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# IG/OG PROGRAM FOR GENERATING AND DISPLAYING NASTRAN INPUT AND OUTPUT DATA

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SUMMARY

Hitachi.Ltd. has developed a software system in structural analysis fields using NASTRAN, and now HITAC users in Japan can use IG/OG (Input Generator/Output Generator) program for NASTRAN. IG/OG saves much time required to make a structure analysis data to interpret the result from an analysis by NASTRAN.

## INTRODUCTION

Generally, large-scale calculations in structure analysis require more than 1000 elements and nodal points even in the analysis of plane structure. In addition, thousands of input data cards must be prepared. In the case of three-dimensional structure having various arbitary shapes, a numerous amount of input data more than these must be prepared. This operation is extremely difficult to be done by hand and also requires much time. On the other hand, the analytical results such as the node displacement outputted for each nodal point, and the elementary stress and force outputted for each element reaches several times the input data. These bring about the fact that prodigious labor and time must be shared for rearranging and retrieving the resultant outputs and preparing all necessary reports.

The IG divides a structural model set by the user into elements, and generates the user communication file used as an input data file to NASTRAN. The IG incorporated in NASTRAN helps to simplify the aforementioned troublesome preparation of input data extremely.

The OG rearranges a numerous amount of output data and plot them graphically or in figures to facilitate the retrieval of analytical results. By writing the file-names used in the OG into the user communication file at the time of NASTRAN execution, the user enables the OG to draw various figures while changing the parameters provided for figure construction, after the completion of NASTRAN execution.

## INPUT GENERATOR

Many excellent automatic mesh generation programs for specific structures such as aircraft and ship have been developed and introduced. For general structures, however,few of those programs are usable. The automatic mesh generation program (IG) of IG/OG inroduced in this paper has been developed for universal applications, for which various new concepts were incorporated.

A whole structure cannot be divided completely at a time . In this system, it is divided into sub-structures called parts which are then inputted. The part is formed by a relatively simple shape such as triangle, quadrilateral, or the like. In the IG the respective parts are mesh-generated and then combined with each other to complete dividing a whole structure in mesh. The number of processings necessary for dividing a structure into parts is only a fraction(several ten times less) of that needed for dividing into structural elements, although it depends on the shape. This brings about the fact that the number of processings needed for data preparation can be reduced greatly. In addition, special data are not required when combining the respective parts with each other, since the combining operation is performed based on the distance between the coordinates of grid points.

The data which can be obtained by automatic mesh generation are limited to some extent, but load and constraint conditions can be created in addition to grid point data and element combination data.

### Part

Ten different kinds of parts are usable in the IG, each having its own divide method. The list of divide methods is as shown below.

(1) Quadratic shape function method
(2) Cubic shape function method
(3) Rotational quadratic plane method
(4) Coon's blending function method
(5) Plane parallelogram method
(6) Rotational parallelogram method
(7) Cylindrical parallelogram method
(8) Rotational plane curve method
(9) Similar translation method
(10) Orthogonally branched pipe method

Different kinds of parts may coexist within the same structure.
A part is defined by specifying boundary lines. Straight line, quadratic curve, cubic curve, and arc are used as boundary lines. The boundary lines usable for each part differ according to the kind of part or divide method. A boundary line is defined by specifying 2 or more points on it. The points used to define boundary line are called characteristic points. For example, straight line is defined by specifying characteristic points at its both ends, and quadratic curve is by 3 points -- 2 at

its both ends and 1 at the intermediate portion of it.

The quadratic shape function method is one in which the plane structure consisting of triangle or quadrilateral is to be divided. The boundary line used in this method is represented by any one of straight line, quadratic curve, and cubic curve.

As shown in Fig. 1, the structure represented by A,E,B,F,C,G,D,H in the coordinate system XY is correlated with the square of abcd in the coordinat system $\alpha\beta$ . Shape function is used to correlate the points in the coordinate system $\alpha\beta$ with the points in the coordinate system XY. The shape function is the same as those often used in the finite element method. Dividing operation is performed on the square in the coordinate system $\alpha\beta$ . By obtaining the points corresponding to the grid points generated by the aformentioned dividing operation, the structure of A,E,B,F,C,G,D,H is substanaially divided.

The cubic shape function method is the same as the quadratic shape function method, except that part shape is 3-dimensional.

The rotational quadratic plane method is an application of the quadratic shape function method. The section of thick-wall shell generated by rotating a plane around an axis is divided by using the quadratic shape function method. In the circumferential direction, the shell is divided evenly at the specified angle.

The Cooh's blending function method is one in which the method of creating a free curve used in numerical control is applied to automatic mesh generation.

In the plane parallelogram method, a structure approximating a quadrilateral, whose opposing edges run almost in parallel, is divided into parts. Each edge is defined as an aggregate of straight line, quadratic curve, and arc. If the opposing edges are not in parallel, an additional line can be specified at the intermediate portion of them, whereby the shapes of divided elements can be improved considerably.

The rotational parallelogram method is one in which the plane parallelogram method is utilized for a thick-wall shell generated by rotating a parallelogram around an axis, like in the rotational quadratic plane method. The section of the shell is divided by using the plane parallelogram method. In the circumferential direction, the shell is divided evenly at the specified angle.

In the cylindrical parallelogram method, the section of a cylinder is divided by using the plane parallelogram method. In the axial direction, the cylinder is divided evenly at the specified length.

The rotational plane curve method is one in which a thin-wall shell generated by rotating a curve defined on XZ plane is divided. The curve is defined as an aggregate of straight line, quadratic curve, and arc.

The similar translation method is one in which the surface generated by translating a straight line along acurve is divided. The curve is defined as an aggregate of straight line and arc.

The orthogonally branched pipe method is one which can be applied only to orthogonally branched pipe. However, such pipe can be combined with other parts.

## Mesh Pattern

Fifteen different kinds of mesh patterns are available, whereby the normal dividing operations are satisfied. For example, the follwing patterns are included; a quadrilateral is divided into triangles by using shorter diagonal line instead of longer one, or the number of divisions is increased or decreased as dividing operation moves in a certain direction.

Each pattern has the corresponding code, thus a pattern to be used is selected by specifying the code corresponding to the part.

## Load Generation

Loads such as grid point force and pressure can be generated. The amount of each component contained in grid point force and the amount of pressure must be represented by the linear function of grid point coordinate values. Pressure is assumed to be applied in the direction parpendicular to plane element. Grid point force is given for each component.

## Constraint

A special part can be used for defining only the constraint condition of grid point. This part is linear, being represented by straight line, quadratic curve, or cubic curve. The boundary condition along the contour of structure can be generated easily by using the part.

## Three-Views

In the analysis of complex structure, it is troublesome to input the coordinate values of characteristic points for defining the boundary lines. The IG is capable of inputting the coordinate values by using three-views in addition to inputting them directly This greatly helps to simplify the analysis of complex structure.

## Command

The data incorporated in the IG are classified into the data used to define a structure and those necessary for activating the actual mesh generation. The data needed for activating the generation are called commands. The following commands are available.

(1) AUTOMESH

Activates the automatic mesh generation of part.

(2) TRANS

Tranlates automaically-mesh- generated parts similarly; i.e., the specified values are added respectively toeach grid point coordinate.

(3) ROTATE

Rotates automatically-mesh- generated part. This command is capable of placing the part at any desired position in combination with TRANS.

(4) SCALE

Contracts and expands part.

(5) REFLECT

Reflects part. For example, when a part is reflected on X axis, the sign representing the X value of grid point coordinate is reflected.

(6) ERASE

Eliminates part of grid points or elements within a part.

(7) COMBINE

combines the respective parts which have been mesh-generated by AUTOMESH command and operated by other commands.

(8) PLOT

Plots the data obtained by automatic mesh generation on the XY plotter.

(9) PRINT

Lists up the results of automatic mesh generation.

(10) ADD

Adds the data which cannot be created by the IG such as shape data or material data in the format of NASTRAN

(11) ADDEND

Indicates the end of additional data beginning with ADD command.

## Output of IG

The output of IG is available as shown below.

(1) NASTRAN input user communication file

This file serves as an input to NASTRAN.

(2) Mesh-generated structure projection

The results of automatic mesh generation are plotted on the XY plotter.

(3) List of created data

The results of automatic mesh generation are listed up.

## OUTPUT GENERATOR

The OG edits the results of NASTRAN. Attempts are being made to support the following functions in the feature; the aforementioned results are to be drawn on the XY plotter and graphic display, and the specified contents are to be listed up in the specified format. Currently, the OG supports the plotter function which is the same as that of NASTRAN and the function capable of drawing principal stress

diagram.
The input of OG is the output user communication file of NASTRAN. This file is prepared while execution is carried out in NASTRAN. The module for creating the file has been developed newly.

## Principal Stress Diagram

Principal stresses occurring in the elements of a plane can be drawn on the XY plotter in which their amounts and directions are shown by arrows. The principal stresses calculated in NASTRAN are read and displayed via the output user communication file. The pen drawing the diagram can be changed automatically according to whether the stress is compressive or tensile.

## User Communication File

Some of rigid formats supported by NASTRAN are looped. By writing the files created in the looped portions by the OUTPUT module, the data blocks having the same name are written as many times as the number of loops. These data blocks cause a confusion when they are referred to.
In the OUTPUT2 module currently supported, only the first and last data blocks are referred to although a number of data blocks having the same name exist. To cope with this, OUTPUT5 module has been developed newly. IN the OUTPUT5 module, data blocks are outputted separately for each loop, and loop number can be affixed to each data block. Therefore, any desired data block can be referred to by specifying the loop name or loop number or data block name. In addition, the OUTPUT5 module is capable of taking out not only data blocks but parameters.
The following is an example of alteration card in rigid format 8 used to create the user communication file.

```
1. ALTER 2
2. PARAM
      .
      .
      .
   ALTER 103
   PARAM//C,N,ADD/C,N,O/C,N,O/$
   ALTER 106
   PARAM//C,N,ADD/V,N,LOOP/V,N,LOOP/C,N,1/$
   OUTPUT5,,,,//C,N,O/V,N,UCF/C,N,X/C,N,B/V,N,LOOP/$
      .
      .
      .
```

In ALTER 106, 1 is added to parameter LOOP, and the LOOP value is written in OUTPUT5 next to ALTER 106.

## EXAMPLES

The first example is one to divide a structure like a rocket shown in Fig.12. The fuselage which is axisymmetric is divided in the rotational plane curve method, and the wing is divided in the quadratic shape function method. 664 elements and 616 grid points are generated. The number of input cards to IG is 30.

The second example is a holed plate. A quarter of it is divided in the plane parallelogram method and the quadratic shape function method. It is easy to divide the part near the hole into smaller elements. 88 elements and 195 grid points are generated from 61 input cards.

The third example is a solid structure with the shape of L shown in Fig.14. The characteristic points of this example are inputted using three-views. For a simple structure like this it is not necessary to use three-views. 228 elements and 488 grid points are generated from 84 input cards.

The fourth example is also a solid structure as shown in Fig.15. The cylindrical parallelogram method is used. The input cards are shown in Fig.16 and the result which is drawn on XY plotter is shown in Fig.17.

## CONCLUDING REMARKS

An automatic mesh generation program was developed for universal applications, in which the structure of arbitrary shape is divided into simple-shape sub-structures which are further divided into elements, and then the sub-structures are combined with each other to complete dividing the whole structure in mesh. The number of processings necessary for data preparation is reduced to several ten times less. The characteristic points defining the sub-structures can be defined by inputting the coordinate values directly and by using three-views. In the analysis of complex structure, characteristic points can be defined easily by using three-views.

A new output module was developed to support the function of editing outputs, by which the data blocks prepared in DMAP loop can be assigned accurately to addresses.

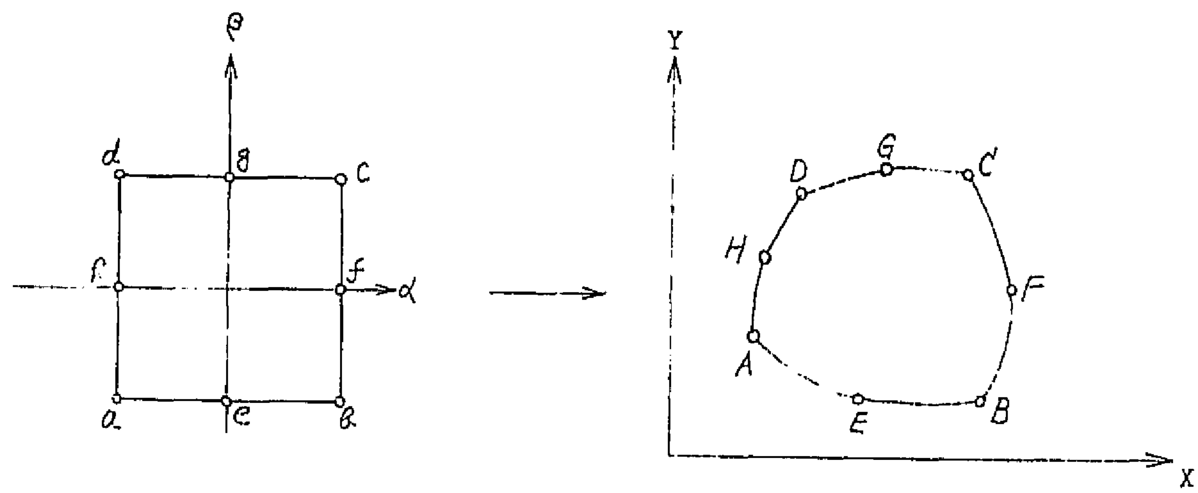


Fig.1 Quadratic shape function method

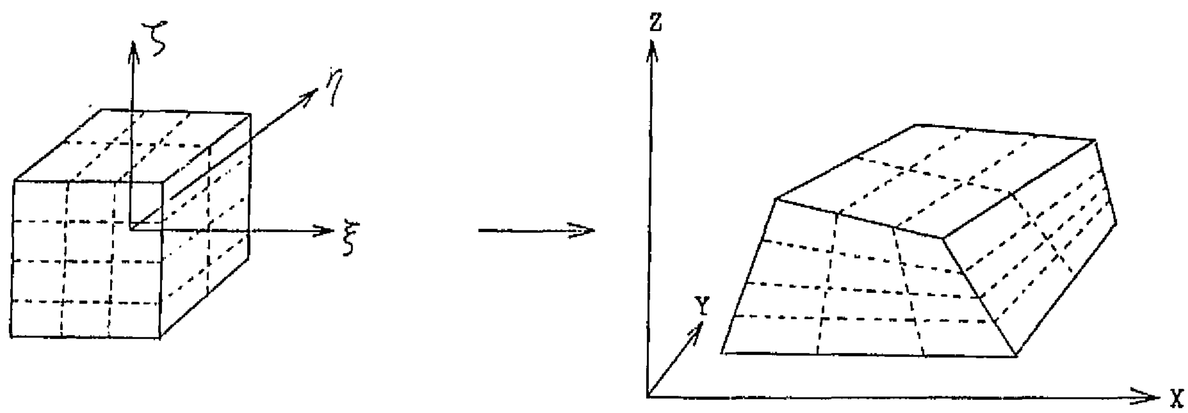


Fig.2 Cubic shape function method

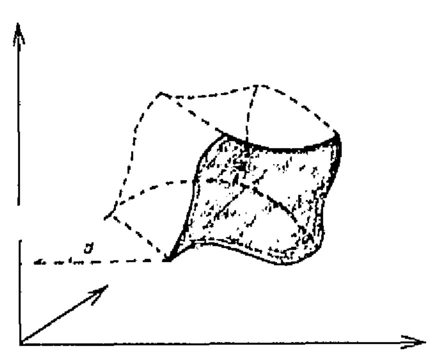

Fig.3 Rotational quadratic
plane method

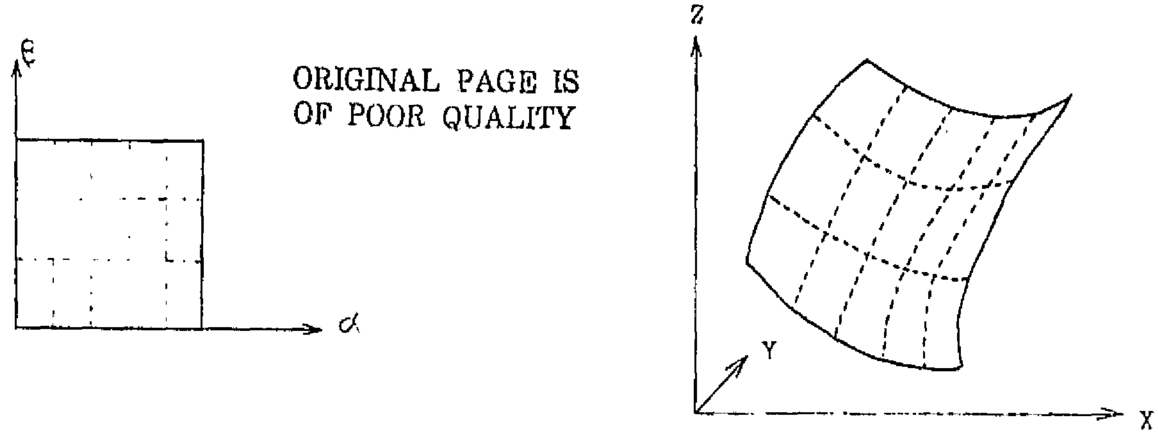


Fig.4 Coon's blending function method

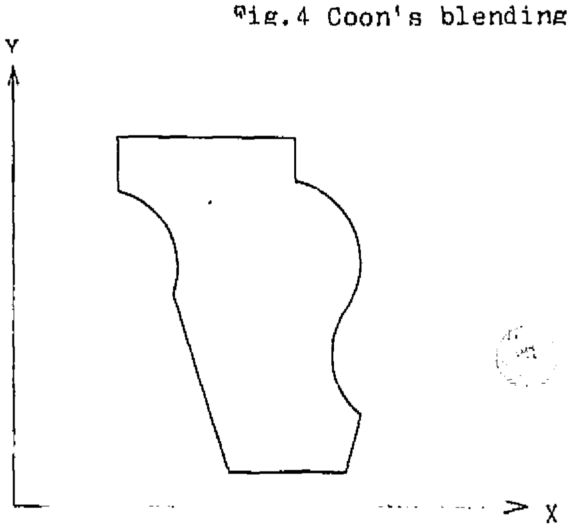


Fig.5 Plane parallelogram method

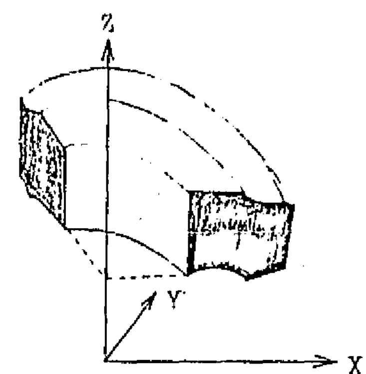


Fig.6 Rotational parallelogram method

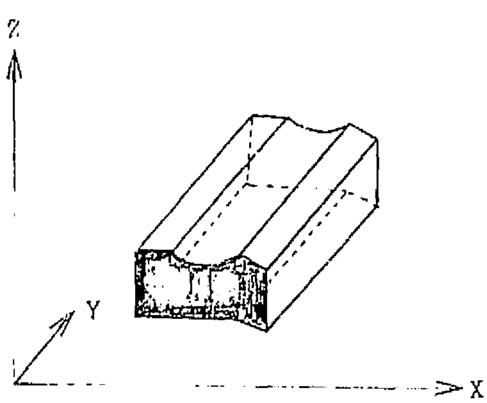


Fig.7 Cylindrical parallelogram method

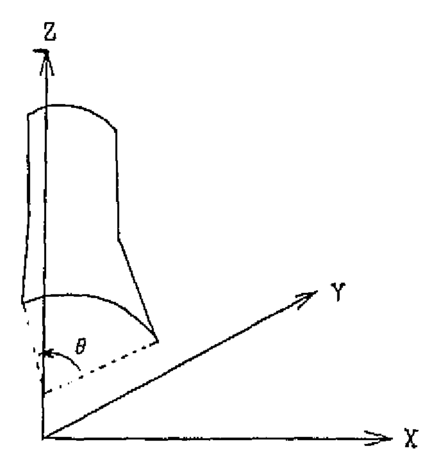


Fig.8 Rotational plane curve method

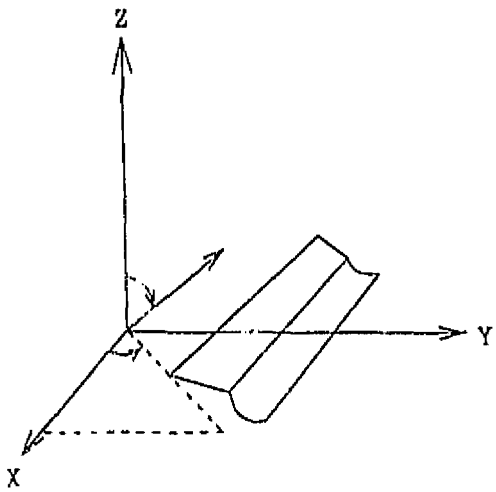


Fig.9 Similar translation method

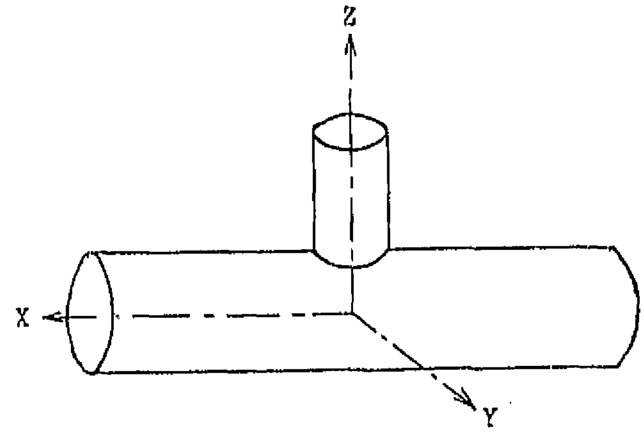


Fig.10 Orthogonally branched pipe method

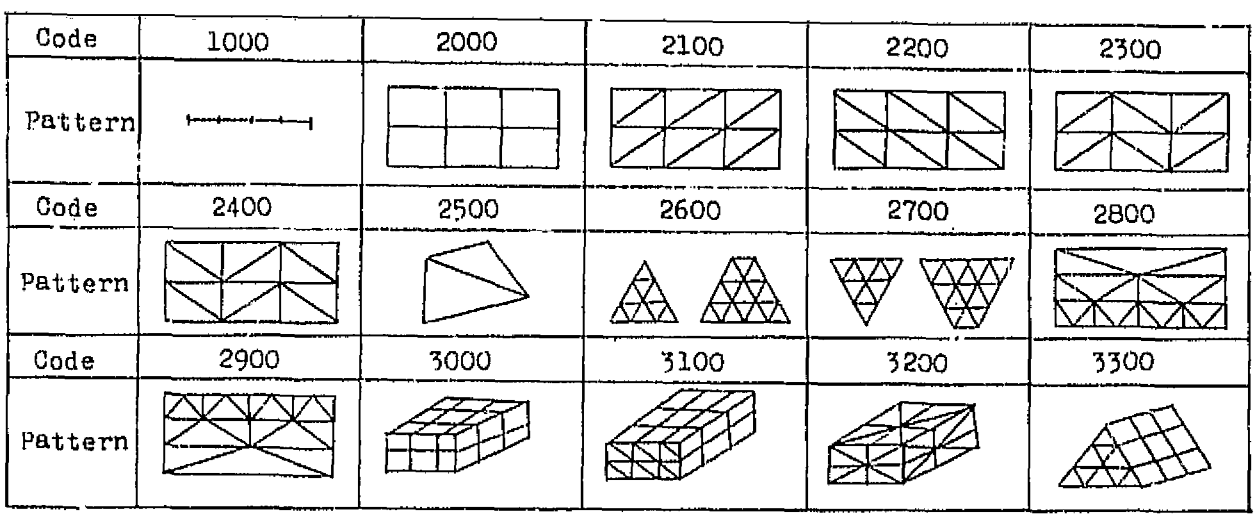


Fig.11 Mesh Pattern and Code

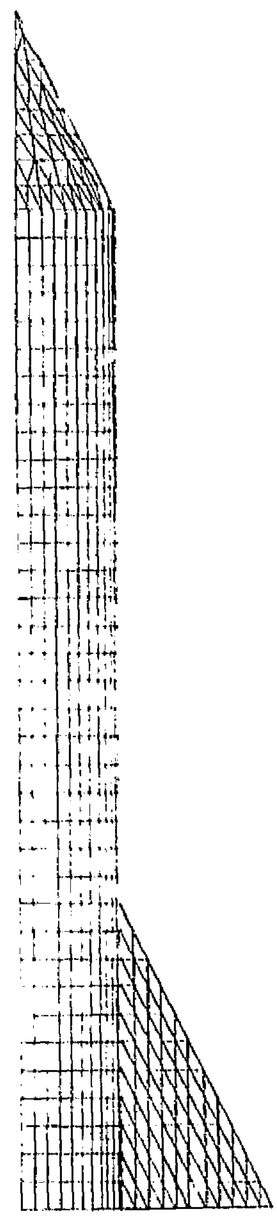

Fig.12 Example 1

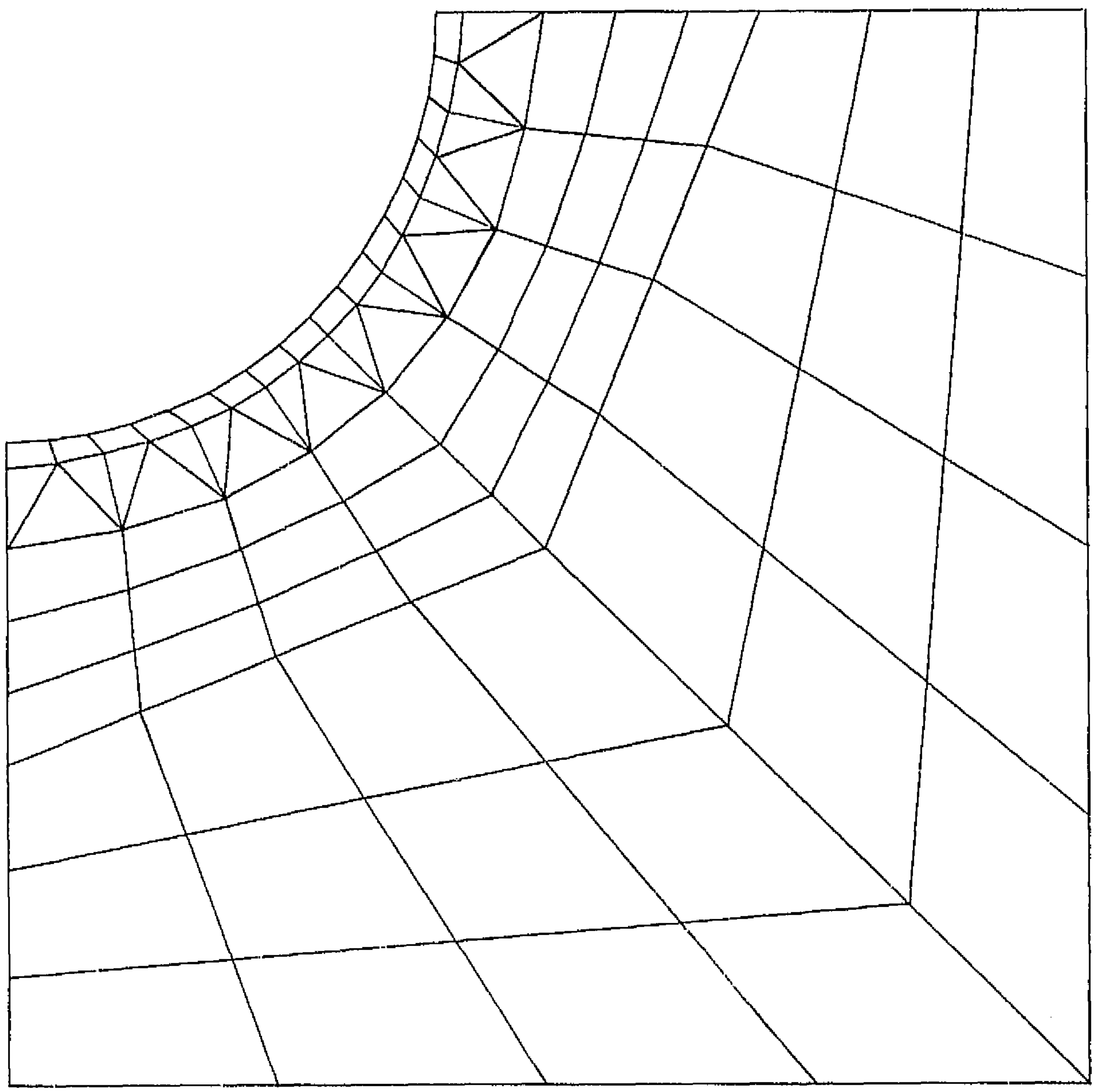

Fig.1? Example 2 A quarter holed plate

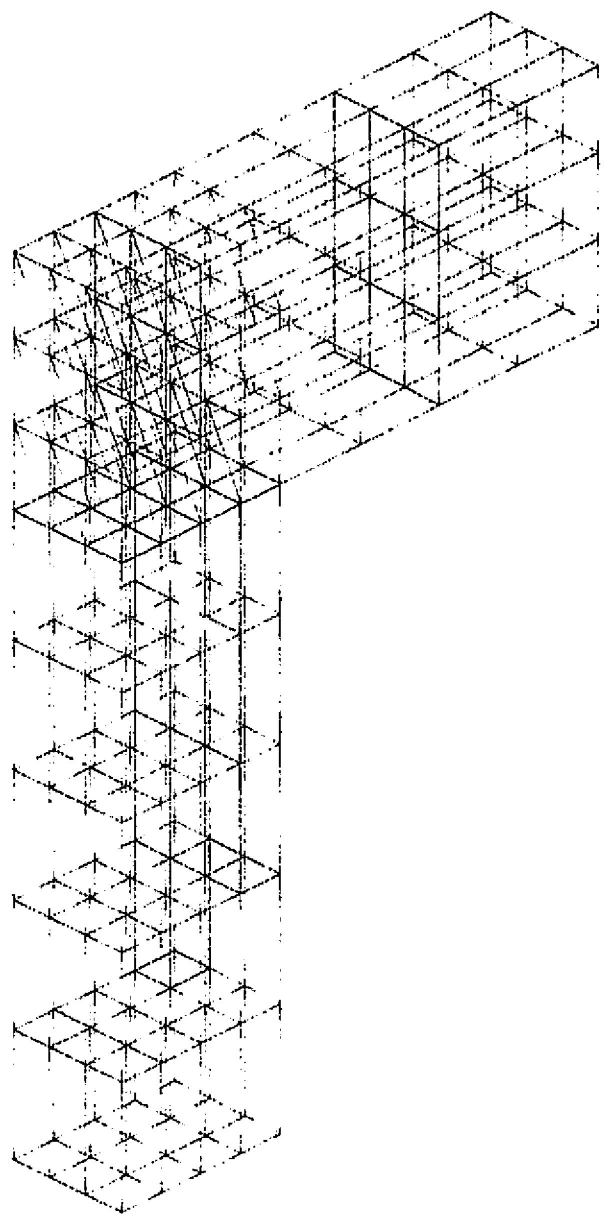

Fig.14 Example 3

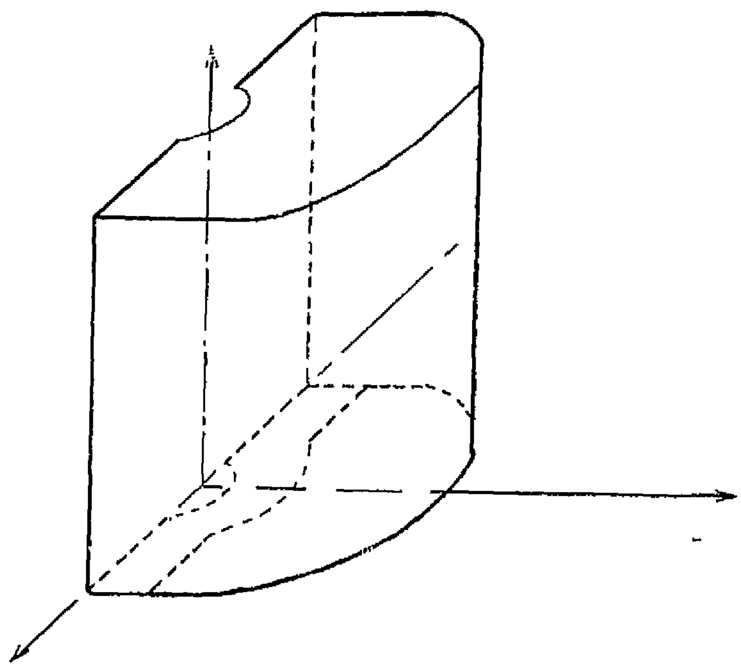

Fig.15 Examnle 4,A solid column

```
*****                 I N P U T   D A T A   L I S T                 *****

(CARD NO )   .......1.......2.......3.......4.......5.......6.......7.......8.......9.......0

(    1)      TITLE   MODEL(6)
(    2)      CONTROL NONE    1
(    3)      BLOCK   D       R
(    4)      POINT   1       0.0             400,0
(    5)      POINT   2       0.0             100,0
(    6)      POINT   3       100.0           0.0
(    7)      POINT   4       0.0             -100.0
(    8)      POINT   5       0.0             -400,0
(    9)      POINT   6       150,0           400,0
(   10)      POINT   7       150,0           200.0
(   11)      POINT   8       250.0           0,0
(   12)      POINT   9       150.0           -200.0
(   13)      POINT   10      150,0           -400,0
(   14)      POINT   11      300.0           400.0
(   15)      POINT   12      640.0           0.0
(   16)      POINT   13      300.0           -400.0
(   17)      LINEAR  1               1       2
(   18)      ARC     2               2       3       4
(   19)      LINEAR  3               4       5
(   20)      ARC     4               11      12      13
(   21)      LINEAR  5               6       7
(   22)      ARC     6               7       8       9
(   23)      LINEAR  7               9       10
(   24)      PART    100     CLPL    3000    3       8       5
(   25)              HEXA1   1       1                                       1000.0
(   26)      LINE    4       8
(   27)      LINE    1       2       2       4       3       2
(   28)      LINE    5       2       6       4       7       2
(   29)      AUTOMESH100
(   30)      COMBINE MODEL06 1       0.1
(   31)      PRINT
(   32)      PLOT    ORTH    A3      2
(   33)              60.0    30.0    0,0
```

Fig.16 Input data of Example 4

Fig.

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OF POOR QUALITY

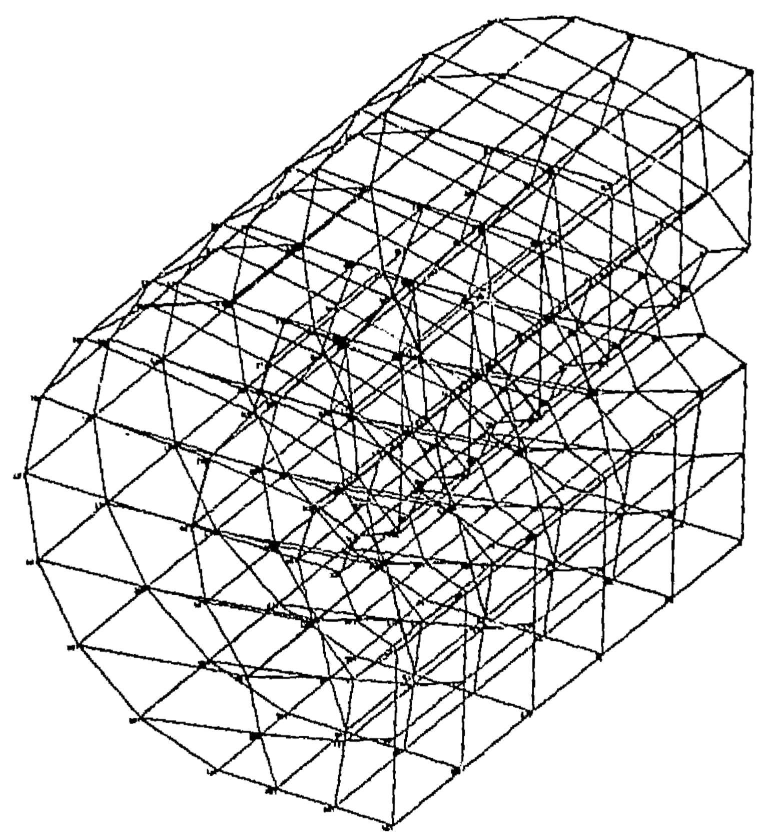

Fig.17 Result of Example 4