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GENSURF: A MESH GENERATOR FOR 3D FINITE ELEMENT ANALYSIS OF SURFACE AND CORNER CRACKS IN FINITE THICKNESS PLATES SUBJECTED TO MODE-I LOADINGS

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Acknowledgements

This computer program *gensurf* and its companion program *surf3d* were first written in 1976 and since then they have been continuously updated. This report describes the program as it stands today. This documentation was performed at the NASA Langley Research Center under contracts NAS1-18599 and NAS1-19317.

ABSTRACT

A computer program that generates three-dimensional (3D) finite element models for cracked 3D solids was written. This computer program, *gensurf*, uses minimal input data to generate 3D finite element models for isotropic solids with elliptic or part-elliptic cracks. These models can be used with a 3D finite element program called *surf3d.* This report documents this mesh generator. In this manual the capabilities, limitations, and organization of *gensurf* are described. The procedures used to develop 3D finite element models and the input for and the output of *gensurf* are explained. Several examples are included to illustrate the use of this program. Several input data files are included with this manual so that the users can edit these files to conform to their crack configuration and use them with *gensurf.*

INTRODUCTION

Stress-intensity factors are the fundamental quantities that are needed to predict fatigue crack propagation rates and crack growth profiles. Surface and corner cracks usually initiate at imperfections and nicks in metallic structures. These cracks usually grow into near or part elliptical shapes. Therefore stress-intensity factors for these elliptical crack shapes are needed. A computer program, *surf3d*, that uses the 3D finite element method was developed to calculate the stress-intensity factors for surface and corner cracks in finite-thickness plates or in plates with circular holes.

To develop the 3D finite element models for the program *surf3d*, a mesh generator program, *gensurf* that utilizes minimal input was also developed. The purpose of this manual is to document this mesh generator, to describe the procedures followed to develop the models, and to describe the input to the mesh generator. Several examples are presented and several sample data files are included with this manual. The user can edit these data files to build the data file for the case of interest.

First, the crack configurations and loading that can be modeled with *gensurf* are discussed. The program specifications and organization is presented next. Then the procedure for the development of the model and the models for elliptic cracks are explained. The input data that is required by the program and the output from the program are presented. Finally, several example problems and their output are presented. Appendix A presents names and functions of subroutines and major program variables.

CRACK CONFIGURATIONS AND LOADING

Several crack configurations can be modeled with this mesh generator. The configurations are (see Figure 1) ,

(a) Surface crack in a plate
(b) Embeded crack in a plate
(c) Corner crack in a plate
(d) Corner crack from a circular hole in a plate
(e) Surface crack at a semicircular notch in a plate
(f) Surface crack from a circular hole in a plate

The first three cases, (a), (b), (c) can be analyzed by imposing appropriate boundary conditions on the model shown in Fig. 2(b). Similarly, the next three cases, (d), (e), and (f) can be analyzed by imposing appropriate boundary conditions on the model shown in Figure 2(c). The boundary conditions for all the six cases are described below.

For all the six cases, $v = 0$ is prescribed for all nodes on the uncracked portion (hatched portion in Figure 1), including the nodes on the crack front, on the y = 0 plane.

(a) Surface crack in a plate : (Figure 1(a))
  $u = 0$ for all nodes on the $x = 0$ plane
  $w = 0$ for the node at $(W, h, 0)$
(b) Embedded crack in a plate :
  $u = 0$ for all nodes on the $x = 0$ plane

$w = 0$ for all nodes on the $z = 0$ plane

(c) Corner crack in a plate :

$u = 0$ for nodes at $(0, h, 0)$ and $(0, h, -t)$

$w = 0$ for the node at $(W, h, 0)$

(d) Corner crack from a circular hole :

$u = 0$ for all nodes on the $x = -R$ plane

$w = 0$ for the node at $(W, h, 0)$

(e) Surface crack from a semicircular hole :

$u = 0$ for nodes at $(-R, h, 0)$ and $(-R, h, -t)$

$w = 0$ for all nodes on the $z = 0$ plane

(f) Surface crack from a circular hole :

$u = 0$ for all nodes on the $x = -R$ plane

$w = 0$ for all nodes on the $z = 0$ plane

LOADING

Four types of loading can be imposed on the models. These are

(a) Remote tensile loading
(b) Remote bending loading about the x-axis
(c) Remote bending loading about the z-axis
(d) Uniform crack face pressure loading

The three loading conditions (a), (b), and (c), are illustrated in Figure 3. These loadings are assumed to be applied on the $y = h$ plane as shown in Figure 3.

The uniform pressure loading condition on the crack face is assumed to be described by

$$\sigma_y = -1$$

for all the nodes on the crack face. Note that nonuniform crack face pressure loading is not allowed in the program.

PROGRAM SPECIFICATIONS

The program *gensurf* is written in FORTRAN 77. The program was compiled and successfully executed on a variety of UNIX machines - like SUN Workstations, Convex (C-120 and C-220), CRAY-YMP and CRAY-2 computers.

The program dimensions can be easily changed by changing the PARAMETER statements in the program. The variables in the parameter statements are as follows:

MAXNOD : Maximum number of nodes in the 3D finite element model. Current value is 5000

MAXEL :	Maximum number of elements in the 3D finite element model. Current value is 4000
MAXBC:	Maximum number of boundary conditions. Current value is 1000
MAXNA:	Maximum number of external loads. Current value is 100.
MAXRHS:	Maximum number of right hand sides, i.e. different loading conditions. Current value is 8.
MAXK:	Maximum number of stations at which the stress-intensity factors are evaluated. Current value is 20.
MAXKE:	Maximum number of nodes ahead and normal to the crack forces are evaluated and used in the force method. Current value is 5.
NNODE:	Number of nodes on the Hex-8 element. Current value is 8. This variable cannot be changed.
NFREE:	Degrees of freedom per node. Current value is 3. This variable cannot be changed.

To change the value of MAXNOD globally in the program to 6000, for example, use the visual editor, *vi* and execute the following command:

:1,$s/MAXNOD =5000/MAXNOD =6000/g

The above command will replace $MAXNOD = 5000$ with $MAXNOD = 6000$ globally.

PROGRAM ORGANIZATION

The program is organized into the main program, a major subprogram (BUILD) and 9 other subprograms. Most of the input data is read in the main program and the remainder is read in BUILD. The model is built in BUILD and subprograms PLIST and PLOAD are used to print the boundary conditions and the pressure loadings data sets. To evaluate the model, the subprogram EVALM calculates the total volume of the solid that is modeled. EVALM also picks up elements that may have negative volumes. Note that volumes of elements can be negative when the elements are defined improperly, i.e. if the nodal connectivity does not correspond to a right handed coordinate system or when the element folds on itself. The total volume of the model is displayed on the screen in an interactive session. The user can compare the calculated volume with the actual volume of the solid.

PROCEDURE FOR DEVELOPMENT OF MODEL

The model is developed by dividing the solid, into three regions (see Figure 4). The first region, region I, is the region that contains the crack. This is a solid with a square cross section with side t units and height h units. Region II is a transitional region that connects regions I and III. Region III is a solid with rectangular cross section and height h. The three regions are developed as described below.

1. A rectangular region with a width of t units and height h on the $z = 0$ plane is modeled with quadrilateral elements. At $(a, 0)$ the location of the crack tip, singularity elements are used as shown in Figure 5. For convenience in presentation, this part of the model on the $z = 0$ plane is termed as the base model.

2. The $z = 0$ plane modeled in step 1 is utilized to build a cylindrical block with a radius of t units and made up of N–layers (or wedges), as shown in Figure 5. In Figure 5, 4 equal layers ($NLAYER = 4$) and 5 planes are used to model the cylindrical solid. Thus the angle between two consecutive planes is 22°1/2 (90°/ Number of layers).

3. This quarter circle solid is transformed into a solid with a square cross section with side t units and with a height h (Figure 5(c)). The procedure to perform this transformation is as follows:

Figure 6 shows the $y = 0$ plane (crack plane). For all nodes that are a distance less than R_{sq}, no transformation is performed and for all nodes that are at a distance greater than R_{sq} the new coordinates are computed by computing the radial distance r and the angle ϕ as follows:

$$
\begin{aligned}
r &= \sqrt{x^2 + z^2} \\
\phi &= \tan^{-1} |z|/x \\
r' &= \frac{(r - R_{sq})}{(t - R_{sq})} \cdot (r_d - R_{sq}) + R_{sq} \\
x' &= r' cos\ \phi \\
z' &= -r' sin\ \phi
\end{aligned}
\tag{1}
$$

with

$$
r_d = \begin{cases} t/cos\ \phi, & 0 \le \phi \le \pi/4 \\ t/sin\ \phi, & \pi/4 \le \phi \le \pi/2. \end{cases}
$$

This transformation is applied to all nodes in the model. After this transformation, a solid with a square cross section with a side of t units and height of h units is modeled and this is region I shown in Figure 5.

4. The connecting region between region I and region III, is modeled with rectangular parallelopiped elements. This can be accomplished by knowing all the nodes on the $x = t$ plane and $x = x_s$, the starting $x-$coordinate of region III (see figure 4). Note that the number of nodes on the vertical line on the $z = 0$ plane with $x = x_s$ are chosen to be identically equal to the number of nodes ($NADH$) on the line with $x = t$ (see figure 5(a)) of the base model. This choice is convenient to develop a simple rectangular idealization for the connecting region.

5. Region III is modeled with rectangular parllelopiped elements. This is achieved by choosing $NADL$ number of x-coordinates between x_s and W; the $y-$coordinates of all the $NADH$ nodes are known from the base model and the $z-$coordinates are chosen to be

$$z = -t/NTW * i; \qquad i = 1, NTW$$

where NTW = number of layers between $0 \leq \phi \leq 45°$ and is usually chosen as $NTW = NLAYER/2$, ($NTW = 2$ in Figure 5(c)).

This completes the modeling of the solid for circular cracks. The model on the $y = 0$ or $y = h$ planes is shown in Figure 7.

MODELS FOR ELLIPTIC CRACKS

The procedure outlined in the previous section gives a model for a circular crack (with $a/c = 1$). The model for an elliptic crack for ($a/c < 1$) can be generated after the model for $a/c = 1$ is accomplished. The coordinates of the circular crack model are transformed by a conformal transformation as follows.

Let (x', y', z') and (x, y, z) are the coordinates in an elliptic crack model and the circular crack model, respectively. The (x', y', z') are obtained from (x, y, z) for an elliptic crack with an (a/c) ratio as

$$x' = \sqrt{r^2 + c^2 - a^2} \quad cos\ \phi$$
$$y' = y$$
$$z' = -\sqrt{r^2 + c^2 - a^2} \quad sin\ \phi$$

where

$$r^2 = x^2 + z^2 \qquad \text{and} \qquad tan\ \phi = |z|/x \tag{2}$$

The transformations of Eq. (2), are valid everywhere except at the origin (0,0,0). To avoid the singularity at the origin, the smallest $x-$coordinate in the base model is taken as $0.001a$. The effect of this is shown in Figure 8. The hole with the radius of $0.001a$ in any y =constant plane is transformed into a very oblong ellipse (Figure 8), with length of the semi-major axis approximately equal to $\sqrt{c^2 - a^2}$ and a semi-minor axis length of $0.001a$.

All radial lines in any y=constant plane of the circular crack model are transformed to hyperbolas and all circles with the origin at $(0, y, 0)$ are transformed to confocal ellipses as shown in Figure 8. The advantage of this conformal transformation is that the normality of the mesh at the crack front is preserved. Note that *normality of the mesh is a requirement* for the force method for calculating stress intensity factors.

This conformal transformation is applied to all nodal coordinates in the circular mesh model, when the $x-$coordinate is less than or equal to 4 times the semi-major axis of the elliptic crack, c. This restriction is imposed so that the modeled solid is still rectangular with width $= W$. After the transformation, the modeling on any $y =$ constant plane will be as shown in Figure 8(c).

Element Nodal Connectivity Definitions

Non-singular elements: The nodal connectivity of the elements in the base model (Figure 3) is given starting at any node i and the element is described anticlockwise as,

i j k l

To define the element as a non-singular element, the $INDX$ of the element is input as zero.

Singularity elements: The nodal connectivity of the singularity elements is given as (Figure 3a)

m m n p

To define the element as a singularity element the $INDX$ of the element is input as unity.

INPUT DATA

The required input data is described in this section. The data can be created on a file, LFN, and is given as input to the mesh generator. Several sample input data files for various crack configurations are attached. These files can be edited to create the user's data file. (Throughout the rest of this manual, for convenience in presentation, the words/phrases cards, card sets, lines, and data sets are used interchangeably.)

Input line	Number of lines	Cols	FORMAT	Variable	Description
1	1	1-80	20A4	TITLE	Title of the Problem.
2	1	-	*†	EYOUNG, ANU	Young's modulus and Poisson's ratio.
		† denotes free format			
3	1	-	*	NPOIN,NELEM	Nodes and elements in the base model.
4	*	1-10	F10.5	X1	$x-$coordinate
		11-15	I5	JCORD(1)	Node Numbers with this
		16-20	I5	JCORD(2)	coordinates in columns 11 through 60.
		...			
		...			
		...			
		56-60	I5	JCORD(10)	
		1-10	F10.5	Y1	$y-$coordinate
		11-15	I5	JCORD(1)	Node Numbers with this
		16-20	I5	JCORD(2)	coordinates in columns 11 through 60.
		...			
		...			
		...			
		56-60	I5	JCORD(10)	
					2 sets of cords of this format, with each set terminated by a zero or blank in columns 11 - 15. First set of cords is for $x-$coordinates, and the second set of for $y-$coordinates.

				****	*Input until all $x-$and $y-$coordinates are specified. End each coordinate with a blank line with 0.000 0 0 ....*
5	NELEM	1 - 5	I5	I	Element number.
		6 - 10	I5	NOD(I,1)	Element connectivity starting at a corner node in the counter clockwise direction.
		11 - 15	I5	NOD(I,2)	
		.	.	.	
		.	.	.	
		.	.	NOD(I,NNODE)	
				****	*One card for each element, thus NELEM lines.*
6	1	—	*	NLOAD	Number of concentrated loads.
7	*	—	*	NA(1)	Degree of freedom in which load is applied.
				NA(2)	
				.	
				.	
				NA(NLOAD)	NLOAD integer values to be read.
8	*	—	*	XY(1)	Magnitudes of the loads XY(I) applied in NA(I) degree of freedom direction.
				XY(2)	
				.	
				.	
				.	
				XY(NLOAD)	NLOAD values to be read.
9	1	—	*	NSINGU	Number of singularity elements in base model.
10	*	—	*	ICOD(1,1)	Node numbers for COD nodes on the crack face.
				ICOD(1,2)	
				.	
				.	
				ICOD(1,5)	5 nodal numbers are read.
11	*	—	*	NTIP(1,1)	Element numbers of singularity elements, NSINGU values to be read.
				NTIP(1,2)	
				—	
				NTIP(1,NSINGU)	

12	*	—	*	KELEM(1,1) KELEM(1,2) KELEM(1,3) . KELEM(1,5)	Elements ahead of the crack front, on the $y = 0$ plane. These are the elements that are used to calculate the forces at the MNODE nodes and used in the force-method to evaluate stress-intensity factors. Five values to be read.
13	*	—	*	MNODE(1,1) MNODE(1,2) MNODE(1,3) . MNODE(1,5)	Nodes ahead of the crack front, in the base model. These are the nodes where forces are calculated and used in the force-method to evaluate stress-intensity factors. Five values to be read.
14	1	—	*	HT	Height of the model, h.
				RSQ	Radius above which the mesh slowly becomes a square.
				AOT	a/t ratio.
				AA	a.
				CC	c.
				TCONST	The constant by which the square mesh is scaled (usually set to unity).
				WIDTH	Width of the model, W.
15	1	—	*	ROT	R/t, For problems without a hole, read this as 0.0.
				AOC	a/c ratio.
				****	*The following two cards are skipped if ROT = 0.0.*
16	1	—	*	NH	Number of layers in the hole region (see Figure 11).
17	1	—	*	PER(1) PER(2) --- PER(NH)	Percent of the hole radius where the $x = 0$ plane is replicated. (see Figure 11 and 12).
18	1	—	*	NADH	Number of elements in the $y-$ direction at $x = t$ in the base model.
				NADL	Number of elements in the $x-$ direction between $t < x \leq W$.

19	1	--	*	NELEL	Number of elements that have distributed loading applied to one of its boundaries, in the base model (in the $z = 0$ plane).
20	1	---	*	KELEL(1) KELEL(2) . KELEL(NELEL)	Element number of each of the NELEL elements. NELEL integer values to be read.
21	1	—	*	YADH(1) YADH(2) . . YADH(NADH+1)	$y-$coordinates of the nodes on the $x = t$ line in the base model. (NADH+1) real values to be read.
22	1	----	*	XADL(1) XADL(2) . XADL(NADL)	$x-$coordinates of the vertical lines on the $z = 0$ plane, for $t < x \leq W$. $NADL$ values of $x-$coordinates to be read. Note that the XADL(NADL)=W, Width of the solid.
23	NADH	---	*	NOD(IP,1) NOD(IP,2)	Node numbers of the first two nodes in the region I at $x = t$ on the $z = 0$ plane. (See Figure 10, for example).

Interactive Data

This section describes the interactive input requested by *gensurf*. While giving the interactive input for alphanumeric variables (like *POUT*), use either upper or lower cases. Do not mix the cases. For example, use *SHORT* or *short* for the variable *POUT*. Do not use *Short* or *sHort* or *sHORT*, etc. When the variable is misspelled or when the upper and lower cases are mixed the program requests the input for the same variable and keeps on requesting until a correct entry is made.

Variable	**Choice**	**Description**
POUT		*Output option*
	SHORT or short	Short output
	XLONG or xlong	Long output.
CTYPE		*Type of crack*
	SURF or surf	Surface crack in a plate
	EMBE or embe	Embeded crack in a plate
	CORN or corn	Corner crack in a plate
	CHOL or chol	Corner crack at a hole
	SSEM or ssem	Surface crack in a semi-circular edge notch
	SHOL or shol	Surface crack at a circular hole.
LTYPE		*Type of distributed loading*
	REMOTE or remote	Remote loading
	CFACE or cface	Crack face pressure loading - only uniform loading can be applied.
LTYPE		*Type of loads*
	TENS or tens	Uniform tensile loading.
	BENDX or bendx	Bending stress about x-axis $\sigma_b(-z,0) = 1$ $\sigma_b(z,-t) = -1$
	BENDZ or bendz	Bending stresses about z-axis $\sigma_b(x,0) = 1$ $\sigma_b(x,W) = -1$

NPDISP	1 or 0	1- if there are prescribed displacements. 0- if there are no prescribed displacements.
NX, *NY*, *NZ*	1 or 0	NX=1: Prescribed displacement are on an x =constant face. NX=0: No prescribed displacements on an x =constant face, etc.
HX, *HY*, *HZ*	Value of the $x-$, $y-$, and $z-$coordinates of the faces	Hx =25.0 denotes that on the x =25 face and that there are prescribed displacements. Similar definitions for Hy and Hz.
U, *V*, *W*	Value of the prescribed displacements	U =1.0e-6 denotes that on the x = Hx face a value of 10^{-6} is prescribed for the $U-$displacement.

OUTPUT

The output from the *gensurf* is written on the file with the file name supplied by the user(at the start of the interactive session). This file contains the complete description of the 3D finite element model and is the data file for *surf3d*. This file contains the following items.

- Title of the problem
- Output option
- Number of nodes and elements in the model
- Node number, $x-$, $y-$, and $z-$ coordinates for each node in the model.
- Element number, nodal connectivity and the index code for each element in the model.
- Node number, integers identifying the degree of freedom that is being prescribed zero value.
- Number of right hand sides (loading conditions).
- First element number, last element number, increment, load index and the face number for elements where traction loading is prescribed.
- Node number, magnitude of tractions in the three degree of freedom directions.
- Node number, prescribed displacement indices, and magnitude of prescribed displacements in the three degree of freedom directions.
- Renumbering option- 1 or 0. Unity when renumber scheme is supplied. (*gensurf* gives the renumbering scheme and hence the option is unity.)
- The renumbering scheme for all the nodes in the model.
- Number of external loads
- Degrees of freedom where external loads are prescribed.
- Magnitude of external loads in the degrees of freedom described above.
- Number of singularity elements and number of layers (wedges) that describe the crack front.
- Node numbers used in the COD method.
- Node numbers at the crack front for each layer in the model.
- Element numbers of the singularity elements for each layer in the model.
- Element numbers ahead of the crack front for each layer of the model.
- Node numbers ahead of the crack front for each layer of the model. These are the nodes where forces are evaluated and used in the force method.
- Number of loading conditions.
- Height and width of the model, (a/t) ratio, $(R+t)$ value, and (a/c) ratio.

EXAMPLES

To illustrate the use of the mesh generator several examples are presented in this section. The input data files for several cases, shown in Table 1 are attached with this program.

Table 1: Data file names for various surface crack configurations

	a/t		
a/c	0.2	0.5	0.8
1.0	ds12	ds15	ds18
0.6	ds62	ds65	ds68
0.4	ds42	ds45	ds48
0.2	ds22	ds25	ds28

Example 1: Surface crack in a plate with $a/c = 0.2$ and $a/t = 0.8$ (Figure 1(a))

Consider a surface crack in a plate with $a = 1, c = 5, t = 1.25$; $a/t = 0.8$ and $a/c = 0.2$. The total height of the solid is 250.0 (or $h = 125.0$). The total width of the solid is 100 (or $W = 50.0$). The base model is modeled with 151 nodes and 128 elements as shown in Figure 9. Eight singularity elements are used at the crack tip at $(a, 0)$. The rest of the base model is modeled with 120 quadrilateral elements. The input data file, *ds*28, is presented in Table 2. The interactive session that used *ds*28 is shown in Table 3. The output of the mesh generator, *dout*28, is presented, partially, in Table 4. The complete file is available on the disk.

Example 2: Surface crack in a plate with $a/c = 1.0$ and $a/t = 0.8$

Figure 10 presents a model for $a/c = 1$ and $a/t = 0.8$. This model is created with the same base line model as Example-1 (for $a/c = 0.2$ and $a/t = 0.8$.) In this figure various nodes and elements are identified. This model is created with 8-layers ($NLAYER = 8$). The last node in region I, 1359, is on the plane $x = 0$ and the next node, 1360, is on the $z = 0$ plane at $(x_s, 0)$ and the nodes are numbered as shown in Figure 10. The complete output file, *dout*18, from the mesh generator is available on the disk.

Example 3: Corner crack from a hole with $a/c = 1, a/t = 0.8, R/t = 1.0$ (Figure 1(d))

Consider a corner crack (with $a = c = 1$) from a circular hole in a plate with $h = 125$, $W = 50$,and $R = t = 1.25$. The base model is as shown in Figure 9. Again eight singularity elements are used at $(a, 0)$. The input data file, *dch*18, is presented in Table 5. The interactive session that used *dch*18 is presented in Table 6. The output of the mesh generator, *dcorn*18, is presented partially in Table 7. The complete data file is available on the disk.

Figure 11 presents schematically this model. (Note that all the mesh details are not shown in this figure, the purpose of this figure is to present the details of the nodes and elements.) The circular hole is modeled with 5-layers ($NH = 5$). The position of the planes that are in the hole region are defined by the variable, $PER(I), I = 1, NH$. Details of the position of the planes are shown in this figure. The region-I is modeled with 8-layers ($NLAYER = 8$), and is identical to that shown in Example-2. The first plane in the hole region, H-1, has nodes 1360 through 1510; the second plane, H-2, has nodes 1511 through 1661, and so on. Similarly, the first layer in the hole region has elements 1025 through 1153; the second layer has 1154 through 1281 and so on. The nodes in region III are from 2115 through 2964 with elements from 1665 through 2304.

Figure 12 presents the details of the modeling of the hole with 5- and 7- Layers, ($NH = 5$ and 7). The values of the variable PER are also defined in this figure. Obviously, as the NH value increases, the shape of the circular hole is better approximated.

Example 4: Surface crack in a plate with $a/c = 1$ and $a/t = 0.2$ - Prescribed displacements

This example illustrates the use of *gensurf* for problems involving prescribed displacements instead of prescribed tractions. Consider a surface crack in a plate with $a = 1, c = 1, t = 5.0$; $a/t = 0.2$ and $a/c = 1.0$. The total height of the solid is 250.0 (or $h = 125.0$). The total width of the solid is 50 (or $W = 25.0$). The input data file for this example is *ds12d* and is available on the disk. The interactive session is presented in Table 8. In this session, note the errors that were made (by misspelling and mixing upper and lower cases) in entering the names of the alphanumeric variables and how the program requests the correct input until a correct entry is made.

In this example, displacements normal to the plane $y = 125$ are prescribed to be equal to $2.0 \cdot 10^{-7}$. The data file created by *gensurf* is called *dpdisp12*. Partial listing of this data file is presented in Table 9 and the complete data file is available in the disk supplied with this manual.

Restrictions

The use of *gensurf* for generating models for corner and surface cracks from holes and notches for circular hole radius-to-thickness ratios greater than unity, i.e. $R/t > 1$, *is not recommended.* For configurations with $R/t > 1$, the elements in the region between the plane H-1 (see Figure 11) and the $x = 0$ plane have very poor aspect ratios. These models with poor aspect ratios do not yield accurate stress concentrations and stress-intensity factor results. In contrast, for configurations with $R/t < 1$ the models generated by *gensurf.f* do not suffer from these shortcomings.

APPENDIX A

SUBROUTINES, MAJOR PROGRAM VARIABLES AND COMMON BLOCKS

A.1: SUBROUTINES

Name	*Function*
1. *BUILD*	This subprogram builds the model and writes the output files.
2. *DERJ*	Evaluates the derivatives of the shape functions and the Jacobian at the integration point.
3. *EVALM*	Evaluates the total volume of the solid modeled. Flags elements that are not described properly or those with negative volumes.
4. *LOAD*	Evaluates the magnitudes of the nodal tractions on the loaded elements.
5. *MATMUL*	Obtains the product of two matrices.
6. *PDISP*	Processes and prints the prescribed displacements.
7. *PLIST*	Processes and prints the boundary condition data.
8. *PLOAD*	Processes and prints the traction type loading data.
9. *ZEROLN*	Zeros out a integer array.
10. *ZEROLV*	Zeros out a real array.

A.2: MAJOR PROGRAM VARIABLES

Variable Name	*Common*	*Description*
X(MAXNOD,NFREE)	*BNOD*	Coordinates of all the nodes in the model.
NOD(MAXEL,NNODE)	*BNOD*	Nodal connectivity of elements.

LIST(MAXBC)	*CLIST*	Boundary condition array. $LIST(I)$ defines that the degree of freedom that is prescribed to have a zero value.
NA(MAXNA)	*CLIST*	This array defines the degree of freedom where external loads are prescribed.
XY(MAXNA)	*CLIST*	This array defined the magnitudes of the external loads corresponding to the degree of freedom defined in the array NA.
NLOAD	*CLIST*	Number of external loads prescribed.
ICOD(MAXK, MAXKE)	*COD*	Nodes on the crack plane and behind the crack front where the COD is calculated and used to evaluate the stress-intensity factors.
NCASE	*COMB*	Number of loading cases.
AOT	*COMB*	a/t ratio.
NSINGU	*COMB*	Number of singularity elements in the base model.
RPT	*COMB*	$(R+t)$ value.
AOC	*COMB*	a/c ratio.
WIDTH	*COMB*	Width or half-width of the solid, W.
NINDX(MAXEL)	*IND*	Index of each element in the model. The index is unity for singularity elements and zero for non-singular elements.
INDX	*IND*	The value of the $INDEX$ for the element that is being processed.
NPOIN	*INTGR*	Number of nodes in the model.
NELEM	*INTGR*	Number of elements in the model.
MTIP	*INTNST*	Nodes defining the crack front for each layer of the model.
NTIP	*INTNST*	Singularity elements in each layer around the crack front.

KELEM	*INTNST*	Elements ahead of the crack front and on the crack plane.
MNODE	*INTNST*	Nodes ahead of the crack front and on the crack plane for each layer of the model.
NLAYER	*INTNST*	Number of layers (wedges) in the model.
JOLD(MAXNOD)	*RENUM*	Array which relates old node numbers to the new node numbers. $JOLD(IN)$ gives the old node number of the new node IN. This array is complementary to $JNEW$.
JNEW(MAXNOD)	*RENUM*	Array which relates new node numbers to the old node numbers $JNEW(IO)$ gives the new node number of the old number IO. This array is complementary to $JOLD$.
LINDX(MAXEL,2)	*ULOAD*	Load index for element I defined as $LINDX(I,1) = 1$ or 0 $LINDX(I,2) = IFACE$ $LINDX(I,1) = 1$ defines that there is traction type loading on element I. Zero defines that no tractions are prescribed on the element. $LINDX(I,2) =$ defines the face number on which the tractions type loading is prescribed. The faces are defined by the parent coordinates as follows:

Parent Coordinate	IFACE
$\xi = 0$	1
$\xi = 1$	2
$\eta = 0$	3
$\eta = 1$	4
$\zeta = 0$	5
$\zeta = 1$	6.

LIND	*ULOAD*	Load index for the element that is being processed.
AA		Deepest point (semi-minor axis) of the crack, a.
ANGL(20)		The array of the angles that defines the orientation of radial planes in region. $NLAYER$ values angles define the $NLAYER-$ (wedge) model.

APPENDIX B

Compilation and Execution of *gensurf*

The program *gensurf.f* is available in the main directory, *gen*, of the disk supplied with this manual. This main directory has also two subdirectories - *genin* and *genout*. The subdirectory *genin* contains all the input files referred in this manual, including the files listed in Table 1. The subdirectory *genout* contains all the output files created by *gensurf.f* and referred in this manual.

To compile *gensurf* use the following commands.

For convex computers use

fc -cfc -72 -o gen.e gensurf.f

where the flag *-cfc* is to emulate of Cray Fortran compiler, *-72* is to restrict reading the source upto 72 columns. The flag *-o gen.e* names the executable as *gen.e*. The default is *a.out*. That is

fc -cfc -72 gensurf.f

names the executable as *a.out*.

Similarly, for the Sun-, Dec- etc. type work stations use

f77 -72 -o gen.e gensurf.f

To execute the program type *gen.e* or *a.out* depending on how the executable is named. The program will start asking for interactive input as in Tables 3, 6, etc.

Lower to upper case conversions

After the output is generated to change all the lower case letters in the file to the upper case letters use the script file called *trans*. This file is in the main directory *gen*. For example, an output file, *tout*, is created by *gensurf.f*. To change all the letters in this file to upper case letters, type

trans tout

The system response will be

```
remove tout.n?
```

Type *y* to remove temporary files. All the lower case letters in the file *tout* are now changed to upper case letters. If the original file does not contain any lower case letters then the above command has no effect on the file.

The script file *trans* contains the following statements.

```
#

tr a-z A-Z <$1> $1.n

cp $1.n $1

rm $1.n
```

```
SURFACE CRACK-REMOTE TENSION    A/C=0.2 ,A/T=0.8
  30.0e6    0.3                     Eyoung, Nu
 151  128
 1.00000    1    6   15   24   33   42   51   60   69   89
 1.01320    2    0    0    0    0    0    0    0    0    0
 1.01220    3    0    0    0    0    0    0    0    0    0
 1.00930    4    0    0    0    0    0    0    0    0    0
 1.00510    5    0    0    0    0    0    0    0    0    0
  .99490    7    0    0    0    0    0    0    0    0    0
  .99070    8    0    0    0    0    0    0    0    0    0
  .98780    9    0    0    0    0    0    0    0    0    0
  .98680   10    0    0    0    0    0    0    0    0    0
 1.02640   11    0    0    0    0    0    0    0    0    0
 1.02440   12    0    0    0    0    0    0    0    0    0
 1.01870   13    0    0    0    0    0    0    0    0    0
 1.01010   14    0    0    0    0    0    0    0    0    0
 0.98990   16    0    0    0    0    0    0    0    0    0
  .98130   17    0    0    0    0    0    0    0    0    0
  .97560   18    0    0    0    0    0    0    0    0    0
  .97360   19    0    0    0    0    0    0    0    0    0
 1.04000   20    0    0    0    0    0    0    0    0    0
 1.03700   21    0    0    0    0    0    0    0    0    0
 1.02830   22    0    0    0    0    0    0    0    0    0
 1.01530   23    0    0    0    0    0    0    0    0    0
  .98470   25    0    0    0    0    0    0    0    0    0
  .97170   26    0    0    0    0    0    0    0    0    0
  .96300   27    0    0    0    0    0    0    0    0    0
  .96000   28    0    0    0    0    0    0    0    0    0
 1.07000   29    0    0    0    0    0    0    0    0    0
 1.06467   30    0    0    0    0    0    0    0    0    0
 1.04950   31   82    0    0    0    0    0    0    0    0
 1.02680   32    0    0    0    0    0    0    0    0    0
 0.97320   34    0    0    0    0    0    0    0    0    0
  .95050   35   76    0    0    0    0    0    0    0    0
  .93533   36    0    0    0    0    0    0    0    0    0
  .93000   37    0    0    0    0    0    0    0    0    0
 1.11000   38    0    0    0    0    0    0    0    0    0
 1.10163   39    0    0    0    0    0    0    0    0    0
 1.07778   40    0    0    0    0    0    0    0    0    0
 1.04210   41    0    0    0    0    0    0    0    0    0
  .95790   43    0    0    0    0    0    0    0    0    0
  .92222   44    0    0    0    0    0    0    0    0    0
  .89837   45    0    0    0    0    0    0    0    0    0
  .89000   46    0    0    0    0    0    0    0    0    0
 1.15000   47   48   49    0    0    0    0    0    0    0
 1.07500   50    0    0    0    0    0    0    0    0    0
  .92500   52    0    0    0    0    0    0    0    0    0
  .85000   53   54   55   83    0    0    0    0    0    0
 1.20000   56   57   58    0    0    0    0    0    0    0
 1.10000   59   75    0    0    0    0    0    0    0    0
  .90000   61    0    0    0    0    0    0    0    0    0
  .80000   62   63   64   77    0    0    0    0    0    0
 1.25000   65   66   67   74   81   88   95  102  107  112
 1.25000  117  122  127  132  137  142  147
 1.12500   68    0    0    0    0    0    0    0    0    0
  .87500   70    0    0    0    0    0    0    0    0    0
  .75000   71   72   73   90    0    0    0    0    0    0
  .65000   78   79   80   84    0    0    0    0    0    0
  .45000   85   86   87    0    0    0    0    0    0    0
  .50000   91    0    0    0    0    0    0    0    0    0
  .25000   92   93   94    0    0    0    0    0    0    0
  .93750   96  103  108  113  118  123  128  133  138  143
  .93750  148
  .62500   97  104  109  114  119  124  129  134  139  144
  .62500  149
  .31250   98  105  110  115  120  125  130  135  140  145
  .31250  150
  .00100   99  100  101  106  111  116  121  126  131  136
  .00100  141  146  151
 0.0000     0
 0.00000    1    2   10   11   19   20   28   29   37   38
 0.00000   46   47   55   56   64   65   73   80   87   94
 0.00000  101    0    0    0    0    0    0    0    0    0
  .00510    3    9    0    0    0    0    0    0    0    0
  .00930    4    8   12   18    0    0    0    0    0    0
```

.01220	5	6	7	0	0	0	0	0	0	0
.01870	13	17	0	0	0	0	0	0	0	0
.02440	14	16	0	0	0	0	0	0	0	0
.02640	15	30	36	0	0	0	0	0	0	0
.01530	21	27	0	0	0	0	0	0	0	0
.02830	22	26	0	0	0	0	0	0	0	0
.03700	23	25	0	0	0	0	0	0	0	0
.04000	24	0	0	0	0	0	0	0	0	0
.04950	31	35	0	0	0	0	0	0	0	0
.06467	32	34	0	0	0	0	0	0	0	0
.07000	33	0	0	0	0	0	0	0	0	0
.04210	39	45	0	0	0	0	0	0	0	0
.07778	40	44	0	0	0	0	0	0	0	0
.10163	41	43	0	0	0	0	0	0	0	0
.11000	42	0	0	0	0	0	0	0	0	0
.07500	48	54	0	0	0	0	0	0	0	0
.15000	49	50	51	52	53	0	0	0	0	0
.10000	57	63	0	0	0	0	0	0	0	0
.20000	58	59	60	61	62	0	0	0	0	0
.12500	66	72	0	0	0	0	0	0	0	0
.25000	67	68	69	70	71	0	0	0	0	0
.35000	74	75	76	77	78	0	0	0	0	0
.17500	79	0	0	0	0	0	0	0	0	0
.55000	81	82	83	84	85	0	0	0	0	0
.27500	86	0	0	0	0	0	0	0	0	0
.75000	88	89	90	91	92	0	0	0	0	0
.37500	93	0	0	0	0	0	0	0	0	0
1.00000	95	96	97	98	99	0	0	0	0	0
.50000	100	0	0	0	0	0	0	0	0	0
1.50000	102	103	104	105	106	0	0	0	0	0
2.50000	107	108	109	110	111	0	0	0	0	0
4.00000	112	113	114	115	116	0	0	0	0	0
7.00000	117	118	119	120	121	0	0	0	0	0
11.00000	122	123	124	125	126	0	0	0	0	0
20.00000	127	128	129	130	131	0	0	0	0	0
35.00000	132	133	134	135	136	0	0	0	0	0
55.00000	137	138	139	140	141	0	0	0	0	0
85.00000	142	143	144	145	146	0	0	0	0	0
125.00000	147	148	149	150	151	0	0	0	0	0
0.0000	0									

1	1	1	2	3	0	0	0	0	1
2	1	1	3	4	0	0	0	0	1
3	1	1	4	5	0	0	0	0	1
4	1	1	5	6	0	0	0	0	1
5	1	1	6	7	0	0	0	0	1
6	1	1	7	8	0	0	0	0	1
7	1	1	8	9	0	0	0	0	1
8	1	1	9	10	0	0	0	0	1
9	3	2	11	12	0	0	0	0	0
10	4	3	12	13	0	0	0	0	0
11	5	4	13	14	0	0	0	0	0
12	6	5	14	15	0	0	0	0	0
13	7	6	15	16	0	0	0	0	0
14	8	7	16	17	0	0	0	0	0
15	9	8	17	18	0	0	0	0	0
16	10	9	18	19	0	0	0	0	0
17	12	11	20	21	0	0	0	0	0
18	13	12	21	22	0	0	0	0	0
19	14	13	22	23	0	0	0	0	0
20	15	14	23	24	0	0	0	0	0
21	16	15	24	25	0	0	0	0	0
22	17	16	25	26	0	0	0	0	0
23	18	17	26	27	0	0	0	0	0
24	19	18	27	28	0	0	0	0	0
25	21	20	29	30	0	0	0	0	0
26	22	21	30	31	0	0	0	0	0
27	23	22	31	32	0	0	0	0	0
28	24	23	32	33	0	0	0	0	0
29	25	24	33	34	0	0	0	0	0
30	26	25	34	35	0	0	0	0	0
31	27	26	35	36	0	0	0	0	0
32	28	27	36	37	0	0	0	0	0
33	30	29	38	39	0	0	0	0	0
34	31	30	39	40	0	0	0	0	0
35	32	31	40	41	0	0	0	0	0

36	33	32	41	42	0	0	0	0	0
37	34	33	42	43	0	0	0	0	0
38	35	34	43	44	0	0	0	0	0
39	36	35	44	45	0	0	0	0	0
40	37	36	45	46	0	0	0	0	0
41	39	38	47	48	0	0	0	0	0
42	40	39	48	49	0	0	0	0	0
43	41	40	49	50	0	0	0	0	0
44	42	41	50	51	0	0	0	0	0
45	43	42	51	52	0	0	0	0	0
46	44	43	52	53	0	0	0	0	0
47	45	44	53	54	0	0	0	0	0
48	46	45	54	55	0	0	0	0	0
49	48	47	56	57	0	0	0	0	0
50	49	48	57	58	0	0	0	0	0
51	50	49	58	59	0	0	0	0	0
52	51	50	59	60	0	0	0	0	0
53	52	51	60	61	0	0	0	0	0
54	53	52	61	62	0	0	0	0	0
55	54	53	62	63	0	0	0	0	0
56	55	54	63	64	0	0	0	0	0
57	57	56	65	66	0	0	0	0	0
58	58	57	66	67	0	0	0	0	0
59	59	58	67	68	0	0	0	0	0
60	60	59	68	69	0	0	0	0	0
61	61	60	69	70	0	0	0	0	0
62	62	61	70	71	0	0	0	0	0
63	63	62	71	72	0	0	0	0	0
64	64	63	72	73	0	0	0	0	0
65	75	68	67	74	0	0	0	0	0
66	76	69	68	75	0	0	0	0	0
67	77	70	69	76	0	0	0	0	0
68	78	71	70	77	0	0	0	0	0
69	79	72	71	78	0	0	0	0	0
70	73	72	79	80	0	0	0	0	0
71	82	75	74	81	0	0	0	0	0
72	83	76	75	82	0	0	0	0	0
73	84	77	76	83	0	0	0	0	0
74	85	78	77	84	0	0	0	0	0
75	86	79	78	85	0	0	0	0	0
76	80	79	86	87	0	0	0	0	0
77	89	82	81	88	0	0	0	0	0
78	90	83	82	89	0	0	0	0	0
79	91	84	83	90	0	0	0	0	0
80	92	85	84	91	0	0	0	0	0
81	93	86	85	92	0	0	0	0	0
82	87	86	93	94	0	0	0	0	0
83	96	89	88	95	0	0	0	0	0
84	97	90	89	96	0	0	0	0	0
85	98	91	90	97	0	0	0	0	0
86	99	92	91	98	0	0	0	0	0
87	100	93	92	99	0	0	0	0	0
88	94	93	100	101	0	0	0	0	0
89	103	96	95	102	0	0	0	0	0
90	104	97	96	103	0	0	0	0	0
91	105	98	97	104	0	0	0	0	0
92	106	99	98	105	0	0	0	0	0
93	108	103	102	107	0	0	0	0	0
94	109	104	103	108	0	0	0	0	0
95	110	105	104	109	0	0	0	0	0
96	111	106	105	110	0	0	0	0	0
97	113	108	107	112	0	0	0	0	0
98	114	109	108	113	0	0	0	0	0
99	115	110	109	114	0	0	0	0	0
100	116	111	110	115	0	0	0	0	0
101	118	113	112	117	0	0	0	0	0
102	119	114	113	118	0	0	0	0	0
103	120	115	114	119	0	0	0	0	0
104	121	116	115	120	0	0	0	0	0
105	123	118	117	122					
106	124	119	118	123					
107	125	120	119	124					
108	126	121	120	125					
109	128	123	122	127					
110	129	124	123	128					

```
111  130  125  124  129
112  131  126  125  130
113  133  128  127  132
114  134  129  128  133
115  135  130  129  134
116  136  131  130  135
117  138  133  132  137
118  139  134  133  138
119  140  135  134  139
120  141  136  135  140
121  143  138  137  142
122  144  139  138  143
123  145  140  139  144
124  146  141  140  145
125  148  143  142  147
126  149  144  143  148
127  150  145  144  149
128  151  146  145  150
  1                         NLOAD
  1                         NA
0.0                         XY
  8                         NSINGU
 10   19   28   37   46                          ICOD
  1    2    3    4    5     6    7    8          Ntip
  1    9   17   25   33                          Kelem
  2   11   20   29   38                          Mnode
  1                                              Ncase
125.0    1.07     0.8      1.0      5.0      1.0      50.0
  8                                                NLAYER
11.25    22.5     33.75   45.0    56.25    67.5    78.75    90.0    ANGL
0.0      0.2                R/T,A/C
 16   13                    NADH,NADL
  4                         NELEL -NUMBER OF LOADED ELEMENTS
125  126  127  128          KELEL -LOADED ELEMENT NUMBERS
0.0      0.125     0.25     0.35     0.55     0.75     1.0      1.5
2.5     4.0      7.0      11.0     20.0     35.0     55.0     85.0
125.0                       YADL
1.35     1.6      2.0      3.0      5.0      8.0     10.0     13.0
16.0     20.0     25.0     35.0     50.0     XADL
 66   65
 67   66
 74   67
 81   74
 88   81
 95   88
102   95
107  102
112  107
117  112
122  117
127  122
132  127
137  132
142  137
147  142
```

Table 2: Input data file ds28.

```
blackb 63% a.out
 FILE NAME ON WHICH THE INPUT EXISTS
ds28
 FILE NAME FOR WRITING THE OUPUT
dout28
 OUTPUT OPTION ---- CHOICES ARE:
 SHORT OR short
 XLONG OR xlong
short
 INPUT TYPE OF LOADING: CHOICES ARE
      REMOTE: REMOTE LOADING ON Y=H
      CFACE : CRACK FACE PRESSURE LOADING
remote
remote
 INPUT TYPE OF CRACK : CHOICES ARE
    SURF : SURFACE CRACK
    EMBE : EMBEDDED SURFACE CRACK
    CORN : CORNER CRACK IN A PLATE
    CHOL : CORNER CRACK FROM A HOLE
    SSEM : SURFACE CRACK AT A SEMI-CIRCULAR HOLE
    SHOL : SURFACE CRACK FROM A HOLE
surf
surf
 INPUT LOAD TYPE. THE CHOICES ARE:
     TENS OR tens   : REMOTE TENSION ALONG THE Y-AXIS
    BENDX OR bendx  : REMOTE BENDING ABOUT THE X-AXIS
    BENDZ OR bendz  : REMOTE BENDING ABOUT THE Z-AXIS

 NOTE THAT FOR THE LTYPE=CFACE ONLY UNIFORM CRACK-FACE
 PRESSURE LOADING IS ALLOWED IN THIS MESH GENERATOR
tens
          **************************************************
                VOLUME OF THE SOLID =        0.781202E+04
          **************************************************


          --------------------------------------------------
                THE MODEL HAS NO WEIRD ELEMENTS
          --------------------------------------------------


 PRESCRIBED DISPLACEMENTS
 INPUT 1 IF THERE ARE DISPLACEMENTS and
 INPUT 0 IF THERE ARE NONE
0
  THERE ARE                         0 PRESCIBED DISPLACEMENTS
STOP:
blackb 64%
```

Table 3: Intreactive session with the data file *ds28*.

```
  SURFACE CRACK-REMOTE TENSION   A/C=0.2 ,A/T=0.8
SHORT
    0.30000E+08    0.30000E+00
 2464 1856
    1         5.000000000         0.000000000         0.000000000
    2         5.002656718         0.000000000         0.000000000
    .
    .
    .
    .
 2463        50.000000000        85.000000000        -1.250000000
 2464        50.000000000       125.000000000        -1.250000000
    1  152     1    2  153  152    1    3  154    1
    2  152     1    3  154  152    1    4  155    1
    .
    .
    .
    .
 1853 2444 2443 2460 2461 2223 2222 2239 2240    0
 1854 2445 2444 2461 2462 2224 2223 2240 2241    0
 1855 2446 2445 2462 2463 2225 2224 2241 2242    0
 1856 2447 2446 2463 2464 2226 2225 2242 2243    0
         1    0    1    0
         2    0    1    0
         .
         .
         .
         .
      1358    1    0    0
      1359    1    0    0
      2464    0    0    1
         0    0    0    0
         1
REMOTE
       125  125    1    1    4
       126  126    1    1    4
       127  127    1    1    4
         .
         .
         .
         .
      1824 1824    1    1    4
      1840 1840    1    1    4
      1856 1856    1    1    4
         0    0    0    0    0
       147    0.0000    1.0000    0.0000
       148    0.0000    1.0000    0.0000
         .
         .
         .
         .
      2413    0.0000    1.0000    0.0000
      2430    0.0000    1.0000    0.0000
      2447    0.0000    1.0000    0.0000
      2464    0.0000    1.0000    0.0000
         0    0.0000    0.0000    0.0000
         0    0    0    0    0.00000E+00    0.00000E+00    0.00000E+00
         1
         1          2          3          4          5
         6          7          8          9         10
        11         12         13         14         15
         .
         .
         .
         .
         .
       908        917        926        935        944
      1059       1068       1077       1086       1095
      1059       1068       1077       1086       1095
      1210       1219       1228       1237       1246
  125.0000    50.0000     0.8000     1.2500     0.2000
```

Table 4: Output file dout28.

```
CORNER CRACK IN A PLATE - Deep Crack CASE A/C=1 A/T=0.8 R/t=1
 30.0e6              0.3              Eyoung, Nu
 151  128
1.00000    1    6   15   24   33   42   51   60   69   89
1.01320    2    0    0    0    0    0    0    0    0    0
1.01220    3    0    0    0    0    0    0    0    0    0
1.00930    4    0    0    0    0    0    0    0    0    0
1.00510    5    0    0    0    0    0    0    0    0    0
 .99490    7    0    0    0    0    0    0    0    0    0
 .99070    8    0    0    0    0    0    0    0    0    0
 .98780    9    0    0    0    0    0    0    0    0    0
 .98680   10    0    0    0    0    0    0    0    0    0
1.02640   11    0    0    0    0    0    0    0    0    0
1.02440   12    0    0    0    0    0    0    0    0    0
1.01870   13    0    0    0    0    0    0    0    0    0
1.01010   14    0    0    0    0    0    0    0    0    0
0.98990   16    0    0    0    0    0    0    0    0    0
 .98130   17    0    0    0    0    0    0    0    0    0
 .97560   18    0    0    0    0    0    0    0    0    0
 .97360   19    0    0    0    0    0    0    0    0    0
1.04000   20    0    0    0    0    0    0    0    0    0
1.03700   21    0    0    0    0    0    0    0    0    0
1.02830   22    0    0    0    0    0    0    0    0    0
1.01530   23    0    0    0    0    0    0    0    0    0
 .98470   25    0    0    0    0    0    0    0    0    0
 .97170   26    0    0    0    0    0    0    0    0    0
 .96300   27    0    0    0    0    0    0    0    0    0
 .96000   28    0    0    0    0    0    0    0    0    0
1.07000   29    0    0    0    0    0    0    0    0    0
1.06467   30    0    0    0    0    0    0    0    0    0
1.04950   31   82    0    0    0    0    0    0    0    0
1.02680   32    0    0    0    0    0    0    0    0    0
0.97320   34    0    0    0    0    0    0    0    0    0
 .95050   35   76    0    0    0    0    0    0    0    0
 .93533   36    0    0    0    0    0    0    0    0    0
 .93000   37    0    0    0    0    0    0    0    0    0
1.11000   38    0    0    0    0    0    0    0    0    0
1.10163   39    0    0    0    0    0    0    0    0    0
1.07778   40    0    0    0    0    0    0    0    0    0
1.04210   41    0    0    0    0    0    0    0    0    0
 .95790   43    0    0    0    0    0    0    0    0    0
 .92222   44    0    0    0    0    0    0    0    0    0
 .89837   45    0    0    0    0    0    0    0    0    0
 .89000   46    0    0    0    0    0    0    0    0    0
1.15000   47   48   49    0    0    0    0    0    0    0
1.07500   50    0    0    0    0    0    0    0    0    0
 .92500   52    0    0    0    0    0    0    0    0    0
 .85000   53   54   55   83    0    0    0    0    0    0
1.20000   56   57   58    0    0    0    0    0    0    0
1.10000   59   75    0    0    0    0    0    0    0    0
 .90000   61    0    0    0    0    0    0    0    0    0
 .80000   62   63   64   77    0    0    0    0    0    0
1.25000   65   66   67   74   81   88   95  102  107  112
1.25000  117  122  127  132  137  142  147
1.12500   68    0    0    0    0    0    0    0    0    0
 .87500   70    0    0    0    0    0    0    0    0    0
 .75000   71   72   73   90    0    0    0    0    0    0
 .65000   78   79   80   84    0    0    0    0    0    0
 .45000   85   86   87    0    0    0    0    0    0    0
 .50000   91    0    0    0    0    0    0    0    0    0
 .25000   92   93   94    0    0    0    0    0    0    0
 .93750   96  103  108  113  118  123  128  133  138  143
 .93750  148
 .62500   97  104  109  114  119  124  129  134  139  144
 .62500  149
 .31250   98  105  110  115  120  125  130  135  140  145
 .31250  150
 .00100   99  100  101  106  111  116  121  126  131  136
 .00100  141  146  151
0.0000     0
0.00000    1    2   10   11   19   20   28   29   37   38
0.00000   46   47   55   56   64   65   73   80   87   94
0.00000  101    0    0    0    0    0    0    0    0    0
 .00510    3    9    0    0    0    0    0    0    0    0
 .00930    4    8   12   18    0    0    0    0    0    0
```

.01220	5	6	7	0	0	0	0	0	0	0
.01870	13	17	0	0	0	0	0	0	0	0
.02440	14	16	0	0	0	0	0	0	0	0
.02640	15	30	36	0	0	0	0	0	0	0
.01530	21	27	0	0	0	0	0	0	0	0
.02830	22	26	0	0	0	0	0	0	0	0
.03700	23	25	0	0	0	0	0	0	0	0
.04000	24	0	0	0	0	0	0	0	0	0
.04950	31	35	0	0	0	0	0	0	0	0
.06467	32	34	0	0	0	0	0	0	0	0
.07000	33	0	0	0	0	0	0	0	0	0
.04210	39	45	0	0	0	0	0	0	0	0
.07778	40	44	0	0	0	0	0	0	0	0
.10163	41	43	0	0	0	0	0	0	0	0
.11000	42	0	0	0	0	0	0	0	0	0
.07500	48	54	0	0	0	0	0	0	0	0
.15000	49	50	51	52	53	0	0	0	0	0
.10000	57	63	0	0	0	0	0	0	0	0
.20000	58	59	60	61	62	0	0	0	0	0
.12500	66	72	0	0	0	0	0	0	0	0
.25000	67	68	69	70	71	0	0	0	0	0
.35000	74	75	76	77	78	0	0	0	0	0
.17500	79	0	0	0	0	0	0	0	0	0
.55000	81	82	83	84	85	0	0	0	0	0
.27500	86	0	0	0	0	0	0	0	0	0
.75000	88	89	90	91	92	0	0	0	0	0
.37500	93	0	0	0	0	0	0	0	0	0
1.00000	95	96	97	98	99	0	0	0	0	0
.50000	100	0	0	0	0	0	0	0	0	0
1.50000	102	103	104	105	106	0	0	0	0	0
2.50000	107	108	109	110	111	0	0	0	0	0
4.00000	112	113	114	115	116	0	0	0	0	0
7.00000	117	118	119	120	121	0	0	0	0	0
11.00000	122	123	124	125	126	0	0	0	0	0
20.00000	127	128	129	130	131	0	0	0	0	0
35.00000	132	133	134	135	136	0	0	0	0	0
55.00000	137	138	139	140	141	0	0	0	0	0
85.00000	142	143	144	145	146	0	0	0	0	0
125.00000	147	148	149	150	151	0	0	0	0	0
0.0000	0									

1	1	1	2	3	0	0	0	0	1
2	1	1	3	4	0	0	0	0	1
3	1	1	4	5	0	0	0	0	1
4	1	1	5	6	0	0	0	0	1
5	1	1	6	7	0	0	0	0	1
6	1	1	7	8	0	0	0	0	1
7	1	1	8	9	0	0	0	0	1
8	1	1	9	10	0	0	0	0	1
9	3	2	11	12	0	0	0	0	0
10	4	3	12	13	0	0	0	0	0
11	5	4	13	14	0	0	0	0	0
12	6	5	14	15	0	0	0	0	0
13	7	6	15	16	0	0	0	0	0
14	8	7	16	17	0	0	0	0	0
15	9	8	17	18	0	0	0	0	0
16	18	19	10	9	0	0	0	0	0
17	12	11	20	21	0	0	0	0	0
18	13	12	21	22	0	0	0	0	0
19	14	13	22	23	0	0	0	0	0
20	15	14	23	24	0	0	0	0	0
21	16	15	24	25	0	0	0	0	0
22	17	16	25	26	0	0	0	0	0
23	18	17	26	27	0	0	0	0	0
24	27	28	19	18	0	0	0	0	0
25	21	20	29	30	0	0	0	0	0
26	22	21	30	31	0	0	0	0	0
27	23	22	31	32	0	0	0	0	0
28	24	23	32	33	0	0	0	0	0
29	25	24	33	34	0	0	0	0	0
30	26	25	34	35	0	0	0	0	0
31	27	26	35	36	0	0	0	0	0
32	36	37	28	27	0	0	0	0	0
33	30	29	38	39	0	0	0	0	0
34	31	30	39	40	0	0	0	0	0
35	32	31	40	41	0	0	0	0	0

36	33	32	41	42	0	0	0	0	0
37	34	33	42	43	0	0	0	0	0
38	35	34	43	44	0	0	0	0	0
39	36	35	44	45	0	0	0	0	0
40	45	46	37	36	0	0	0	0	0
41	39	38	47	48	0	0	0	0	0
42	40	39	48	49	0	0	0	0	0
43	41	40	49	50	0	0	0	0	0
44	42	41	50	51	0	0	0	0	0
45	43	42	51	52	0	0	0	0	0
46	44	43	52	53	0	0	0	0	0
47	45	44	53	54	0	0	0	0	0
48	54	55	46	45	0	0	0	0	0
49	48	47	56	57	0	0	0	0	0
50	49	48	57	58	0	0	0	0	0
51	50	49	58	59	0	0	0	0	0
52	51	50	59	60	0	0	0	0	0
53	52	51	60	61	0	0	0	0	0
54	53	52	61	62	0	0	0	0	0
55	54	53	62	63	0	0	0	0	0
56	63	64	55	54	0	0	0	0	0
57	57	56	65	66	0	0	0	0	0
58	58	57	66	67	0	0	0	0	0
59	59	58	67	68	0	0	0	0	0
60	60	59	68	69	0	0	0	0	0
61	61	60	69	70	0	0	0	0	0
62	62	61	70	71	0	0	0	0	0
63	63	62	71	72	0	0	0	0	0
64	72	73	64	63	0	0	0	0	0
65	75	68	67	74	0	0	0	0	0
66	76	69	68	75	0	0	0	0	0
67	77	70	69	76	0	0	0	0	0
68	78	71	70	77	0	0	0	0	0
69	79	72	71	78	0	0	0	0	0
70	79	80	73	72	0	0	0	0	0
71	82	75	74	81	0	0	0	0	0
72	83	76	75	82	0	0	0	0	0
73	84	77	76	83	0	0	0	0	0
74	85	78	77	84	0	0	0	0	0
75	86	79	78	85	0	0	0	0	0
76	86	87	80	79	0	0	0	0	0
77	89	82	81	88	0	0	0	0	0
78	90	83	82	89	0	0	0	0	0
79	91	84	83	90	0	0	0	0	0
80	92	85	84	91	0	0	0	0	0
81	93	86	85	92	0	0	0	0	0
82	93	94	87	86	0	0	0	0	0
83	96	89	88	95	0	0	0	0	0
84	97	90	89	96	0	0	0	0	0
85	98	91	90	97	0	0	0	0	0
86	99	92	91	98	0	0	0	0	0
87	100	93	92	99	0	0	0	0	0
88	100	101	94	93	0	0	0	0	0
89	103	96	95	102	0	0	0	0	0
90	104	97	96	103	0	0	0	0	0
91	105	98	97	104	0	0	0	0	0
92	106	99	98	105	0	0	0	0	0
93	108	103	102	107	0	0	0	0	0
94	109	104	103	108	0	0	0	0	0
95	110	105	104	109	0	0	0	0	0
96	111	106	105	110	0	0	0	0	0
97	113	108	107	112	0	0	0	0	0
98	114	109	108	113	0	0	0	0	0
99	115	110	109	114	0	0	0	0	0
100	116	111	110	115	0	0	0	0	0
101	118	113	112	117	0	0	0	0	0
102	119	114	113	118	0	0	0	0	0
103	120	115	114	119	0	0	0	0	0
104	121	116	115	120	0	0	0	0	0
105	123	118	117	122					
106	124	119	118	123					
107	125	120	119	124					
108	126	121	120	125					
109	128	123	122	127					
110	129	124	123	128					

```
111  130  125  124  129
112  131  126  125  130
113  133  128  127  132
114  134  129  128  133
115  135  130  129  134
116  136  131  130  135
117  138  133  132  137
118  139  134  133  138
119  140  135  134  139
120  141  136  135  140
121  143  138  137  142
122  144  139  138  143
123  145  140  139  144
124  146  141  140  145
125  148  143  142  147
126  149  144  143  148
127  150  145  144  149
128  151  146  145  150
  1                           NLOAD
  1                           NA
0.0                           XY
  8                           Nsingu
 10    19    28    37   46                                  ICOD
  1     2     3     4    5    6     7     8                 Ntip
  1     9    17    25   33                                  Kelem
  2    11    20    29   38                                  Mnode
  1                                                         Ncase
125.0     1.07      0.8      1.0       1.0        1.0       25.0
  8                                                         NLAYER
11.25     22.5      33.75    45.0      56.25      67.5      78.75     90.0    ANGL
1.0       1.0                                               R/T,A/C
 5                                                          NH
0.95      0.85      0.7      0.4    0.0                     PER(I), I=1,NH
 16    10                    NADH,NADL
  4                          NUMBER OF LOADED ELEMENTS
125  126  127  128           ELEMENT NUMBERS
0.0       0.125      0.25      0.35      0.55      0.75      1.0      1.5
2.5     4.0        7.0       11.0      20.0      35.0      55.0     85.0
125.0                        YADL
1.4       1.6        1.8       2.0       2.5       3.5       5.0      8.0
13.0      25.0               XADL
 66   65
 67   66
 74   67
 81   74
 88   81
 95   88
102   95
107  102
112  107
117  112
122  117
127  122
132  127
137  132
142  137
147  142
```

Table 5: Input data file dch18.

```
a.out
 FILE NAME ON WHICH THE INPUT EXISTS
dch18
 FILE NAME FOR WRITING THE OUPUT
dcorn18
 OUTPUT OPTION ---- CHOICES ARE:
 SHORT OR short
 XLONG OR xlong
short
 INPUT TYPE OF LOADING: CHOICES ARE
      REMOTE: REMOTE LOADING ON Y=H
      CFACE : CRACK FACE PRESSURE LOADING
remote
remote
 INPUT TYPE OF CRACK : CHOICES ARE
    SURF : SURFACE CRACK
    EMBE : EMBEDDED SURFACE CRACK
    CORN : CORNER CRACK IN A PLATE
    CHOL : CORNER CRACK FROM A HOLE
    SSEM : SURFACE CRACK AT A SEMI-CIRCULAR HOLE
    SHOL : SURFACE CRACK FROM A HOLE
chol
chol
 INPUT LOAD TYPE. THE CHOICES ARE:
     TENS OR tens   : REMOTE TENSION ALONG THE Y-AXIS
    BENDX OR bendx : REMOTE BENDING ABOUT THE X-AXIS
    BENDZ OR bendz : REMOTE BENDING ABOUT THE Z-AXIS

 NOTE THAT FOR THE LTYPE=CFACE ONLY UNIFORM CRACK-FACE
 PRESSURE LOADING IS ALLOWED IN THIS MESH GENERATOR
tens
          **************************************************
                VOLUME OF THE SOLID =        0.409990E+04
          **************************************************


          --------------------------------------------------
                THE MODEL HAS NO WEIRD ELEMENTS
          --------------------------------------------------


 PRESCRIBED DISPLACEMENTS
 INPUT 1 IF THERE ARE DISPLACEMENTS and
 INPUT 0 IF THERE ARE NONE
0
  THERE ARE                      0 PRESCIBED DISPLACEMENTS
STOP:
```

Table 6: Interactive session with the data file *dch18*.

```
   CORNER CRACK IN A PLATE - DEEP CRACK CASE A/C=1 A/T=0.8 R/T=1
SHORT
   0.30000E+08    0.30000E+00
 2964 2304
    1          1.000000000          0.000000000          0.000000000
    2          1.013200000          0.000000000          0.000000000
    .
    .
    .
    .
    .
 2959         25.000000000         11.000000000         -1.250000000
 2960         25.000000000         20.000000000         -1.250000000
 2961         25.000000000         35.000000000         -1.250000000
 2962         25.000000000         55.000000000         -1.250000000
 2963         25.000000000         85.000000000         -1.250000000
 2964         25.000000000        125.000000000         -1.250000000
    1  152    1    2  153  152    1    3  154    1
    2  152    1    3  154  152    1    4  155    1
    .
    .
    .
    .
    .
 2300 2943 2942 2959 2960 2773 2772 2789 2790    0
 2301 2944 2943 2960 2961 2774 2773 2790 2791    0
 2302 2945 2944 2961 2962 2775 2774 2791 2792    0
 2303 2946 2945 2962 2963 2776 2775 2792 2793    0
 2304 2947 2946 2963 2964 2777 2776 2793 2794    0
         1    0    1    0
         2    0    1    0
        11    0    1    0
         .
         .
         .
         .
         .
      2112    1    0    0
      2113    1    0    0
      2114    1    0    0
      2964    0    0    1
         0    0    0    0
         1
REMOTE
       125  125    1    1    4
       126  126    1    1    4
       127  127    1    1    4
         .
         .
         .
         .
         .
      2256 2256    1    1    4
      2272 2272    1    1    4
      2288 2288    1    1    4
      2304 2304    1    1    4
         0    0    0    0    0
       147    0.0000    1.0000    0.0000
       148    0.0000    1.0000    0.0000
       149    0.0000    1.0000    0.0000
       150    0.0000    1.0000    0.0000
         .
         .
         .
         .
      2947    0.0000    1.0000    0.0000
      2964    0.0000    1.0000    0.0000
         0    0.0000    0.0000    0.0000
         0    0    0    0    0.00000E+00    0.00000E+00    0.00000E+00
         1
         1         2         3         4         5
         6         7         8         9        10
        11        12        13        14        15
         .
         .
```

.
.
.

1210	1219	1228	1237	1246
125.0000	25.0000	0.8000	2.5000	1.0000

Table 7: Output file dcorn18.

```
a.out
 FILE NAME ON WHICH THE INPUT EXISTS
ds12d
 FILE NAME FOR WRITING THE OUPUT
dpdsip12
 OUTPUT OPTION ---- CHOICES ARE:
 SHORT OR short
 XLONG OR xlong
shortdd
 W R O N G   C H O I C E S -- T R Y AGAIN
 OUTPUT OPTION ---- CHOICES ARE:
 SHORT OR short
 XLONG OR xlong
s   Shio       Ort
 W R O N G   C H O I C E S -- T R Y AGAIN
 OUTPUT OPTION ---- CHOICES ARE:
 SHORT OR short
 XLONG OR xlong
sHORT
 W R O N G   C H O I C E S -- T R Y AGAIN
 OUTPUT OPTION ---- CHOICES ARE:
 SHORT OR short
 XLONG OR xlong
short

 INPUT TYPE OF LOADING: CHOICES ARE
      REMOTE: REMOTE LOADING ON Y=H
      CFACE : CRACK FACE PRESSURE LOADING
Remote
Remote
 W R O N G   C H O I C E S -- T R Y AGAIN
 INPUT TYPE OF LOADING: CHOICES ARE
      REMOTE: REMOTE LOADING ON Y=H
      CFACE : CRACK FACE PRESSURE LOADING
remote
remote
 INPUT TYPE OF CRACK : CHOICES ARE
    SURF : SURFACE CRACK
    EMBE : EMBEDDED SURFACE CRACK
    CORN : CORNER CRACK IN A PLATE
    CHOL : CORNER CRACK FROM A HOLE
    SSEM : SURFACE CRACK AT A SEMI-CIRCULAR HOLE
    SHOL : SURFACE CRACK FROM A HOLE
Surf
Surf
 W R O N G   C H O I C E S -- T R Y AGAIN
 INPUT TYPE OF CRACK : CHOICES ARE
    SURF : SURFACE CRACK
    EMBE : EMBEDDED SURFACE CRACK
    CORN : CORNER CRACK IN A PLATE
    CHOL : CORNER CRACK FROM A HOLE
    SSEM : SURFACE CRACK AT A SEMI-CIRCULAR HOLE
    SHOL : SURFACE CRACK FROM A HOLE
surF
surF
 W R O N G   C H O I C E S -- T R Y AGAIN
 INPUT TYPE OF CRACK : CHOICES ARE
    SURF : SURFACE CRACK
```

```
    EMBE : EMBEDDED SURFACE CRACK
    CORN : CORNER CRACK IN A PLATE
    CHOL : CORNER CRACK FROM A HOLE
    SSEM : SURFACE CRACK AT A SEMI-CIRCULAR HOLE
    SHOL : SURFACE CRACK FROM A HOLE
surf
surf
 INPUT LOAD TYPE. THE CHOICES ARE:
     TENS OR tens  : REMOTE TENSION ALONG THE Y-AXIS
    BENDX OR bendx : REMOTE BENDING ABOUT THE X-AXIS
    BENDZ OR bendz : REMOTE BENDING ABOUT THE Z-AXIS

 NOTE THAT FOR THE LTYPE=CFACE ONLY UNIFORM CRACK-FACE
 PRESSURE LOADING IS ALLOWED IN THIS MESH GENERATOR
tenS
 W R O N G   C H O I C E S -- T R Y AGAIN
 INPUT LOAD TYPE. THE CHOICES ARE:
     TENS OR tens  : REMOTE TENSION ALONG THE Y-AXIS
    BENDX OR bendx : REMOTE BENDING ABOUT THE X-AXIS
    BENDZ OR bendz : REMOTE BENDING ABOUT THE Z-AXIS

 NOTE THAT FOR THE LTYPE=CFACE ONLY UNIFORM CRACK-FACE
 PRESSURE LOADING IS ALLOWED IN THIS MESH GENERATOR
Tens
 W R O N G   C H O I C E S -- T R Y AGAIN
 INPUT LOAD TYPE. THE CHOICES ARE:
     TENS OR tens  : REMOTE TENSION ALONG THE Y-AXIS
    BENDX OR bendx : REMOTE BENDING ABOUT THE X-AXIS
    BENDZ OR bendz : REMOTE BENDING ABOUT THE Z-AXIS

 NOTE THAT FOR THE LTYPE=CFACE ONLY UNIFORM CRACK-FACE
 PRESSURE LOADING IS ALLOWED IN THIS MESH GENERATOR
tens
           **************************************************
                 VOLUME OF THE SOLID =        0.156250E+05
           **************************************************


           --------------------------------------------------
                 THE MODEL HAS NO WEIRD ELEMENTS
           --------------------------------------------------


 PRESCRIBED DISPLACEMENTS
 INPUT 1 IF THERE ARE DISPLACEMENTS and
 INPUT 0 IF THERE ARE NONE
1
 PRESCIBED DISPLACEMENTS ON
 X=CONSTANT,  OR Y=CONSTANT, OR Z=CONSTANT PLANES
 INPUT 1 FOR THE PRESCIBED FACE  AND 0 FOR OTHERS
 FOR EXAMPLE
 0,1,0
 0, 125.0, 0
 DENOTES THAT THE Y= 125.0 FACE HAS
 PRESCRIBED DISPLACEMENTS
 NOTE THAT TWO LINES  - THREE INTEGERS
 and THREE FLOATING POINT NUMBERS ARE READ
0,1,0
```

```
0,125.0,0
 NOW READ THE MAGNITUDE OF THE DISPLACEMENTS
 READ THREE VALUES OF DISPLACEMENTS
  FOR EXAMPLE- 0.0, 1.0e-6, 0.0
0.0,0.       2.0e-7,0.0
  THERE ARE                      83 PRESCIBED DISPLACEMENTS
STOP:
blackb 9%
```

Table 8: Inteactive session with data file *ds12d*.

```
   SURFACE CRACK IN A PLATE TENSION AND BENDING  A/C=1.0 A/T=0.2
short
    0.30000E+08     0.30000E+00
 2161 1664
    1          1.000000000          0.000000000          0.000000000
    2          1.013200000          0.000000000          0.000000000
    .
    .
    .
    .
 2159         25.000000000         45.000000000         -5.000000000
 2160         25.000000000         85.000000000         -5.000000000
 2161         25.000000000        125.000000000         -5.000000000
    1  210    1    2  211  210    1    3  212    1
    2  210    1    3  212  210    1    4  213    1
    3  210    1    4  213  210    1    5  214    1
    .
    .
    .
    .
 1662 2145 2144 2158 2159 2089 2088 2102 2103    0
 1663 2146 2145 2159 2160 2090 2089 2103 2104    0
 1664 2147 2146 2160 2161 2091 2090 2104 2105    0
         1    0    1    0
         2    0    1    0
        11    0    1    0
         .
         .
         .
         .
      1880    1    0    0
      1881    1    0    0
      2161    0    0    1
         0    0    0    0
         1
remote
         0    0    0    0    0
         0    0.0000    0.0000    0.0000
       203    0    1    0    0.00000E+00    0.20000E-06    0.00000E+00
       204    0    1    0    0.00000E+00    0.20000E-06    0.00000E+00
       205    0    1    0    0.00000E+00    0.20000E-06    0.00000E+00
       206    0    1    0    0.00000E+00    0.20000E-06    0.00000E+00
       207    0    1    0    0.00000E+00    0.20000E-06    0.00000E+00
       208    0    1    0    0.00000E+00    0.20000E-06    0.00000E+00
       209    0    1    0    0.00000E+00    0.20000E-06    0.00000E+00
       412    0    1    0    0.00000E+00    0.20000E-06    0.00000E+00
       413    0    1    0    0.00000E+00    0.20000E-06    0.00000E+00
       414    0    1    0    0.00000E+00    0.20000E-06    0.00000E+00
       415    0    1    0    0.00000E+00    0.20000E-06    0.00000E+00
       416    0    1    0    0.00000E+00    0.20000E-06    0.00000E+00
       417    0    1    0    0.00000E+00    0.20000E-06    0.00000E+00
       418    0    1    0    0.00000E+00    0.20000E-06    0.00000E+00
       621    0    1    0    0.00000E+00    0.20000E-06    0.00000E+00
       622    0    1    0    0.00000E+00    0.20000E-06    0.00000E+00
       623    0    1    0    0.00000E+00    0.20000E-06    0.00000E+00
       624    0    1    0    0.00000E+00    0.20000E-06    0.00000E+00
       625    0    1    0    0.00000E+00    0.20000E-06    0.00000E+00
       626    0    1    0    0.00000E+00    0.20000E-06    0.00000E+00
       627    0    1    0    0.00000E+00    0.20000E-06    0.00000E+00
       830    0    1    0    0.00000E+00    0.20000E-06    0.00000E+00
       831    0    1    0    0.00000E+00    0.20000E-06    0.00000E+00
       832    0    1    0    0.00000E+00    0.20000E-06    0.00000E+00
       833    0    1    0    0.00000E+00    0.20000E-06    0.00000E+00
       834    0    1    0    0.00000E+00    0.20000E-06    0.00000E+00
       835    0    1    0    0.00000E+00    0.20000E-06    0.00000E+00
       836    0    1    0    0.00000E+00    0.20000E-06    0.00000E+00
      1039    0    1    0    0.00000E+00    0.20000E-06    0.00000E+00
      1040    0    1    0    0.00000E+00    0.20000E-06    0.00000E+00
      1041    0    1    0    0.00000E+00    0.20000E-06    0.00000E+00
      1042    0    1    0    0.00000E+00    0.20000E-06    0.00000E+00
      1043    0    1    0    0.00000E+00    0.20000E-06    0.00000E+00
      1044    0    1    0    0.00000E+00    0.20000E-06    0.00000E+00
      1045    0    1    0    0.00000E+00    0.20000E-06    0.00000E+00
      1248    0    1    0    0.00000E+00    0.20000E-06    0.00000E+00
      1249    0    1    0    0.00000E+00    0.20000E-06    0.00000E+00
```

```
    1250    0    1    0     0.00000E+00     0.20000E-06     0.00000E+00
    1251    0    1    0     0.00000E+00     0.20000E-06     0.00000E+00
    1252    0    1    0     0.00000E+00     0.20000E-06     0.00000E+00
    1253    0    1    0     0.00000E+00     0.20000E-06     0.00000E+00
    1254    0    1    0     0.00000E+00     0.20000E-06     0.00000E+00
    1457    0    1    0     0.00000E+00     0.20000E-06     0.00000E+00
    1458    0    1    0     0.00000E+00     0.20000E-06     0.00000E+00
    1459    0    1    0     0.00000E+00     0.20000E-06     0.00000E+00
    1460    0    1    0     0.00000E+00     0.20000E-06     0.00000E+00
    1461    0    1    0     0.00000E+00     0.20000E-06     0.00000E+00
    1462    0    1    0     0.00000E+00     0.20000E-06     0.00000E+00
    1463    0    1    0     0.00000E+00     0.20000E-06     0.00000E+00
    1666    0    1    0     0.00000E+00     0.20000E-06     0.00000E+00
    1667    0    1    0     0.00000E+00     0.20000E-06     0.00000E+00
    1668    0    1    0     0.00000E+00     0.20000E-06     0.00000E+00
    1669    0    1    0     0.00000E+00     0.20000E-06     0.00000E+00
    1670    0    1    0     0.00000E+00     0.20000E-06     0.00000E+00
    1671    0    1    0     0.00000E+00     0.20000E-06     0.00000E+00
    1672    0    1    0     0.00000E+00     0.20000E-06     0.00000E+00
    1875    0    1    0     0.00000E+00     0.20000E-06     0.00000E+00
    1876    0    1    0     0.00000E+00     0.20000E-06     0.00000E+00
    1877    0    1    0     0.00000E+00     0.20000E-06     0.00000E+00
    1878    0    1    0     0.00000E+00     0.20000E-06     0.00000E+00
    1879    0    1    0     0.00000E+00     0.20000E-06     0.00000E+00
    1880    0    1    0     0.00000E+00     0.20000E-06     0.00000E+00
    1881    0    1    0     0.00000E+00     0.20000E-06     0.00000E+00
    1895    0    1    0     0.00000E+00     0.20000E-06     0.00000E+00
    1909    0    1    0     0.00000E+00     0.20000E-06     0.00000E+00
    1923    0    1    0     0.00000E+00     0.20000E-06     0.00000E+00
    1937    0    1    0     0.00000E+00     0.20000E-06     0.00000E+00
    1951    0    1    0     0.00000E+00     0.20000E-06     0.00000E+00
    1965    0    1    0     0.00000E+00     0.20000E-06     0.00000E+00
    1979    0    1    0     0.00000E+00     0.20000E-06     0.00000E+00
    1993    0    1    0     0.00000E+00     0.20000E-06     0.00000E+00
    2007    0    1    0     0.00000E+00     0.20000E-06     0.00000E+00
    2021    0    1    0     0.00000E+00     0.20000E-06     0.00000E+00
    2035    0    1    0     0.00000E+00     0.20000E-06     0.00000E+00
    2049    0    1    0     0.00000E+00     0.20000E-06     0.00000E+00
    2063    0    1    0     0.00000E+00     0.20000E-06     0.00000E+00
    2077    0    1    0     0.00000E+00     0.20000E-06     0.00000E+00
    2091    0    1    0     0.00000E+00     0.20000E-06     0.00000E+00
    2105    0    1    0     0.00000E+00     0.20000E-06     0.00000E+00
    2119    0    1    0     0.00000E+00     0.20000E-06     0.00000E+00
    2133    0    1    0     0.00000E+00     0.20000E-06     0.00000E+00
    2147    0    1    0     0.00000E+00     0.20000E-06     0.00000E+00
    2161    0    1    0     0.00000E+00     0.20000E-06     0.00000E+00
       0    0    0    0     0.00000E+00     0.00000E+00     0.00000E+00
       1
       1          2          3          4          5
       6          7          8          9         10
      11         12         13         14         15
       .
       .
       .
       .
       .
    1256       1265       1274       1283       1292
    1465       1474       1483       1492       1501
    1465       1474       1483       1492       1501
    1674       1683       1692       1701       1710
125.0000    25.0000     0.2000     5.0000     1.0000
```

Table 9: Output file dpdisp12.

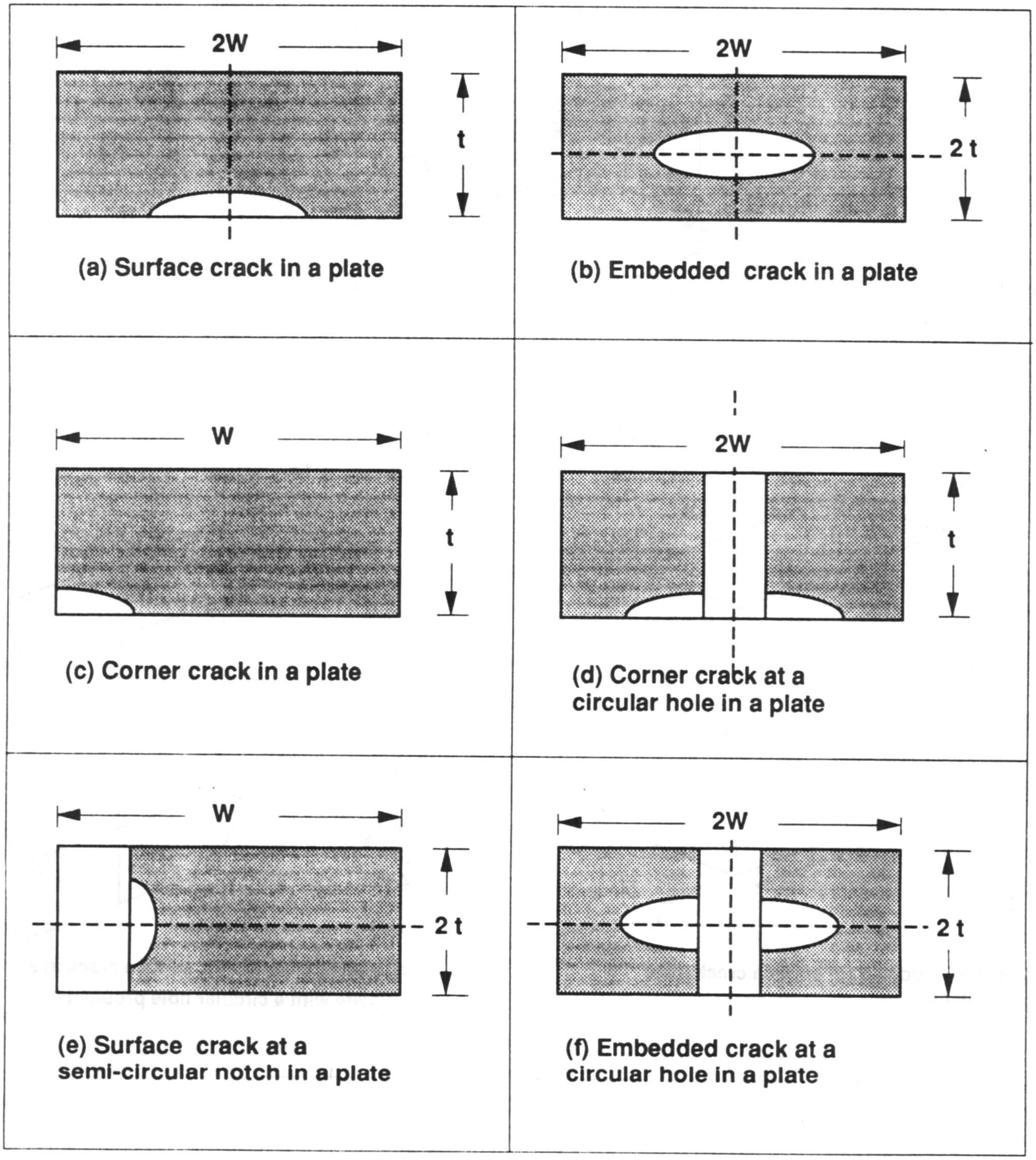
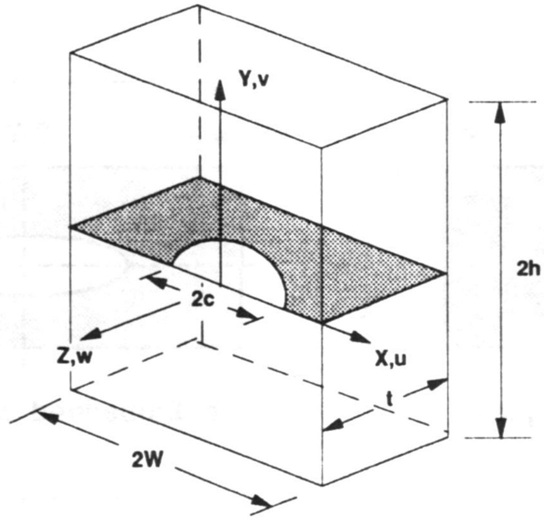
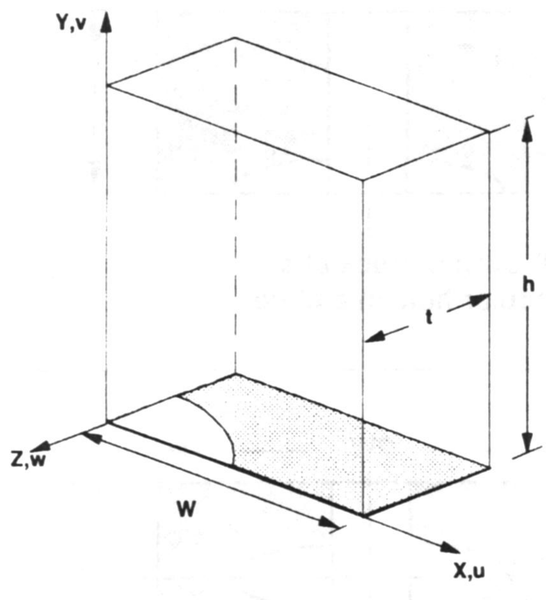


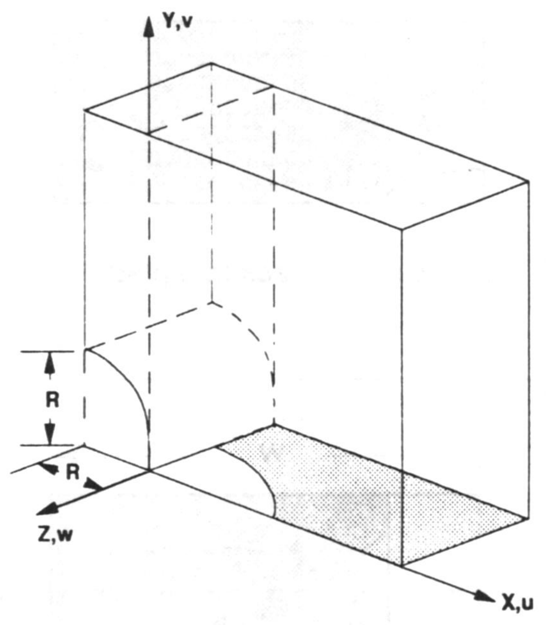
Figure 1: Crack Configurations.
(Elliptic crack: Semi-major axis= c ; Semi-minor axis= a)



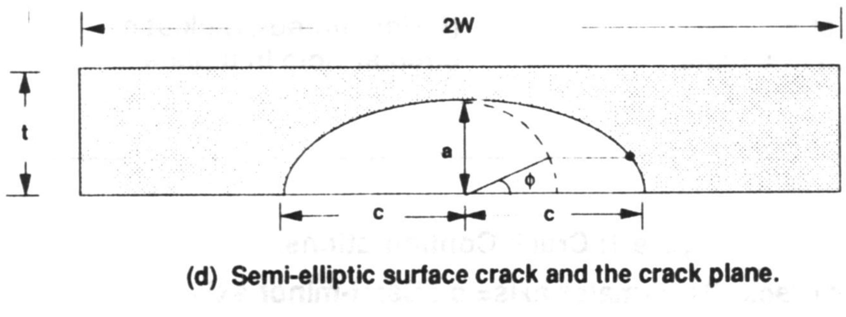
(a) Surface crack in a plate



(b) Region modeled for surface crack plate problems.

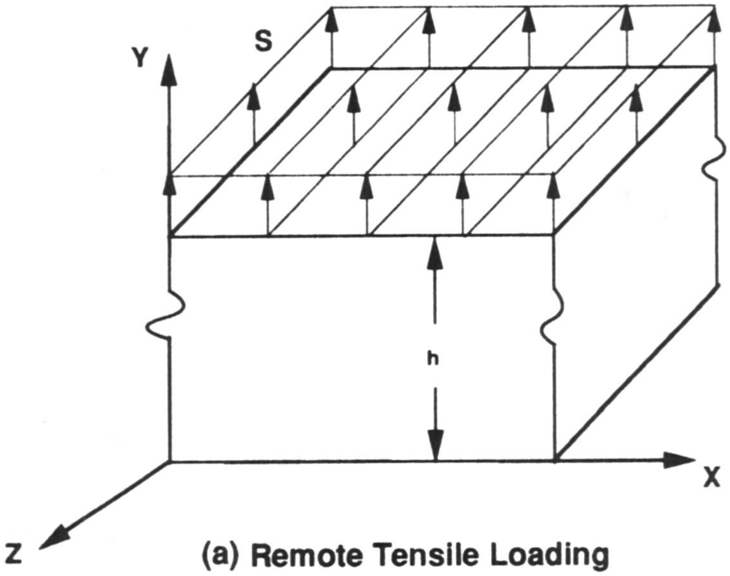


(c) Region modeled for surface crack in a plate with a circular hole problems.



(d) Semi-elliptic surface crack and the crack plane.

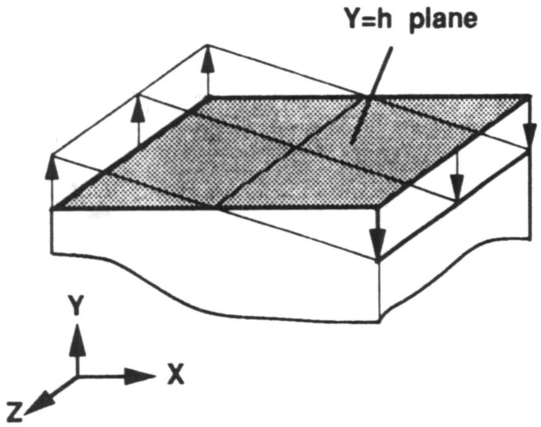
Figure 2: Surface crack in a finite thickness plate.



(a) Remote Tensile Loading

$\sigma_y = S$ on $y=h$

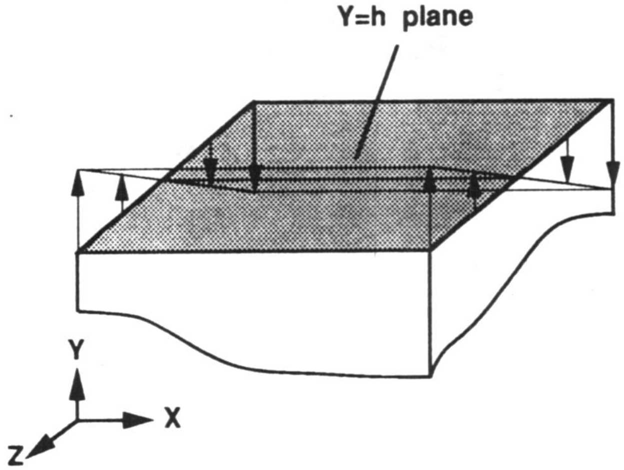
$0 \leq Z < -t \;;\; 0 \leq X \leq W$



(b) Bending about z-axis

$\sigma_y = 1 - 2X / W$

$0 \leq X \leq W$



(c) Bending about x-axis

$\sigma_y = 1 + 2\,(Z / t)$

$0 \leq Z \leq -t$

Figure 3: Remote loading applied to the models.

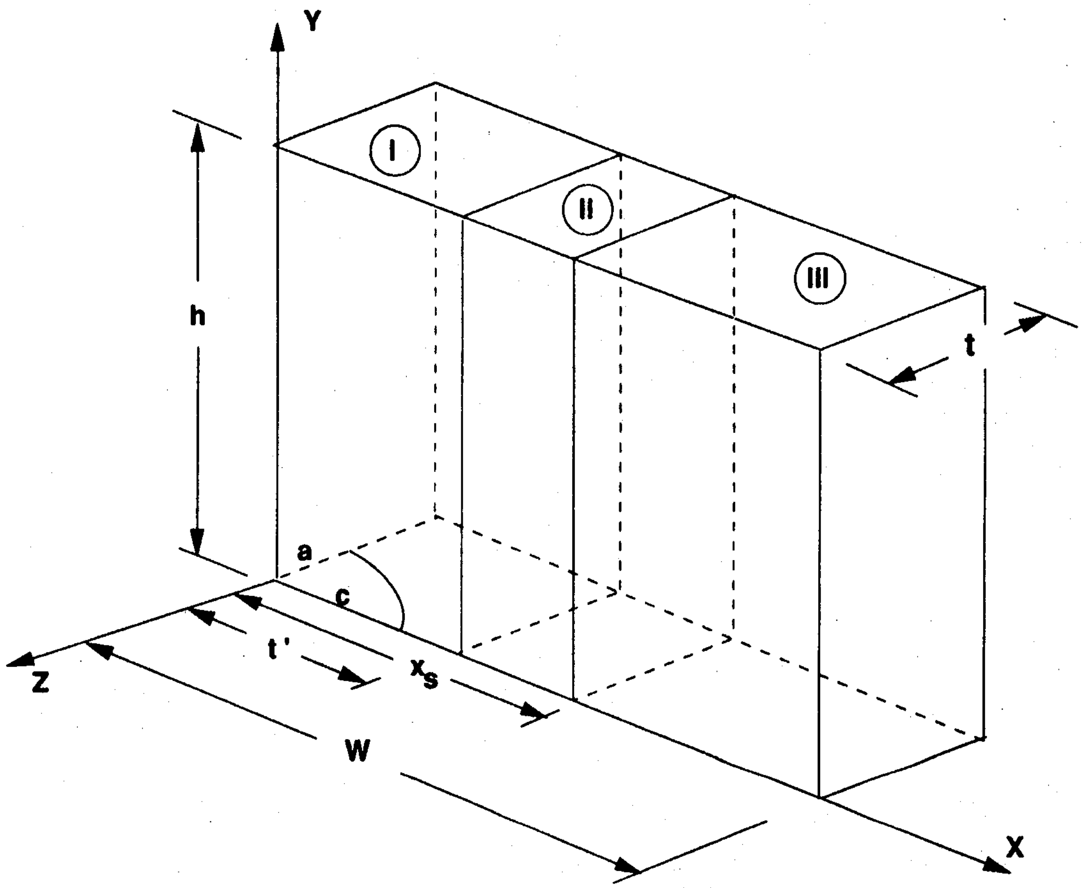


Figure 4. Regions I, II and III, used to build the model.

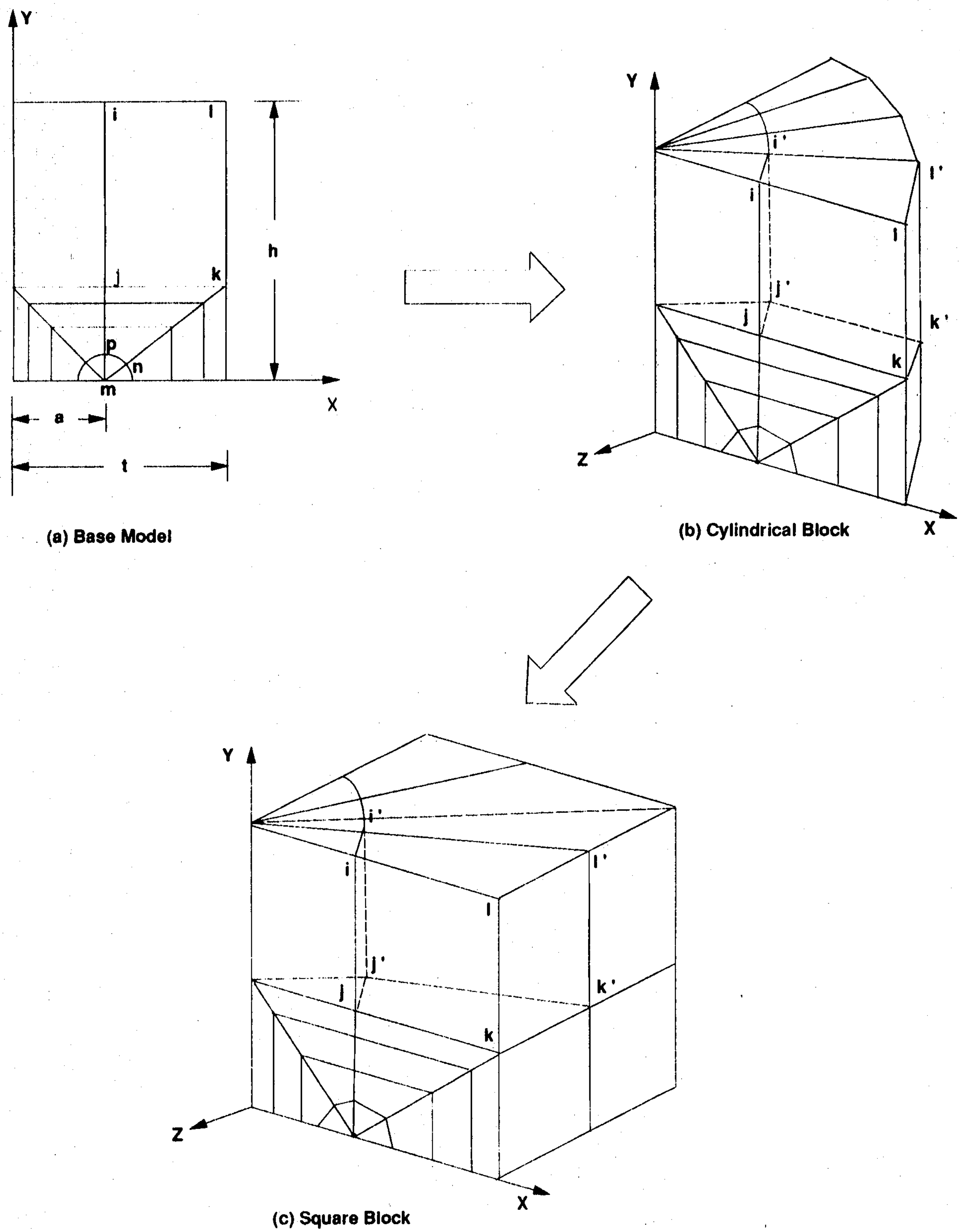


Figure 5. Development of square bock with the surface crack from the base model.

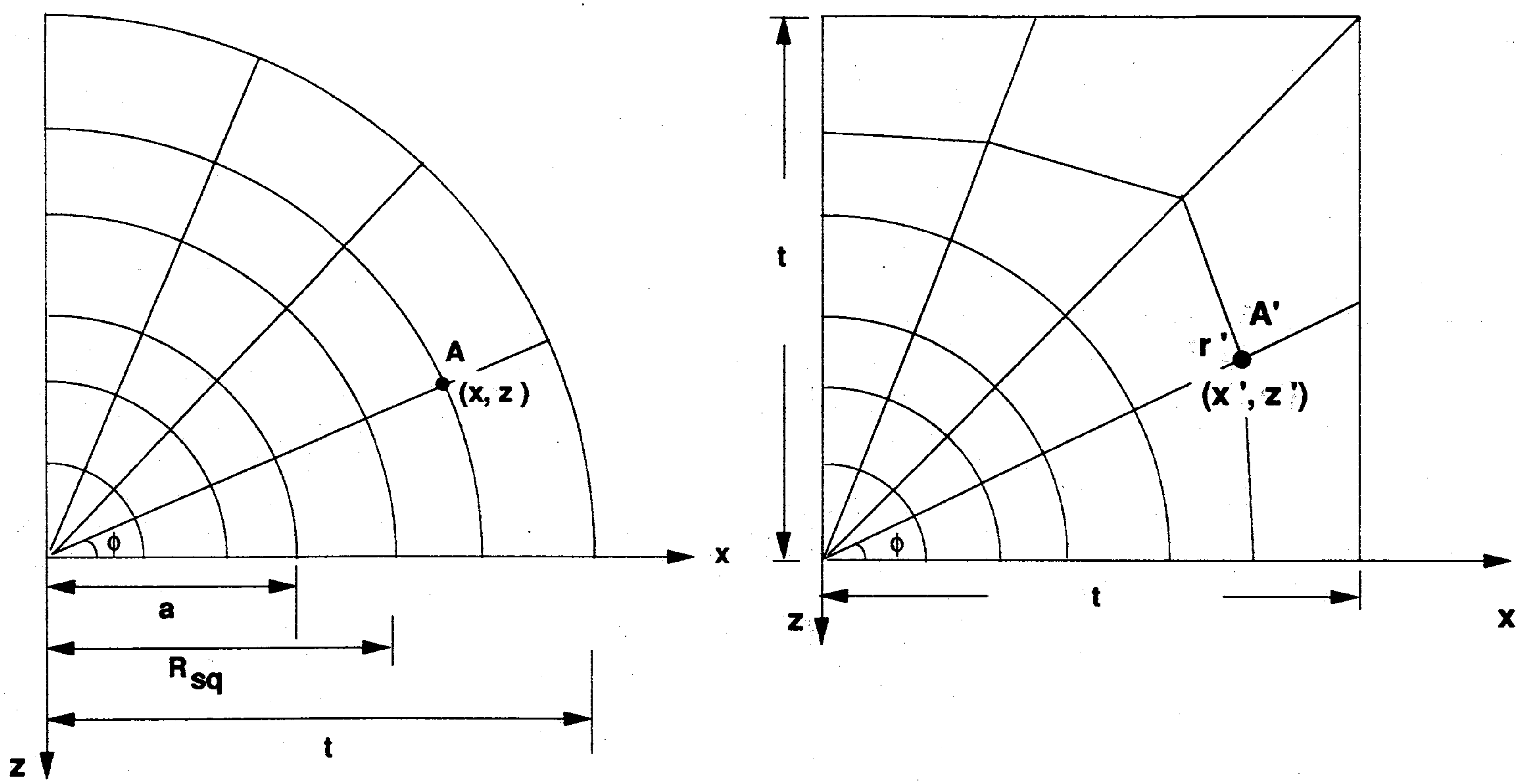


Figure 6. Circular block to square block transformations

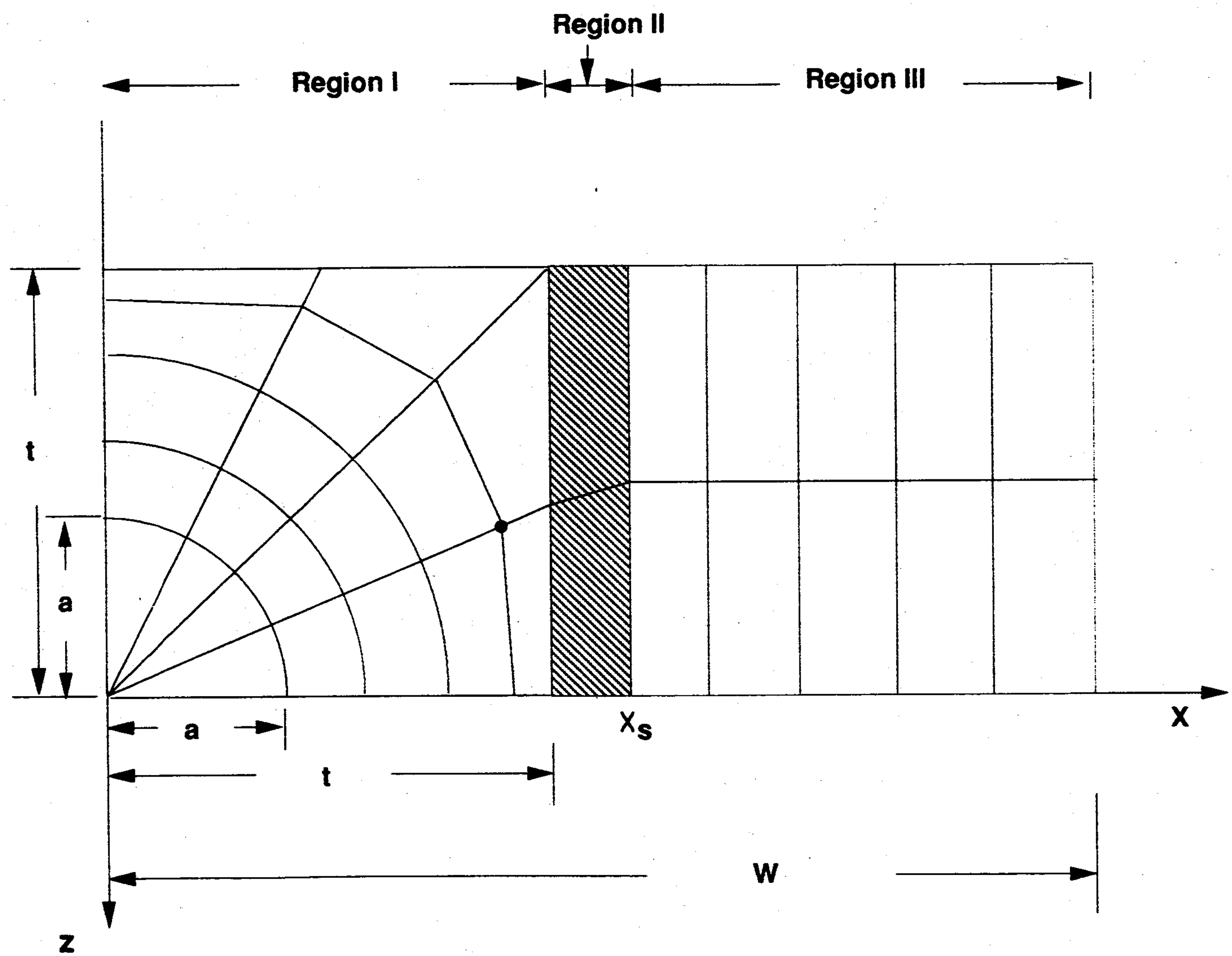
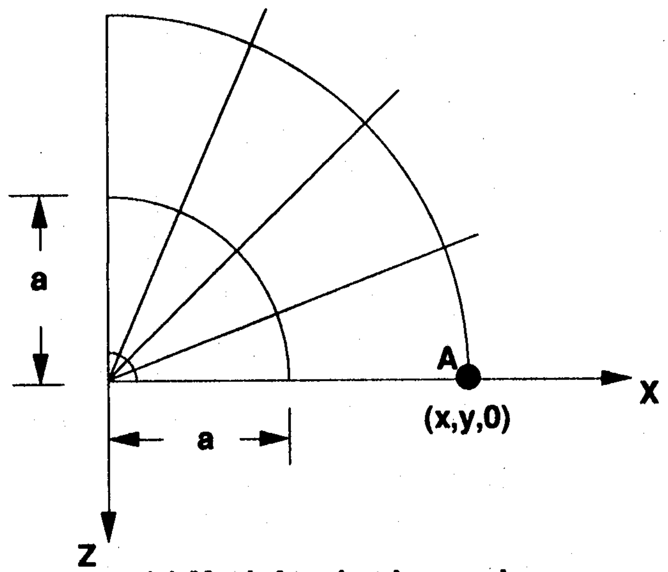
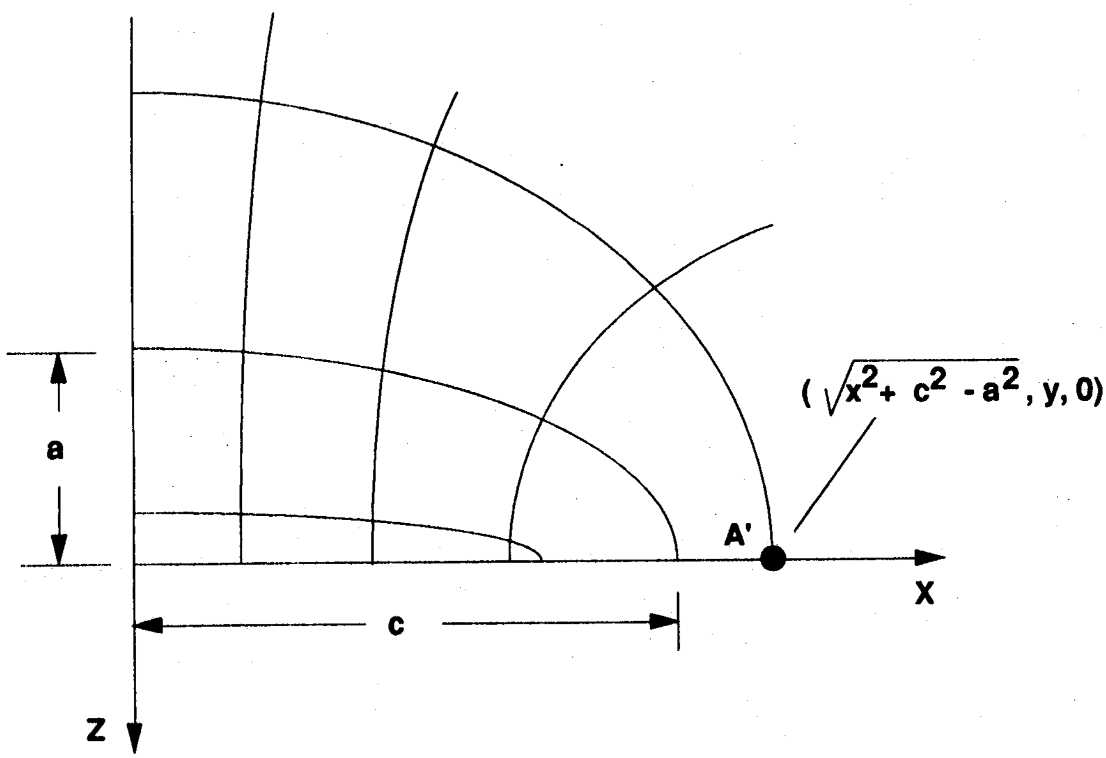


Figure 7. Completed model - View on y=0 or y=h planes (Nlayer=4)

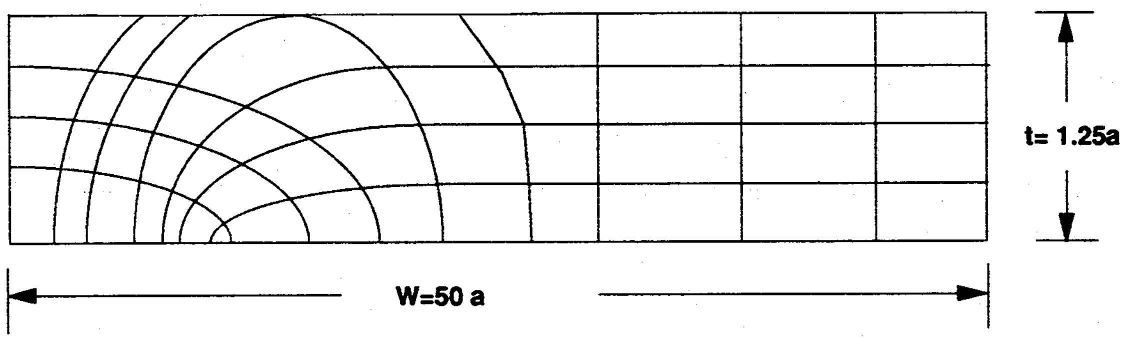


(a) Mesh for circular cracks



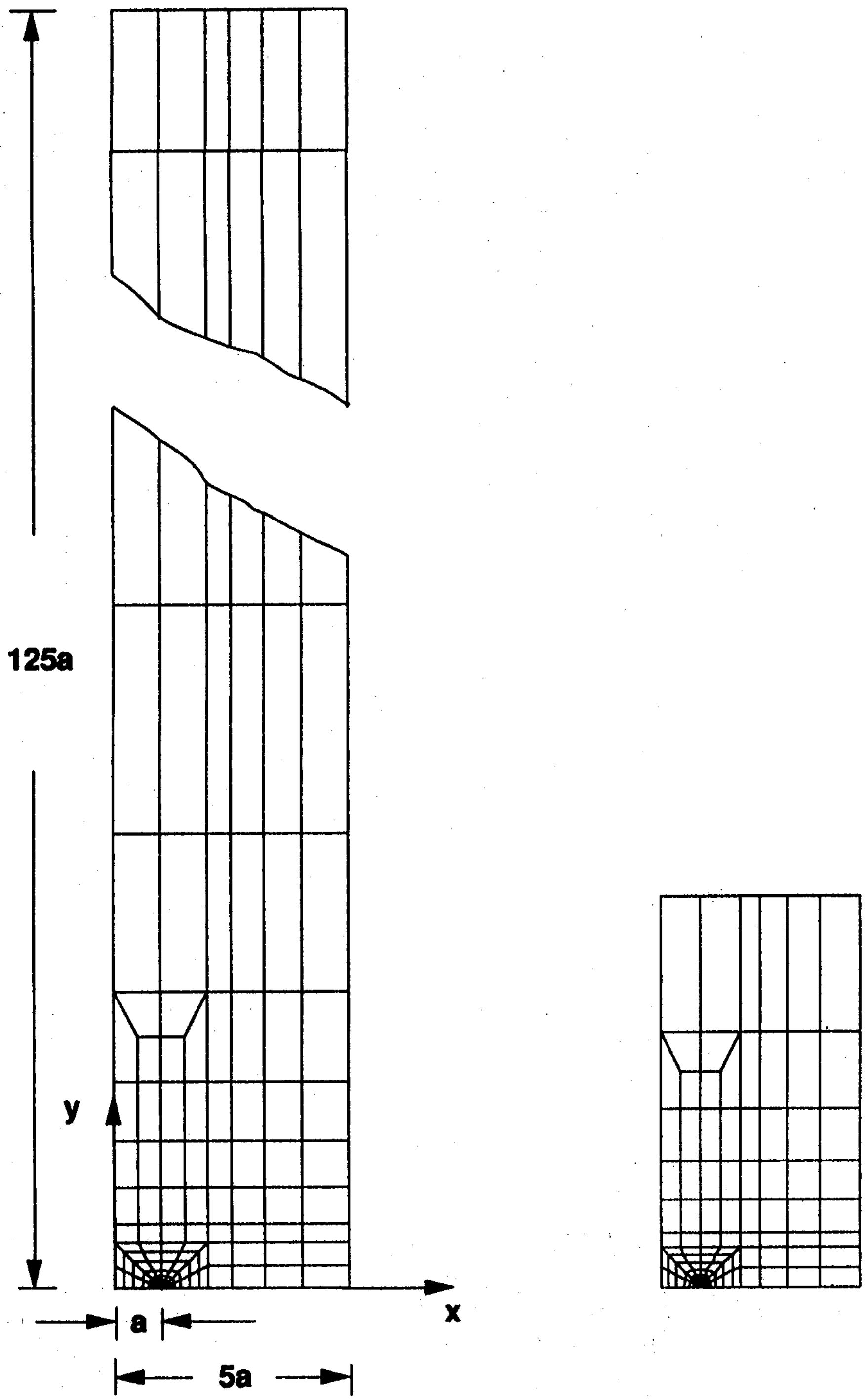
(b) Mesh for elliptic cracks

Figure 8. Conformal transformation from circle to elliptic meshes.



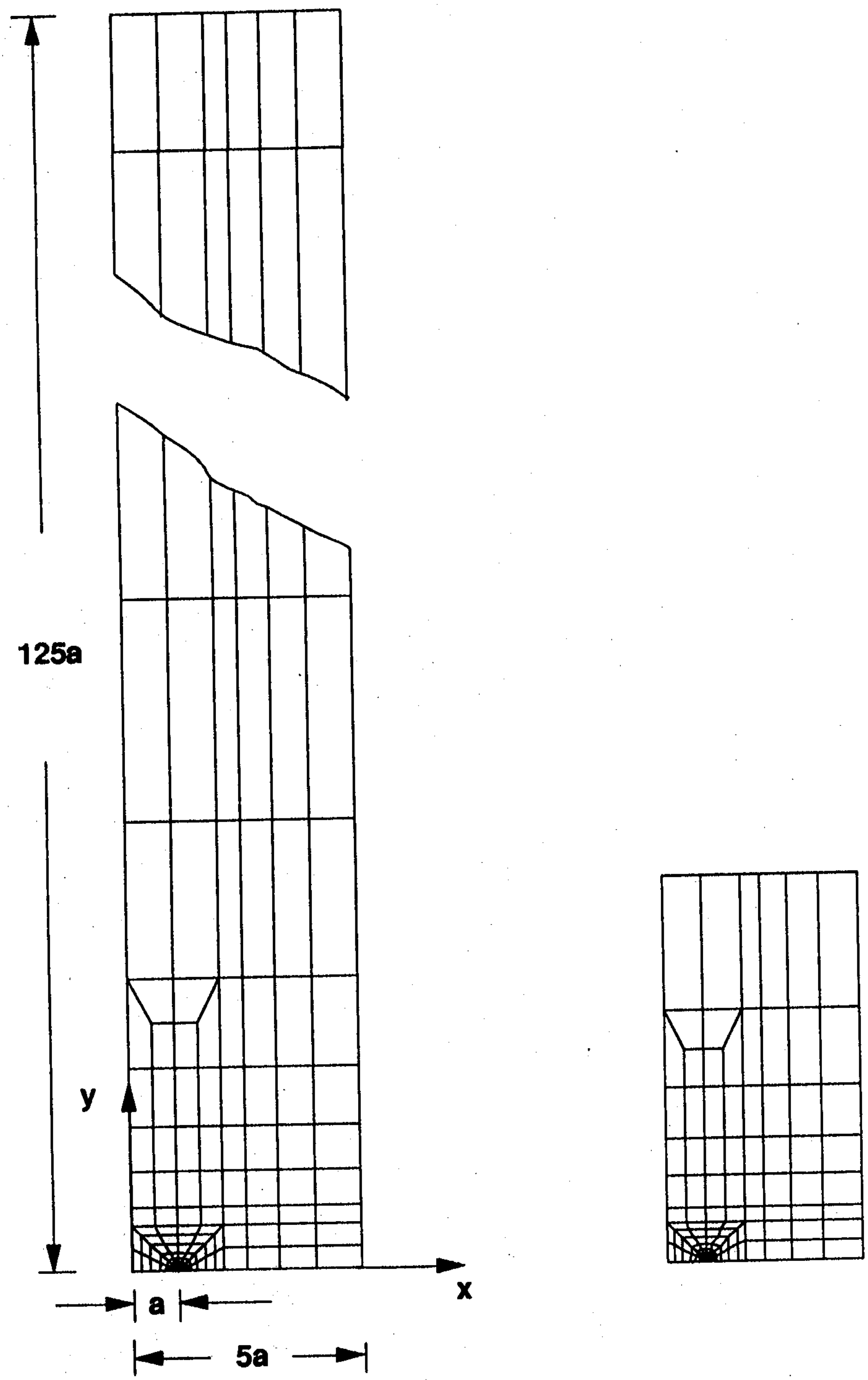
(c) . Modeling on the y=0 or y=h planes for an elliptic crack

Figure 8. (Concluded).



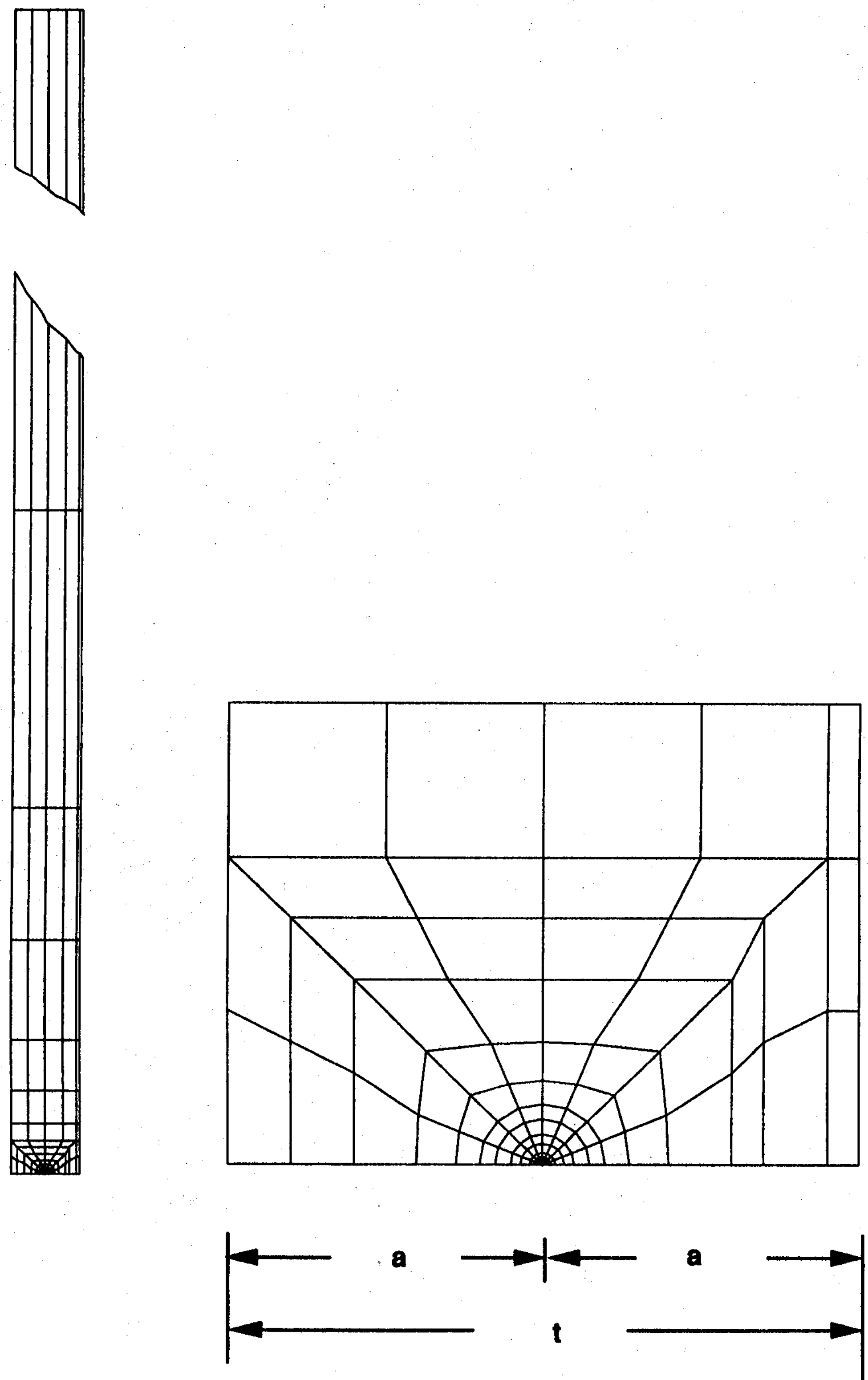
(a) Base model for a/t=0.2

Figure 9: Base Models used for a/t= 0.2, 0.5 and 0.8.



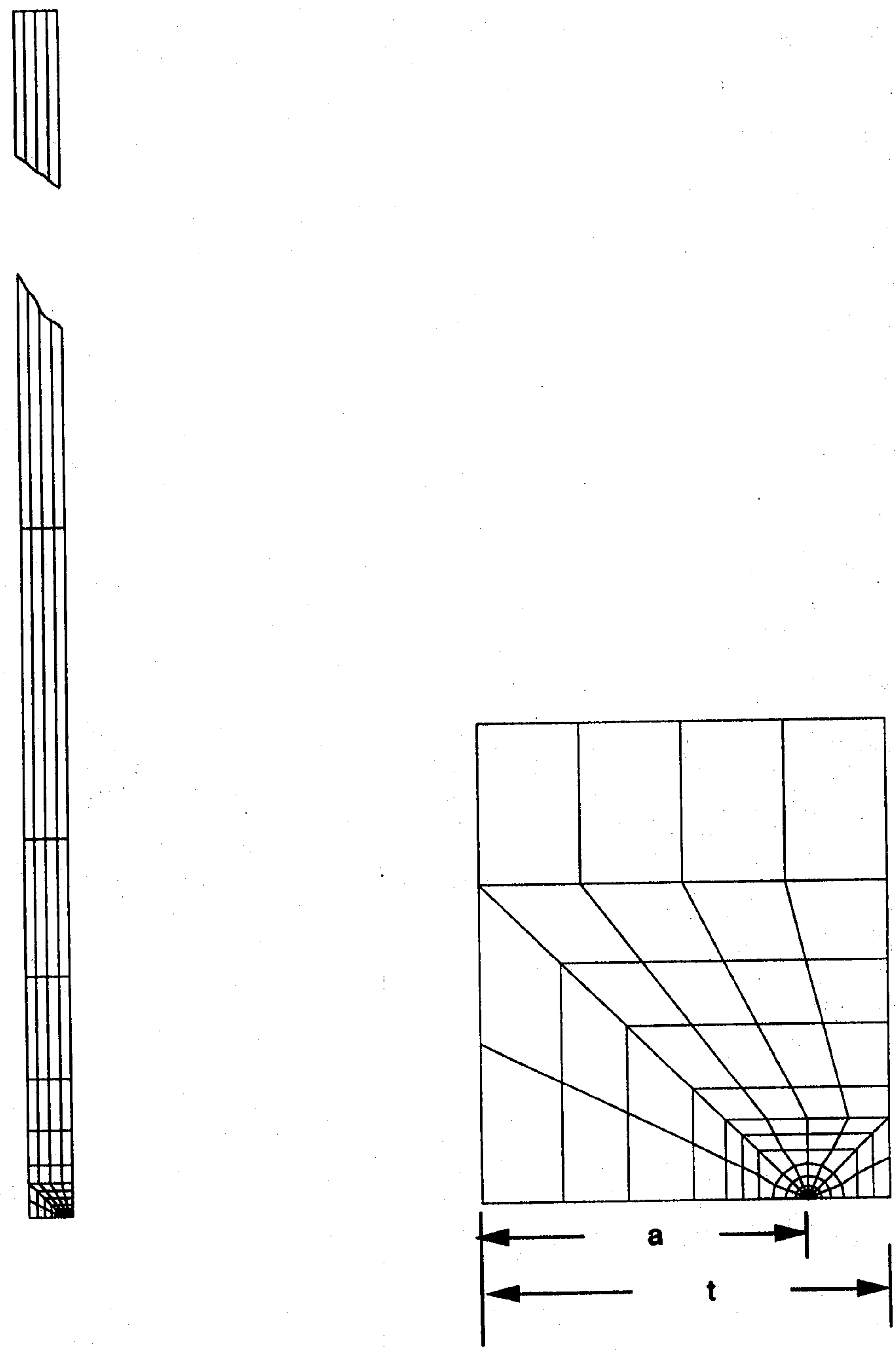
(a) Base model for a/t=0.2

Figure 9: Base Models used for a/t= 0.2, 0.5 and 0.8.



(b) Base model for a/t=0.5

Figure 9: (Continued).



(c) Base model for a/t=0.8

Figure 9: (Concluded).

Node numbers on the Planes that Model the hole

Plane	PER(I)*	Node Numbers
H-1	0.95R	1360 - 1510
H-2	0.85R	1511 - 1661
H-3	0.70R	1662 - 1812
H-4	0.40R	1813 - 1963
H-5	0.00R	1964 - 2114

* position of the planes in terms of the hole radius.

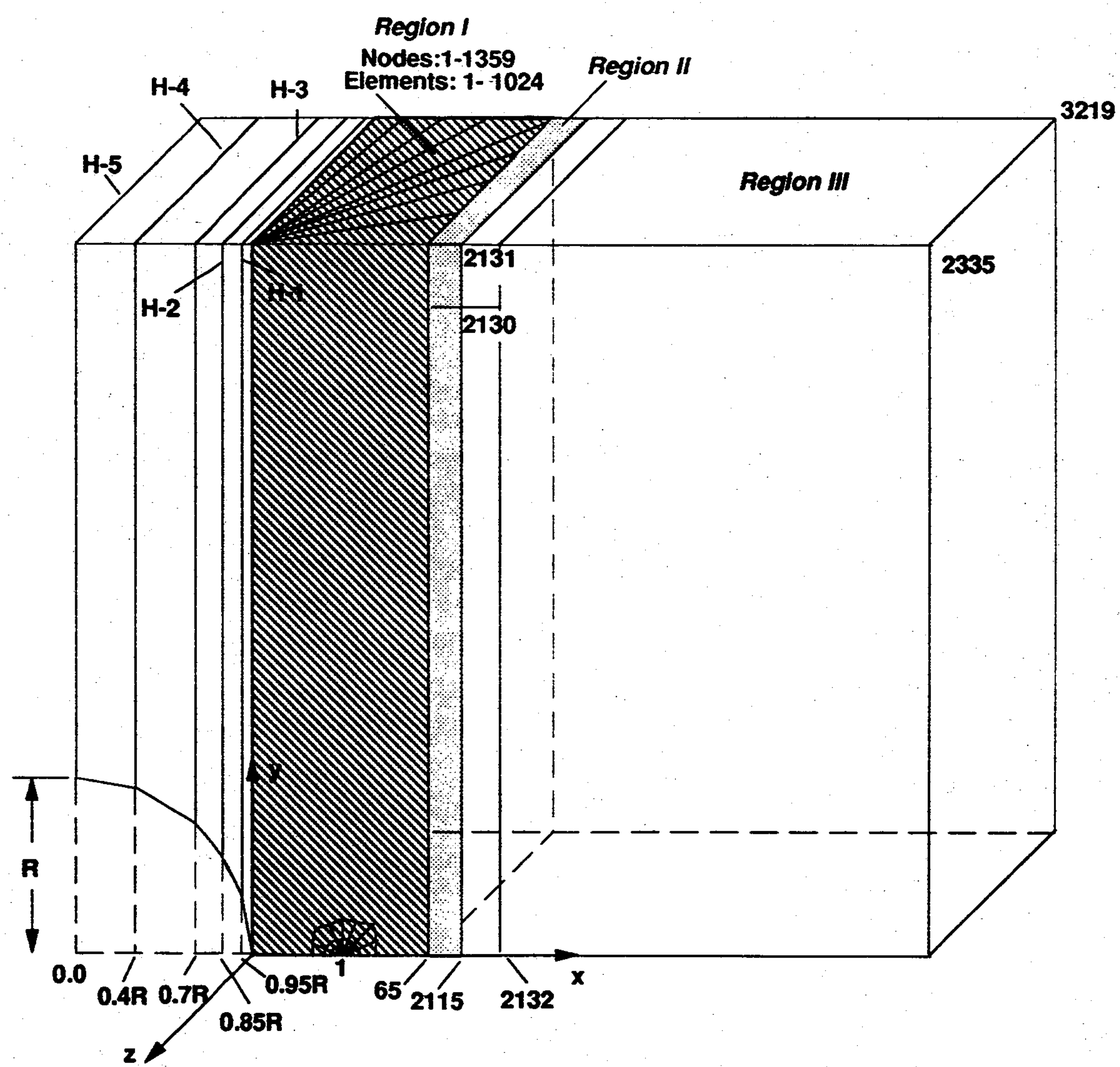
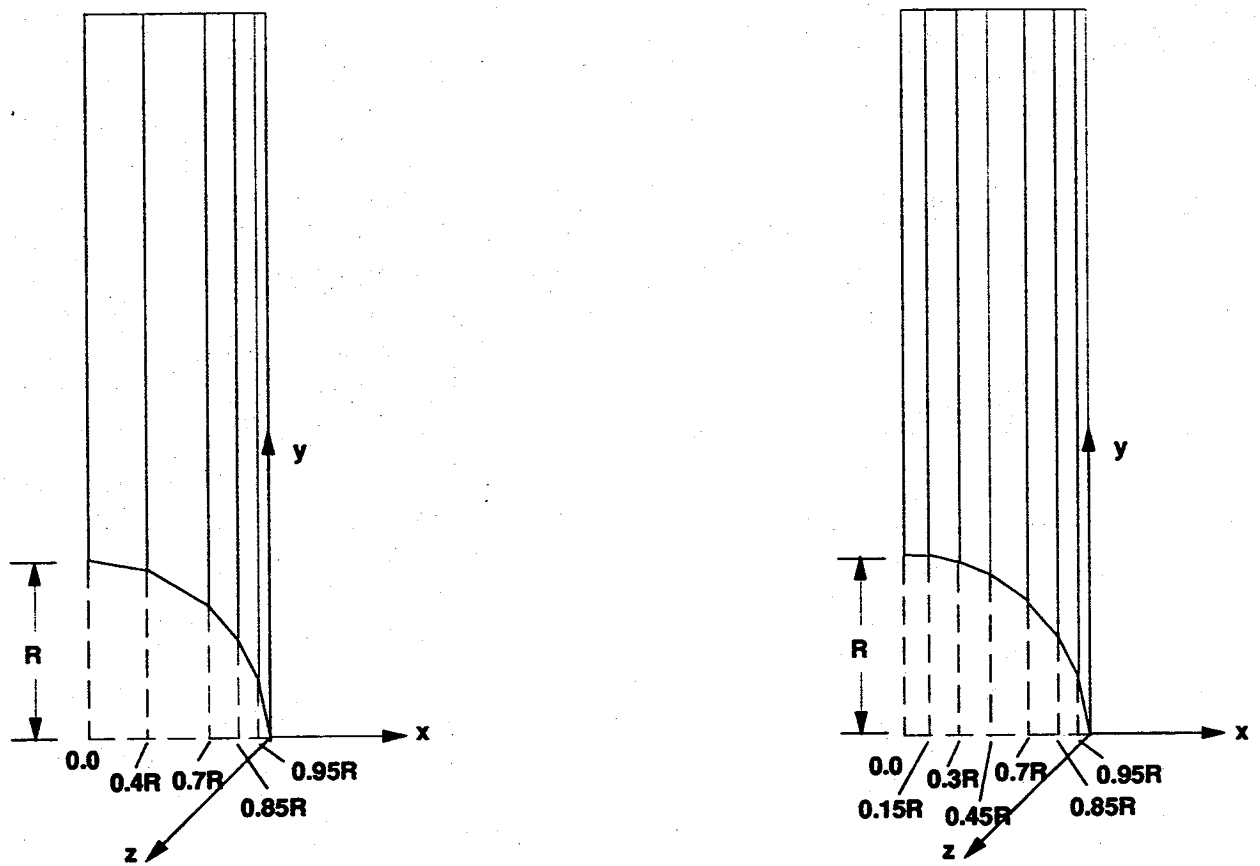


Figure 11: Surface Crack in a plate with a Circular Hole

(a/c=1; a/t=0.8, R/t=1)

(Nlayers on the hole, NH=5 ; NLAYER=8)



(a) Number of layers on the hole, NH=5.
PER(I)= 0.95, 0.85, 0.7, 0.4, 0.0

(b) Number of layers on the hole, NH=7
(PER(I)= 0.95, 0.85, 0.7, 0.45, 0.3, 0.15, 0.0

Figure 12: Modeling of the hole and the associated input data.

REPORT DOCUMENTATION PAGE

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13. ABSTRACT *(Maximum 200 words)*

A computer program that generates three-dimensional (3D) finite element models for cracked 3D solids was written. This computer program, gensurf, uses minimal input data to generate 3D finite element models for isotropic solids with elliptic or part-elliptic cracks. These models can be used with a 3D finite element program called surf3d. This report documents this mesh generator. In this manual the capabilities, limitations, and organization of gensurf are described. The procedures used to develop 3D finite element models and the input for and the output of gensurf are explained. Several examples are included to illustrate the use of this program. Several input data files are included with this manual so that the users can edit these files to conform to their crack configuration and use them with gensurf.

14. SUBJECT TERMS

Stress-intensity; Fatigue crack propagation, Finite-element; Surface and corner cracks; Finite-thickness plates

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