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COLUMBUS PROJECT

MIRROR BLANK 8 MT. DIAM F1 - F1.2

FINITE ELEMENT MODELS

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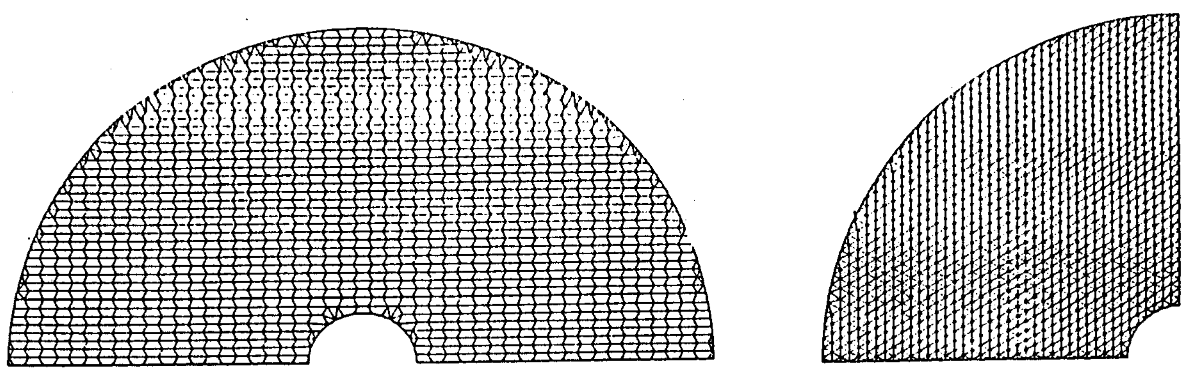

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1. INTRODUCTION

In this report we describe the finite element models used for the 8 mt blank mirror analysis. We have utilised three different models when the focal lenght is equal F1 and two models when it is F1.2.
In the follows we initially describe the material and geometrical characteristics common to all models and afterwards the finite element models used in our analysis.

The finite elements program utilised is the SAP V. The results of finite elements analysis have been post-processed using our own programs.

All the data and results, if not differently specified, are reported using these units:

- lenghts .... millimeter
- forces .... Newton
- angles .... radian

2. CHARACTERISTICS COMMON TO ALL MODELS

In the follows we report the main mechanical and geometrical characteristics common to all models.

2.1. Mechanical characteristics

The material characteristics used for the finite elements analysis are:

Young modulus .... = 57487.0 $\frac{N}{mm^2}$

Poisson ratio .... = 0.195

Specific gravity .... = 0.00002139 $\frac{N}{mm^3}$

Expansion coefficient .... = $2.8 * 10^{-6}$ / °C

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2.2. Geometrical characteristics

The main geometrical dimensions of the 8 meter blank mirror are (see figure 1):

External radius	= 3962.5 mm
Internal radius	= 600. mm
Upper plate thickness	= 25. mm
Lower plate thickness	= 25. mm
Back plate holes diameter	= 100. mm
Rib thickness	= 12. mm
External rib thickness	= 25. mm

Exagonal cells (measured in the middle of the ribs)

Internal radius	= 96.43 mm
External radius	= 111.35 mm

From previous analysis on a 1.8 mt blank mirror we concluded that it is possible to neglect the back plate holes presence in the finite element model, on condition that we consider a thinner lower plate. In this way also the lower plate stiffeness doesn't change significantly.
So in order to don't increase to much the degree of freedom number, we neglect these holes in all the models.
The "equivalent back plate thickness" can be computed by:

$$t = \frac{V}{A}$$

where: V = cell volume of lower plate
A = cell area of lower plate without hole

$$V = [\ 111.35 * 96.43 * 3 - \pi * 50^2\ ] * 25 = 608961.5\ mm^3$$

$$A = 111.35 * 96.43 * 3 = 32212.4\ mm^2$$

The upper surface curvature radius depend, of course, from the focal lenght; for the analysis whit focal lenght = F1 the curvature radius is = 16000.0 mm whereas when the focal lenght is F1.2 it is 19200.0 mm.

3. NUMERICAL MODELS

We have utilised three different models when the focal lenght is equal F1 and two models when it is F1.2.
In all the numerical models we haven't considered the overlappings beetween the finite element junctions and the upper and lower extensions beyond external ribs. In fact their effect is probably not very significantly; only when we will know the real thickness pattern it will be meaningfull to perform an analysis so accurate taken in account the real thicknesses, the overlappings and the connections.

3.1. Numerical models for focal lenght = F1

The three models with focal lenght = F1 are:

M1- Plane elements one half mirror

M2- Shell elements one quarter mirror

M3- Plane elements one quarter mirror

3.1.1. Plane elements one half mirror

Since the blank mirror has only three fixed points (120 degrees spaced) if these point aren't unloaded there is only one symmetry plane. So we have modelled one half blank mirror with plane elements (in order to limit the total number of d.o.f.) having 3 degrees of freedom for each node, to evaluate the dead weight effects on fixed points and the foundamental frequency. In fact in our previous report (Report n.101 rev.1, Milano, 1987, March 30th) we concluded that it is possible to model the blank mirror with plane elements as regard the analysis of dead weight on three fixed points.

In figure 2 is reported the cartesian reference system used. The Z axis is in the axial direction, while the X axis is the symmetry axis in dead weight analysis and symmetry or antisymmetry one in dynamic analysis.
The total number of d.o.f. of M1 model is = 19211 when X axis is a symmetry axis and it is = 19036 when X axis is antisymmetry one.

The blank mirror has been modelled using 6480 nodes arranged in four layer. The node number is increased of 1 for each corresponding node going from the lower plate to the upper one: so the nodes on the lower plate have a number lesser of 3 respect the corresponding on the upper plate.

The numerical model is composed by 4 element groups: lower surface, upper surface, ribs and trusses.

The lower and upper surfaces have been equally modelled using triangular and quadrilateral thin plane elements having the thickness specified at point 2.1 . Since the plane elements haven't stiffeness perpendicular to their surface there aren't nodes inside cells on the upper plate.
On figures I and II are reported the node and element numeration respectively for lower and upper plates.

The ribs have been modelled using quadrilateral plane elements. Each vertical wall is composed by three equally spaced elements.
On figures III, IV and V is reported the element numeration for upper, intermediate and lower layer.

The truss elements have been introduced only for few nodes belonging the external ring. They are nodes where only almost coplanar elements converge and so in order to fix them out of plane we introduced some trusses. These trusses are without weight: we checked that they were almost unloaded so that we can affirm that they don't affect significantly the results.

3.1.2. Shell elements one quarter mirror

When the three fixed points are unloaded the blank mirror has two symmetry planes if horizontal, and a symmetry plane (X=0) and an antisymmetry one (Y=0) if vertical, so it is possible to model only one quarter blank mirror. In our already mentioned Report n.101 rev. 1 we noticed that it is possible to utilise a simplified model for the preliminary study about the axial support optimization (mirror in horizontal position) but if the blank mirror is in vertical position (lateral support optimization) it is necessary to use a refined model.
So we have performed the numerical model M2 for the lateral support optimization using refined shell plate elements having 6 d.o.f for each node. This model has been also utilised for a refined analysis of the axial support optimization.

In figure 3 is reported the cartesian reference system used. The Z axis is in the axial direction, the Y axis is the symmetry axis while the X axis is a symmetry one when the mirror is in horizzontal position or antisymmetry one if it is in vertical position.
The total number of d.o.f. of M2 model is = 21689.

The blank mirror has been modelled using 8357 nodes (only ~45% active) arranged in four layer. The node number is increased of 50 for each corresponding node going from the lower plate to the upper one: so the nodes on the lower plate have a number lesser of 150 respect the corresponding on the upper plate.
The numerical model is composed by 3 element groups: lower surface, upper surface and ribs.

The lower surface has been modelled using triangular and quadrilateral thin shell elements having the thickness specified at point 2.1 .
On figure VI is reported the node and element numeration for lower plate.

The upper surface has been modelled using triangular thin shell elements having the thickness specified at point 2.1 . We have introduced nodes inside all cells of the upper surface in order to thicken the optical surface representation and to seize the inside cell deformation.
On figure VII is reported the node and element numeration for upper plate.

The ribs have been modelled using quadrilateral shell elements. Each vertical wall is composed by three equally spaced elements.
On figures VIII, IX and X is reported the element numeration respectively for upper, intermediate and lower layer.

3.1.3. Plane elements one quarter mirror

The simplified numerical model M3 has been performed in order to quickly examinate and comparate a great number of axial support patterns. In this way we will can discard the worst patterns and we will carry on the analysis using the refined model M2.
So we have modelled one quarter mirror using plane elements. This model has the same node numeration of model M2 but the total number of d.o.f. is ~10000. There are 4 elements groups likewise model M1:
lower and upper surfaces equally modelled (without nodes inside cells);
ribs;
trusses belonging the external ring.

3.2. Numerical models for focal lenght = F1.2

The two models with focal lenght = F1.2 are:

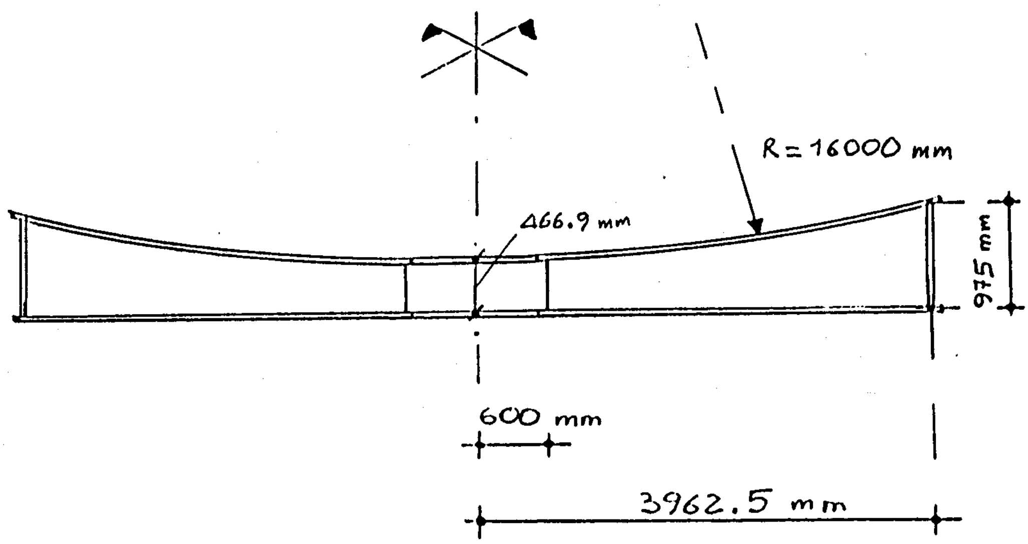
M4- Plane elements one half mirror

M5- Shell elements one quarter mirror

M6- Plane elements one quarter mirror

These F1.2 models differ from the analogous utilised in the analysis of the blank mirror focal lenght F1 only for geometrical characteristic (see figure 1). For their description and node-element numeration we refer to the points 3.1.1 and 3.1.2 .

CROSS SECTION OF F1 MIRROR



CROSS SECTION OF F1.2 MIRROR

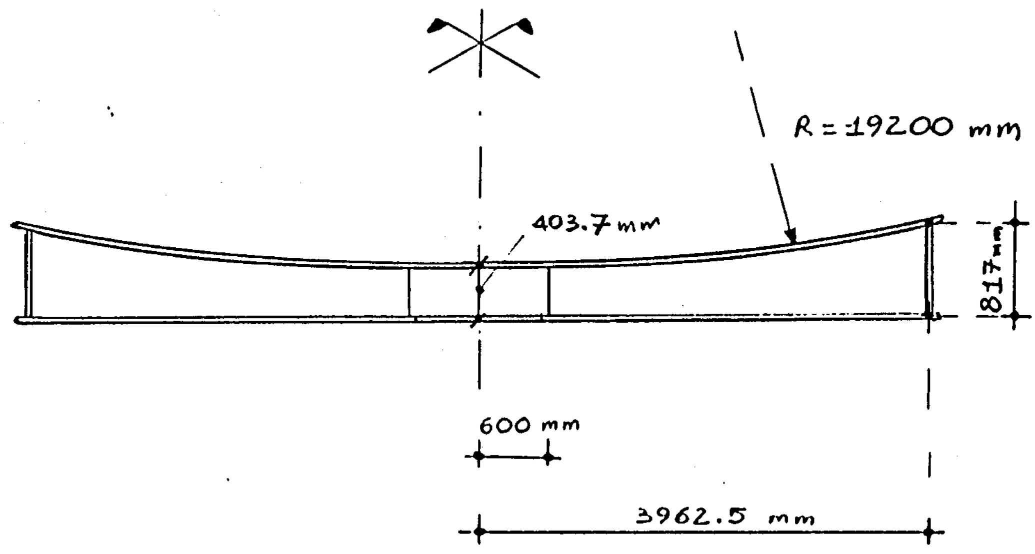


Figure 1

L O W E R   P L A T E

the Z axis is in the axial direction

(right hand reference: Z Y X)

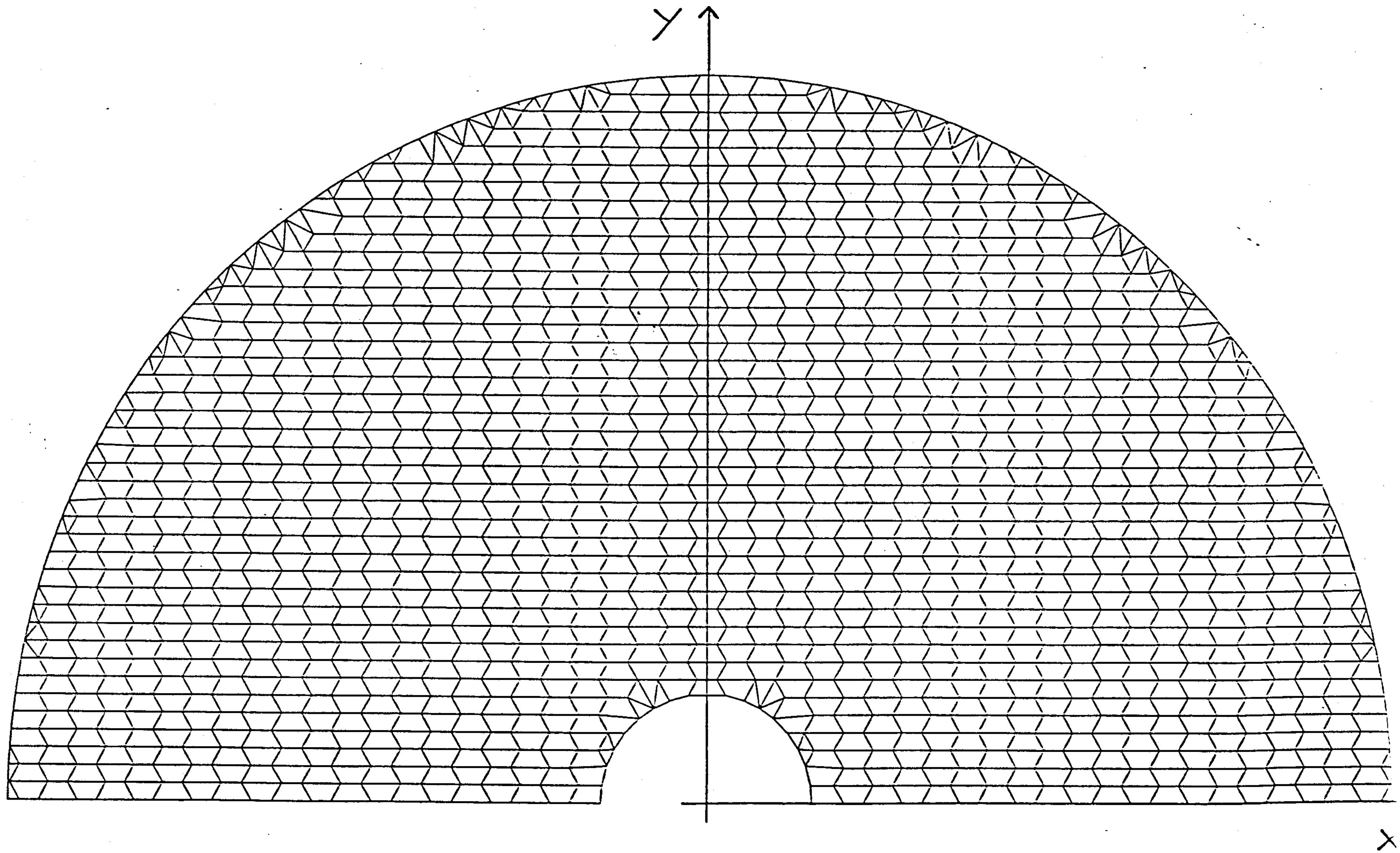
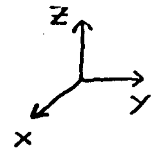


Figure 2

L O W E R   P L A T E

the Z axis is in the axial direction (right hand reference: )

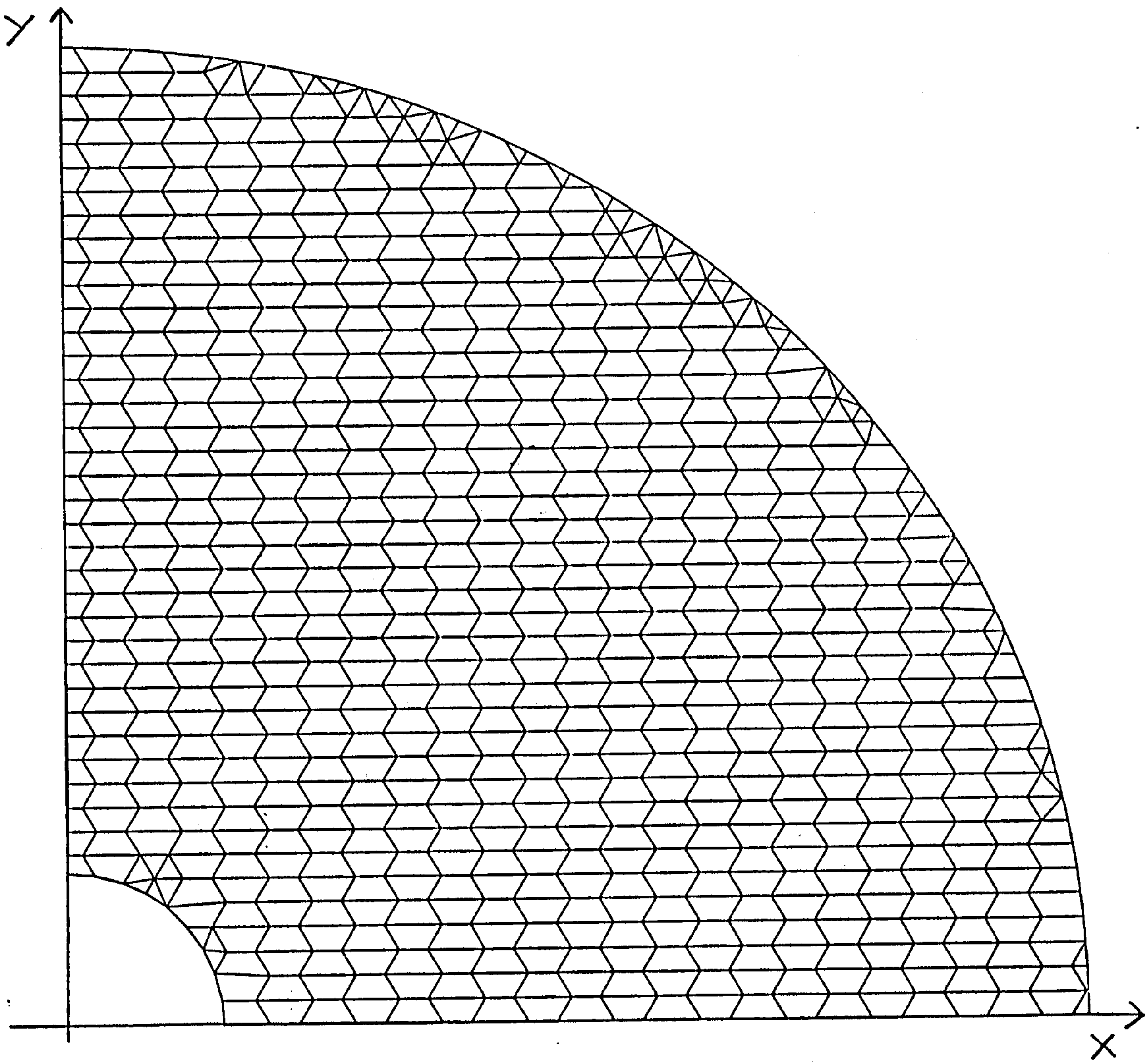


Figure 3