- MESH GENERATION FOR FOLDED AUTOMOBILE AIRBAGS USING MSC/XL -

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Abstract

The preparation of meshes for the analysis of automobile airbags is a complex process and requires a number of advanced pre-processing features to enable the modelling of the initially folded configuration. This task has been performed using MSC/XL Version 2A, a powerful pre- and post-processor intended for use with The MacNeal-Schwendler Corporation's finite element analysis software. It involves generating two circular surfaces, joining them at the edges and the folding-up of this bag into its initial square-like shape (size ratio between folded and unfolded = 1 : 5 ; total amount of folds equals 12) for an analysis involving MSC/DYTRAN. The type of problem to be analysed is broadly described before indicating the above-mentioned features and the sequence of actions necessary to generate this mesh.

1. Introduction

The need for generating finite element airbag meshes arose after the successful coupling/interfacing of programs MSC/DYTRAN, an explicit transient dynamics program, and program MADYMO, a program able to simulate the dynamic motion of one or more linkage systems (Refer to references 1, 2 & 3). These linkage systems involve rigid bodies connected via ball and socket type joints and were developed especially for the simulation of the motion of the human body during an impact situation by the Dutch research organization TNO Road-Vehicles Research institute. This coupling hence enabled the modelling of various car crash scenarios and the interaction between the human body and an expanding airbag, a situation of great interest to the automobile manufacturers of the world. Several separate analyses were made using the above coupling to see the affect of various components on the protection of the driver. Analyses with airbags used in conjunction with & without safety belts were made. The airbag, safety-belts and the deformable rim of the steering wheel were modelled using MSC/DYTRAN, the dummy and the hub of the steering wheel using TNO/MADYMO. The main difficulty encountered in generating the mesh components was in the generation of the airbag mesh and consequent folding up of the airbag. For this reason this paper describes only the MSC/XL features needed/used in generating such a mesh .

In practise, the airbag needs to be fully deflated before it is folded using a specific pre-defined fold pattern. It is then normally placed in the hub of the steering wheel for the driver's seat or in the dashboard for the front passenger's seat. Obviously the location, deflated & inflated shapes and fold patterns vary greatly from one manufacturer to another. In this hypothetical example, a possible driver's airbag was modelled as being of circular shape, fixed on the bottom surface to the hub of the steering wheel and folded through a total of twelve 170-180 degree folds, ending up as a compact square-shaped body. This final folded format would hence correspond closely to an actual airbag in use and provide a starting (deflated & folded) point for the analysis to start from.

In order to clearly describe the mesh generation process and problem, this paper follows the basic steps performed by MSC/XL which were :

- Full definition of the problem including boundary conditions, property identification numbers etc.
- Generation of the geometry for airbag
- The finite element meshing of the above geometry
- The application of boundary conditions
- The folding up of the resulting airbag mesh.

This problem was originally chosen as an evaluation task for MSC/XL as it involves many problematic manipulations of the mesh, all of which are described in the relevant sections together with XL's solution of these problems.

2. Brief Problem description

The components of the entire model are as follows :

- a completely folded airbag modelled with triangular membrane elements & consisting of two circular skins of fabric sewn together along the circumference.
- optional seat-belts also modelled with triangular membrane elements.
- steering wheel including a hub and deformable rim.
- the housing of the airbag including the cover.
- the driver of the automobile modelled with MADYMO rigid ellipsoids.
- parts of the driver modelled with "element-shaped" rigid bodies.

The loading/boundary conditions are as follows :

- the lower skin of the airbag is fixed (see section on defining boundary conditions)
- the internal pressure which causes the inflation of the airbag is calculated using uniform pressure laws.

The DYTRAN master-slave contact algorithm is used to deal with the complicated contact situations that occur during the unfolding/inflation process. The property identification numbers assigned to the various patches of elements generated by the meshing procedure are then used as a way of defining the various master-slave contact sets. This of course prevents the penenetration of slave surfaces by master nodes and ensures that the airbag does not become internally "tangled" and inflates correctly.

3. Generation of Geometry

The shape of the airbag is circular and symmetric with respect to the x and y axes. It is possible to take advantage of this symmetry when generating the mesh by first defining one quadrant, then by reflecting this quadrant about the axes, and lastly by duplicating this surface so as to generate the lower skin of the airbag. This part of the generation is not trivial as the sub-surfaces/patches of elements within the entire surface must be defined so as to agree with the fold lines defined previously. This requires several functions requiring the intersection of surfaces and curves to generate the correct fold lines and secondary arcs. The above mesh generation can be separated into several distinct actions, which are described in detail below. Where commands are necessary as opposed to using the menu entries, the form of these commands are given in italics.

Preparation of work-space :

- Activate program by typing XL <return> (refer to the appropriate figure to see the normal interactive screens of MSC/XL).
- Unpost the tiles representing the menus, history and Q(uick) A(ccess) M(enu)'S to enable a larger work-space and hence more detail.

Drawing of primary Arc :

- First define a point at x=336 , y=0 , z=0 (radius of airbag=336 mm.)
- Use the "Sweep Point" option to generate the primary arc and point 2 by sweeping point 1 through an angle of 90 degrees.
- As secondary arcs will be defined next (requiring the intersection of surfaces), it is necessary to convert this primary arc to a primary surface (unit depth in z-direction) by translating this arc ∂z=1mm and defining a surface between the two arcs.

Definition of secondary arcs :

- The secondary arcs are generated by intersecting the primary surface with a series of temporary "dummy" surfaces (defined along fold lines) resulting in arcs 2 to 8. These secondary arcs will be used to define the various sub-surfaces/patches within the quadrant.

Definition of interior points :

- The points generated as a result of the secondary arcs are used to define temporary fold lines. The intersection of these temporary fold lines are then used to define the interior points of the quadrant before deleting the lines.

Definition of sub-surfaces/patches :

- The sub-surfaces can now be defined using a mixture of secondary arcs and interior points, hence respecting both the circular boundary and the fold lines.

Definition of second, third and fourth quadrants (upper skin of airbag) :

- Using the "Reflect Surface" option, the upper left quadrant can be formed.
- Both of the upper quadrants are then in turn reflected to provide the entire airbag shape.

Definition of lower skin of airbag :

- Using the "Translate Surface" option, the lower skin can be generated by translating the upper skin a distance of zero. Both skins occupy the same position in space.

Definition of separate PARTS corresponding to upper & lower skins of airbag :

- *First define a PART #1 (PART #0 exists as default set-up).*
- *Put surfaces compromising upper skin into PART #0 (surfaces 1to 72).*
- *Put surfaces compromising lower skin into PART #1 (surfaces 73 to 144).*
- *Post only PART #0 to View #6 to enable separate representation/manipulation of the upper skin of the airbag.*
- *Post only PART #1 to View #7 to enable separate representation/manipulation of the upper skin of the airbag.*

NOTE : each sub-surface requires a unique P(roperty) ID(entification) number for the master-slave contact sets. For this reason it is necessary to separately generate all sub-surfaces before meshing them. If this was not the case, one could have meshed only the upper right quadrant surface before directly reflecting/translating the finite elements (rather than the sub-surfaces) in order to generate the complete mesh.

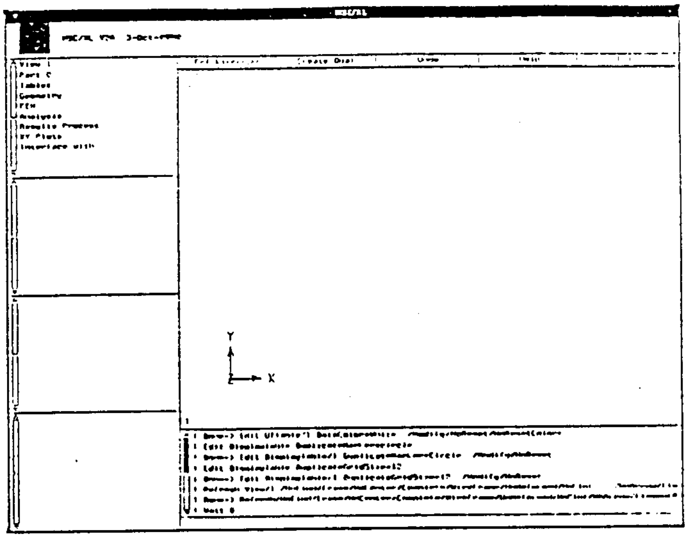

Figure 3.1 : Interactive mode (default mode) of MSC/XL screens.

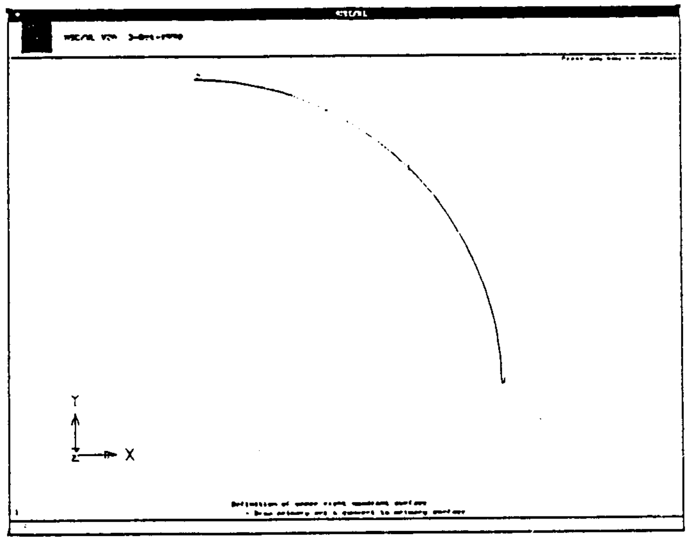

Figure 3.2 : Primary arc.

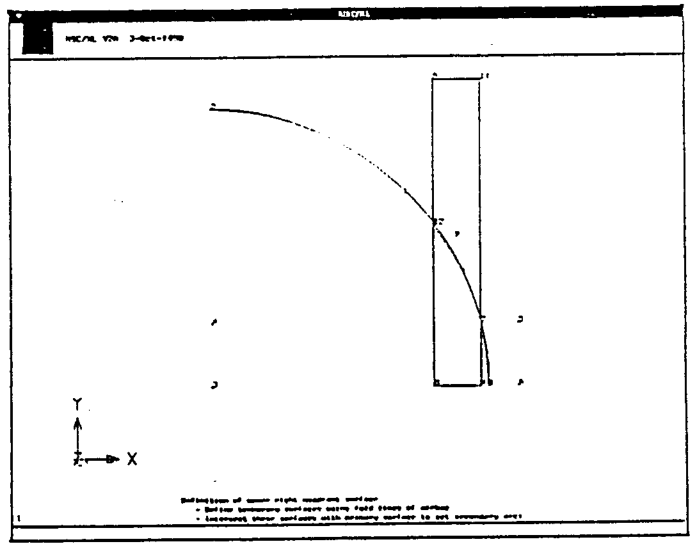

Figure 3.3 : Definition of secondary arcs.

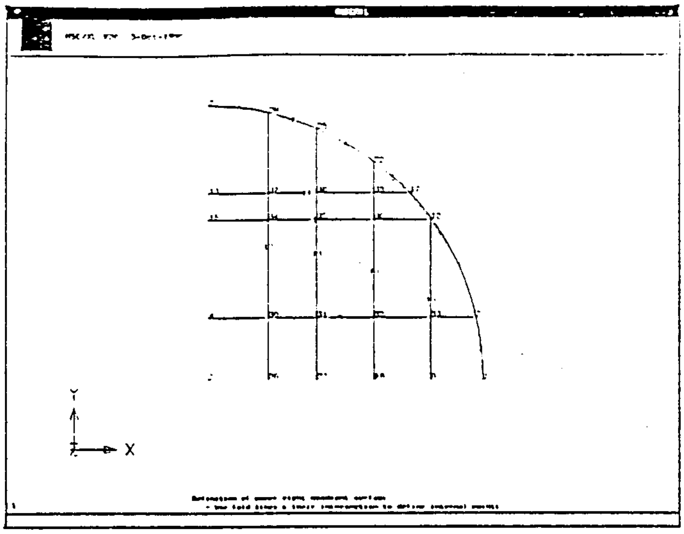

Figure 3.4 : Definition of interior points of mesh

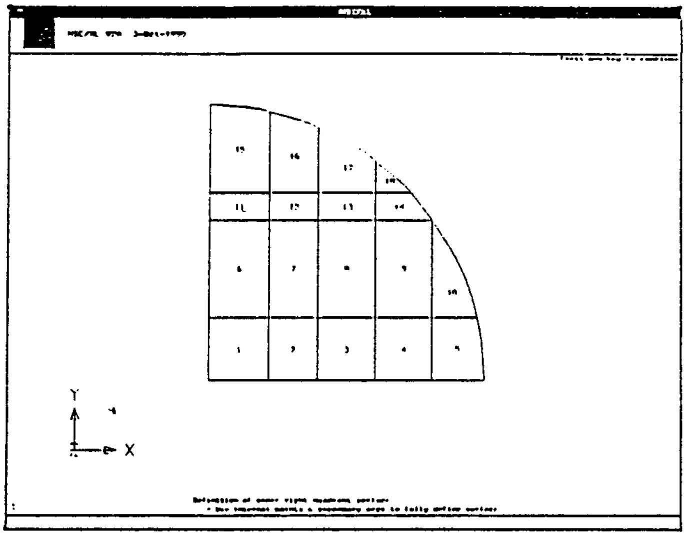

Figure 3.5 : Definition of upper right quadrant including points & secondary arcs.

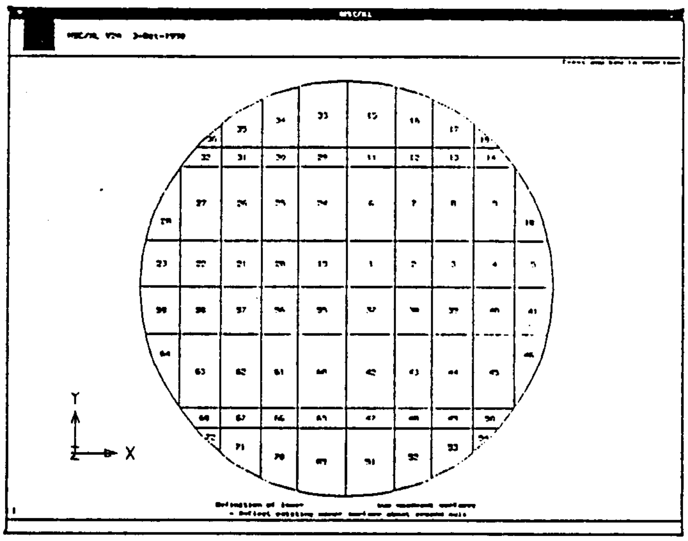

Figure 3.6 : Definition of upper & lower surfaces using reflection & translation.

4. Finite element meshing of Geometry

The basic geometry of the airbag's skins has now been generated and placed into the following views (Views 2 to 5 are reserved for visualisation of results of analysis) :

View 1 : Complete model (upper & lower skins)
View 6 : upper skin of airbag
View 7 : lower skin of airbag

Both surfaces now require meshing which is done per sub-surface/patch in order to later specify the contact master-slave sets using property identification numbers.

Meshing of upper surface (View 6) :

- Mesh each sub-surface using either parametric meshing techniques (uniform discretization) or Delaunay meshing techniques (different possible split allowed along each side of the element). Note that only triangular membrane elements are used (known in MSC trerminology as the TRIA3 element).

Checking of mesh for upper surface (View 6) - duplicate grid points :

- Search for all duplicate grid points (generated by the separate meshing of each sub-surface/patch) - the grid points are identified by a circle placed at the node.
- Equivalence/eliminate them (XL option)

Checking of mesh for upper surface (View 6) - reversed element normals :

- Search for all adjacent elements having a reversed topologies and hence reversed normals (generated by the reflection of the quadrants) - these elements are identified by a red line placed between the two elements.
- Reverse the normals of all the elements in upper left & lower right quadrants.

Meshing of lower surface (View 7):

- Follow same procedure as for upper surface except add an offset to all of the property identification numbers for each sub-surface/patch (offset=100).

Checking of mesh for lower surface (View 7) :

- Search for all duplicate grid points and equivalence/eliminate them.
- Search for reversed normals. For this lower skin, reverse the normals of all the elements in the lower left & upper right quadrants (this means that the normals for the lower and upper skins are opposite in direction).

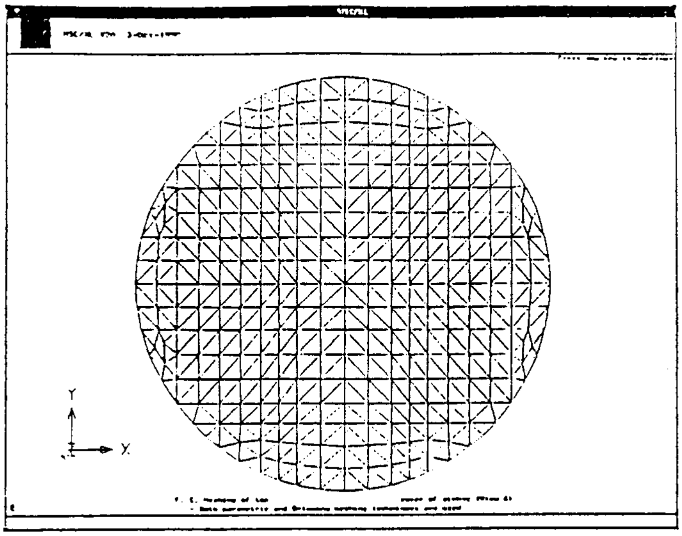

Figure 4.1 : Finite element meshing of upper surface.

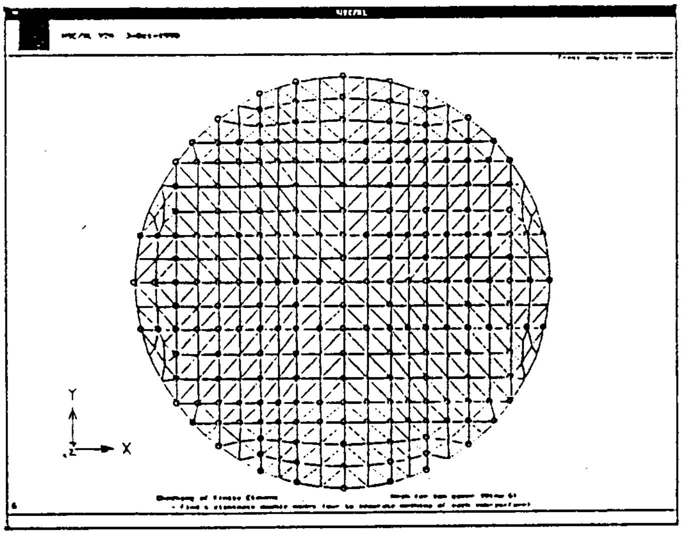

Figure 4.2 : Checking and elimination of double grid points.

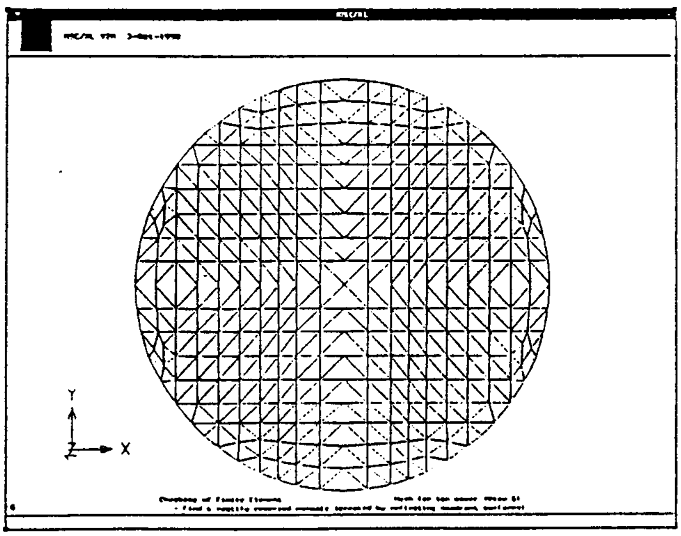

Figure 4.3 : Checking for and elimination of reversed normals (due to reflection of surfaces).

5. Joining of skins & application of boundary conditions

The finite element meshes have been generated for both the lower and upper skins of the airbag. The two skins now must be sewn/joined together along the edges and the boundary conditions have to be applied.

Joining of upper and lower skins along circumference (View 1) :

- Select View 1 to include both the upper and lower skin.
- Now, the grid points along the edge must be identified. The very useful "Define Group" function can be used for this in the following form :

*Define Group Name=joinededge Type=Grid Criterion =" (sqrt(x*x*+y*y) > 332)"*

(This groups all grid points that are outside a radius of 332 mm into one group identified by a character string = "joinededge")

- Display *only* these grid points using the name *"joinededge"* to identify them.
- Use the option "Find duplicate grid points" under menu "Check FEM" ; this should place a circle on every node on the circumference (only those nodes "displayed" in the view will be checked").
- Lastly, equivalence these nodes (i.e. the two skins are joined together along the circumference)

Application of single point constraints (boundary conditions) (View 7) :

- Select View 7 to enable separate manipulation of the lower skin of the airbag.
- Now, the grid points within the area |x|<=76 & |y|<=76 must be identified as all lower skin grid points within this area must have a S(ingle) P(oint) C(onstraint) applied. Again the useful "Define Group" function can be used for this in the following form :

*Define Group Name=fixedarea Type=Grid Criterion="((sqrt(x*x)<=76)&(sqrt(y*y)<=76))"*

(This groups all grid points that are within the above area into one group identified by a character string = "fixedarea")

- Display *only* these grid points using the name *"fixedarea"* to identify them.
- Apply the single point constraints to these nodes using the identifier *"fixedarea"*.
- Check the above constraints by displaying all SPC's in the view. If necessary, use the zoom option to see whether the correct constraint has been applied.

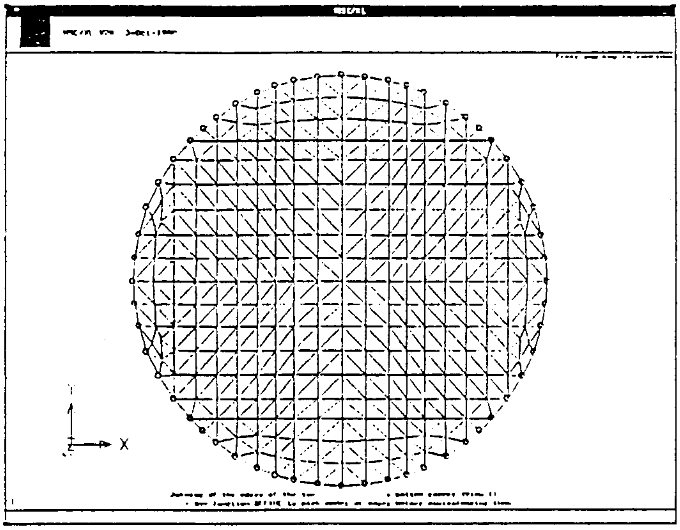

Figure 5.1 : Joining of edges of airbag.

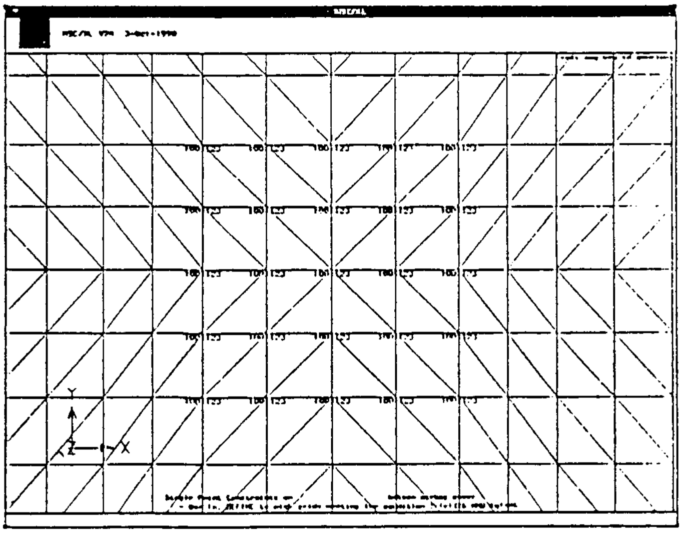

Figure 5.2 : Application of S(ingle) P(oint) C(onstraint)'S

6. Folding of airbag into initial configuration for analysis

The mesh has been prepared and defined in the preceding sections. To provide a realistic starting point, the airbag now has to be folded up into its initial configuration. This requires both the possibility of identifying the elements for each fold and rotating them simultaneously about the fold lines through angles of 180 degrees (horizontal folds) or 170 degrees (vertical folds). Note that these folds are done in increments of 60/50 degrees - this is solely to aid the visual representation of the folding process. To actually prepare such a mesh, all of these folds would be immediately through 180/170 degrees.

Definition of element groups to be folded (View 1) :

- Select View 1 to include both the upper and lower skin
- The elements contained within each "fold" group must be identified. Once again the useful "Define Group" function can be used for this in the following form :
  (Note that property identification numbers generated by the meshing process are used for the grouping criterion)

Define Group Name=foldv2 Type=Element Criterion ="((fmod(pid,10)=1)or(fmod(pid,10)=2))"

(the above would be for the second vertical fold, known as foldv2; this groups all elements meeting the above criterion in one group identified by a character string = "foldv2")

- Display each of these fold groups separately to visually check that the correct group has been identified.

Folding up of the airbag into its initial configuration :

- Change the angle of viewing for View 1 for a clearer representation.
- Using the option "Rotate elements about a vector", rotate each fold group about the relevant fold line starting with horizontal folds (3) and proceeding to the vertical folds (8), again using the appropriate group identifier to indicate the elements to be rotated.
- View the final folded mesh through the X-Z plane to examine the fold pattern.
- Zoom in on the mesh to show the maximum amount of detail.

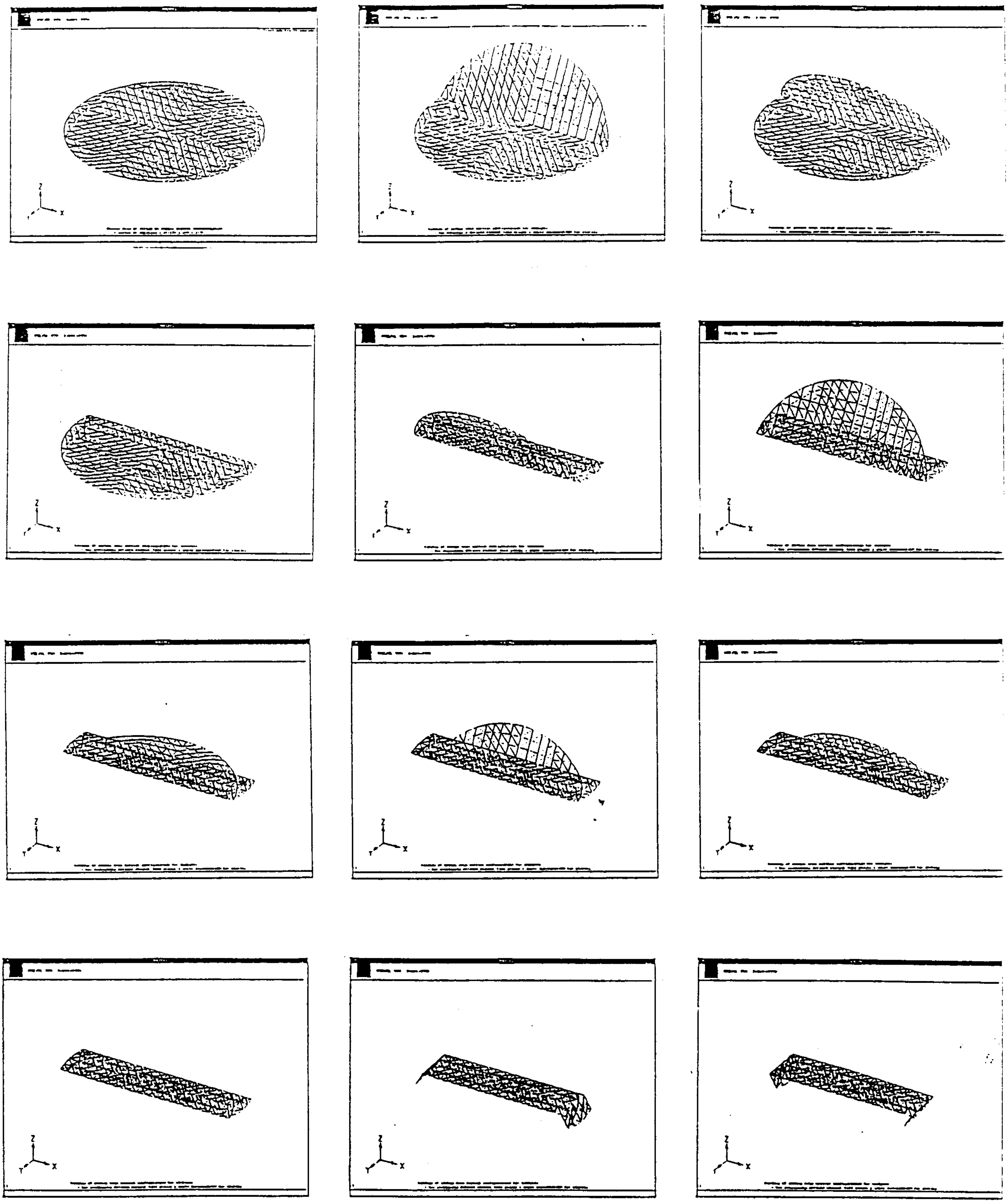

Figure 6.1 : Folding of airbag into initial configuration (left to right ; top to bottom)

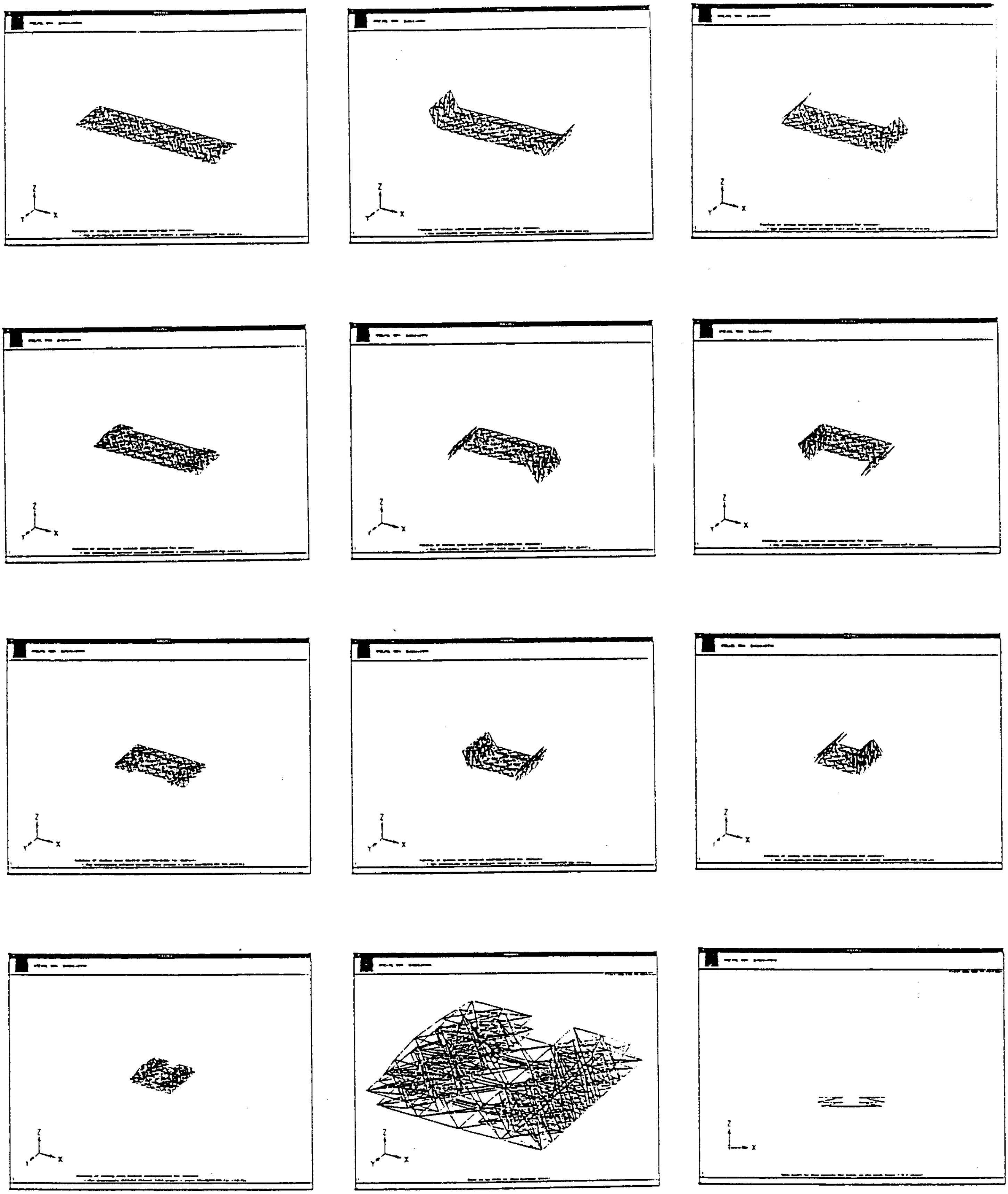

Figure 6.1 (continued) : Folding of airbag into initial configuration
(left to right ; top to bottom)

7. Conclusions/Final comments :

This example of a folded airbag proved to be an excellent task for evaluating MSC/XL as an interactive open-architecture pre-processor. The generation and subsequent manipulation of the mesh required many standard menu-driven features plus the use of fairly advanced MSC/XL features such as the grouping criterion used in joining the mesh edges and defining the element fold groups. The potential of "play-back" files was investigated with respect to a self-guided demonstration package (conatct author for a listing).

The relevance of this process can be seen with respect to planned developments for MSC/XL, including the full linking of MSC/DYTRAN to MSC/XL. Such a link would for example enable a user to prepare the mesh following the above sequence, analyse the problem without leaving the XL environment (using a "spawn" process), eventually examining the results using the post-processing potential of MSC/XL. In the case of an airbag, one would hence be able to first fold up the airbag and then examine the airbag inflating from within MSC/XL.

References

1. "Unfolding of Airbags", DYTRAN AN24, C.J.L. Florie, A.J.Buijk.
2. "MADYMO User's Manual 3D (1988)", Version 4.2 TNO Road Vehicles Institute, Department of Injury Protection.
3. "Inflation of folded driver and passenger airbag", DYTRAN paper (to be published), C.J.L.Florie and A.J.Buijk.