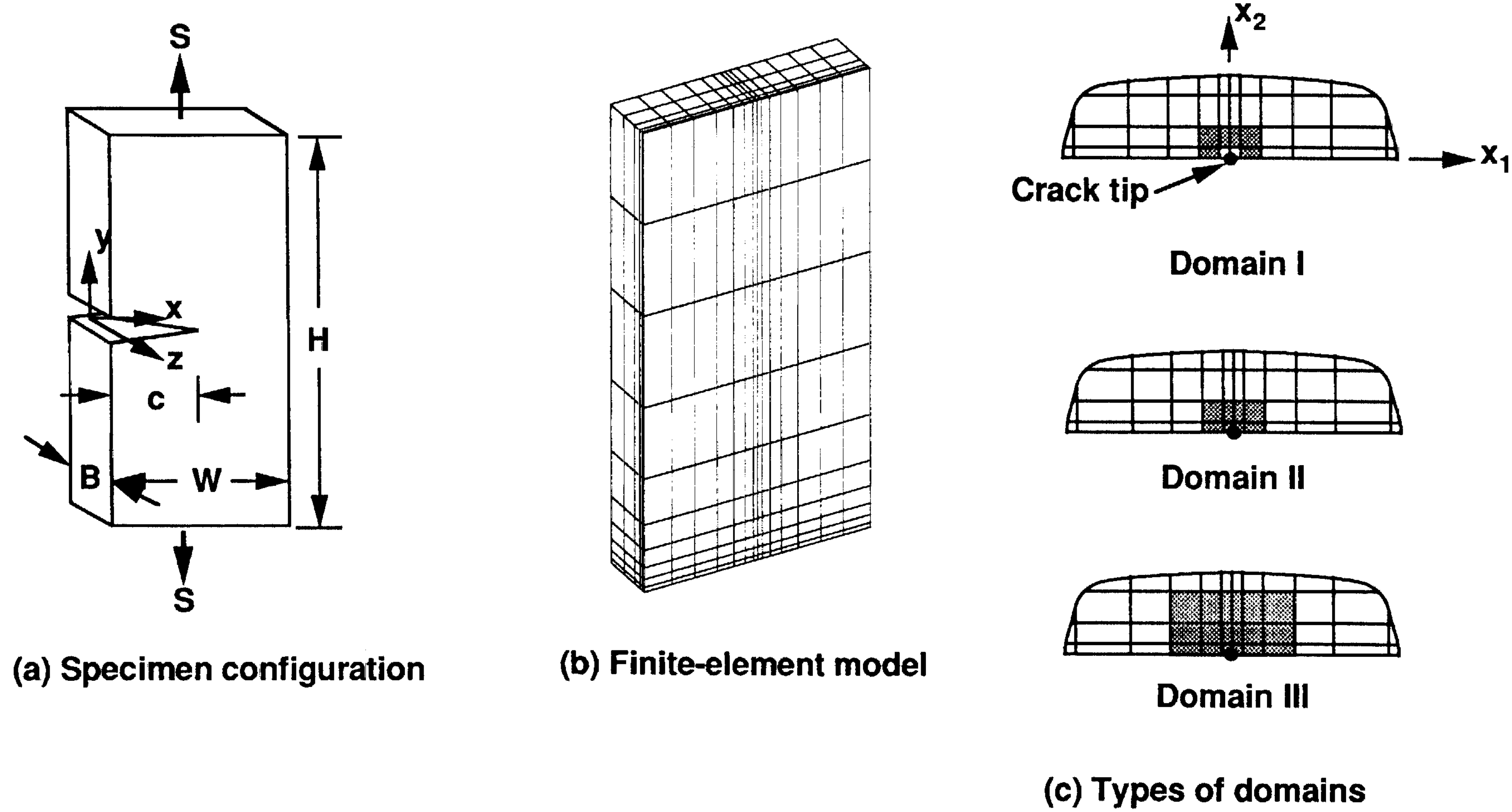
(b) Idealization at the crack plane

(c) Typical section across the crack front

Figure 10. Finite-element idealization of a single edge notched tension specimen

ELASTIC-PLASTIC ANALYSIS OF SINGLE-EDGE-CRACKED PLATE SUBJECTED TO TENSION

A single-edge-crack-tension specimen (see Fig. 11(a)) with a = 0.5m, W = 1.0m, B = 0.5m, and H = 4.m, made of A36 steel with E = 207,000 MPa, ν = 0.3 and elastic limit stress σ_0= 283.4 MPa was analyzed. The material stress-strain curve was represented by nine linear segments given in the analysis file "sent.dat". Figure 11(b) shows the FE model of one-fourth of the specimen. The model had five unequal layers in the z-direction, with total of 700 elements and 990 nodes. The nodal coordinates and the element connectivity are given in the file "SENTM" and a partial listing of the file is included here. The analysis data file is given in file "sent.dat" and a listing is also included in the manual. The first yield point occurred in element 693 at a stress level S = 19.15 MPa. The plastic analysis was continued to a value of S = 80 MPa. Three domain definitions (as shown in the Fig. 11(c)) were used to calculate the J-integral at several points along the crack front. In the three domains shown in Figure 11(c), the nodes on the outer boundary of the domain had deLorenzi's s-function equal to zero (s = 0) and all of the remaining nodes had s = 1. The J-integrals were calculated at 0.0 (midplane), 0.10, 0.18, 0.22, and 0.24mm from the midplane of the specimen. All fifteen values of the J-integrals, three at each point, are given in the output file. Listings of three files: the analysis file (sent.dat), the mesh file (SENTM), and the output file (sent.res) are given in the manual. All three files are included with the program file.



(a) Specimen configuration

(b) Finite-element model

(c) Types of domains

Figure 11.- Single-edge-crack-tension specimen and the finite-element model

LISTING OF ANALYSIS, MESH AND OUTPUT FILES

```
ELLIPTIC SURFACE CRACK   A/C=2, A/T=.8, W=48T, R=3T
SURAC2M
0.0         45.0        100.00      1.00     .002      1.0        1.0
   0 5380 4375    5   -1  2  1  1
   1
1.00000    0.3      1.000000     0.0      0.00
1      1 4375     1
   1
   2
  173   00   00
5366    1    0    0
2801    0    0    1
2816    0    0    1
2831    0    0    1
2846    0    0    1
2861    0    0    1
2876    0    0    1
2891    0    0    1
2906    0    0    1
2921    0    0    1
2936    0    0    1
2951    0    0    1
2966    0    0    1
2981    0    0    1
2996    0    0    1
3011    0    0    1
3026    0    0    1
3041    0    0    1
3056    0    0    1
3071    0    0    1
3086    0    0    1
3101    0    0    1
3116    0    0    1
3131    0    0    1
3146    0    0    1
3161    0    0    1
3176    0    0    1
3191    0    0    1
3206    0    0    1
3221    0    0    1
3236    0    0    1
3251    0    0    1
3266    0    0    1
3281    0    0    1
3296    0    0    1
3311    0    0    1
3326    0    0    1
3341    0    0    1
3356    0    0    1
3371    0    0    1
3386    0    0    1
3401    0    0    1
3416    0    0    1
3431    0    0    1
3446    0    0    1
3461    0    0    1
3476    0    0    1
3491    0    0    1
3506    0    0    1
3521    0    0    1
```

3536	0	0	1
3551	0	0	1
3566	0	0	1
3581	0	0	1
3596	0	0	1
3611	0	0	1
3626	0	0	1
3641	0	0	1
3656	0	0	1
3671	0	0	1
3686	0	0	1
3701	0	0	1
3716	0	0	1
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4526	0	0	1
4541	0	0	1
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4571	0	0	1
4586	0	0	1
4601	0	0	1
4616	0	0	1
4631	0	0	1
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4751	0	0	1
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5051	0	0	1
5066	0	0	1
5081	0	0	1
5096	0	0	1
5111	0	0	1
5126	0	0	1
5141	0	0	1
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5186	0	0	1
5201	0	0	1
5216	0	0	1
5231	0	0	1
5246	0	0	1
5261	0	0	1
5276	0	0	1
5291	0	0	1
5306	0	0	1
5321	0	0	1

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5351    0    0    1
5366    0    0    1
  0     5  2.00      1.0       .995
 0.30     .015       200    0 666    0 553
 13  SETS OF G AT MID POINT OF THE CRACK SEGMENT
 3
 2, 953, 954
2786, 2771, 2996, 2981
2, 968,969
2771, 2756, 2981, 2966
2, 983, 984
2756, 2741, 2966, 2951
2, 998, 999
2741, 2726, 2951, 2936
2, 1013, 1014
2726, 2711, 2936, 2921
2, 1028, 1029
2711, 2696, 2921, 2906
2, 1043, 1044
2696, 2681, 2906,2891
2, 1058, 1059
2681, 2666, 2891, 2876
2, 1073, 1074
2666, 2651, 2876, 2861
2, 1088, 1089
2651, 2636, 2861, 2846
2, 1103, 1104
2636, 2621, 2846, 2831
2, 1118, 1119
2621, 2606, 2831, 2816
2, 1133, 1134
2606, 2591, 2816,2801
   13    DOMAINS    13 SETS  J-Calculation
   1    DOMAIN #2
      .0000
   6    1
 952 1197 1198 1199 1200  955
   5
2786 2787 2997 3207 3206
2996 2981
   1
     4.5300
  12    2
 952 1197 1198 1199 1200  955
 967 1212 1213 1214 1215  970
   5
2771 2772 2982 3192 3191
2996 2981 2966
   1
    9.2300
  12    2
 967 1212 1213 1214 1215  970
 982 1227 1228 1229 1230  985
   5
2756 2757 2967 3177 3176
2981 2966 2951
   1
    14.2900
  12    2
```

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 982 1227 1228 1229 1230  985
 997 1242 1243 1244 1245 1000
   5
2741 2742 2952 3162 3161
2966 2951 2936
   1
    19.9600
  12    2
 997 1242 1243 1244 1245 1000
1012 1257 1258 1259 1260 1015
   5
2726 2727 2937 3147 3146
2951 2936 2921
   1
    26.5700
  12    2
1012 1257 1258 1259 1260 1015
1027 1272 1273 1274 1275 1030
   5
2711 2712 2922 3132 3131
2936 2921 2906
   1
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  12    2
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1042 1287 1288 1289 1290 1045
   5
2696 2697 2907 3117 3116
2921 2906 2891
   1
    44.4600
  12    2
1042 1287 1288 1289 1290 1045
1057 1302 1303 1304 1305 1060
   5
2681 2682 2892 3102 3101
2906 2891 2876
   1
    56.9800
  12    2
1057 1302 1303 1304 1305 1060
1072 1317 1318 1319 1320 1075
   5
2666 2667 2877 3087 3086
2891 2876 2861
   1
    66.9700
  12    2
1072 1317 1318 1319 1320 1075
1087 1332 1333 1334 1335 1090
   5
2651 2652 2862 3072 3071
2876 2861 2846
   1
    74.3000
  12    2
1087 1332 1333 1334 1335 1090
1102 1347 1348 1349 1350 1105
   5
2636 2637 2847 3057 3056
```

```
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   1
     82.0400
  12     2
1102 1347 1348 1349 1350 1105
1117 1362 1363 1364 1365 1120
   5
2621 2622 2832 3042 3041
2846 2831 2816
   1
     86.0000
  12     2
1117 1362 1363 1364 1365 1120
1132 1377 1378 1379 1380 1135
   5
2606 2607 2817 3027 3026
2831 2816 2801
 1.0       HALT
```

0 NO RENUMBERING SCHEME

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2	-.3000000E+01	.0000000E+00	.3200000E+01
3	-.3000000E+01	.0000000E+00	.3600000E+01
4	-.3000000E+01	.0000000E+00	.4400000E+01
5	-.3000000E+01	.0000000E+00	.5950000E+01
6	-.3000000E+01	.0000000E+00	.9150000E+01
7	-.3000000E+01	.0000000E+00	.1525000E+02
8	-.3000000E+01	.0000000E+00	.2575000E+02
9	-.3000000E+01	.0000000E+00	.4575000E+02
10	-.3000000E+01	.0000000E+00	.1000000E+03

*** CONTINUED ***

5371	.4500000E+02	.0000000E+00	.2500000E+00
5372	.4500000E+02	.0000000E+00	.4500000E+00
5373	.4500000E+02	.0000000E+00	.8500000E+00
5374	.4500000E+02	.0000000E+00	.1650000E+01
5375	.4500000E+02	.0000000E+00	.3200000E+01
5376	.4500000E+02	.0000000E+00	.6400000E+01
5377	.4500000E+02	.0000000E+00	.1250000E+02
5378	.4500000E+02	.0000000E+00	.2300000E+02
5379	.4500000E+02	.0000000E+00	.4300000E+02
5380	.4500000E+02	.0000000E+00	.1000000E+03

1	1	161	171	11	2	162	172	12
2	11	171	181	21	12	172	182	22
3	21	181	191	31	22	182	192	32
4	31	191	201	41	32	192	202	42
5	41	201	211	51	42	202	212	52
6	51	211	221	61	52	212	222	62
7	61	221	231	71	62	222	232	72
8	71	231	241	81	72	232	242	82
9	81	241	251	91	82	242	252	92
10	91	251	261	101	92	252	262	102

*** CONTINUED ***

4366	5199	5289	5274	5184	5200	5290	5275	5185	0	0	0	0	0	0	1
4367	5184	5274	5259	5169	5185	5275	5260	5170	0	0	0	0	0	0	1
4368	5169	5259	5244	5154	5170	5260	5245	5155	0	0	0	0	0	0	1
4369	5154	5244	5229	5139	5155	5245	5230	5140	0	0	0	0	0	0	1
4370	5139	5229	5214	5124	5140	5230	5215	5125	0	0	0	0	0	0	1
4371	5289	5379	5364	5274	5290	5380	5365	5275	0	0	0	0	0	0	1
4372	5274	5364	5349	5259	5275	5365	5350	5260	0	0	0	0	0	0	1
4373	5259	5349	5334	5244	5260	5350	5335	5245	0	0	0	0	0	0	1
4374	5244	5334	5319	5229	5245	5335	5320	5230	0	0	0	0	0	0	1
4375	5229	5319	5304	5214	5230	5320	5305	5215	0	0	0	0	0	0	1

```
      TOTAL COMMON BLOCK MAIN LENGTH=  16262593
 1


        ELLIPTIC SURFACE CRACK   A/C=2, A/T=.8, W=48T, R=3T
      Mesh file: SURAC2M
      CRACK=     0.0000  WIDTH=   45.0000  THICK=  100.0000
      HEIGHT=    1.0000  DAX=  0.002000  SCALE=   1.00000
      NORMAL STRESS (PRSUR) :    1.0000


      LPR= 0  NNODE= 5380  NELM= 4375  NLAYER= 5  NEP=-1  IOPTON=  2
      Calculate G by VCCT Method Y/N 1/0: 1
      Calculate J by EDI Method  Y/N 1/0: 1



           MODULUS, NU, YIELD STRESS, AM, & ROM:  0.1000E+01  0.3000E+00  0.1000E+01  0.0000E+00  0.0000E+00
     1    1 4375    1


           Renumber the mesh OR Not (1/0): 0
           INODXO   INODYO   INODZO   INODXC   INODYC  INODZC
            435      655      284      90      355      396
                 Maximum Bandwidth=       9531


           Total Storage Required for Stiffness Matrix=    10886442
      SUM OF FORCES IN x, y, z DIRECTIONS DUE TO PRESSURE:-0.580904E-12 0.154909E-10 0.480000E+02
 1
      No. OF SYMMETRIC BOUNDARY CONDITIONS =  1
            SYMMETRIC PLANE NUMBERS ARE :  2


      No. OF NODES: FIXED=173  LOADED=  0  DISPLACED=  0


   Node    u     v     w
  5366     1     0     0
  2801     0     0     1
  2816     0     0     1
  2831     0     0     1
  2846     0     0     1
  2861     0     0     1
  2876     0     0     1
```

2891	0	0	1
2906	0	0	1
2921	0	0	1
2936	0	0	1
2951	0	0	1
2966	0	0	1
2981	0	0	1
2996	0	0	1
3011	0	0	1
3026	0	0	1
3041	0	0	1
3056	0	0	1
3071	0	0	1
3086	0	0	1
3101	0	0	1
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3461	0	0	1
3476	0	0	1
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3551	0	0	1

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3641	0	0	1
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4196	0	0	1
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4226	0	0	1

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4316	0	0	1
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4796	0	0	1
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4826	0	0	1
4841	0	0	1
4856	0	0	1
4871	0	0	1
4886	0	0	1
4901	0	0	1

```
    4916    0    0    1
    4931    0    0    1
    4946    0    0    1
    4961    0    0    1
    4976    0    0    1
    4991    0    0    1
    5006    0    0    1
    5021    0    0    1
    5036    0    0    1
    5051    0    0    1
    5066    0    0    1
    5081    0    0    1
    5096    0    0    1
    5111    0    0    1
    5126    0    0    1
    5141    0    0    1
    5156    0    0    1
    5171    0    0    1
    5186    0    0    1
    5201    0    0    1
    5216    0    0    1
    5231    0    0    1
    5246    0    0    1
    5261    0    0    1
    5276    0    0    1
    5291    0    0    1
    5306    0    0    1
    5321    0    0    1
    5336    0    0    1
    5351    0    0    1
    5366    0    0    1
      READING DATA + STIFFNESS + ASSEMBLY =  0.3064E+02
      SOLUTION TIME  SECS=  0.1059E+03
   1

      ELEMENT#    0  GAUSS PT= 0  LOAD FACTOR AT  YIELD=0.100000E+01
      CPU FOR ELASTIC STRESS EVALUATION=  0.4225E+00

         CRACK GROWTH CRITERION NTYP= 0 and CTOD =0.2000E+01
         NUMBER OF INCREMENTS TO RELEASE CRACK TIP FORCE= 5
         CRACK OPENING DISPLACEMENT ACCURCY=  0.9950E+00


         INCREMENTAL LOAD FACTOR=    0.3000
```

```
      ALLOWABLE ERROR ON STRESS=    0.0150
      MAXIMUM NUMBER OF ITERATION= 200
      RELAXATION PARAMETER= 1.00
      PRINT DISPLACEMENTS AT NODES    0 TO  666
      PRINT STRESSES IN ELEMENTS    0 TO  553
1

      APPLIED LOAD= 0.10000E+01       CRACK=   0.00000        WIDTH=  45.00000
1

   NUMBER OF G-CALCULATIONS = 13
   CRACK PLANE SYMMETRY Y/N 1, 2, 3/0:  3
   G-REGION NO.= 1
   NO. OF ELEMENTS =  2
   ELEMENT NOS:   953  954
   DISP. NODES:  2786 2771
   FORCE NODES: 2996 2981
   TOTAL G =  0.64519E+01

   GI = 0.64519E+01     GII = 0.00000E+00     GIII= 0.00000E+00
   ------------------------------------------------------------


   G-REGION NO.= 2
   NO. OF ELEMENTS =  2
   ELEMENT NOS:   968  969
   DISP. NODES:  2771 2756
   FORCE NODES: 2981 2966
   TOTAL G =  0.63931E+01

   GI = 0.63931E+01     GII = 0.00000E+00     GIII= 0.00000E+00
   ------------------------------------------------------------


   G-REGION NO.= 3
   NO. OF ELEMENTS =  2
   ELEMENT NOS:   983  984
   DISP. NODES:  2756 2741
   FORCE NODES: 2966 2951
   TOTAL G =  0.62783E+01
```

```
GI = 0.62783E+01     GII = 0.00000E+00     GIII= 0.00000E+00
-----------------------------------------------------------


G-REGION NO.= 4
NO. OF ELEMENTS =  2
ELEMENT NOS:   998  999
DISP. NODES:  2741 2726
FORCE NODES: 2951 2936
TOTAL G =  0.61113E+01

GI = 0.61113E+01     GII = 0.00000E+00     GIII= 0.00000E+00
-----------------------------------------------------------


G-REGION NO.= 5
NO. OF ELEMENTS =  2
ELEMENT NOS:  1013 1014
DISP. NODES:  2726 2711
FORCE NODES: 2936 2921
TOTAL G =  0.59069E+01

GI = 0.59069E+01     GII = 0.00000E+00     GIII= 0.00000E+00
-----------------------------------------------------------


G-REGION NO.= 6
NO. OF ELEMENTS =  2
ELEMENT NOS:  1028 1029
DISP. NODES:  2711 2696
FORCE NODES: 2921 2906
TOTAL G =  0.56964E+01

GI = 0.56964E+01     GII = 0.00000E+00     GIII= 0.00000E+00
-----------------------------------------------------------
```

```
G-REGION NO.= 7
NO. OF ELEMENTS =  2
ELEMENT NOS:  1043 1044
DISP. NODES:  2696 2681
FORCE NODES: 2906 2891
TOTAL G =  0.54908E+01


GI = 0.54908E+01     GII = 0.00000E+00     GIII= 0.00000E+00
-----------------------------------------------------------


G-REGION NO.= 8
NO. OF ELEMENTS =  2
ELEMENT NOS:  1058 1059
DISP. NODES:  2681 2666
FORCE NODES: 2891 2876
TOTAL G =  0.53392E+01


GI = 0.53392E+01     GII = 0.00000E+00     GIII= 0.00000E+00
-----------------------------------------------------------


G-REGION NO.= 9
NO. OF ELEMENTS =  2
ELEMENT NOS:  1073 1074
DISP. NODES:  2666 2651
FORCE NODES: 2876 2861
TOTAL G =  0.52906E+01


GI = 0.52906E+01     GII = 0.00000E+00     GIII= 0.00000E+00
-----------------------------------------------------------


G-REGION NO.=10
NO. OF ELEMENTS =  2
ELEMENT NOS:  1088 1089
DISP. NODES:  2651 2636
FORCE NODES: 2861 2846
TOTAL G =  0.53517E+01
```

```
GI = 0.53517E+01     GII = 0.00000E+00     GIII= 0.00000E+00
-------------------------------------------------------------


G-REGION NO.=11
NO. OF ELEMENTS =  2
ELEMENT NOS:  1103 1104
DISP. NODES:  2636 2621
FORCE NODES: 2846 2831
TOTAL G =  0.55386E+01

GI = 0.55386E+01     GII = 0.00000E+00     GIII= 0.00000E+00
-------------------------------------------------------------


G-REGION NO.=12
NO. OF ELEMENTS =  2
ELEMENT NOS:  1118 1119
DISP. NODES:  2621 2606
FORCE NODES: 2831 2816
TOTAL G =  0.57406E+01

GI = 0.57406E+01     GII = 0.00000E+00     GIII= 0.00000E+00
-------------------------------------------------------------


G-REGION NO.=13
NO. OF ELEMENTS =  2
ELEMENT NOS:  1133 1134
DISP. NODES:  2606 2591
FORCE NODES: 2816 2801
TOTAL G =  0.58225E+01

GI = 0.58225E+01     GII = 0.00000E+00     GIII= 0.00000E+00
-------------------------------------------------------------
```

```
1

 NUMBER OF EDI DOMAINS: 13
 DOMAIN NO. =  1
  ROTATION FROM X-AXIS:      0.00
 ROTATIONAL MATRIX =  1.0 0.0 0.0 0.0 0.0-1.0 0.0 1.0 0.0
 NUMBER OF ELEMENTS  AND SEGMENTS IN DOMAIN:   6  1
ELEMENTS IN THIS DOMAIN:
       952 1197 1198 1199 1200  955
 NUMBER OF NODES IN ITH DOMAIN WITH S=1 VALUE:  5
 NODES ON S= 1 CONTOUR:
      2786 2787 2997 3207 3206
 NODES ON THE CRACK FRONT:  2996 2981
 DOMAIN NO. =  2
  ROTATION FROM X-AXIS:      4.53
 ROTATIONAL MATRIX =  1.0 0.0 0.1 0.1 0.0-1.0 0.0 1.0 0.0
 NUMBER OF ELEMENTS  AND SEGMENTS IN DOMAIN:  12  2
ELEMENTS IN THIS DOMAIN:
       952 1197 1198 1199 1200  955  967 1212 1213 1214
      1215  970
 NUMBER OF NODES IN ITH DOMAIN WITH S=1 VALUE:  5
 NODES ON S= 1 CONTOUR:
      2771 2772 2982 3192 3191
 NODES ON THE CRACK FRONT:  2996 2981 2966
 DOMAIN NO. =  3
  ROTATION FROM X-AXIS:      9.23
 ROTATIONAL MATRIX =  1.0 0.0 0.2 0.2 0.0-1.0 0.0 1.0 0.0
 NUMBER OF ELEMENTS  AND SEGMENTS IN DOMAIN:  12  2
ELEMENTS IN THIS DOMAIN:
       967 1212 1213 1214 1215  970  982 1227 1228 1229
      1230  985
 NUMBER OF NODES IN ITH DOMAIN WITH S=1 VALUE:  5
 NODES ON S= 1 CONTOUR:
      2756 2757 2967 3177 3176
 NODES ON THE CRACK FRONT:  2981 2966 2951
 DOMAIN NO. =  4
  ROTATION FROM X-AXIS:     14.29
 ROTATIONAL MATRIX =  1.0 0.0 0.2 0.2 0.0-1.0 0.0 1.0 0.0
 NUMBER OF ELEMENTS  AND SEGMENTS IN DOMAIN:  12  2
ELEMENTS IN THIS DOMAIN:
       982 1227 1228 1229 1230  985  997 1242 1243 1244
      1245 1000
 NUMBER OF NODES IN ITH DOMAIN WITH S=1 VALUE:  5
 NODES ON S= 1 CONTOUR:
```

```
     2741 2742 2952 3162 3161
 NODES ON THE CRACK FRONT:  2966 2951 2936
 DOMAIN NO. =  5
  ROTATION FROM X-AXIS:     19.96
 ROTATIONAL MATRIX =  0.9 0.0 0.3 0.3 0.0-0.9 0.0 1.0 0.0
 NUMBER OF ELEMENTS  AND SEGMENTS IN DOMAIN:  12  2
ELEMENTS IN THIS DOMAIN:
      997 1242 1243 1244 1245 1000 1012 1257 1258 1259
     1260 1015
 NUMBER OF NODES IN ITH DOMAIN WITH S=1 VALUE:  5
 NODES ON S= 1 CONTOUR:
     2726 2727 2937 3147 3146
 NODES ON THE CRACK FRONT:  2951 2936 2921
 DOMAIN NO. =  6
  ROTATION FROM X-AXIS:     26.57
 ROTATIONAL MATRIX =  0.9 0.0 0.4 0.4 0.0-0.9 0.0 1.0 0.0
 NUMBER OF ELEMENTS  AND SEGMENTS IN DOMAIN:  12  2
ELEMENTS IN THIS DOMAIN:
     1012 1257 1258 1259 1260 1015 1027 1272 1273 1274
     1275 1030
 NUMBER OF NODES IN ITH DOMAIN WITH S=1 VALUE:  5
 NODES ON S= 1 CONTOUR:
     2711 2712 2922 3132 3131
 NODES ON THE CRACK FRONT:  2936 2921 2906
 DOMAIN NO. =  7
  ROTATION FROM X-AXIS:     34.54
 ROTATIONAL MATRIX =  0.8 0.0 0.6 0.6 0.0-0.8 0.0 1.0 0.0
 NUMBER OF ELEMENTS  AND SEGMENTS IN DOMAIN:  12  2
ELEMENTS IN THIS DOMAIN:
     1027 1272 1273 1274 1275 1030 1042 1287 1288 1289
     1290 1045
 NUMBER OF NODES IN ITH DOMAIN WITH S=1 VALUE:  5
 NODES ON S= 1 CONTOUR:
     2696 2697 2907 3117 3116
 NODES ON THE CRACK FRONT:  2921 2906 2891
 DOMAIN NO. =  8
  ROTATION FROM X-AXIS:     44.46
 ROTATIONAL MATRIX =  0.7 0.0 0.7 0.7 0.0-0.7 0.0 1.0 0.0
 NUMBER OF ELEMENTS  AND SEGMENTS IN DOMAIN:  12  2
ELEMENTS IN THIS DOMAIN:
     1042 1287 1288 1289 1290 1045 1057 1302 1303 1304
     1305 1060
 NUMBER OF NODES IN ITH DOMAIN WITH S=1 VALUE:  5
 NODES ON S= 1 CONTOUR:
     2681 2682 2892 3102 3101
```

```
 NODES ON THE CRACK FRONT:  2906 2891 2876
 DOMAIN NO. =  9
  ROTATION FROM X-AXIS:     56.98
 ROTATIONAL MATRIX =  0.5 0.0 0.8 0.8 0.0-0.5 0.0 1.0 0.0
 NUMBER OF ELEMENTS  AND SEGMENTS IN DOMAIN:  12  2
ELEMENTS IN THIS DOMAIN:
      1057 1302 1303 1304 1305 1060 1072 1317 1318 1319
      1320 1075
 NUMBER OF NODES IN ITH DOMAIN WITH S=1 VALUE:  5
 NODES ON S= 1 CONTOUR:
      2666 2667 2877 3087 3086
 NODES ON THE CRACK FRONT:  2891 2876 2861
 DOMAIN NO. = 10
  ROTATION FROM X-AXIS:     66.97
 ROTATIONAL MATRIX =  0.4 0.0 0.9 0.9 0.0-0.4 0.0 1.0 0.0
 NUMBER OF ELEMENTS  AND SEGMENTS IN DOMAIN:  12  2
ELEMENTS IN THIS DOMAIN:
      1072 1317 1318 1319 1320 1075 1087 1332 1333 1334
      1335 1090
 NUMBER OF NODES IN ITH DOMAIN WITH S=1 VALUE:  5
 NODES ON S= 1 CONTOUR:
      2651 2652 2862 3072 3071
 NODES ON THE CRACK FRONT:  2876 2861 2846
 DOMAIN NO. = 11
  ROTATION FROM X-AXIS:     74.30
 ROTATIONAL MATRIX =  0.3 0.0 1.0 1.0 0.0-0.3 0.0 1.0 0.0
 NUMBER OF ELEMENTS  AND SEGMENTS IN DOMAIN:  12  2
ELEMENTS IN THIS DOMAIN:
      1087 1332 1333 1334 1335 1090 1102 1347 1348 1349
      1350 1105
 NUMBER OF NODES IN ITH DOMAIN WITH S=1 VALUE:  5
 NODES ON S= 1 CONTOUR:
      2636 2637 2847 3057 3056
 NODES ON THE CRACK FRONT:  2861 2846 2831
 DOMAIN NO. = 12
  ROTATION FROM X-AXIS:     82.04
 ROTATIONAL MATRIX =  0.1 0.0 1.0 1.0 0.0-0.1 0.0 1.0 0.0
 NUMBER OF ELEMENTS  AND SEGMENTS IN DOMAIN:  12  2
ELEMENTS IN THIS DOMAIN:
      1102 1347 1348 1349 1350 1105 1117 1362 1363 1364
      1365 1120
 NUMBER OF NODES IN ITH DOMAIN WITH S=1 VALUE:  5
 NODES ON S= 1 CONTOUR:
      2621 2622 2832 3042 3041
 NODES ON THE CRACK FRONT:  2846 2831 2816
```

```
 DOMAIN NO. = 13
  ROTATION FROM X-AXIS:     86.00
 ROTATIONAL MATRIX =  0.1 0.0 1.0 1.0 0.0-0.1 0.0 1.0 0.0
 NUMBER OF ELEMENTS  AND SEGMENTS IN DOMAIN:  12  2
ELEMENTS IN THIS DOMAIN:
      1117 1362 1363 1364 1365 1120 1132 1377 1378 1379
      1380 1135
 NUMBER OF NODES IN ITH DOMAIN WITH S=1 VALUE:  5
 NODES ON S= 1 CONTOUR:
      2606 2607 2817 3027 3026
 NODES ON THE CRACK FRONT:  2831 2816 2801


J-integral values in the order defined in data

Domain#: 1  J Integral =  0.6426E+01
Domain#: 2  J Integral =  0.6398E+01
Domain#: 3  J Integral =  0.6313E+01
Domain#: 4  J Integral =  0.6177E+01
Domain#: 5  J Integral =  0.5997E+01
Domain#: 6  J Integral =  0.5796E+01
Domain#: 7  J Integral =  0.5600E+01
Domain#: 8  J Integral =  0.5429E+01
Domain#: 9  J Integral =  0.5351E+01
Domain#:10  J Integral =  0.5360E+01
Domain#:11  J Integral =  0.5477E+01
Domain#:12  J Integral =  0.5686E+01
Domain#:13  J Integral =  0.5977E+01
 NONE of the elements are yielded
```

```
3-D    SENT -M3- A/W=.5 ,W=1.
SENTM
00.5000    1.00       0.2500      2.00     .002       1.0  1.0
  0  990  700    5   +4    2    1    1
  1
207000.    0.3       283.40      -1.0     0.00
  9
283.4     0.00136
283.4     0.0105
354.3     0.0283
395.8     0.046
423.5     0.0642
440.6     0.0832
450.6     0.10
470.0     0.20
470.0     0.30
  1    1  700  1
  1
  3
  6   00   00
  1    1    0    0
  2    1    0    0
  3    1    0    0
  4    1    0    0
  5    1    0    0
  6    1    0    0
  0    5  2.00      1.0       .995
0.30     .015       200    1  50    1  20
5     3D-VCCT G-CALCULATION   5-REGIONS
2
2  133  134
937, 938,  943, 944
2  273, 274
938, 939,  944, 945
2  413, 414
939, 940,  945, 946
2  553, 554
940, 941,  946, 947
2  693, 694
941, 942,  947, 948
15     DOMAINS   5 LAYERS  J-Calculation
  0  DOMAIN#  1      LAYER#  1
  .500    .000    .000  1.000    .000    .000    .500    .500    .000
  6    1    1
132  135  118  119  120  121
  5    0
937  949  847  853  859
943  944
  0  DOMAIN#  2      LAYER#  1
  .500    .000    .000  1.000    .000    .000    .500    .500    .000
  8    1    1
133  134  132  135  118  119  120  121
  6    0
943  937  949  847  853  859
943  944
  0  DOMAIN#  3      LAYER#  1
  .500    .000    .000  1.000    .000    .000    .500    .500    .000
 18    1    1
133  134  132  135  118  119  120  121  131  136  117  122  103  104  105
106  107  108
```

```
 15    0
943  937  949  847  853  859  931  955  841  865  751  757  763  769  775
943  944
  0  DOMAIN#  1      LAYER#  2
  .500     .000     .000  1.000     .000     .000     .500     .500     .000
 12    2    1
132  135  118  119  120  121  272  275  258  259  260  261
  5    0
938  950  848  854  860
943  944  945
  0  DOMAIN#  2      LAYER#  2
  .500     .000     .000  1.000     .000     .000     .500     .500     .000
 16    2    1
133  134  132  135  118  119  120  121  273  274  272  275  258  259  260
261
  6    0
944  938  950  848  854  860
943  944  945
  0  DOMAIN#  3      LAYER#  2
  .500     .000     .000  1.000     .000     .000     .500     .500     .000
 36    2    1
133  134  132  135  118  119  120  121  131  136  117  122  103  104  105
106  107  108  273  274  272  275  258  259  260  261  271  276  257  262
243  244  245  246  247  248
 15    0
944  938  950  848  854  860  932  956  842  866  752  758  764  770  776
943  944  945
  0  DOMAIN#  1      LAYER#  3
  .500     .000     .000  1.000     .000     .000     .500     .500     .000
 12    2    1
272  275  258  259  260  261  412  415  398  399  400  401
  5    0
939  951  849  855  861
944  945  946
  0  DOMAIN#  2      LAYER#  3
  .500     .000     .000  1.000     .000     .000     .500     .500     .000
 16    2    1
273  274  272  275  258  259  260  261  413  414  412  415  398  399  400
401
  6    0
945  939  951  849  855  861
944  945  946
  0  DOMAIN#  3      LAYER#  3
  .500     .000     .000  1.000     .000     .000     .500     .500     .000
 36    2    1
273  274  272  275  258  259  260  261  271  276  257  262  243  244  245
246  247  248  413  414  412  415  398  399  400  401  411  416  397  402
383  384  385  386  387  388
 15    0
945  939  951  849  855  861  933  957  843  867  753  759  765  771  777
944  945  946
  0  DOMAIN#  1      LAYER#  4
  .500     .000     .000  1.000     .000     .000     .500     .500     .000
 12    2    1
412  415  398  399  400  401  552  555  538  539  540  541
  5    0
940  952  850  856  862
945  946  947
  0  DOMAIN#  2      LAYER#  4
  .500     .000     .000  1.000     .000     .000     .500     .500     .000
```

```
 16    2    1
413  414  412  415  398  399  400  401  553  554  552  555  538  539  540
541
  6    0
946  940  952  850  856  862
945  946  947
  0  DOMAIN#  3      LAYER#  4
 .500    .000    .000   1.000    .000     .000     .500     .500     .000
 36    2    1
413  414  412  415  398  399  400  401  411  416  397  402  383  384  385
386  387  388  553  554  552  555  538  539  540  541  551  556  537  542
523  524  525  526  527  528
 15    0
946  940  952  850  856  862  934  958  844  868  754  760  766  772  778
945  946  947
  0  DOMAIN#  1      LAYER#  5
 .500    .000    .000   1.000    .000     .000     .500     .500     .000
 12    2    1
552  555  538  539  540  541  692  695  678  679  680  681
  5    0
941  953  851  857  863
946  947  948
  0  DOMAIN#  2      LAYER#  5
 .500    .000    .000   1.000    .000     .000     .500     .500     .000
 16    2    1
553  554  552  555  538  539  540  541  693  694  692  695  678  679  680
681
  6    0
947  941  953  851  857  863
946  947  948
  0  DOMAIN#  3      LAYER#  5
 .500    .000    .000   1.000    .000     .000     .500     .500     .000
 36    2    1
553  554  552  555  538  539  540  541  551  556  537  542  523  524  525
526  527  528  693  694  692  695  678  679  680  681  691  696  677  682
663  664  665  666  667  668
 15    0
947  941  953  851  857  863  935  959  845  869  755  761  767  773  779
946  947  948
80.0            MAX LOAD FACTOR
80.0      HALT
```

2 MESH FILE: SENTM; 990-NODES, 700-ELEMENTS

1	.0000000E+00	.2000000E+01	.0000000E+00
2	.0000000E+00	.2000000E+01	.1000000E+00
3	.0000000E+00	.2000000E+01	.1800000E+00
4	.0000000E+00	.2000000E+01	.2200000E+00
5	.0000000E+00	.2000000E+01	.2400000E+00
6	.0000000E+00	.2000000E+01	.2500000E+00
7	.1200000E+00	.2000000E+01	.0000000E+00
8	.1200000E+00	.2000000E+01	.1000000E+00
9	.1200000E+00	.2000000E+01	.1800000E+00
10	.1200000E+00	.2000000E+01	.2200000E+00
11	.1200000E+00	.2000000E+01	.2400000E+00
12	.1200000E+00	.2000000E+01	.2500000E+00
13	.2200000E+00	.2000000E+01	.0000000E+00
14	.2200000E+00	.2000000E+01	.1000000E+00
15	.2200000E+00	.2000000E+01	.1800000E+00
16	.2200000E+00	.2000000E+01	.2200000E+00
17	.2200000E+00	.2000000E+01	.2400000E+00
18	.2200000E+00	.2000000E+01	.2500000E+00
19	.3200000E+00	.2000000E+01	.0000000E+00
20	.3200000E+00	.2000000E+01	.1000000E+00
21	.3200000E+00	.2000000E+01	.1800000E+00
22	.3200000E+00	.2000000E+01	.2200000E+00
23	.3200000E+00	.2000000E+01	.2400000E+00
24	.3200000E+00	.2000000E+01	.2500000E+00
25	.3950000E+00	.2000000E+01	.0000000E+00

*** CONTINUED ***

966	.6050000E+00	.0000000E+00	.2500000E+00
967	.6800000E+00	.0000000E+00	.0000000E+00
968	.6800000E+00	.0000000E+00	.1000000E+00
969	.6800000E+00	.0000000E+00	.1800000E+00
970	.6800000E+00	.0000000E+00	.2200000E+00
971	.6800000E+00	.0000000E+00	.2400000E+00
972	.6800000E+00	.0000000E+00	.2500000E+00
973	.7800000E+00	.0000000E+00	.0000000E+00
974	.7800000E+00	.0000000E+00	.1000000E+00
975	.7800000E+00	.0000000E+00	.1800000E+00
976	.7800000E+00	.0000000E+00	.2200000E+00
977	.7800000E+00	.0000000E+00	.2400000E+00
978	.7800000E+00	.0000000E+00	.2500000E+00
979	.8800000E+00	.0000000E+00	.0000000E+00
980	.8800000E+00	.0000000E+00	.1000000E+00
981	.8800000E+00	.0000000E+00	.1800000E+00
982	.8800000E+00	.0000000E+00	.2200000E+00
983	.8800000E+00	.0000000E+00	.2400000E+00
984	.8800000E+00	.0000000E+00	.2500000E+00
985	.1000000E+01	.0000000E+00	.0000000E+00
986	.1000000E+01	.0000000E+00	.1000000E+00
987	.1000000E+01	.0000000E+00	.1800000E+00
988	.1000000E+01	.0000000E+00	.2200000E+00
989	.1000000E+01	.0000000E+00	.2400000E+00
990	.1000000E+01	.0000000E+00	.2500000E+00

1	91	97	7	1	92	98	8	2	1	0	1
2	97	103	13	7	98	104	14	8	1	0	1
3	103	109	19	13	104	110	20	14	1	0	1
4	109	115	25	19	110	116	26	20	1	0	1
5	115	121	31	25	116	122	32	26	1	0	1
6	121	127	37	31	122	128	38	32	1	0	1

7	127	133	43	37	128	134	44	38	1	0	1
8	133	139	49	43	134	140	50	44	1	0	1
9	139	145	55	49	140	146	56	50	1	0	1
10	145	151	61	55	146	152	62	56	1	0	1
11	151	157	67	61	152	158	68	62	1	0	1
12	157	163	73	67	158	164	74	68	1	0	1
13	163	169	79	73	164	170	80	74	1	0	1
14	169	175	85	79	170	176	86	80	1	0	1
15	181	187	97	91	182	188	98	92	1		
16	187	193	103	97	188	194	104	98	1		
17	193	199	109	103	194	200	110	104	1		
18	199	205	115	109	200	206	116	110	1		
19	205	211	121	115	206	212	122	116	1		
20	211	217	127	121	212	218	128	122	1		
21	217	223	133	127	218	224	134	128	1		
22	223	229	139	133	224	230	140	134	1		
23	229	235	145	139	230	236	146	140	1		
24	235	241	151	145	236	242	152	146	1		
25	241	247	157	151	242	248	158	152	1		

*** CONTINUED ***

676	833	839	749	743	834	840	750	744	1
677	839	845	755	749	840	846	756	750	1
678	845	851	761	755	846	852	762	756	1
679	851	857	767	761	852	858	768	762	1
680	857	863	773	767	858	864	774	768	1
681	863	869	779	773	864	870	780	774	1
682	869	875	785	779	870	876	786	780	1
683	875	881	791	785	876	882	792	786	1
684	881	887	797	791	882	888	798	792	1
685	887	893	803	797	888	894	804	798	1
686	893	899	809	803	894	900	810	804	1
687	905	911	821	815	906	912	822	816	1
688	911	917	827	821	912	918	828	822	1
689	917	923	833	827	918	924	834	828	1
690	923	929	839	833	924	930	840	834	1
691	929	935	845	839	930	936	846	840	1
692	935	941	851	845	936	942	852	846	1
693	941	947	857	851	942	948	858	852	1
694	947	953	863	857	948	954	864	858	1
695	953	959	869	863	954	960	870	864	1
696	959	965	875	869	960	966	876	870	1
697	965	971	881	875	966	972	882	876	1
698	971	977	887	881	972	978	888	882	1
699	977	983	893	887	978	984	894	888	1
700	983	989	899	893	984	990	900	894	1

```
    TOTAL COMMON BLOCK MAIN LENGTH=   6762593
1


     3-D    SENT -M3- A/W=.5 ,W=1.
    Mesh file: SENTM
    CRACK=     0.5000  WIDTH=    1.0000  THICK=    0.2500
    HEIGHT=    2.0000  DAX=  0.002000  SCALE=   1.00000
    NORMAL STRESS (PRSUR) :    1.0000


    LPR= 0  NNODE=  990  NELM=  700  NLAYER= 5  NEP= 4  IOPTON=  2
    Calculate G by VCCT Method Y/N 1/0: 1
    Calculate J by EDI Method  Y/N 1/0: 1


         MODULUS, NU, YIELD STRESS, AM, & ROM:  0.2070E+06  0.3000E+00  0.2834E+03 -0.1000E+01  0.0000E+00
         Material # 1     Number of Segments =   9
         No       Stress           Strain
          1     0.2834E+03      0.1360E-02
          2     0.2834E+03      0.1050E-01
          3     0.3543E+03      0.2830E-01
          4     0.3958E+03      0.4600E-01
          5     0.4235E+03      0.6420E-01
          6     0.4406E+03      0.8320E-01
          7     0.4506E+03      0.1000E+00
          8     0.4700E+03      0.2000E+00
          9     0.4700E+03      0.3000E+00
    1    1  700    1


         Renumber the mesh OR Not (1/0): 0
         INODXO   INODYO   INODZO   INODXC   INODYC  INODZC
           66       90      165       66       90     165
               Maximum Bandwidth=        294


         Total Storage Required for Stiffness Matrix=      792261
     SUM OF FORCES IN x, y, z DIRECTIONS DUE TO PRESSURE: 0.000000E+00 0.250000E+00-0.355271E-13
1
     No. OF SYMMETRIC BOUNDARY CONDITIONS =  1
          SYMMETRIC PLANE NUMBERS ARE :  3
```

```
    No. OF NODES: FIXED=  6  LOADED=  0  DISPLACED=  0


  Node    u    v    w
    1     1    0    0
    2     1    0    0
    3     1    0    0
    4     1    0    0
    5     1    0    0
    6     1    0    0
     READING DATA + STIFFNESS + ASSEMBLY =  0.2506E+01
     SOLUTION TIME  SECS=  0.5592E+01
1

     ELEMENT#  693  GAUSS PT= 2  LOAD FACTOR AT  YIELD=0.191538E+02
     CPU FOR ELASTIC STRESS EVALUATION=  0.6746E-01

          CRACK GROWTH CRITERION NTYP= 0 and CTOD =0.2000E+01
          NUMBER OF INCREMENTS TO RELEASE CRACK TIP FORCE= 5
          CRACK OPENING DISPLACEMENT ACCURCY=  0.9950E+00



          INCREMENTAL LOAD FACTOR=    0.3000
          ALLOWABLE ERROR ON STRESS=    0.0150
          MAXIMUM NUMBER OF ITERATION= 200
          RELAXATION PARAMETER= 1.00
          PRINT DISPLACEMENTS AT NODES    1 TO   50
          PRINT STRESSES IN ELEMENTS    1 TO   20
1

          APPLIED LOAD= 0.19154E+02       CRACK=   0.50000         WIDTH=   1.00000
```

Node	Coordinate x	y	z	Displacement u	v	w	Force Fx	Fy	Fz
1	0.0000E+00	0.2000E+01	0.0000E+00	0.9091E-40	0.5517E-03	-0.6095E-39	-0.9091E-05	0.5746E-01	0.6095E-04
2	0.0000E+00	0.2000E+01	0.1000E+00	0.4243E-40	0.5517E-03	-0.2782E-05	-0.4243E-05	0.1034E+00	0.8176E-14
3	0.0000E+00	0.2000E+01	0.1800E+00	-0.8878E-40	0.5517E-03	-0.5007E-05	0.8878E-05	0.6895E-01	0.7638E-14
4	0.0000E+00	0.2000E+01	0.2200E+00	-0.5638E-40	0.5517E-03	-0.6119E-05	0.5638E-05	0.3448E-01	0.3779E-14
5	0.0000E+00	0.2000E+01	0.2400E+00	-0.1965E-40	0.5517E-03	-0.6675E-05	0.1965E-05	0.1724E-01	-0.3883E-13
6	0.0000E+00	0.2000E+01	0.2500E+00	0.3146E-40	0.5517E-03	-0.6953E-05	-0.3146E-05	0.5746E-02	-0.1267E-13
7	0.1200E+00	0.2000E+01	0.0000E+00	-0.3329E-05	0.4945E-03	-0.8707E-39	0.3659E-13	0.1053E+00	0.8707E-04

8	0.1200E+00	0.2000E+01	0.1000E+00	-0.3330E-05	0.4945E-03	-0.2782E-05	-0.9165E-14	0.1896E+00	-0.4850E-13
9	0.1200E+00	0.2000E+01	0.1800E+00	-0.3331E-05	0.4945E-03	-0.5008E-05	0.4903E-13	0.1264E+00	0.1750E-13
10	0.1200E+00	0.2000E+01	0.2200E+00	-0.3331E-05	0.4945E-03	-0.6120E-05	-0.1858E-13	0.6321E-01	0.5278E-15
11	0.1200E+00	0.2000E+01	0.2400E+00	-0.3331E-05	0.4945E-03	-0.6677E-05	0.2621E-13	0.3160E-01	0.1383E-13
12	0.1200E+00	0.2000E+01	0.2500E+00	-0.3331E-05	0.4945E-03	-0.6955E-05	0.1088E-12	0.1053E-01	0.2869E-14
13	0.2200E+00	0.2000E+01	0.0000E+00	-0.6090E-05	0.4469E-03	-0.1598E-39	0.2675E-14	0.9577E-01	0.1598E-04
14	0.2200E+00	0.2000E+01	0.1000E+00	-0.6091E-05	0.4469E-03	-0.2783E-05	-0.4679E-14	0.1724E+00	-0.1925E-13
15	0.2200E+00	0.2000E+01	0.1800E+00	-0.6092E-05	0.4469E-03	-0.5010E-05	0.4989E-13	0.1149E+00	0.2155E-13
16	0.2200E+00	0.2000E+01	0.2200E+00	-0.6092E-05	0.4469E-03	-0.6124E-05	0.4950E-13	0.5746E-01	0.1438E-13
17	0.2200E+00	0.2000E+01	0.2400E+00	-0.6092E-05	0.4469E-03	-0.6681E-05	0.8758E-15	0.2873E-01	-0.2961E-13
18	0.2200E+00	0.2000E+01	0.2500E+00	-0.6091E-05	0.4469E-03	-0.6960E-05	0.7769E-14	0.9577E-02	-0.8800E-14
19	0.3200E+00	0.2000E+01	0.0000E+00	-0.8828E-05	0.3993E-03	-0.3597E-40	-0.8522E-13	0.8380E-01	0.3597E-05
20	0.3200E+00	0.2000E+01	0.1000E+00	-0.8829E-05	0.3993E-03	-0.2785E-05	0.4818E-13	0.1508E+00	0.1159E-13
21	0.3200E+00	0.2000E+01	0.1800E+00	-0.8830E-05	0.3993E-03	-0.5014E-05	0.3782E-15	0.1006E+00	0.1863E-13
22	0.3200E+00	0.2000E+01	0.2200E+00	-0.8829E-05	0.3993E-03	-0.6129E-05	0.3159E-13	0.5028E-01	0.6839E-14
23	0.3200E+00	0.2000E+01	0.2400E+00	-0.8829E-05	0.3993E-03	-0.6686E-05	0.2568E-13	0.2514E-01	-0.4040E-13
24	0.3200E+00	0.2000E+01	0.2500E+00	-0.8828E-05	0.3993E-03	-0.6965E-05	-0.2865E-13	0.8380E-02	0.6561E-14
25	0.3950E+00	0.2000E+01	0.0000E+00	-0.1087E-04	0.3636E-03	0.1775E-39	-0.1751E-13	0.5986E-01	-0.1775E-04
26	0.3950E+00	0.2000E+01	0.1000E+00	-0.1087E-04	0.3636E-03	-0.2786E-05	-0.8317E-13	0.1077E+00	0.1462E-13
27	0.3950E+00	0.2000E+01	0.1800E+00	-0.1087E-04	0.3636E-03	-0.5017E-05	0.9997E-14	0.7183E-01	-0.7194E-14
28	0.3950E+00	0.2000E+01	0.2200E+00	-0.1087E-04	0.3636E-03	-0.6132E-05	-0.1192E-13	0.3591E-01	0.3058E-13
29	0.3950E+00	0.2000E+01	0.2400E+00	-0.1087E-04	0.3636E-03	-0.6690E-05	-0.3564E-13	0.1796E-01	-0.3793E-13
30	0.3950E+00	0.2000E+01	0.2500E+00	-0.1087E-04	0.3636E-03	-0.6969E-05	-0.3300E-13	0.5986E-02	0.1602E-14
31	0.4450E+00	0.2000E+01	0.0000E+00	-0.1222E-04	0.3398E-03	0.2216E-39	0.8427E-13	0.4070E-01	-0.2216E-04
32	0.4450E+00	0.2000E+01	0.1000E+00	-0.1222E-04	0.3398E-03	-0.2787E-05	0.4767E-13	0.7326E-01	0.8983E-14
33	0.4450E+00	0.2000E+01	0.1800E+00	-0.1222E-04	0.3398E-03	-0.5018E-05	-0.2388E-13	0.4884E-01	-0.1027E-13
34	0.4450E+00	0.2000E+01	0.2200E+00	-0.1222E-04	0.3398E-03	-0.6134E-05	-0.1225E-13	0.2442E-01	0.4364E-14
35	0.4450E+00	0.2000E+01	0.2400E+00	-0.1222E-04	0.3398E-03	-0.6692E-05	-0.3929E-13	0.1221E-01	-0.1552E-13
36	0.4450E+00	0.2000E+01	0.2500E+00	-0.1222E-04	0.3398E-03	-0.6971E-05	-0.3192E-13	0.4070E-02	-0.7376E-14
37	0.4800E+00	0.2000E+01	0.0000E+00	-0.1317E-04	0.3231E-03	0.1691E-39	-0.1326E-12	0.2634E-01	-0.1691E-04
38	0.4800E+00	0.2000E+01	0.1000E+00	-0.1317E-04	0.3231E-03	-0.2787E-05	-0.4532E-13	0.4741E-01	-0.2965E-13
39	0.4800E+00	0.2000E+01	0.1800E+00	-0.1317E-04	0.3231E-03	-0.5019E-05	0.6967E-14	0.3160E-01	-0.2994E-14
40	0.4800E+00	0.2000E+01	0.2200E+00	-0.1317E-04	0.3231E-03	-0.6135E-05	0.1011E-12	0.1580E-01	0.3019E-14
41	0.4800E+00	0.2000E+01	0.2400E+00	-0.1317E-04	0.3231E-03	-0.6693E-05	0.7123E-13	0.7901E-02	0.1159E-13
42	0.4800E+00	0.2000E+01	0.2500E+00	-0.1317E-04	0.3231E-03	-0.6972E-05	-0.8461E-14	0.2634E-02	-0.2639E-15
43	0.5000E+00	0.2000E+01	0.0000E+00	-0.1371E-04	0.3136E-03	0.1312E-39	0.1296E-13	0.1915E-01	-0.1312E-04
44	0.5000E+00	0.2000E+01	0.1000E+00	-0.1371E-04	0.3136E-03	-0.2787E-05	0.9035E-13	0.3448E-01	0.7517E-14
45	0.5000E+00	0.2000E+01	0.1800E+00	-0.1371E-04	0.3136E-03	-0.5019E-05	-0.6900E-13	0.2298E-01	0.3698E-15
46	0.5000E+00	0.2000E+01	0.2200E+00	-0.1371E-04	0.3136E-03	-0.6135E-05	0.6594E-13	0.1149E-01	0.1656E-13
47	0.5000E+00	0.2000E+01	0.2400E+00	-0.1371E-04	0.3136E-03	-0.6693E-05	-0.6808E-13	0.5746E-02	0.2340E-14
48	0.5000E+00	0.2000E+01	0.2500E+00	-0.1371E-04	0.3136E-03	-0.6972E-05	0.2549E-14	0.1915E-02	-0.1964E-13
49	0.5200E+00	0.2000E+01	0.0000E+00	-0.1425E-04	0.3040E-03	0.1712E-39	-0.3630E-13	0.2634E-01	-0.1712E-04
50	0.5200E+00	0.2000E+01	0.1000E+00	-0.1425E-04	0.3040E-03	-0.2787E-05	-0.3508E-13	0.4741E-01	0.5209E-14
51	0.5200E+00	0.2000E+01	0.1800E+00	-0.1425E-04	0.3040E-03	-0.5019E-05	0.1309E-12	0.3160E-01	0.4936E-14
52	0.5200E+00	0.2000E+01	0.2200E+00	-0.1425E-04	0.3040E-03	-0.6135E-05	-0.5213E-13	0.1580E-01	0.4603E-14

53	0.5200E+00	0.2000E+01	0.2400E+00	-0.1425E-04	0.3040E-03	-0.6693E-05	0.5852E-13	0.7901E-02	-0.2022E-13
54	0.5200E+00	0.2000E+01	0.2500E+00	-0.1425E-04	0.3040E-03	-0.6972E-05	-0.1996E-13	0.2634E-02	0.8779E-15
55	0.5550E+00	0.2000E+01	0.0000E+00	-0.1520E-04	0.2874E-03	0.2377E-39	-0.7536E-14	0.4070E-01	-0.2377E-04
56	0.5550E+00	0.2000E+01	0.1000E+00	-0.1520E-04	0.2874E-03	-0.2787E-05	-0.4177E-14	0.7326E-01	-0.3978E-14
57	0.5550E+00	0.2000E+01	0.1800E+00	-0.1520E-04	0.2874E-03	-0.5018E-05	0.2924E-13	0.4884E-01	0.7967E-14
58	0.5550E+00	0.2000E+01	0.2200E+00	-0.1520E-04	0.2874E-03	-0.6134E-05	0.7244E-13	0.2442E-01	-0.5577E-14
959	0.5550E+00	0.0000E+00	0.2400E+00	-0.9540E-03	0.4575E-36	-0.4121E-04	-0.3858E-13	-0.4575E-01	-0.5995E-14
960	0.5550E+00	0.0000E+00	0.2500E+00	-0.9554E-03	0.1277E-36	-0.4298E-04	0.1173E-13	-0.1277E-01	-0.2826E-14
961	0.6050E+00	0.0000E+00	0.0000E+00	-0.9427E-03	0.1963E-35	0.6758E-37	-0.3175E-13	-0.1963E+00	-0.6758E-02
962	0.6050E+00	0.0000E+00	0.1000E+00	-0.9427E-03	0.3477E-35	-0.1345E-04	-0.4463E-13	-0.3477E+00	-0.4113E-13
963	0.6050E+00	0.0000E+00	0.1800E+00	-0.9431E-03	0.2186E-35	-0.2519E-04	0.1134E-12	-0.2186E+00	-0.1151E-13
964	0.6050E+00	0.0000E+00	0.2200E+00	-0.9446E-03	0.9793E-36	-0.3101E-04	-0.3866E-13	-0.9793E-01	-0.6384E-15
965	0.6050E+00	0.0000E+00	0.2400E+00	-0.9464E-03	0.4344E-36	-0.3366E-04	-0.2183E-13	-0.4344E-01	0.2715E-14
966	0.6050E+00	0.0000E+00	0.2500E+00	-0.9478E-03	0.1318E-36	-0.3487E-04	-0.2577E-13	-0.1318E-01	0.3015E-14
967	0.6800E+00	0.0000E+00	0.0000E+00	-0.9313E-03	0.1595E-35	0.1409E-37	0.1199E-12	-0.1595E+00	-0.1409E-02
968	0.6800E+00	0.0000E+00	0.1000E+00	-0.9318E-03	0.2812E-35	-0.1016E-04	0.1792E-12	-0.2812E+00	-0.3196E-13
969	0.6800E+00	0.0000E+00	0.1800E+00	-0.9339E-03	0.1751E-35	-0.1796E-04	-0.2465E-12	-0.1751E+00	0.2234E-14
970	0.6800E+00	0.0000E+00	0.2200E+00	-0.9365E-03	0.7925E-36	-0.2149E-04	-0.4323E-13	-0.7925E-01	0.2203E-13
971	0.6800E+00	0.0000E+00	0.2400E+00	-0.9386E-03	0.3625E-36	-0.2311E-04	-0.2032E-13	-0.3625E-01	0.1185E-14
972	0.6800E+00	0.0000E+00	0.2500E+00	-0.9399E-03	0.1136E-36	-0.2388E-04	-0.3617E-13	-0.1136E-01	-0.5183E-14
973	0.7800E+00	0.0000E+00	0.0000E+00	-0.9223E-03	0.6778E-36	-0.1014E-37	-0.1337E-12	-0.6778E-01	0.1014E-02
974	0.7800E+00	0.0000E+00	0.1000E+00	-0.9235E-03	0.1184E-35	-0.4978E-05	-0.2399E-12	-0.1184E+00	0.4086E-13
975	0.7800E+00	0.0000E+00	0.1800E+00	-0.9269E-03	0.7249E-36	-0.8521E-05	-0.5004E-13	-0.7249E-01	0.1699E-13
976	0.7800E+00	0.0000E+00	0.2200E+00	-0.9300E-03	0.3279E-36	-0.1006E-04	0.8765E-13	-0.3279E-01	0.6292E-14
977	0.7800E+00	0.0000E+00	0.2400E+00	-0.9320E-03	0.1513E-36	-0.1076E-04	0.1375E-12	-0.1513E-01	0.8495E-14
978	0.7800E+00	0.0000E+00	0.2500E+00	-0.9331E-03	0.4785E-37	-0.1111E-04	-0.8480E-13	-0.4785E-02	-0.5176E-14
979	0.8800E+00	0.0000E+00	0.0000E+00	-0.9169E-03	-0.6927E-36	-0.1784E-37	-0.6596E-12	0.6927E-01	0.1784E-02
980	0.8800E+00	0.0000E+00	0.1000E+00	-0.9184E-03	-0.1254E-35	-0.6980E-07	-0.7236E-12	0.1254E+00	0.1782E-13
981	0.8800E+00	0.0000E+00	0.1800E+00	-0.9224E-03	-0.8405E-36	0.9234E-07	-0.1151E-12	0.8405E-01	0.9395E-14
982	0.8800E+00	0.0000E+00	0.2200E+00	-0.9257E-03	-0.4163E-36	0.2297E-06	-0.2591E-13	0.4163E-01	0.1610E-13
983	0.8800E+00	0.0000E+00	0.2400E+00	-0.9277E-03	-0.2058E-36	0.2964E-06	0.3831E-13	0.2058E-01	-0.3225E-14
984	0.8800E+00	0.0000E+00	0.2500E+00	-0.9288E-03	-0.6790E-37	0.3261E-06	-0.9446E-13	0.6790E-02	-0.2003E-14
985	0.1000E+01	0.0000E+00	0.0000E+00	-0.9100E-03	-0.1052E-35	-0.2081E-37	-0.2110E-12	0.1052E+00	0.2081E-02
986	0.1000E+01	0.0000E+00	0.1000E+00	-0.9117E-03	-0.1890E-35	0.5067E-05	-0.3712E-12	0.1890E+00	-0.1173E-13
987	0.1000E+01	0.0000E+00	0.1800E+00	-0.9161E-03	-0.1249E-35	0.9780E-05	-0.1908E-12	0.1249E+00	-0.4025E-14
988	0.1000E+01	0.0000E+00	0.2200E+00	-0.9196E-03	-0.6115E-36	0.1246E-04	-0.6705E-13	0.6115E-01	0.6815E-14
989	0.1000E+01	0.0000E+00	0.2400E+00	-0.9217E-03	-0.2998E-36	0.1385E-04	0.4298E-13	0.2998E-01	-0.4620E-14
990	0.1000E+01	0.0000E+00	0.2500E+00	-0.9229E-03	-0.9833E-37	0.1454E-04	-0.5273E-13	0.9833E-02	-0.5416E-14

1

```
NUMBER OF G-CALCULATIONS =  5
CRACK PLANE SYMMETRY Y/N 1, 2, 3/0:  2
G-REGION NO.= 1
NO. OF ELEMENTS =  2
ELEMENT NOS:    133  134
```

```
DISP. NODES:    937  938
FORCE NODES:  943  944
TOTAL G =   0.20933E-01


GI = 0.20933E-01      GII = 0.00000E+00      GIII= 0.00000E+00
------------------------------------------------------------



G-REGION NO.= 2
NO. OF ELEMENTS =  2
ELEMENT NOS:    273  274
DISP. NODES:    938  939
FORCE NODES:  944  945
TOTAL G =   0.20408E-01


GI = 0.20408E-01      GII = 0.00000E+00      GIII= 0.00000E+00
------------------------------------------------------------



G-REGION NO.= 3
NO. OF ELEMENTS =  2
ELEMENT NOS:    413  414
DISP. NODES:    939  940
FORCE NODES:  945  946
TOTAL G =   0.19326E-01


GI = 0.19326E-01      GII = 0.00000E+00      GIII= 0.00000E+00
------------------------------------------------------------



G-REGION NO.= 4
NO. OF ELEMENTS =  2
ELEMENT NOS:    553  554
DISP. NODES:    940  941
FORCE NODES:  946  947
TOTAL G =   0.17798E-01


GI = 0.17798E-01      GII = 0.00000E+00      GIII= 0.00000E+00
```

```
------------------------------------------------------------

G-REGION NO.= 5
NO. OF ELEMENTS =  2
ELEMENT NOS:    693  694
DISP. NODES:    941  942
FORCE NODES:   947  948
TOTAL G =  0.15914E-01

GI = 0.15914E-01     GII = 0.00000E+00     GIII= 0.00000E+00
------------------------------------------------------------

1

 NUMBER OF EDI DOMAINS: 15
 DOMAIN NO. =  1
 3-POINTS COORDS:  0.50  0.00  0.00  1.00  0.00  0.00  0.50  0.50  0.00
 ROTATIONAL MATRIX =  1.0 0.0 0.0 0.0 1.0 0.0 0.0 0.0 1.0
 NUMBER OF ELEMENTS  AND SEGMENTS IN DOMAIN:   6  1
ELEMENTS IN THIS DOMAIN:
       132  135  118  119  120  121
 NUMBER OF NODES IN ITH DOMAIN WITH S=1 VALUE:  5
 NODES ON S= 1 CONTOUR:
       937  949  847  853  859
 NODES ON THE CRACK FRONT:   943  944
 DOMAIN NO. =  2
 3-POINTS COORDS:  0.50  0.00  0.00  1.00  0.00  0.00  0.50  0.50  0.00
 ROTATIONAL MATRIX =  1.0 0.0 0.0 0.0 1.0 0.0 0.0 0.0 1.0
 NUMBER OF ELEMENTS  AND SEGMENTS IN DOMAIN:   8  1
ELEMENTS IN THIS DOMAIN:
       133  134  132  135  118  119  120  121
 NUMBER OF NODES IN ITH DOMAIN WITH S=1 VALUE:  6
 NODES ON S= 1 CONTOUR:
       943  937  949  847  853  859
 NODES ON THE CRACK FRONT:   943  944
 DOMAIN NO. =  3
 3-POINTS COORDS:  0.50  0.00  0.00  1.00  0.00  0.00  0.50  0.50  0.00
 ROTATIONAL MATRIX =  1.0 0.0 0.0 0.0 1.0 0.0 0.0 0.0 1.0
 NUMBER OF ELEMENTS  AND SEGMENTS IN DOMAIN:  18  1
ELEMENTS IN THIS DOMAIN:
```

```
       133  134  132  135  118  119  120  121  131  136
       117  122  103  104  105  106  107  108
 NUMBER OF NODES IN ITH DOMAIN WITH S=1 VALUE: 15
 NODES ON S= 1 CONTOUR:
       943  937  949  847  853  859  931  955  841  865
       751  757  763  769  775
 NODES ON THE CRACK FRONT:   943  944
 DOMAIN NO. =  4
 3-POINTS COORDS:  0.50  0.00  0.00  1.00  0.00  0.00  0.50  0.50  0.00
 ROTATIONAL MATRIX =  1.0 0.0 0.0 0.0 1.0 0.0 0.0 0.0 1.0
 NUMBER OF ELEMENTS  AND SEGMENTS IN DOMAIN:  12  2
ELEMENTS IN THIS DOMAIN:
       132  135  118  119  120  121  272  275  258  259
       260  261
 NUMBER OF NODES IN ITH DOMAIN WITH S=1 VALUE:  5
 NODES ON S= 1 CONTOUR:
       938  950  848  854  860
 NODES ON THE CRACK FRONT:   943  944  945
 DOMAIN NO. =  5
 3-POINTS COORDS:  0.50  0.00  0.00  1.00  0.00  0.00  0.50  0.50  0.00
 ROTATIONAL MATRIX =  1.0 0.0 0.0 0.0 1.0 0.0 0.0 0.0 1.0
 NUMBER OF ELEMENTS  AND SEGMENTS IN DOMAIN:  16  2
ELEMENTS IN THIS DOMAIN:
       133  134  132  135  118  119  120  121  273  274
       272  275  258  259  260  261
 NUMBER OF NODES IN ITH DOMAIN WITH S=1 VALUE:  6
 NODES ON S= 1 CONTOUR:
       944  938  950  848  854  860
 NODES ON THE CRACK FRONT:   943  944  945
 DOMAIN NO. =  6
 3-POINTS COORDS:  0.50  0.00  0.00  1.00  0.00  0.00  0.50  0.50  0.00
 ROTATIONAL MATRIX =  1.0 0.0 0.0 0.0 1.0 0.0 0.0 0.0 1.0
 NUMBER OF ELEMENTS  AND SEGMENTS IN DOMAIN:  36  2
ELEMENTS IN THIS DOMAIN:
       133  134  132  135  118  119  120  121  131  136
       117  122  103  104  105  106  107  108  273  274
       272  275  258  259  260  261  271  276  257  262
       243  244  245  246  247  248
 NUMBER OF NODES IN ITH DOMAIN WITH S=1 VALUE: 15
 NODES ON S= 1 CONTOUR:
       944  938  950  848  854  860  932  956  842  866
       752  758  764  770  776
 NODES ON THE CRACK FRONT:   943  944  945
 DOMAIN NO. =  7
 3-POINTS COORDS:  0.50  0.00  0.00  1.00  0.00  0.00  0.50  0.50  0.00
```

```
 ROTATIONAL MATRIX =  1.0 0.0 0.0 0.0 1.0 0.0 0.0 0.0 1.0
 NUMBER OF ELEMENTS  AND SEGMENTS IN DOMAIN:  12  2
ELEMENTS IN THIS DOMAIN:
       272  275  258  259  260  261  412  415  398  399
       400  401
 NUMBER OF NODES IN ITH DOMAIN WITH S=1 VALUE:  5
 NODES ON S= 1 CONTOUR:
       939  951  849  855  861
 NODES ON THE CRACK FRONT:   944  945  946
 DOMAIN NO. =  8
 3-POINTS COORDS:  0.50  0.00  0.00  1.00  0.00  0.00  0.50  0.50  0.00
 ROTATIONAL MATRIX =  1.0 0.0 0.0 0.0 1.0 0.0 0.0 0.0 1.0
 NUMBER OF ELEMENTS  AND SEGMENTS IN DOMAIN:  16  2
ELEMENTS IN THIS DOMAIN:
       273  274  272  275  258  259  260  261  413  414
       412  415  398  399  400  401
 NUMBER OF NODES IN ITH DOMAIN WITH S=1 VALUE:  6
 NODES ON S= 1 CONTOUR:
       945  939  951  849  855  861
 NODES ON THE CRACK FRONT:   944  945  946
 DOMAIN NO. =  9
 3-POINTS COORDS:  0.50  0.00  0.00  1.00  0.00  0.00  0.50  0.50  0.00
 ROTATIONAL MATRIX =  1.0 0.0 0.0 0.0 1.0 0.0 0.0 0.0 1.0
 NUMBER OF ELEMENTS  AND SEGMENTS IN DOMAIN:  36  2
ELEMENTS IN THIS DOMAIN:
       273  274  272  275  258  259  260  261  271  276
       257  262  243  244  245  246  247  248  413  414
       412  415  398  399  400  401  411  416  397  402
       383  384  385  386  387  388
 NUMBER OF NODES IN ITH DOMAIN WITH S=1 VALUE: 15
 NODES ON S= 1 CONTOUR:
       945  939  951  849  855  861  933  957  843  867
       753  759  765  771  777
 NODES ON THE CRACK FRONT:   944  945  946
 DOMAIN NO. = 10
 3-POINTS COORDS:  0.50  0.00  0.00  1.00  0.00  0.00  0.50  0.50  0.00
 ROTATIONAL MATRIX =  1.0 0.0 0.0 0.0 1.0 0.0 0.0 0.0 1.0
 NUMBER OF ELEMENTS  AND SEGMENTS IN DOMAIN:  12  2
ELEMENTS IN THIS DOMAIN:
       412  415  398  399  400  401  552  555  538  539
       540  541
 NUMBER OF NODES IN ITH DOMAIN WITH S=1 VALUE:  5
 NODES ON S= 1 CONTOUR:
       940  952  850  856  862
 NODES ON THE CRACK FRONT:   945  946  947
```

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DOMAIN NO. = 11
3-POINTS COORDS:  0.50  0.00  0.00  1.00  0.00  0.00  0.50  0.50  0.00
ROTATIONAL MATRIX =  1.0 0.0 0.0 0.0 1.0 0.0 0.0 0.0 1.0
NUMBER OF ELEMENTS  AND SEGMENTS IN DOMAIN:  16  2
ELEMENTS IN THIS DOMAIN:
      413  414  412  415  398  399  400  401  553  554
      552  555  538  539  540  541
NUMBER OF NODES IN ITH DOMAIN WITH S=1 VALUE:  6
NODES ON S= 1 CONTOUR:
      946  940  952  850  856  862
NODES ON THE CRACK FRONT:  945  946  947
DOMAIN NO. = 12
3-POINTS COORDS:  0.50  0.00  0.00  1.00  0.00  0.00  0.50  0.50  0.00
ROTATIONAL MATRIX =  1.0 0.0 0.0 0.0 1.0 0.0 0.0 0.0 1.0
NUMBER OF ELEMENTS  AND SEGMENTS IN DOMAIN:  36  2
ELEMENTS IN THIS DOMAIN:
      413  414  412  415  398  399  400  401  411  416
      397  402  383  384  385  386  387  388  553  554
      552  555  538  539  540  541  551  556  537  542
      523  524  525  526  527  528
NUMBER OF NODES IN ITH DOMAIN WITH S=1 VALUE: 15
NODES ON S= 1 CONTOUR:
      946  940  952  850  856  862  934  958  844  868
      754  760  766  772  778
NODES ON THE CRACK FRONT:  945  946  947
DOMAIN NO. = 13
3-POINTS COORDS:  0.50  0.00  0.00  1.00  0.00  0.00  0.50  0.50  0.00
ROTATIONAL MATRIX =  1.0 0.0 0.0 0.0 1.0 0.0 0.0 0.0 1.0
NUMBER OF ELEMENTS  AND SEGMENTS IN DOMAIN:  12  2
ELEMENTS IN THIS DOMAIN:
      552  555  538  539  540  541  692  695  678  679
      680  681
NUMBER OF NODES IN ITH DOMAIN WITH S=1 VALUE:  5
NODES ON S= 1 CONTOUR:
      941  953  851  857  863
NODES ON THE CRACK FRONT:  946  947  948
DOMAIN NO. = 14
3-POINTS COORDS:  0.50  0.00  0.00  1.00  0.00  0.00  0.50  0.50  0.00
ROTATIONAL MATRIX =  1.0 0.0 0.0 0.0 1.0 0.0 0.0 0.0 1.0
NUMBER OF ELEMENTS  AND SEGMENTS IN DOMAIN:  16  2
ELEMENTS IN THIS DOMAIN:
      553  554  552  555  538  539  540  541  693  694
      692  695  678  679  680  681
NUMBER OF NODES IN ITH DOMAIN WITH S=1 VALUE:  6
NODES ON S= 1 CONTOUR:
```

```
       947  941  953  851  857  863
 NODES ON THE CRACK FRONT:   946  947  948
 DOMAIN NO. = 15
 3-POINTS COORDS:  0.50  0.00  0.00  1.00  0.00  0.00  0.50  0.50  0.00
 ROTATIONAL MATRIX =  1.0 0.0 0.0 0.0 1.0 0.0 0.0 0.0 1.0
 NUMBER OF ELEMENTS  AND SEGMENTS IN DOMAIN:  36  2
ELEMENTS IN THIS DOMAIN:
       553  554  552  555  538  539  540  541  551  556
       537  542  523  524  525  526  527  528  693  694
       692  695  678  679  680  681  691  696  677  682
       663  664  665  666  667  668
 NUMBER OF NODES IN ITH DOMAIN WITH S=1 VALUE: 15
 NODES ON S= 1 CONTOUR:
       947  941  953  851  857  863  935  959  845  869
       755  761  767  773  779
 NODES ON THE CRACK FRONT:   946  947  948


J-integral values in the order defined in data

Domain#: 1  J Integral =  0.2070E-01
Domain#: 2  J Integral =  0.2076E-01
Domain#: 3  J Integral =  0.2094E-01
Domain#: 4  J Integral =  0.2046E-01
Domain#: 5  J Integral =  0.2054E-01
Domain#: 6  J Integral =  0.2072E-01
Domain#: 7  J Integral =  0.1976E-01
Domain#: 8  J Integral =  0.1987E-01
Domain#: 9  J Integral =  0.2005E-01
Domain#:10  J Integral =  0.1865E-01
Domain#:11  J Integral =  0.1874E-01
Domain#:12  J Integral =  0.1891E-01
Domain#:13  J Integral =  0.1744E-01
Domain#:14  J Integral =  0.1720E-01
Domain#:15  J Integral =  0.1732E-01
```


1

Node	x	y	z	Stress-xx	Stress-yy	Stress-zz	Stress-xy	Stress-yz	Stress-xz
1	0.0000E+00	0.2000E+01	0.0000E+00	0.6312E-01	0.1930E+02	0.5124E-01	-0.3619E-02	-0.2356E-02	-0.1497E-13
2	0.0000E+00	0.2000E+01	0.1000E+00	0.6051E-01	0.1930E+02	0.5056E-01	-0.2362E-02	0.3824E-02	-0.3657E-04
3	0.0000E+00	0.2000E+01	0.1800E+00	0.5668E-01	0.1929E+02	0.4957E-01	0.1149E-02	0.5984E-02	-0.5587E-03
4	0.0000E+00	0.2000E+01	0.2200E+00	0.5608E-01	0.1929E+02	0.4906E-01	0.4421E-02	0.5822E-02	-0.1046E-02
5	0.0000E+00	0.2000E+01	0.2400E+00	0.5642E-01	0.1929E+02	0.4793E-01	0.6696E-02	0.5361E-02	-0.1309E-02
6	0.0000E+00	0.2000E+01	0.2500E+00	0.5710E-01	0.1930E+02	0.4762E-01	0.8053E-02	0.5380E-02	-0.1429E-02

7	0.1200E+00	0.2000E+01	0.0000E+00	0.5036E-01	0.1924E+02	0.2722E-01	0.9579E-02	-0.2732E-02	-0.6144E-03
8	0.1200E+00	0.2000E+01	0.1000E+00	0.4811E-01	0.1923E+02	0.2585E-01	0.1099E-01	-0.2970E-03	-0.1346E-02
9	0.1200E+00	0.2000E+01	0.1800E+00	0.4486E-01	0.1923E+02	0.2337E-01	0.1500E-01	-0.3239E-03	-0.2068E-02
10	0.1200E+00	0.2000E+01	0.2200E+00	0.4406E-01	0.1923E+02	0.2159E-01	0.1869E-01	-0.8925E-04	-0.1583E-02
11	0.1200E+00	0.2000E+01	0.2400E+00	0.4405E-01	0.1923E+02	0.2013E-01	0.2113E-01	0.6167E-03	-0.6569E-03
12	0.1200E+00	0.2000E+01	0.2500E+00	0.4438E-01	0.1923E+02	0.1968E-01	0.2254E-01	0.1079E-02	-0.2597E-03
13	0.2200E+00	0.2000E+01	0.0000E+00	0.6100E-01	0.1917E+02	0.7019E-02	0.2177E-01	-0.1944E-02	-0.7952E-03
14	0.2200E+00	0.2000E+01	0.1000E+00	0.5935E-01	0.1916E+02	0.4893E-02	0.2352E-01	-0.1648E-02	-0.2227E-02
15	0.2200E+00	0.2000E+01	0.1800E+00	0.5679E-01	0.1916E+02	0.8203E-03	0.2819E-01	-0.2147E-02	-0.3069E-02
16	0.2200E+00	0.2000E+01	0.2200E+00	0.5567E-01	0.1916E+02	-0.2148E-02	0.3212E-01	-0.1581E-02	-0.2134E-02
17	0.2200E+00	0.2000E+01	0.2400E+00	0.5520E-01	0.1915E+02	-0.3922E-02	0.3458E-01	-0.7916E-03	-0.8578E-03
18	0.2200E+00	0.2000E+01	0.2500E+00	0.5515E-01	0.1915E+02	-0.4512E-02	0.3594E-01	-0.4516E-03	-0.3463E-03
19	0.3200E+00	0.2000E+01	0.0000E+00	0.8172E-01	0.1911E+02	-0.8276E-02	0.2293E-01	-0.9623E-03	-0.6648E-03
20	0.3200E+00	0.2000E+01	0.1000E+00	0.8066E-01	0.1910E+02	-0.1063E-01	0.2437E-01	-0.2368E-02	-0.2257E-02
21	0.3200E+00	0.2000E+01	0.1800E+00	0.7857E-01	0.1910E+02	-0.1512E-01	0.2805E-01	-0.3256E-02	-0.3023E-02
22	0.3200E+00	0.2000E+01	0.2200E+00	0.7705E-01	0.1910E+02	-0.1812E-01	0.3113E-01	-0.2509E-02	-0.2062E-02
23	0.3200E+00	0.2000E+01	0.2400E+00	0.7630E-01	0.1910E+02	-0.1950E-01	0.3311E-01	-0.1515E-02	-0.8669E-03
24	0.3200E+00	0.2000E+01	0.2500E+00	0.7604E-01	0.1910E+02	-0.1994E-01	0.3423E-01	-0.1170E-02	-0.4133E-03
25	0.3950E+00	0.2000E+01	0.0000E+00	0.1019E+00	0.1908E+02	-0.1330E-01	0.1647E-01	-0.3704E-03	-0.4464E-03
26	0.3950E+00	0.2000E+01	0.1000E+00	0.1011E+00	0.1908E+02	-0.1591E-01	0.1743E-01	-0.2660E-02	-0.1762E-02
27	0.3950E+00	0.2000E+01	0.1800E+00	0.9890E-01	0.1907E+02	-0.2114E-01	0.1986E-01	-0.3712E-02	-0.2471E-02
28	0.3950E+00	0.2000E+01	0.2200E+00	0.9649E-01	0.1907E+02	-0.2490E-01	0.2189E-01	-0.2832E-02	-0.1771E-02
29	0.3950E+00	0.2000E+01	0.2400E+00	0.9493E-01	0.1907E+02	-0.2669E-01	0.2318E-01	-0.1708E-02	-0.6881E-03
30	0.3950E+00	0.2000E+01	0.2500E+00	0.9410E-01	0.1907E+02	-0.2737E-01	0.2392E-01	-0.1351E-02	-0.2191E-03
31	0.4450E+00	0.2000E+01	0.0000E+00	0.1126E+00	0.1907E+02	-0.1420E-01	0.8978E-02	-0.1104E-03	-0.2530E-03
32	0.4450E+00	0.2000E+01	0.1000E+00	0.1120E+00	0.1907E+02	-0.1691E-01	0.9531E-02	-0.2746E-02	-0.1079E-02
33	0.4450E+00	0.2000E+01	0.1800E+00	0.1098E+00	0.1906E+02	-0.2250E-01	0.1089E-01	-0.3853E-02	-0.1553E-02
34	0.4450E+00	0.2000E+01	0.2200E+00	0.1068E+00	0.1906E+02	-0.2662E-01	0.1199E-01	-0.2930E-02	-0.1148E-02
35	0.4450E+00	0.2000E+01	0.2400E+00	0.1046E+00	0.1906E+02	-0.2846E-01	0.1268E-01	-0.1770E-02	-0.5231E-03
36	0.4450E+00	0.2000E+01	0.2500E+00	0.1032E+00	0.1906E+02	-0.2919E-01	0.1307E-01	-0.1418E-02	-0.2665E-03
37	0.4800E+00	0.2000E+01	0.0000E+00	0.1162E+00	0.1907E+02	-0.1439E-01	0.3156E-02	-0.6962E-05	-0.1018E-03
38	0.4800E+00	0.2000E+01	0.1000E+00	0.1157E+00	0.1907E+02	-0.1711E-01	0.3410E-02	-0.2756E-02	-0.4793E-03
39	0.4800E+00	0.2000E+01	0.1800E+00	0.1135E+00	0.1906E+02	-0.2276E-01	0.3978E-02	-0.3880E-02	-0.7046E-03
40	0.4800E+00	0.2000E+01	0.2200E+00	0.1102E+00	0.1906E+02	-0.2698E-01	0.4387E-02	-0.2962E-02	-0.5582E-03
41	0.4800E+00	0.2000E+01	0.2400E+00	0.1077E+00	0.1906E+02	-0.2887E-01	0.4626E-02	-0.1809E-02	-0.2932E-03
42	0.4800E+00	0.2000E+01	0.2500E+00	0.1061E+00	0.1905E+02	-0.2967E-01	0.4757E-02	-0.1462E-02	-0.1666E-03
43	0.5000E+00	0.2000E+01	0.0000E+00	0.1167E+00	0.1907E+02	-0.1434E-01	-0.9364E-03	0.2140E-04	-0.1292E-04
44	0.5000E+00	0.2000E+01	0.1000E+00	0.1162E+00	0.1907E+02	-0.1703E-01	-0.8797E-03	-0.2742E-02	-0.5265E-04
45	0.5000E+00	0.2000E+01	0.1800E+00	0.1140E+00	0.1906E+02	-0.2265E-01	-0.8269E-03	-0.3868E-02	-0.5492E-04
46	0.5000E+00	0.2000E+01	0.2200E+00	0.1107E+00	0.1906E+02	-0.2690E-01	-0.8669E-03	-0.2966E-02	-0.2261E-04
47	0.5000E+00	0.2000E+01	0.2400E+00	0.1080E+00	0.1906E+02	-0.2884E-01	-0.9233E-03	-0.1831E-02	-0.3118E-05
48	0.5000E+00	0.2000E+01	0.2500E+00	0.1063E+00	0.1905E+02	-0.2969E-01	-0.9649E-03	-0.1494E-02	0.7665E-05
49	0.5200E+00	0.2000E+01	0.0000E+00	0.1147E+00	0.1907E+02	-0.1473E-01	-0.4997E-02	0.2692E-04	0.7506E-04
50	0.5200E+00	0.2000E+01	0.1000E+00	0.1143E+00	0.1907E+02	-0.1737E-01	-0.5138E-02	-0.2715E-02	0.3773E-03

CONTINUE

951	0.5200E+00	0.0000E+00	0.1800E+00	0.1641E+03	0.1756E+03	0.5487E+02	0.3637E+02	0.1535E+01	-0.1774E+01
952	0.5200E+00	0.0000E+00	0.2200E+00	0.1507E+03	0.1640E+03	0.3055E+02	0.3558E+02	0.4906E+01	0.2063E+01
953	0.5200E+00	0.0000E+00	0.2400E+00	0.1294E+03	0.1444E+03	0.1305E+02	0.3434E+02	0.1011E+02	0.4715E+01
954	0.5200E+00	0.0000E+00	0.2500E+00	0.9600E+02	0.1132E+03	-0.4002E+01	0.3651E+02	0.1330E+02	0.6882E+01
955	0.5550E+00	0.0000E+00	0.0000E+00	0.1016E+03	0.1042E+03	0.3215E+02	0.1010E+02	-0.7383E-14	0.5502E-02
956	0.5550E+00	0.0000E+00	0.1000E+00	0.1002E+03	0.1033E+03	0.2775E+02	0.1008E+02	0.3788E+00	0.3396E+00
957	0.5550E+00	0.0000E+00	0.1800E+00	0.9401E+02	0.9898E+02	0.1725E+02	0.9918E+01	0.1400E+01	0.3046E+01
958	0.5550E+00	0.0000E+00	0.2200E+00	0.8219E+02	0.8997E+02	0.8499E+01	0.9579E+01	0.2667E+01	0.5913E+01
959	0.5550E+00	0.0000E+00	0.2400E+00	0.6873E+02	0.7716E+02	0.4429E+01	0.9770E+01	0.3107E+01	0.4600E+01
960	0.5550E+00	0.0000E+00	0.2500E+00	0.6268E+02	0.6660E+02	0.2113E+01	0.1047E+02	0.2984E+01	0.3137E+01
961	0.6050E+00	0.0000E+00	0.0000E+00	0.6138E+02	0.6524E+02	0.1014E+02	0.5129E+01	0.4602E-13	-0.2537E-01
962	0.6050E+00	0.0000E+00	0.1000E+00	0.5996E+02	0.6475E+02	0.8309E+01	0.5092E+01	0.3511E+00	0.2176E+01
963	0.6050E+00	0.0000E+00	0.1800E+00	0.5373E+02	0.6101E+02	0.4167E+01	0.4988E+01	0.8784E+00	0.4917E+01
964	0.6050E+00	0.0000E+00	0.2200E+00	0.4531E+02	0.5391E+02	0.9851E+00	0.5027E+01	0.1194E+01	0.4841E+01
965	0.6050E+00	0.0000E+00	0.2400E+00	0.4101E+02	0.4780E+02	0.4151E+00	0.5220E+01	0.1274E+01	0.2499E+01
966	0.6050E+00	0.0000E+00	0.2500E+00	0.3977E+02	0.4382E+02	0.3343E-01	0.5313E+01	0.1199E+01	0.1453E+01
967	0.6800E+00	0.0000E+00	0.0000E+00	0.3700E+02	0.3840E+02	0.1588E+01	0.2786E+01	0.5881E-13	-0.3992E+00
968	0.6800E+00	0.0000E+00	0.1000E+00	0.3542E+02	0.3785E+02	0.1380E+01	0.2766E+01	0.2157E+00	0.2591E+01
969	0.6800E+00	0.0000E+00	0.1800E+00	0.3062E+02	0.3484E+02	0.3979E+00	0.2766E+01	0.4039E+00	0.3929E+01
970	0.6800E+00	0.0000E+00	0.2200E+00	0.2722E+02	0.3121E+02	0.1264E-02	0.2833E+01	0.4889E+00	0.2827E+01
971	0.6800E+00	0.0000E+00	0.2400E+00	0.2632E+02	0.2885E+02	0.2062E+00	0.2900E+01	0.5074E+00	0.1282E+01
972	0.6800E+00	0.0000E+00	0.2500E+00	0.2609E+02	0.2736E+02	0.9419E-01	0.2959E+01	0.5000E+00	0.7202E+00
973	0.7800E+00	0.0000E+00	0.0000E+00	0.1919E+02	0.1431E+02	-0.2565E+00	0.1867E+01	-0.2147E-13	-0.9412E+00
974	0.7800E+00	0.0000E+00	0.1000E+00	0.1798E+02	0.1386E+02	-0.1835E+00	0.1873E+01	0.7715E-01	0.1853E+01
975	0.7800E+00	0.0000E+00	0.1800E+00	0.1555E+02	0.1244E+02	-0.1580E+00	0.1908E+01	0.1288E+00	0.2388E+01
976	0.7800E+00	0.0000E+00	0.2200E+00	0.1472E+02	0.1134E+02	0.1803E+00	0.1956E+01	0.1451E+00	0.1512E+01
977	0.7800E+00	0.0000E+00	0.2400E+00	0.1467E+02	0.1069E+02	0.4188E+00	0.1993E+01	0.1458E+00	0.7426E+00
978	0.7800E+00	0.0000E+00	0.2500E+00	0.1474E+02	0.1031E+02	0.4660E+00	0.2012E+01	0.1370E+00	0.5510E+00
979	0.8800E+00	0.0000E+00	0.0000E+00	0.9121E+01	-0.8224E+01	0.1246E+00	0.1576E+01	0.8105E-14	-0.1244E+01
980	0.8800E+00	0.0000E+00	0.1000E+00	0.8495E+01	-0.8407E+01	0.1640E+00	0.1590E+01	-0.5481E-02	0.1052E+01
981	0.8800E+00	0.0000E+00	0.1800E+00	0.7514E+01	-0.8562E+01	0.2508E+00	0.1632E+01	-0.1744E-01	0.1433E+01
982	0.8800E+00	0.0000E+00	0.2200E+00	0.7258E+01	-0.8410E+01	0.3551E+00	0.1670E+01	-0.2693E-01	0.9274E+00
983	0.8800E+00	0.0000E+00	0.2400E+00	0.7216E+01	-0.8272E+01	0.3352E+00	0.1695E+01	-0.3199E-01	0.4675E+00
984	0.8800E+00	0.0000E+00	0.2500E+00	0.7227E+01	-0.8178E+01	0.3282E+00	0.1710E+01	-0.3435E-01	0.4024E+00
985	0.1000E+01	0.0000E+00	0.0000E+00	-0.4065E+01	-0.4810E+02	-0.5161E+01	0.1390E+01	-0.2246E-13	-0.1418E+01
986	0.1000E+01	0.0000E+00	0.1000E+00	-0.4237E+01	-0.4819E+02	-0.4385E+01	0.1407E+01	-0.6779E-01	0.5086E+00
987	0.1000E+01	0.0000E+00	0.1800E+00	-0.4292E+01	-0.4778E+02	-0.2593E+01	0.1455E+01	-0.1424E+00	0.7750E+00
988	0.1000E+01	0.0000E+00	0.2200E+00	-0.3899E+01	-0.4664E+02	-0.1052E+01	0.1499E+01	-0.1971E+00	0.4342E+00
989	0.1000E+01	0.0000E+00	0.2400E+00	-0.3591E+01	-0.4562E+02	-0.4166E+00	0.1529E+01	-0.2355E+00	0.1371E+00
990	0.1000E+01	0.0000E+00	0.2500E+00	-0.3374E+01	-0.4488E+02	-0.1377E+00	0.1547E+01	-0.2585E+00	0.1591E+00

```
 NONE of the elements are yielded
Total Load Factor:   80.0000 and Strategy =


    Solution Converged :   3 Iterations.  Load = 0.24900E+02

Solution time, Secs =  0.1082E+00

Plastic load vector time, Secs =     0.2733  Wall=    2.1716
Total Time Used in CONTACT      0.8495E-04
    Solution Converged :   4 Iterations.  Load = 0.30646E+02

Solution time, Secs =  0.1448E+00

Plastic load vector time, Secs =     0.3767  Wall=    3.7769
Total Time Used in CONTACT      0.8511E-04
    Solution Converged :   5 Iterations.  Load = 0.36392E+02

Solution time, Secs =  0.1825E+00

Plastic load vector time, Secs =     0.4787  Wall=    6.5327
Total Time Used in CONTACT      0.8544E-04
    Solution Converged :   7 Iterations.  Load = 0.42138E+02

Solution time, Secs =  0.2544E+00

Plastic load vector time, Secs =     0.7028  Wall=    5.6680
Total Time Used in CONTACT      0.8534E-04
1

     APPLIED LOAD= 0.42138E+02       CRACK=    0.50000          WIDTH=    1.00000
```

Node	Coordinate x	Coordinate y	Coordinate z	Displacement x	Displacement y	Displacement z	Force x	Force y	Force z
1	0.0000E+00	0.2000E+01	0.0000E+00	0.2069E-39	0.1252E-02	-0.1352E-38	-0.2069E-04	0.1264E+00	0.1352E-03
2	0.0000E+00	0.2000E+01	0.1000E+00	0.1001E-39	0.1252E-02	-0.6121E-05	-0.1001E-04	0.2275E+00	0.1347E-13
3	0.0000E+00	0.2000E+01	0.1800E+00	-0.1984E-39	0.1252E-02	-0.1102E-04	0.1984E-04	0.1517E+00	-0.1851E-13
4	0.0000E+00	0.2000E+01	0.2200E+00	-0.1285E-39	0.1252E-02	-0.1346E-04	0.1285E-04	0.7585E-01	0.3107E-13
5	0.0000E+00	0.2000E+01	0.2400E+00	-0.4633E-40	0.1252E-02	-0.1469E-04	0.4633E-05	0.3792E-01	-0.8430E-13
6	0.0000E+00	0.2000E+01	0.2500E+00	0.6624E-40	0.1252E-02	-0.1530E-04	-0.6624E-05	0.1264E-01	-0.4038E-13
7	0.1200E+00	0.2000E+01	0.0000E+00	-0.7325E-05	0.1120E-02	-0.1940E-38	-0.2787E-13	0.2318E+00	0.1940E-03
8	0.1200E+00	0.2000E+01	0.1000E+00	-0.7326E-05	0.1120E-02	-0.6121E-05	0.2361E-12	0.4172E+00	-0.3430E-13

9	0.1200E+00	0.2000E+01	0.1800E+00	-0.7329E-05	0.1120E-02	-0.1102E-04	0.1191E-12	0.2781E+00	-0.9392E-14
10	0.1200E+00	0.2000E+01	0.2200E+00	-0.7329E-05	0.1120E-02	-0.1347E-04	0.5058E-13	0.1391E+00	-0.1387E-13
11	0.1200E+00	0.2000E+01	0.2400E+00	-0.7329E-05	0.1120E-02	-0.1469E-04	0.1023E-12	0.6953E-01	0.7369E-14
12	0.1200E+00	0.2000E+01	0.2500E+00	-0.7328E-05	0.1120E-02	-0.1530E-04	0.1429E-12	0.2318E-01	0.4624E-13
13	0.2200E+00	0.2000E+01	0.0000E+00	-0.1340E-04	0.1011E-02	-0.3591E-39	0.2803E-13	0.2107E+00	0.3591E-04
14	0.2200E+00	0.2000E+01	0.1000E+00	-0.1340E-04	0.1011E-02	-0.6123E-05	-0.3554E-13	0.3792E+00	-0.1600E-13
15	0.2200E+00	0.2000E+01	0.1800E+00	-0.1340E-04	0.1011E-02	-0.1102E-04	0.4862E-13	0.2528E+00	-0.2308E-14
16	0.2200E+00	0.2000E+01	0.2200E+00	-0.1340E-04	0.1011E-02	-0.1347E-04	0.1894E-13	0.1264E+00	0.7837E-14
17	0.2200E+00	0.2000E+01	0.2400E+00	-0.1340E-04	0.1011E-02	-0.1470E-04	0.1945E-12	0.6321E-01	-0.4537E-13
18	0.2200E+00	0.2000E+01	0.2500E+00	-0.1340E-04	0.1011E-02	-0.1531E-04	-0.6613E-13	0.2107E-01	-0.7349E-13
19	0.3200E+00	0.2000E+01	0.0000E+00	-0.1942E-04	0.9016E-03	-0.7905E-40	0.1152E-12	0.1844E+00	0.7905E-05
20	0.3200E+00	0.2000E+01	0.1000E+00	-0.1942E-04	0.9016E-03	-0.6127E-05	0.8989E-13	0.3318E+00	-0.2048E-13
21	0.3200E+00	0.2000E+01	0.1800E+00	-0.1942E-04	0.9016E-03	-0.1103E-04	-0.1138E-13	0.2212E+00	0.1003E-13
22	0.3200E+00	0.2000E+01	0.2200E+00	-0.1942E-04	0.9016E-03	-0.1348E-04	-0.4510E-13	0.1106E+00	0.4827E-13
23	0.3200E+00	0.2000E+01	0.2400E+00	-0.1942E-04	0.9016E-03	-0.1471E-04	0.1682E-12	0.5531E-01	-0.3929E-13
24	0.3200E+00	0.2000E+01	0.2500E+00	-0.1942E-04	0.9016E-03	-0.1532E-04	-0.7232E-13	0.1844E-01	-0.5445E-13
25	0.3950E+00	0.2000E+01	0.0000E+00	-0.2391E-04	0.8196E-03	0.3990E-39	-0.6675E-13	0.1317E+00	-0.3990E-04
26	0.3950E+00	0.2000E+01	0.1000E+00	-0.2391E-04	0.8196E-03	-0.6130E-05	-0.8751E-13	0.2370E+00	-0.2246E-13
27	0.3950E+00	0.2000E+01	0.1800E+00	-0.2391E-04	0.8196E-03	-0.1104E-04	-0.5989E-13	0.1580E+00	-0.2926E-13
28	0.3950E+00	0.2000E+01	0.2200E+00	-0.2391E-04	0.8196E-03	-0.1349E-04	0.1037E-12	0.7901E-01	0.4579E-13
29	0.3950E+00	0.2000E+01	0.2400E+00	-0.2391E-04	0.8196E-03	-0.1472E-04	-0.1316E-12	0.3950E-01	0.8986E-14
30	0.3950E+00	0.2000E+01	0.2500E+00	-0.2390E-04	0.8196E-03	-0.1533E-04	-0.7989E-13	0.1317E-01	-0.1004E-12
31	0.4450E+00	0.2000E+01	0.0000E+00	-0.2688E-04	0.7649E-03	0.4974E-39	0.9093E-13	0.8954E-01	-0.4974E-04
32	0.4450E+00	0.2000E+01	0.1000E+00	-0.2689E-04	0.7649E-03	-0.6132E-05	-0.7828E-13	0.1612E+00	0.1354E-13
33	0.4450E+00	0.2000E+01	0.1800E+00	-0.2689E-04	0.7649E-03	-0.1104E-04	0.2263E-12	0.1075E+00	0.2259E-13
34	0.4450E+00	0.2000E+01	0.2200E+00	-0.2689E-04	0.7649E-03	-0.1350E-04	0.7959E-13	0.5373E-01	0.4495E-13
35	0.4450E+00	0.2000E+01	0.2400E+00	-0.2688E-04	0.7649E-03	-0.1472E-04	-0.2770E-13	0.2686E-01	-0.4006E-13
36	0.4450E+00	0.2000E+01	0.2500E+00	-0.2688E-04	0.7649E-03	-0.1534E-04	-0.9388E-13	0.8954E-02	-0.7344E-13
37	0.4800E+00	0.2000E+01	0.0000E+00	-0.2897E-04	0.7266E-03	0.3793E-39	-0.1259E-12	0.5794E-01	-0.3793E-04
38	0.4800E+00	0.2000E+01	0.1000E+00	-0.2897E-04	0.7266E-03	-0.6132E-05	0.3383E-12	0.1043E+00	-0.8447E-14
39	0.4800E+00	0.2000E+01	0.1800E+00	-0.2897E-04	0.7266E-03	-0.1104E-04	0.2306E-12	0.6953E-01	0.2845E-13
40	0.4800E+00	0.2000E+01	0.2200E+00	-0.2897E-04	0.7266E-03	-0.1350E-04	0.3145E-12	0.3476E-01	0.6085E-14
41	0.4800E+00	0.2000E+01	0.2400E+00	-0.2897E-04	0.7266E-03	-0.1473E-04	0.6034E-13	0.1738E-01	-0.3072E-13
42	0.4800E+00	0.2000E+01	0.2500E+00	-0.2897E-04	0.7266E-03	-0.1534E-04	-0.5388E-13	0.5794E-02	-0.1406E-14
43	0.5000E+00	0.2000E+01	0.0000E+00	-0.3016E-04	0.7047E-03	0.2942E-39	0.1276E-12	0.4214E-01	-0.2942E-04
44	0.5000E+00	0.2000E+01	0.1000E+00	-0.3016E-04	0.7047E-03	-0.6132E-05	-0.1506E-12	0.7585E-01	0.1889E-13
45	0.5000E+00	0.2000E+01	0.1800E+00	-0.3016E-04	0.7047E-03	-0.1104E-04	-0.2256E-12	0.5057E-01	0.1378E-13
46	0.5000E+00	0.2000E+01	0.2200E+00	-0.3016E-04	0.7047E-03	-0.1350E-04	-0.1509E-12	0.2528E-01	0.2074E-13
47	0.5000E+00	0.2000E+01	0.2400E+00	-0.3016E-04	0.7047E-03	-0.1473E-04	-0.1027E-12	0.1264E-01	-0.4057E-13
48	0.5000E+00	0.2000E+01	0.2500E+00	-0.3016E-04	0.7047E-03	-0.1534E-04	0.1537E-13	0.4214E-02	0.2077E-14
49	0.5200E+00	0.2000E+01	0.0000E+00	-0.3135E-04	0.6828E-03	0.3843E-39	-0.3807E-12	0.5794E-01	-0.3843E-04
50	0.5200E+00	0.2000E+01	0.1000E+00	-0.3135E-04	0.6828E-03	-0.6132E-05	0.1591E-12	0.1043E+00	0.3006E-13

J-integral values in the order defined in data

```
Domain#: 1  J Integral =  0.1048E+00
Domain#: 2  J Integral =  0.1052E+00
Domain#: 3  J Integral =  0.1076E+00
Domain#: 4  J Integral =  0.1036E+00
Domain#: 5  J Integral =  0.1042E+00
Domain#: 6  J Integral =  0.1065E+00
Domain#: 7  J Integral =  0.9964E-01
Domain#: 8  J Integral =  0.1008E+00
Domain#: 9  J Integral =  0.1032E+00
Domain#:10  J Integral =  0.9137E-01
Domain#:11  J Integral =  0.9268E-01
Domain#:12  J Integral =  0.9555E-01
Domain#:13  J Integral =  0.8028E-01
Domain#:14  J Integral =  0.7836E-01
Domain#:15  J Integral =  0.8147E-01
```

1

Node	x	y	z	Stress-xx	Stress-yy	Stress-zz	Stress-xy	Stress-yz	Stress-xz
1	0.0000E+00	0.2000E+01	0.0000E+00	0.1410E+00	0.4247E+02	0.1143E+00	-0.8154E-02	-0.5239E-02	-0.3360E-12
2	0.0000E+00	0.2000E+01	0.1000E+00	0.1352E+00	0.4246E+02	0.1128E+00	-0.5367E-02	0.8515E-02	-0.5312E-04
3	0.0000E+00	0.2000E+01	0.1800E+00	0.1266E+00	0.4245E+02	0.1106E+00	0.2437E-02	0.1330E-01	-0.1192E-02
4	0.0000E+00	0.2000E+01	0.2200E+00	0.1252E+00	0.4245E+02	0.1095E+00	0.9731E-02	0.1287E-01	-0.2265E-02
5	0.0000E+00	0.2000E+01	0.2400E+00	0.1259E+00	0.4245E+02	0.1070E+00	0.1481E-01	0.1179E-01	-0.2847E-02
6	0.0000E+00	0.2000E+01	0.2500E+00	0.1274E+00	0.4245E+02	0.1063E+00	0.1785E-01	0.1180E-01	-0.3112E-02
7	0.1200E+00	0.2000E+01	0.0000E+00	0.1125E+00	0.4232E+02	0.6074E-01	0.2128E-01	-0.6091E-02	-0.1374E-02
8	0.1200E+00	0.2000E+01	0.1000E+00	0.1075E+00	0.4232E+02	0.5770E-01	0.2440E-01	-0.6752E-03	-0.2976E-02
9	0.1200E+00	0.2000E+01	0.1800E+00	0.1002E+00	0.4231E+02	0.5220E-01	0.3333E-01	-0.7542E-03	-0.4581E-02
10	0.1200E+00	0.2000E+01	0.2200E+00	0.9841E-01	0.4230E+02	0.4826E-01	0.4154E-01	-0.2442E-03	-0.3516E-02
11	0.1200E+00	0.2000E+01	0.2400E+00	0.9837E-01	0.4230E+02	0.4501E-01	0.4700E-01	0.1331E-02	-0.1471E-02
12	0.1200E+00	0.2000E+01	0.2500E+00	0.9910E-01	0.4230E+02	0.4399E-01	0.5014E-01	0.2363E-02	-0.5944E-03
13	0.2200E+00	0.2000E+01	0.0000E+00	0.1361E+00	0.4217E+02	0.1566E-01	0.4843E-01	-0.4340E-02	-0.1779E-02
14	0.2200E+00	0.2000E+01	0.1000E+00	0.1324E+00	0.4216E+02	0.1094E-01	0.5233E-01	-0.3676E-02	-0.4938E-02
15	0.2200E+00	0.2000E+01	0.1800E+00	0.1267E+00	0.4215E+02	0.1861E-02	0.6271E-01	-0.4783E-02	-0.6817E-02
16	0.2200E+00	0.2000E+01	0.2200E+00	0.1242E+00	0.4214E+02	-0.4774E-02	0.7149E-01	-0.3499E-02	-0.4746E-02
17	0.2200E+00	0.2000E+01	0.2400E+00	0.1232E+00	0.4214E+02	-0.8757E-02	0.7698E-01	-0.1710E-02	-0.1908E-02
18	0.2200E+00	0.2000E+01	0.2500E+00	0.1231E+00	0.4214E+02	-0.1008E-01	0.8001E-01	-0.9380E-03	-0.7682E-03
19	0.3200E+00	0.2000E+01	0.0000E+00	0.1820E+00	0.4203E+02	-0.1851E-01	0.5098E-01	-0.2148E-02	-0.1488E-02
20	0.3200E+00	0.2000E+01	0.1000E+00	0.1796E+00	0.4203E+02	-0.2376E-01	0.5417E-01	-0.5268E-02	-0.5016E-02
21	0.3200E+00	0.2000E+01	0.1800E+00	0.1750E+00	0.4202E+02	-0.3376E-01	0.6238E-01	-0.7231E-02	-0.6724E-02
22	0.3200E+00	0.2000E+01	0.2200E+00	0.1717E+00	0.4201E+02	-0.4044E-01	0.6925E-01	-0.5546E-02	-0.4588E-02
23	0.3200E+00	0.2000E+01	0.2400E+00	0.1700E+00	0.4201E+02	-0.4353E-01	0.7364E-01	-0.3312E-02	-0.1929E-02
24	0.3200E+00	0.2000E+01	0.2500E+00	0.1694E+00	0.4201E+02	-0.4451E-01	0.7613E-01	-0.2535E-02	-0.9189E-03
25	0.3950E+00	0.2000E+01	0.0000E+00	0.2265E+00	0.4197E+02	-0.2983E-01	0.3654E-01	-0.8258E-03	-0.9984E-03

26	0.3950E+00	0.2000E+01	0.1000E+00	0.2249E+00	0.4197E+02	-0.3561E-01	0.3868E-01	-0.5913E-02	-0.3918E-02
27	0.3950E+00	0.2000E+01	0.1800E+00	0.2200E+00	0.4196E+02	-0.4724E-01	0.4408E-01	-0.8238E-02	-0.5501E-02
28	0.3950E+00	0.2000E+01	0.2200E+00	0.2147E+00	0.4195E+02	-0.5560E-01	0.4860E-01	-0.6265E-02	-0.3944E-02
29	0.3950E+00	0.2000E+01	0.2400E+00	0.2112E+00	0.4194E+02	-0.5957E-01	0.5148E-01	-0.3758E-02	-0.1532E-02
30	0.3950E+00	0.2000E+01	0.2500E+00	0.2094E+00	0.4194E+02	-0.6107E-01	0.5310E-01	-0.2962E-02	-0.4864E-03
31	0.4450E+00	0.2000E+01	0.0000E+00	0.2501E+00	0.4195E+02	-0.3190E-01	0.1982E-01	-0.2455E-03	-0.5655E-03
32	0.4450E+00	0.2000E+01	0.1000E+00	0.2489E+00	0.4195E+02	-0.3793E-01	0.2105E-01	-0.6103E-02	-0.2401E-02
33	0.4450E+00	0.2000E+01	0.1800E+00	0.2439E+00	0.4194E+02	-0.5035E-01	0.2408E-01	-0.8548E-02	-0.3458E-02
34	0.4450E+00	0.2000E+01	0.2200E+00	0.2373E+00	0.4193E+02	-0.5947E-01	0.2653E-01	-0.6488E-02	-0.2556E-02
35	0.4450E+00	0.2000E+01	0.2400E+00	0.2324E+00	0.4192E+02	-0.6355E-01	0.2806E-01	-0.3920E-02	-0.1162E-02
36	0.4450E+00	0.2000E+01	0.2500E+00	0.2295E+00	0.4192E+02	-0.6516E-01	0.2892E-01	-0.3143E-02	-0.5901E-03
37	0.4800E+00	0.2000E+01	0.0000E+00	0.2579E+00	0.4195E+02	-0.3240E-01	0.6838E-02	-0.1273E-04	-0.2282E-03
38	0.4800E+00	0.2000E+01	0.1000E+00	0.2569E+00	0.4194E+02	-0.3843E-01	0.7405E-02	-0.6118E-02	-0.1068E-02
39	0.4800E+00	0.2000E+01	0.1800E+00	0.2520E+00	0.4193E+02	-0.5096E-01	0.8673E-02	-0.8606E-02	-0.1566E-02
40	0.4800E+00	0.2000E+01	0.2200E+00	0.2448E+00	0.4192E+02	-0.6031E-01	0.9565E-02	-0.6560E-02	-0.1238E-02
41	0.4800E+00	0.2000E+01	0.2400E+00	0.2391E+00	0.4192E+02	-0.6449E-01	0.1010E-01	-0.4001E-02	-0.6488E-03
42	0.4800E+00	0.2000E+01	0.2500E+00	0.2356E+00	0.4192E+02	-0.6624E-01	0.1038E-01	-0.3239E-02	-0.3679E-03
43	0.5000E+00	0.2000E+01	0.0000E+00	0.2588E+00	0.4195E+02	-0.3234E-01	-0.2240E-02	0.5175E-04	-0.3067E-04
44	0.5000E+00	0.2000E+01	0.1000E+00	0.2579E+00	0.4194E+02	-0.3830E-01	-0.2110E-02	-0.6086E-02	-0.1201E-03
45	0.5000E+00	0.2000E+01	0.1800E+00	0.2531E+00	0.4193E+02	-0.5076E-01	-0.1997E-02	-0.8580E-02	-0.1223E-03
46	0.5000E+00	0.2000E+01	0.2200E+00	0.2456E+00	0.4192E+02	-0.6017E-01	-0.2101E-02	-0.6564E-02	-0.5216E-04
47	0.5000E+00	0.2000E+01	0.2400E+00	0.2398E+00	0.4192E+02	-0.6445E-01	-0.2235E-02	-0.4056E-02	-0.1103E-04
48	0.5000E+00	0.2000E+01	0.2500E+00	0.2360E+00	0.4192E+02	-0.6634E-01	-0.2327E-02	-0.3329E-02	0.1132E-04
49	0.5200E+00	0.2000E+01	0.0000E+00	0.2544E+00	0.4195E+02	-0.3321E-01	-0.1127E-01	0.6577E-04	0.1641E-03
50	0.5200E+00	0.2000E+01	0.1000E+00	0.2535E+00	0.4194E+02	-0.3908E-01	-0.1158E-01	-0.6025E-02	0.8370E-03

```
   List of Plastic Elements

 119  120  133  134  259  260  273  274  399  400  401  413  414  415  539  540  541  553  554  555
 679  680  681  693  694  695
    Solution Converged :   9 Iterations.   Load = 0.47885E+02

Solution time, Secs =  0.3316E+00

Plastic load vector time, Secs =    0.9344  Wall=    4.7859
Total Time Used in CONTACT      0.8492E-04
    Solution Converged :  11 Iterations.   Load = 0.53631E+02

Solution time, Secs =  0.4014E+00

Plastic load vector time, Secs =    1.1879  Wall=    9.8317
Total Time Used in CONTACT      0.8493E-04
    Solution Converged :  14 Iterations.   Load = 0.59377E+02
```

```
Solution time, Secs =  0.5077E+00

Plastic load vector time, Secs =    1.5823  Wall=   13.9418
Total Time Used in CONTACT      0.8477E-04
    Solution Converged :  17 Iterations.  Load = 0.65123E+02

Solution time, Secs =  0.6155E+00

Plastic load vector time, Secs =    2.0211  Wall=   17.0349
Total Time Used in CONTACT      0.8547E-04
1

     APPLIED LOAD= 0.65123E+02        CRACK=   0.50000          WIDTH=   1.00000
```

Node	Coordinate x	Coordinate y	Coordinate z	Displacement x	Displacement y	Displacement z	Force x	Force y	Force z
1	0.0000E+00	0.2000E+01	0.0000E+00	0.3334E-39	0.2121E-02	-0.2006E-38	-0.3334E-04	0.1954E+00	0.2006E-03
2	0.0000E+00	0.2000E+01	0.1000E+00	0.1758E-39	0.2121E-02	-0.9459E-05	-0.1758E-04	0.3517E+00	-0.3914E-13
3	0.0000E+00	0.2000E+01	0.1800E+00	-0.3050E-39	0.2121E-02	-0.1702E-04	0.3050E-04	0.2344E+00	0.9420E-15
4	0.0000E+00	0.2000E+01	0.2200E+00	-0.2093E-39	0.2121E-02	-0.2080E-04	0.2093E-04	0.1172E+00	0.3781E-13
5	0.0000E+00	0.2000E+01	0.2400E+00	-0.8234E-40	0.2121E-02	-0.2270E-04	0.8234E-05	0.5861E-01	-0.9159E-13
6	0.0000E+00	0.2000E+01	0.2500E+00	0.8743E-40	0.2121E-02	-0.2364E-04	-0.8743E-05	0.1954E-01	-0.1667E-12
7	0.1200E+00	0.2000E+01	0.0000E+00	-0.1132E-04	0.1891E-02	-0.2829E-38	0.4954E-14	0.3582E+00	0.2829E-03
8	0.1200E+00	0.2000E+01	0.1000E+00	-0.1132E-04	0.1891E-02	-0.9459E-05	0.1798E-12	0.6447E+00	-0.1233E-12
9	0.1200E+00	0.2000E+01	0.1800E+00	-0.1133E-04	0.1891E-02	-0.1703E-04	0.1417E-12	0.4298E+00	0.3322E-15
10	0.1200E+00	0.2000E+01	0.2200E+00	-0.1133E-04	0.1891E-02	-0.2081E-04	0.1467E-13	0.2149E+00	0.9118E-13
11	0.1200E+00	0.2000E+01	0.2400E+00	-0.1133E-04	0.1891E-02	-0.2270E-04	0.3402E-12	0.1075E+00	-0.7421E-13
12	0.1200E+00	0.2000E+01	0.2500E+00	-0.1133E-04	0.1891E-02	-0.2365E-04	0.1989E-12	0.3582E-01	-0.1914E-12
13	0.2200E+00	0.2000E+01	0.0000E+00	-0.2070E-04	0.1700E-02	-0.4337E-39	0.9458E-13	0.3256E+00	0.4337E-04
14	0.2200E+00	0.2000E+01	0.1000E+00	-0.2071E-04	0.1700E-02	-0.9462E-05	-0.1025E-12	0.5861E+00	-0.7612E-13
15	0.2200E+00	0.2000E+01	0.1800E+00	-0.2071E-04	0.1700E-02	-0.1703E-04	0.6348E-13	0.3907E+00	-0.3234E-13
16	0.2200E+00	0.2000E+01	0.2200E+00	-0.2071E-04	0.1700E-02	-0.2082E-04	0.1799E-12	0.1954E+00	0.1669E-12
17	0.2200E+00	0.2000E+01	0.2400E+00	-0.2071E-04	0.1700E-02	-0.2272E-04	0.3493E-14	0.9768E-01	-0.1360E-12
18	0.2200E+00	0.2000E+01	0.2500E+00	-0.2071E-04	0.1700E-02	-0.2366E-04	0.8783E-13	0.3256E-01	-0.1232E-12
19	0.3200E+00	0.2000E+01	0.0000E+00	-0.3001E-04	0.1509E-02	-0.3433E-40	-0.6528E-13	0.2849E+00	0.3433E-05
20	0.3200E+00	0.2000E+01	0.1000E+00	-0.3002E-04	0.1509E-02	-0.9468E-05	-0.2416E-13	0.5128E+00	-0.5422E-13
21	0.3200E+00	0.2000E+01	0.1800E+00	-0.3002E-04	0.1509E-02	-0.1705E-04	-0.1724E-12	0.3419E+00	0.1546E-13
22	0.3200E+00	0.2000E+01	0.2200E+00	-0.3002E-04	0.1509E-02	-0.2084E-04	-0.1047E-12	0.1709E+00	0.6385E-13
23	0.3200E+00	0.2000E+01	0.2400E+00	-0.3002E-04	0.1509E-02	-0.2273E-04	0.3416E-12	0.8547E-01	-0.4195E-14
24	0.3200E+00	0.2000E+01	0.2500E+00	-0.3002E-04	0.1509E-02	-0.2368E-04	-0.2059E-12	0.2849E-01	-0.1793E-13
25	0.3950E+00	0.2000E+01	0.0000E+00	-0.3695E-04	0.1365E-02	0.6850E-39	-0.3238E-12	0.2035E+00	-0.6850E-04
26	0.3950E+00	0.2000E+01	0.1000E+00	-0.3695E-04	0.1365E-02	-0.9473E-05	-0.2721E-12	0.3663E+00	-0.4489E-13

27	0.3950E+00	0.2000E+01	0.1800E+00	-0.3695E-04	0.1365E-02	-0.1706E-04	0.2883E-12	0.2442E+00	-0.4862E-13
28	0.3950E+00	0.2000E+01	0.2200E+00	-0.3695E-04	0.1365E-02	-0.2085E-04	0.1626E-13	0.1221E+00	0.6071E-13
29	0.3950E+00	0.2000E+01	0.2400E+00	-0.3695E-04	0.1365E-02	-0.2275E-04	-0.2537E-12	0.6105E-01	0.6197E-14
30	0.3950E+00	0.2000E+01	0.2500E+00	-0.3695E-04	0.1365E-02	-0.2369E-04	-0.9593E-13	0.2035E-01	-0.1170E-12
31	0.4450E+00	0.2000E+01	0.0000E+00	-0.4155E-04	0.1270E-02	0.8178E-39	0.3364E-12	0.1384E+00	-0.8178E-04
32	0.4450E+00	0.2000E+01	0.1000E+00	-0.4156E-04	0.1270E-02	-0.9475E-05	0.1701E-12	0.2491E+00	0.1157E-12
33	0.4450E+00	0.2000E+01	0.1800E+00	-0.4156E-04	0.1270E-02	-0.1706E-04	0.1684E-12	0.1661E+00	0.3735E-13
34	0.4450E+00	0.2000E+01	0.2200E+00	-0.4156E-04	0.1270E-02	-0.2085E-04	0.1551E-12	0.8303E-01	0.1891E-13
35	0.4450E+00	0.2000E+01	0.2400E+00	-0.4155E-04	0.1270E-02	-0.2275E-04	0.1282E-13	0.4152E-01	-0.3097E-13
36	0.4450E+00	0.2000E+01	0.2500E+00	-0.4155E-04	0.1270E-02	-0.2370E-04	-0.1833E-12	0.1384E-01	-0.1041E-12
37	0.4800E+00	0.2000E+01	0.0000E+00	-0.4477E-04	0.1203E-02	0.6198E-39	0.4887E-12	0.8954E-01	-0.6198E-04
38	0.4800E+00	0.2000E+01	0.1000E+00	-0.4477E-04	0.1203E-02	-0.9476E-05	0.6300E-12	0.1612E+00	-0.2168E-13
39	0.4800E+00	0.2000E+01	0.1800E+00	-0.4478E-04	0.1203E-02	-0.1706E-04	0.1126E-12	0.1075E+00	0.2591E-13
40	0.4800E+00	0.2000E+01	0.2200E+00	-0.4478E-04	0.1203E-02	-0.2086E-04	0.5006E-12	0.5373E-01	0.7367E-13
41	0.4800E+00	0.2000E+01	0.2400E+00	-0.4477E-04	0.1203E-02	-0.2275E-04	0.3737E-12	0.2686E-01	-0.9520E-13
42	0.4800E+00	0.2000E+01	0.2500E+00	-0.4477E-04	0.1203E-02	-0.2370E-04	-0.5781E-13	0.8954E-02	0.2776E-13
43	0.5000E+00	0.2000E+01	0.0000E+00	-0.4661E-04	0.1164E-02	0.4797E-39	-0.9340E-12	0.6512E-01	-0.4797E-04
44	0.5000E+00	0.2000E+01	0.1000E+00	-0.4661E-04	0.1164E-02	-0.9476E-05	-0.7109E-12	0.1172E+00	-0.6031E-13
45	0.5000E+00	0.2000E+01	0.1800E+00	-0.4661E-04	0.1165E-02	-0.1706E-04	-0.1262E-12	0.7815E-01	0.5225E-13
46	0.5000E+00	0.2000E+01	0.2200E+00	-0.4661E-04	0.1165E-02	-0.2086E-04	-0.1213E-12	0.3907E-01	0.7369E-13
47	0.5000E+00	0.2000E+01	0.2400E+00	-0.4661E-04	0.1165E-02	-0.2275E-04	-0.8634E-13	0.1954E-01	-0.4278E-13
48	0.5000E+00	0.2000E+01	0.2500E+00	-0.4661E-04	0.1165E-02	-0.2370E-04	-0.1075E-12	0.6512E-02	-0.4818E-13
49	0.5200E+00	0.2000E+01	0.0000E+00	-0.4845E-04	0.1126E-02	0.6280E-39	0.2029E-12	0.8954E-01	-0.6280E-04
50	0.5200E+00	0.2000E+01	0.1000E+00	-0.4845E-04	0.1126E-02	-0.9476E-05	-0.6313E-13	0.1612E+00	0.5458E-13

J-integral values in the order defined in data

Domain#: 1 J Integral = 0.2928E+00
Domain#: 2 J Integral = 0.2948E+00
Domain#: 3 J Integral = 0.3014E+00
Domain#: 4 J Integral = 0.2874E+00
Domain#: 5 J Integral = 0.2910E+00
Domain#: 6 J Integral = 0.2952E+00
Domain#: 7 J Integral = 0.2683E+00
Domain#: 8 J Integral = 0.2737E+00
Domain#: 9 J Integral = 0.2748E+00
Domain#:10 J Integral = 0.2271E+00
Domain#:11 J Integral = 0.2257E+00
Domain#:12 J Integral = 0.2272E+00
Domain#:13 J Integral = 0.1792E+00
Domain#:14 J Integral = 0.1676E+00
Domain#:15 J Integral = 0.1729E+00

1

Node	x	y	z	Stress-xx	Stress-yy	Stress-zz	Stress-xy	Stress-yz	Stress-xz
1	0.0000E+00	0.2000E+01	0.0000E+00	0.2189E+00	0.6564E+02	0.1781E+00	-0.1215E-01	-0.8164E-02	-0.3576E-12
2	0.0000E+00	0.2000E+01	0.1000E+00	0.2100E+00	0.6563E+02	0.1758E+00	-0.7882E-02	0.1320E-01	0.3004E-04
3	0.0000E+00	0.2000E+01	0.1800E+00	0.1969E+00	0.6561E+02	0.1725E+00	0.4061E-02	0.2062E-01	-0.1601E-02
4	0.0000E+00	0.2000E+01	0.2200E+00	0.1945E+00	0.6561E+02	0.1707E+00	0.1524E-01	0.1995E-01	-0.3185E-02
5	0.0000E+00	0.2000E+01	0.2400E+00	0.1954E+00	0.6561E+02	0.1669E+00	0.2304E-01	0.1821E-01	-0.4052E-02
6	0.0000E+00	0.2000E+01	0.2500E+00	0.1976E+00	0.6561E+02	0.1658E+00	0.2771E-01	0.1822E-01	-0.4450E-02
7	0.1200E+00	0.2000E+01	0.0000E+00	0.1750E+00	0.6541E+02	0.9591E-01	0.3297E-01	-0.9468E-02	-0.2139E-02
8	0.1200E+00	0.2000E+01	0.1000E+00	0.1674E+00	0.6540E+02	0.9132E-01	0.3776E-01	-0.8756E-03	-0.4471E-02
9	0.1200E+00	0.2000E+01	0.1800E+00	0.1562E+00	0.6538E+02	0.8297E-01	0.5146E-01	-0.8359E-03	-0.6891E-02
10	0.1200E+00	0.2000E+01	0.2200E+00	0.1534E+00	0.6538E+02	0.7690E-01	0.6407E-01	0.2182E-04	-0.5317E-02
11	0.1200E+00	0.2000E+01	0.2400E+00	0.1533E+00	0.6538E+02	0.7188E-01	0.7247E-01	0.2485E-02	-0.2272E-02
12	0.1200E+00	0.2000E+01	0.2500E+00	0.1544E+00	0.6538E+02	0.7031E-01	0.7730E-01	0.4105E-02	-0.9688E-03
13	0.2200E+00	0.2000E+01	0.0000E+00	0.2083E+00	0.6516E+02	0.2471E-01	0.7432E-01	-0.6764E-02	-0.2783E-02
14	0.2200E+00	0.2000E+01	0.1000E+00	0.2028E+00	0.6515E+02	0.1763E-01	0.8031E-01	-0.5472E-02	-0.7489E-02
15	0.2200E+00	0.2000E+01	0.1800E+00	0.1944E+00	0.6514E+02	0.3983E-02	0.9630E-01	-0.6947E-02	-0.1035E-01
16	0.2200E+00	0.2000E+01	0.2200E+00	0.1907E+00	0.6513E+02	-0.6125E-02	0.1098E+00	-0.4786E-02	-0.7232E-02
17	0.2200E+00	0.2000E+01	0.2400E+00	0.1892E+00	0.6513E+02	-0.1227E-01	0.1183E+00	-0.1870E-02	-0.2918E-02
18	0.2200E+00	0.2000E+01	0.2500E+00	0.1891E+00	0.6513E+02	-0.1430E-01	0.1230E+00	-0.5927E-03	-0.1179E-02
19	0.3200E+00	0.2000E+01	0.0000E+00	0.2741E+00	0.6496E+02	-0.3068E-01	0.7781E-01	-0.3335E-02	-0.2359E-02
20	0.3200E+00	0.2000E+01	0.1000E+00	0.2707E+00	0.6495E+02	-0.3850E-01	0.8273E-01	-0.7920E-02	-0.7682E-02
21	0.3200E+00	0.2000E+01	0.1800E+00	0.2642E+00	0.6493E+02	-0.5352E-01	0.9542E-01	-0.1073E-01	-0.1028E-01
22	0.3200E+00	0.2000E+01	0.2200E+00	0.2594E+00	0.6492E+02	-0.6379E-01	0.1060E+00	-0.7987E-02	-0.7022E-02
23	0.3200E+00	0.2000E+01	0.2400E+00	0.2569E+00	0.6492E+02	-0.6859E-01	0.1128E+00	-0.4415E-02	-0.2940E-02
24	0.3200E+00	0.2000E+01	0.2500E+00	0.2561E+00	0.6492E+02	-0.7009E-01	0.1166E+00	-0.3146E-02	-0.1372E-02
25	0.3950E+00	0.2000E+01	0.0000E+00	0.3386E+00	0.6486E+02	-0.5014E-01	0.5522E-01	-0.1248E-02	-0.1618E-02
26	0.3950E+00	0.2000E+01	0.1000E+00	0.3365E+00	0.6485E+02	-0.5860E-01	0.5846E-01	-0.8903E-02	-0.6030E-02
27	0.3950E+00	0.2000E+01	0.1800E+00	0.3300E+00	0.6483E+02	-0.7578E-01	0.6678E-01	-0.1226E-01	-0.8400E-02
28	0.3950E+00	0.2000E+01	0.2200E+00	0.3223E+00	0.6482E+02	-0.8838E-01	0.7380E-01	-0.9151E-02	-0.6008E-02
29	0.3950E+00	0.2000E+01	0.2400E+00	0.3172E+00	0.6482E+02	-0.9431E-01	0.7820E-01	-0.5363E-02	-0.2345E-02
30	0.3950E+00	0.2000E+01	0.2500E+00	0.3145E+00	0.6482E+02	-0.9649E-01	0.8065E-01	-0.4173E-02	-0.7513E-03
31	0.4450E+00	0.2000E+01	0.0000E+00	0.3723E+00	0.6482E+02	-0.5443E-01	0.2942E-01	-0.3744E-03	-0.9337E-03
32	0.4450E+00	0.2000E+01	0.1000E+00	0.3709E+00	0.6482E+02	-0.6321E-01	0.3124E-01	-0.9235E-02	-0.3692E-02
33	0.4450E+00	0.2000E+01	0.1800E+00	0.3643E+00	0.6480E+02	-0.8156E-01	0.3591E-01	-0.1272E-01	-0.5281E-02
34	0.4450E+00	0.2000E+01	0.2200E+00	0.3548E+00	0.6479E+02	-0.9511E-01	0.3976E-01	-0.9495E-02	-0.3922E-02
35	0.4450E+00	0.2000E+01	0.2400E+00	0.3476E+00	0.6478E+02	-0.1010E+00	0.4203E-01	-0.5726E-02	-0.1796E-02
36	0.4450E+00	0.2000E+01	0.2500E+00	0.3433E+00	0.6478E+02	-0.1032E+00	0.4329E-01	-0.4607E-02	-0.8852E-03
37	0.4800E+00	0.2000E+01	0.0000E+00	0.3831E+00	0.6482E+02	-0.5559E-01	0.9509E-02	-0.2108E-04	-0.3985E-03
38	0.4800E+00	0.2000E+01	0.1000E+00	0.3821E+00	0.6481E+02	-0.6437E-01	0.1034E-01	-0.9250E-02	-0.1659E-02
39	0.4800E+00	0.2000E+01	0.1800E+00	0.3754E+00	0.6479E+02	-0.8294E-01	0.1234E-01	-0.1275E-01	-0.2442E-02
40	0.4800E+00	0.2000E+01	0.2200E+00	0.3649E+00	0.6478E+02	-0.9673E-01	0.1381E-01	-0.9678E-02	-0.1905E-02
41	0.4800E+00	0.2000E+01	0.2400E+00	0.3567E+00	0.6477E+02	-0.1026E+00	0.1457E-01	-0.6143E-02	-0.9783E-03
42	0.4800E+00	0.2000E+01	0.2500E+00	0.3514E+00	0.6477E+02	-0.1051E+00	0.1487E-01	-0.5091E-02	-0.4789E-03
43	0.5000E+00	0.2000E+01	0.0000E+00	0.3836E+00	0.6482E+02	-0.5580E-01	-0.4358E-02	0.8517E-04	-0.8515E-04

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  44  0.5000E+00  0.2000E+01  0.1000E+00  0.3828E+00  0.6481E+02 -0.6445E-01 -0.4118E-02 -0.9188E-02 -0.2011E-03
  45  0.5000E+00  0.2000E+01  0.1800E+00  0.3762E+00  0.6479E+02 -0.8280E-01 -0.3869E-02 -0.1269E-01 -0.2061E-03
  46  0.5000E+00  0.2000E+01  0.2200E+00  0.3655E+00  0.6478E+02 -0.9645E-01 -0.3977E-02 -0.9639E-02  0.6872E-05
  47  0.5000E+00  0.2000E+01  0.2400E+00  0.3570E+00  0.6478E+02 -0.1019E+00 -0.4161E-02 -0.6330E-02  0.8186E-04
  48  0.5000E+00  0.2000E+01  0.2500E+00  0.3515E+00  0.6477E+02 -0.1042E+00 -0.4524E-02 -0.5480E-02  0.1234E-03
  49  0.5200E+00  0.2000E+01  0.0000E+00  0.3755E+00  0.6482E+02 -0.5756E-01 -0.1824E-01  0.1345E-03  0.2349E-03
  50  0.5200E+00  0.2000E+01  0.1000E+00  0.3749E+00  0.6481E+02 -0.6597E-01 -0.1864E-01 -0.9049E-02  0.1261E-02


     List of Plastic Elements

   92   93   94  104  105  106  107  108  118  119  120  121  122  133  134  135  136  232  233  244
  245  246  247  248  258  259  260  261  262  273  274  275  276  372  373  384  385  386  387  388
  398  399  400  401  402  413  414  415  416  512  513  514  524  525  526  527  528  538  539  540
  541  542  553  554  555  556  651  652  653  654  664  665  666  667  668  678  679  680  681  682
  693  694  695  696
    Solution Converged :  24 Iterations.  Load = 0.70869E+02

 Solution time, Secs =  0.8764E+00

 Plastic load vector time, Secs =    3.1121  Wall=   99.3801
 Total Time Used in CONTACT     0.8493E-04
    Solution Converged :  30 Iterations.  Load = 0.76615E+02

 Solution time, Secs =  0.1089E+01

 Plastic load vector time, Secs =    4.0385  Wall=  118.0216
 Total Time Used in CONTACT     0.8487E-04
    Solution Converged :  30 Iterations.  Load = 0.80000E+02

 Solution time, Secs =  0.1092E+01

 Plastic load vector time, Secs =    4.2677  Wall=   27.9238
 Total Time Used in CONTACT     0.8539E-04
1

      APPLIED LOAD= 0.80000E+02        CRACK=    0.50000          WIDTH=   1.00000


  Node             Coordinate                               Displacement                              Force
          x             y            z            x            y            z            x            y            z

     1  0.0000E+00  0.2000E+01  0.0000E+00  0.3861E-39  0.3001E-02 -0.2134E-38 -0.3861E-04  0.2400E+00  0.2134E-03
     2  0.0000E+00  0.2000E+01  0.1000E+00  0.2090E-39  0.3001E-02 -0.1161E-04 -0.2090E-04  0.4320E+00  0.3311E-13
```

3	0.0000E+00	0.2000E+01	0.1800E+00	-0.3520E-39	0.3000E-02	-0.2090E-04	0.3520E-04	0.2880E+00	-0.8291E-13
4	0.0000E+00	0.2000E+01	0.2200E+00	-0.2513E-39	0.3000E-02	-0.2555E-04	0.2513E-04	0.1440E+00	0.3021E-13
5	0.0000E+00	0.2000E+01	0.2400E+00	-0.1021E-39	0.3000E-02	-0.2787E-04	0.1021E-04	0.7200E-01	-0.9916E-13
6	0.0000E+00	0.2000E+01	0.2500E+00	0.1102E-39	0.3000E-02	-0.2903E-04	-0.1102E-04	0.2400E-01	-0.1950E-12
7	0.1200E+00	0.2000E+01	0.0000E+00	-0.1391E-04	0.2664E-02	-0.2614E-38	0.8072E-13	0.4400E+00	0.2614E-03
8	0.1200E+00	0.2000E+01	0.1000E+00	-0.1391E-04	0.2664E-02	-0.1161E-04	0.1261E-12	0.7920E+00	-0.6930E-13
9	0.1200E+00	0.2000E+01	0.1800E+00	-0.1392E-04	0.2664E-02	-0.2091E-04	0.2063E-12	0.5280E+00	-0.1144E-12
10	0.1200E+00	0.2000E+01	0.2200E+00	-0.1392E-04	0.2664E-02	-0.2555E-04	0.6964E-13	0.2640E+00	-0.4892E-15
11	0.1200E+00	0.2000E+01	0.2400E+00	-0.1392E-04	0.2664E-02	-0.2788E-04	0.5108E-12	0.1320E+00	-0.1571E-13
12	0.1200E+00	0.2000E+01	0.2500E+00	-0.1391E-04	0.2664E-02	-0.2904E-04	0.1837E-12	0.4400E-01	-0.9315E-13
13	0.2200E+00	0.2000E+01	0.0000E+00	-0.2544E-04	0.2383E-02	0.1076E-39	0.9205E-13	0.4000E+00	-0.1076E-04
14	0.2200E+00	0.2000E+01	0.1000E+00	-0.2545E-04	0.2383E-02	-0.1162E-04	0.3961E-13	0.7200E+00	0.1250E-13
15	0.2200E+00	0.2000E+01	0.1800E+00	-0.2545E-04	0.2383E-02	-0.2092E-04	0.6775E-13	0.4800E+00	-0.1856E-12
16	0.2200E+00	0.2000E+01	0.2200E+00	-0.2545E-04	0.2383E-02	-0.2557E-04	0.1101E-12	0.2400E+00	0.1896E-12
17	0.2200E+00	0.2000E+01	0.2400E+00	-0.2545E-04	0.2383E-02	-0.2789E-04	0.3990E-12	0.1200E+00	-0.1674E-12
18	0.2200E+00	0.2000E+01	0.2500E+00	-0.2545E-04	0.2383E-02	-0.2906E-04	-0.1051E-12	0.4000E-01	-0.1308E-12
19	0.3200E+00	0.2000E+01	0.0000E+00	-0.3689E-04	0.2103E-02	0.3394E-39	-0.1991E-12	0.3500E+00	-0.3394E-04
20	0.3200E+00	0.2000E+01	0.1000E+00	-0.3690E-04	0.2103E-02	-0.1162E-04	0.5079E-13	0.6300E+00	0.4470E-13
21	0.3200E+00	0.2000E+01	0.1800E+00	-0.3690E-04	0.2103E-02	-0.2093E-04	-0.5232E-14	0.4200E+00	0.2548E-13
22	0.3200E+00	0.2000E+01	0.2200E+00	-0.3690E-04	0.2103E-02	-0.2558E-04	-0.1164E-12	0.2100E+00	0.1588E-12
23	0.3200E+00	0.2000E+01	0.2400E+00	-0.3690E-04	0.2103E-02	-0.2791E-04	0.2162E-12	0.1050E+00	0.7107E-13
24	0.3200E+00	0.2000E+01	0.2500E+00	-0.3690E-04	0.2103E-02	-0.2907E-04	-0.1009E-12	0.3500E-01	-0.2079E-12
25	0.3950E+00	0.2000E+01	0.0000E+00	-0.4543E-04	0.1892E-02	0.1051E-38	0.1210E-12	0.2500E+00	-0.1051E-03
26	0.3950E+00	0.2000E+01	0.1000E+00	-0.4543E-04	0.1892E-02	-0.1163E-04	-0.3423E-12	0.4500E+00	0.3959E-13
27	0.3950E+00	0.2000E+01	0.1800E+00	-0.4543E-04	0.1892E-02	-0.2094E-04	-0.2773E-12	0.3000E+00	-0.7854E-13
28	0.3950E+00	0.2000E+01	0.2200E+00	-0.4543E-04	0.1892E-02	-0.2560E-04	-0.3108E-12	0.1500E+00	0.7634E-13
29	0.3950E+00	0.2000E+01	0.2400E+00	-0.4543E-04	0.1892E-02	-0.2792E-04	-0.6514E-13	0.7500E-01	0.4967E-13
30	0.3950E+00	0.2000E+01	0.2500E+00	-0.4543E-04	0.1892E-02	-0.2909E-04	-0.1365E-12	0.2500E-01	-0.1123E-12
31	0.4450E+00	0.2000E+01	0.0000E+00	-0.5110E-04	0.1752E-02	0.1146E-38	-0.1427E-12	0.1700E+00	-0.1146E-03
32	0.4450E+00	0.2000E+01	0.1000E+00	-0.5110E-04	0.1752E-02	-0.1163E-04	0.4441E-12	0.3060E+00	-0.1271E-13
33	0.4450E+00	0.2000E+01	0.1800E+00	-0.5110E-04	0.1752E-02	-0.2094E-04	0.6235E-12	0.2040E+00	-0.1797E-13
34	0.4450E+00	0.2000E+01	0.2200E+00	-0.5110E-04	0.1752E-02	-0.2560E-04	0.3360E-12	0.1020E+00	0.2809E-13
35	0.4450E+00	0.2000E+01	0.2400E+00	-0.5110E-04	0.1752E-02	-0.2793E-04	0.1597E-13	0.5100E-01	0.1163E-12
36	0.4450E+00	0.2000E+01	0.2500E+00	-0.5110E-04	0.1752E-02	-0.2910E-04	-0.4201E-12	0.1700E-01	-0.8765E-13
37	0.4800E+00	0.2000E+01	0.0000E+00	-0.5507E-04	0.1654E-02	0.8518E-39	-0.1646E-12	0.1100E+00	-0.8518E-04
38	0.4800E+00	0.2000E+01	0.1000E+00	-0.5507E-04	0.1654E-02	-0.1163E-04	-0.5246E-13	0.1980E+00	-0.4010E-13
39	0.4800E+00	0.2000E+01	0.1800E+00	-0.5507E-04	0.1654E-02	-0.2095E-04	-0.5901E-12	0.1320E+00	0.3039E-13
40	0.4800E+00	0.2000E+01	0.2200E+00	-0.5507E-04	0.1654E-02	-0.2560E-04	0.1866E-12	0.6600E-01	0.1729E-13
41	0.4800E+00	0.2000E+01	0.2400E+00	-0.5507E-04	0.1654E-02	-0.2793E-04	0.6501E-12	0.3300E-01	-0.3333E-13
42	0.4800E+00	0.2000E+01	0.2500E+00	-0.5507E-04	0.1654E-02	-0.2910E-04	-0.1905E-14	0.1100E-01	0.7244E-13
43	0.5000E+00	0.2000E+01	0.0000E+00	-0.5733E-04	0.1597E-02	0.6520E-39	-0.3534E-12	0.8000E-01	-0.6520E-04
44	0.5000E+00	0.2000E+01	0.1000E+00	-0.5733E-04	0.1597E-02	-0.1163E-04	-0.2725E-12	0.1440E+00	-0.4218E-13
45	0.5000E+00	0.2000E+01	0.1800E+00	-0.5733E-04	0.1597E-02	-0.2095E-04	-0.3793E-12	0.9600E-01	-0.2655E-13
46	0.5000E+00	0.2000E+01	0.2200E+00	-0.5733E-04	0.1597E-02	-0.2560E-04	-0.1801E-12	0.4800E-01	0.1661E-12
47	0.5000E+00	0.2000E+01	0.2400E+00	-0.5733E-04	0.1598E-02	-0.2793E-04	-0.3120E-12	0.2400E-01	-0.5829E-14

48	0.5000E+00	0.2000E+01	0.2500E+00	-0.5733E-04	0.1598E-02	-0.2910E-04	-0.2659E-13	0.8000E-02	-0.4974E-13
49	0.5200E+00	0.2000E+01	0.0000E+00	-0.5960E-04	0.1541E-02	0.8545E-39	0.1180E-12	0.1100E+00	-0.8545E-04
50	0.5200E+00	0.2000E+01	0.1000E+00	-0.5960E-04	0.1541E-02	-0.1163E-04	-0.1708E-12	0.1980E+00	-0.1162E-15

J-integral values in the order defined in data

Domain#: 1 J Integral = 0.5640E+00
Domain#: 2 J Integral = 0.5721E+00
Domain#: 3 J Integral = 0.5792E+00
Domain#: 4 J Integral = 0.5430E+00
Domain#: 5 J Integral = 0.5541E+00
Domain#: 6 J Integral = 0.5606E+00
Domain#: 7 J Integral = 0.4797E+00
Domain#: 8 J Integral = 0.4887E+00
Domain#: 9 J Integral = 0.4949E+00
Domain#:10 J Integral = 0.3743E+00
Domain#:11 J Integral = 0.3609E+00
Domain#:12 J Integral = 0.3708E+00
Domain#:13 J Integral = 0.2729E+00
Domain#:14 J Integral = 0.2336E+00
Domain#:15 J Integral = 0.2547E+00

Node	x	y	z	Stress-xx	Stress-yy	Stress-zz	Stress-xy	Stress-yz	Stress-xz
1	0.0000E+00	0.2000E+01	0.0000E+00	0.2556E+00	0.8060E+02	0.2149E+00	-0.1085E-01	-0.1042E-01	-0.4844E-12
2	0.0000E+00	0.2000E+01	0.1000E+00	0.2454E+00	0.8059E+02	0.2116E+00	-0.5788E-02	0.1564E-01	0.1088E-03
3	0.0000E+00	0.2000E+01	0.1800E+00	0.2303E+00	0.8057E+02	0.2065E+00	0.8134E-02	0.2508E-01	-0.1731E-02
4	0.0000E+00	0.2000E+01	0.2200E+00	0.2277E+00	0.8057E+02	0.2039E+00	0.2091E-01	0.2528E-01	-0.3563E-02
5	0.0000E+00	0.2000E+01	0.2400E+00	0.2289E+00	0.8058E+02	0.1995E+00	0.2970E-01	0.2412E-01	-0.4583E-02
6	0.0000E+00	0.2000E+01	0.2500E+00	0.2315E+00	0.8058E+02	0.1984E+00	0.3494E-01	0.2452E-01	-0.5060E-02
7	0.1200E+00	0.2000E+01	0.0000E+00	0.2047E+00	0.8034E+02	0.1216E+00	0.4022E-01	-0.1176E-01	-0.2470E-02
8	0.1200E+00	0.2000E+01	0.1000E+00	0.1961E+00	0.8033E+02	0.1157E+00	0.4595E-01	-0.3274E-03	-0.4973E-02
9	0.1200E+00	0.2000E+01	0.1800E+00	0.1835E+00	0.8032E+02	0.1049E+00	0.6202E-01	0.6831E-03	-0.7688E-02
10	0.1200E+00	0.2000E+01	0.2200E+00	0.1801E+00	0.8031E+02	0.9694E-01	0.7654E-01	0.2363E-02	-0.5926E-02
11	0.1200E+00	0.2000E+01	0.2400E+00	0.1798E+00	0.8031E+02	0.9072E-01	0.8609E-01	0.5571E-02	-0.2469E-02
12	0.1200E+00	0.2000E+01	0.2500E+00	0.1810E+00	0.8031E+02	0.8886E-01	0.9155E-01	0.7611E-02	-0.9672E-03
13	0.2200E+00	0.2000E+01	0.0000E+00	0.2329E+00	0.8004E+02	0.3296E-01	0.8575E-01	-0.8499E-02	-0.3234E-02
14	0.2200E+00	0.2000E+01	0.1000E+00	0.2270E+00	0.8003E+02	0.2462E-01	0.9290E-01	-0.5600E-02	-0.8354E-02
15	0.2200E+00	0.2000E+01	0.1800E+00	0.2178E+00	0.8002E+02	0.8683E-02	0.1117E+00	-0.6406E-02	-0.1152E-01
16	0.2200E+00	0.2000E+01	0.2200E+00	0.2139E+00	0.8001E+02	-0.3185E-02	0.1274E+00	-0.3382E-02	-0.8079E-02
17	0.2200E+00	0.2000E+01	0.2400E+00	0.2123E+00	0.8001E+02	-0.1028E-01	0.1372E+00	0.2336E-03	-0.3393E-02
18	0.2200E+00	0.2000E+01	0.2500E+00	0.2124E+00	0.8001E+02	-0.1252E-01	0.1426E+00	0.1857E-02	-0.1505E-02
19	0.3200E+00	0.2000E+01	0.0000E+00	0.2927E+00	0.7978E+02	-0.4213E-01	0.8812E-01	-0.4291E-02	-0.2822E-02

20	0.3200E+00	0.2000E+01	0.1000E+00	0.2896E+00	0.7977E+02	-0.5069E-01	0.9413E-01	-0.8525E-02	-0.8852E-02
21	0.3200E+00	0.2000E+01	0.1800E+00	0.2833E+00	0.7975E+02	-0.6714E-01	0.1091E+00	-0.1108E-01	-0.1182E-01
22	0.3200E+00	0.2000E+01	0.2200E+00	0.2787E+00	0.7975E+02	-0.7846E-01	0.1215E+00	-0.7469E-02	-0.8110E-02
23	0.3200E+00	0.2000E+01	0.2400E+00	0.2765E+00	0.7974E+02	-0.8371E-01	0.1294E+00	-0.3034E-02	-0.3412E-02
24	0.3200E+00	0.2000E+01	0.2500E+00	0.2760E+00	0.7974E+02	-0.8523E-01	0.1339E+00	-0.1362E-02	-0.1569E-02
25	0.3950E+00	0.2000E+01	0.0000E+00	0.3537E+00	0.7965E+02	-0.7301E-01	0.6156E-01	-0.1524E-02	-0.2041E-02
26	0.3950E+00	0.2000E+01	0.1000E+00	0.3525E+00	0.7964E+02	-0.8158E-01	0.6574E-01	-0.9702E-02	-0.7257E-02
27	0.3950E+00	0.2000E+01	0.1800E+00	0.3468E+00	0.7963E+02	-0.9986E-01	0.7558E-01	-0.1316E-01	-0.9890E-02
28	0.3950E+00	0.2000E+01	0.2200E+00	0.3389E+00	0.7962E+02	-0.1140E+00	0.8372E-01	-0.9339E-02	-0.7011E-02
29	0.3950E+00	0.2000E+01	0.2400E+00	0.3335E+00	0.7961E+02	-0.1210E+00	0.8885E-01	-0.4681E-02	-0.2712E-02
30	0.3950E+00	0.2000E+01	0.2500E+00	0.3306E+00	0.7961E+02	-0.1235E+00	0.9169E-01	-0.3095E-02	-0.7938E-03
31	0.4450E+00	0.2000E+01	0.0000E+00	0.3856E+00	0.7961E+02	-0.8171E-01	0.3177E-01	-0.1810E-03	-0.1287E-02
32	0.4450E+00	0.2000E+01	0.1000E+00	0.3863E+00	0.7960E+02	-0.8962E-01	0.3422E-01	-0.9991E-02	-0.4647E-02
33	0.4450E+00	0.2000E+01	0.1800E+00	0.3813E+00	0.7959E+02	-0.1082E+00	0.3966E-01	-0.1369E-01	-0.6348E-02
34	0.4450E+00	0.2000E+01	0.2200E+00	0.3708E+00	0.7958E+02	-0.1238E+00	0.4412E-01	-0.9779E-02	-0.4456E-02
35	0.4450E+00	0.2000E+01	0.2400E+00	0.3629E+00	0.7957E+02	-0.1309E+00	0.4695E-01	-0.5309E-02	-0.1975E-02
36	0.4450E+00	0.2000E+01	0.2500E+00	0.3582E+00	0.7957E+02	-0.1334E+00	0.4839E-01	-0.3953E-02	-0.1034E-02
37	0.4800E+00	0.2000E+01	0.0000E+00	0.3933E+00	0.7959E+02	-0.8511E-01	0.8338E-02	0.3722E-03	-0.6084E-03
38	0.4800E+00	0.2000E+01	0.1000E+00	0.3955E+00	0.7959E+02	-0.9237E-01	0.9529E-02	-0.9914E-02	-0.2094E-02
39	0.4800E+00	0.2000E+01	0.1800E+00	0.3917E+00	0.7958E+02	-0.1104E+00	0.1188E-01	-0.1359E-01	-0.2971E-02
40	0.4800E+00	0.2000E+01	0.2200E+00	0.3798E+00	0.7957E+02	-0.1262E+00	0.1337E-01	-0.9469E-02	-0.2314E-02
41	0.4800E+00	0.2000E+01	0.2400E+00	0.3700E+00	0.7956E+02	-0.1340E+00	0.1447E-01	-0.5157E-02	-0.1263E-02
42	0.4800E+00	0.2000E+01	0.2500E+00	0.3647E+00	0.7956E+02	-0.1370E+00	0.1522E-01	-0.4129E-02	-0.9188E-03
43	0.5000E+00	0.2000E+01	0.0000E+00	0.3906E+00	0.7959E+02	-0.8650E-01	-0.7842E-02	0.5627E-03	-0.1579E-03
44	0.5000E+00	0.2000E+01	0.1000E+00	0.3933E+00	0.7959E+02	-0.9339E-01	-0.7385E-02	-0.9710E-02	-0.4646E-03
45	0.5000E+00	0.2000E+01	0.1800E+00	0.3900E+00	0.7958E+02	-0.1112E+00	-0.6934E-02	-0.1338E-01	-0.6677E-03
46	0.5000E+00	0.2000E+01	0.2200E+00	0.3776E+00	0.7957E+02	-0.1280E+00	-0.7601E-02	-0.9335E-02	-0.8919E-03
47	0.5000E+00	0.2000E+01	0.2400E+00	0.3670E+00	0.7956E+02	-0.1373E+00	-0.7971E-02	-0.4618E-02	-0.6791E-03
48	0.5000E+00	0.2000E+01	0.2500E+00	0.3609E+00	0.7956E+02	-0.1411E+00	-0.7452E-02	-0.3228E-02	-0.5739E-03
49	0.5200E+00	0.2000E+01	0.0000E+00	0.3832E+00	0.7959E+02	-0.8775E-01	-0.2214E-01	0.6603E-03	0.2603E-03
50	0.5200E+00	0.2000E+01	0.1000E+00	0.3853E+00	0.7959E+02	-0.9462E-01	-0.2253E-01	-0.9497E-02	0.9574E-03

List of Plastic Elements

79	80	90	91	92	93	94	95	96	104	105	106	107	108	109	118	119	120	121	122
123	132	133	134	135	136	137	219	220	230	231	232	233	234	235	236	244	245	246	247
248	249	258	259	260	261	262	263	272	273	274	275	276	277	359	360	361	370	371	372
373	374	375	376	384	385	386	387	388	389	398	399	400	401	402	403	412	413	414	415
416	417	498	499	500	501	510	511	512	513	514	515	516	524	525	526	527	528	529	538
539	540	541	542	543	553	554	555	556	557	638	639	640	641	642	650	651	652	653	654
655	656	664	665	666	667	668	669	678	679	680	681	682	683	693	694	695	696		

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15. Supplementary Notes

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16. Abstract

ZIP3D is an elastic and an elastic-plastic finite-element program to analyze cracks in three-dimensional solids. The program may also be used to analyze uncracked bodies or multi-body problems involving contacting surfaces. For crack problems, the program has several unique features including the calculation of mixed-mode strain energy release rates using the three-dimensional virtual crack closure technique, the calculation of the J-integral using the equivalent domain integral method, the capability to extend the crack front under monotonic or cyclic loading, and the capability to close or open the crack surfaces during cyclic loading. This report includes three sections: a theoretical section, a user manual section, and two example problems (with input and output files). The theories behind the various aspects of the program are explained briefly in the theoretical section. Line-by-line data preparation is presented in the user manual. Input data and results for an elastic analysis of a surface crack in a plate and for an elastic-plastic analysis of a single-edge-crack-tension specimen are presented in the example section.

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