N87-25889

GEOMETRIC DESCRIPTION AND GRID GENERATION FOR SPACE VEHICLES

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ABSTRACT

The understanding and analysis of Three-dimensional fluid behavior around reentry vehicles, like the Space Shuttle Orbiter, is of considerable importance for flight applications. Vehicle designers need pressure, heat transfer, and shear distributions to support design activities. Traditionally these have been obtained by experimental data. Significant reduction in design costs can be obtained if the calculated results based on finite difference procedures are used to verify and supplement experimental results.

Computing the flowfield over Space Shuttle Orbiter, which has complex cross-sectional geometries is a major problem. A first step in this direction is development of body definition and grid generation procedure. In this project a digitized body definition and grid generation procedure, developed earlier at JSC, is modified and applied to the Shuttle Orbiter X24C-10D. Two-dimensional grid and body defintion for varous sections of the space vehicle is obtained using the differential equation method.

This study demonstrates that this geometry and grid generation rpocedure can be applied to other aerospace vehicles such as aerospaceplane.

1. INTRODUCTION

Analysis of three-dimensional fluid behavior around reentry vehicle such as X-24C-10D is of considerable importance for flight applications. A vehicle like this can produce very complex flow fields. The flow field changes radically with leeside of vehicle becoming dominated by large regions of cross flow separation, when angle of attack is increased. Calculated results are useful to verify and supplement the experimental results. For the chosen aircraft a detailed experimental data base exists in the form of a flow field pitot survey, surface pressures, heat transfer, force and moment measurements.[1, 2, 3]

A first step in calculating the flow parameters using finite difference methods is to generate a satisfactory grid. The grid generation process must achieve the following:

1. Develop accurate surface definition
2. Distribute grid points on the body surface
3. Generate a clustred smoothly varying interior mesh.

Algebraic or differentiated equation techniques[4] can be used to generate grid on complicated three-dimensional problems. In this study a digitized body definition and grid generation procedure developed earlier at Johnson Space Center is modified and applied to the Shuttle Orbiter X-24C-10D in order to test the procedure. This hypersonic research aircraft is selected in this investigation for its rather blunt leading edges, canopy, strake fin and wing formations, which are typical of those encountered in a modern aerospace vehicle. The object of this testing is to apply this procedure to other aerospace vehicles such as the aerospaceplane at a later date. A differential equation method developed by Thompson et al.[5] and windslow[6] is used to generate two-dimensional elliptic grid in each cross section plane between two control surfaces.

2. PROCEDURE

The block diagram of the digitized procedure used to generate the body and the two-dimensional grid for various sections of the Shuttle Orbiter X-25C-10D is shown in figure 2. X-axis is chosen along the body axis. The X=constant plane in which Y and Z vary is chosen as a plane normal to the body axis. Coordinates of points on various segments of sections of the body are obtained from a blue print supplied by Martin Marietta Corporation, Denver, Colorado. The coordinate system is constructed by a series of coaxial cross sections. In each cross section plane a two-dimensional grid system is established between the body contour and an ellipse.

The grid is generated by using the differential equation method, which is one of the highly developed techniques for generating acceptable grids. The procedure transforms the physical plane in to computational plane where the mapping is controlled by a poission equation. Elliptic partial differential equations are used to generate the grids.

The mapping is constructed by specifying the desired grid points (Y,Z) on the boundary of the physical domain. The distribution of points on the interior is then determined by solving:

$$\xi_{yy} + \xi_{zz} = P(\xi, \eta)$$
$$\eta_{yy} + \eta_{zz} = Q(\xi, \eta) \qquad \ldots\ldots (1)$$

Where (,) represent the coordinates in the computational domain and P and Q are terms which control point spacing on the interior of physical domain. Equations (1) are then transformed to computational space by interchanging the roles of the independent and dependent variables. This yields a system of two elliptic equations of the form

$$\alpha Y_{\xi\xi} - 2\beta Y_{\xi\eta} + \gamma Y_{\eta\eta} = -J^2 (P \cdot Y_\xi + Q \cdot Y_\eta)$$

$$\alpha Z_{\xi\xi} - 2\beta Z_{\xi\eta} + \gamma Z_{\eta\eta} = -J^2 (P \cdot Z_\xi + Q \cdot Z_\eta)$$

Where

$$\alpha = Y_\eta^2 + Z_\eta^2$$
$$\beta = Y_\xi Y_\eta + Z_\xi Z_\eta$$
$$\gamma = Y_\xi^2 + Z_\xi^2$$

$$J = \frac{\partial (Y, Z)}{\partial (\xi, \eta)} = Y_\xi Z_\eta - Y_\eta Z_\xi$$

. . . . (2)

This system of equations is solved on a uniformly spaced grid in the computational plane. This provides the (Y,Z) coordinates of each point in the physical space. The advantage of using this method is that the grid is smooth, the transformation is one to one and complex boundaries are easily treated. All of this is accomplished by the main program GRID. The functions of the subroutines used in the program are given below briefly.

INPUT- Specifies number of points in normal and circumferential direction of grid, number of segments in a section of body and number of points supplied in each segment.

GEOM- Interpolates body points (obtained from a blue print) between two given meridionals.

PNTIB- Distributes points on the body at equal space.

PNT2B- Helps to distribute and cluster the points on the body.

KEYPT- Defines points on a section of the body

COEFF- Patches the end points of each segment of a section of the body.

CUBSPL- Fits cubic splines inbetween points.

TRID- Solves a tridiagonal system of equations.

PLOT- Calls various plotting routines.

3. CONCLUDING REMARKS and RECOMMENDATIONS

A digitized procedure is used to obtain body definition and two-dimensional grid perpendicular to the body axis. A few sections of the body defined by this procedure along with elliptic grid at several axial stations is presented in figures 4 to 8. The body definition obtained by the method for each section is remarkably close to the ones obtained by the author[7] analytically for the same reentry vehicle. In figure 3 a section of the body at axial station X=430 before the elliptic grid is generated is shown. The advantage of this method is that it is very easy to obtain any body section and two-dimensional grid by supplying a few points on segments of the Shuttle Orbiter. It is highy recommended that this procedure be used for other aerospace vehicles such as aerospaceplane to obtain body definition and grid.

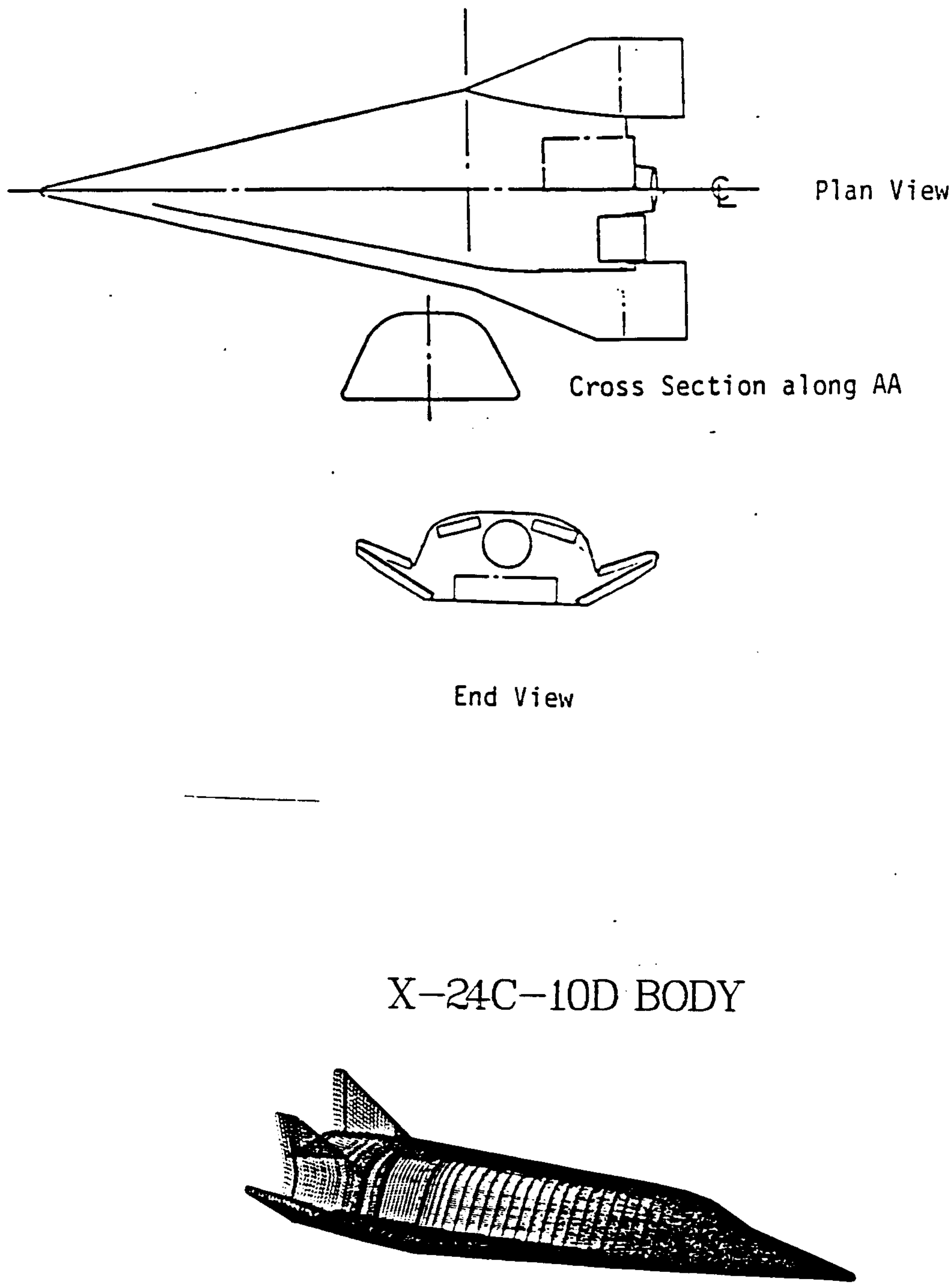

Figure 1 X24C-10D Configuration

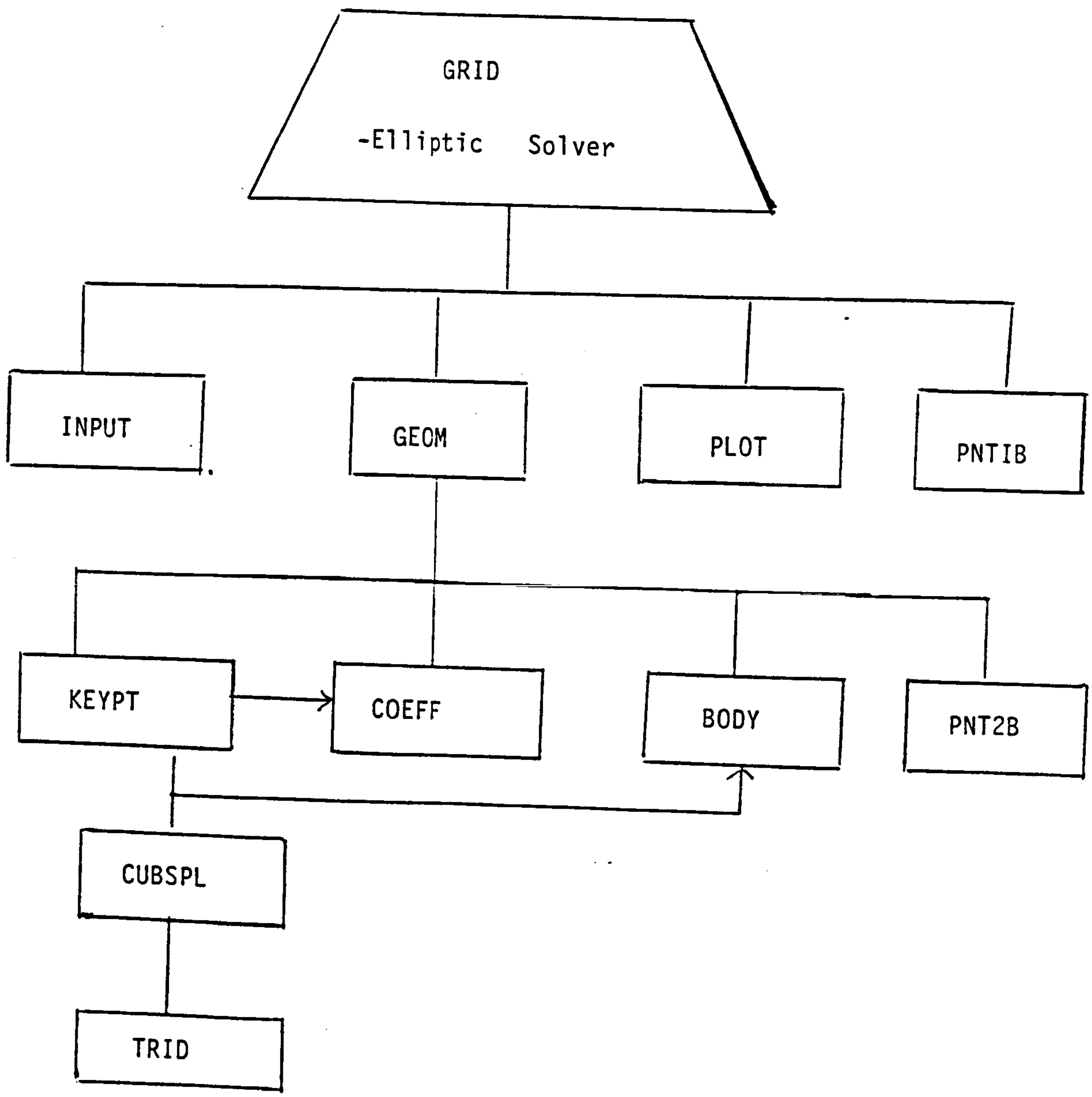

Figure 2: Digitized Body Definition and Grid Generation Procedure - Block Diagram

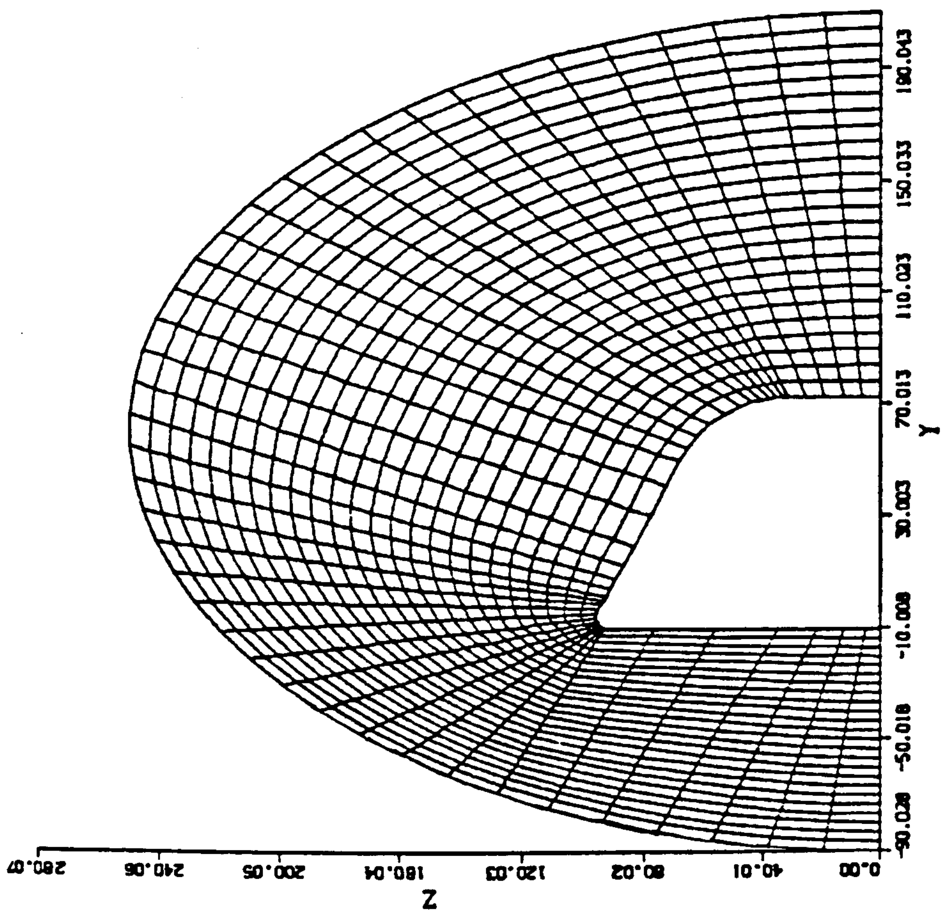

Figure 3: Body Profile for Shuttle Orbiter X - 24C - 10D at Axial Station X = 430 before the Elliptic Grid is Generated.

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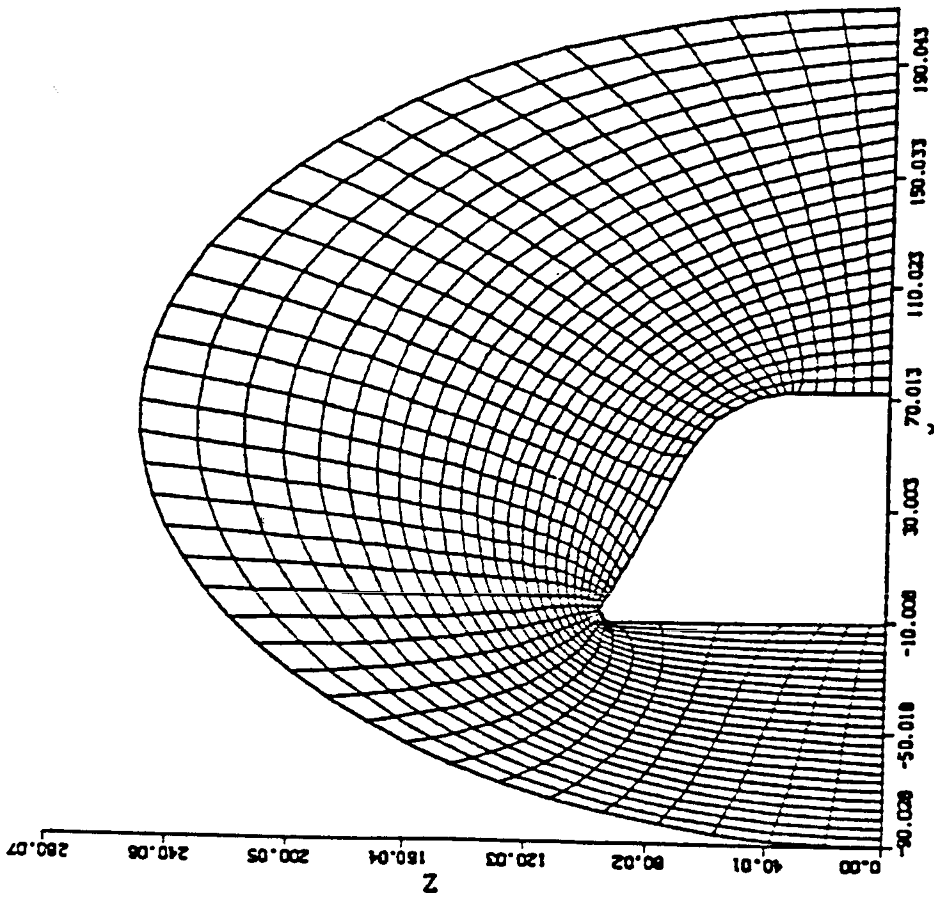

Figure 4: Body Profile and Elliptic Grid for Shuttle Orbiter X-24C-10D at Axial Station X=430.

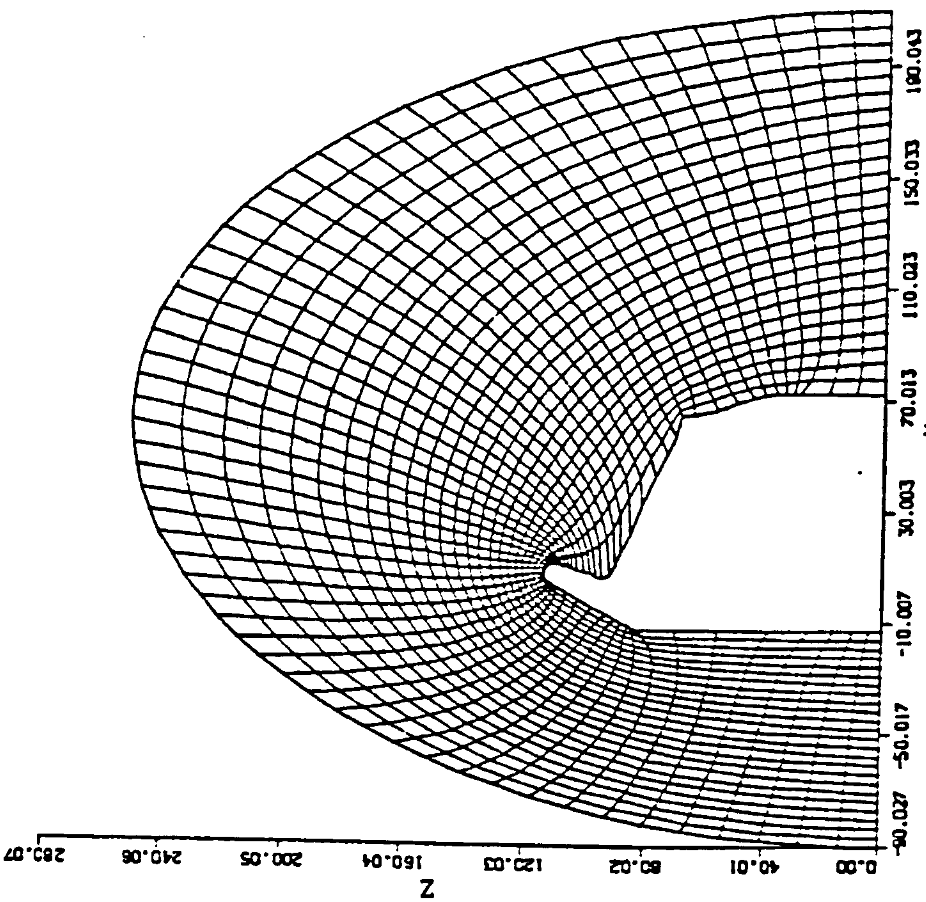

Figure 5: Body Profile and Elliptic Grid at Axial Station X=475.

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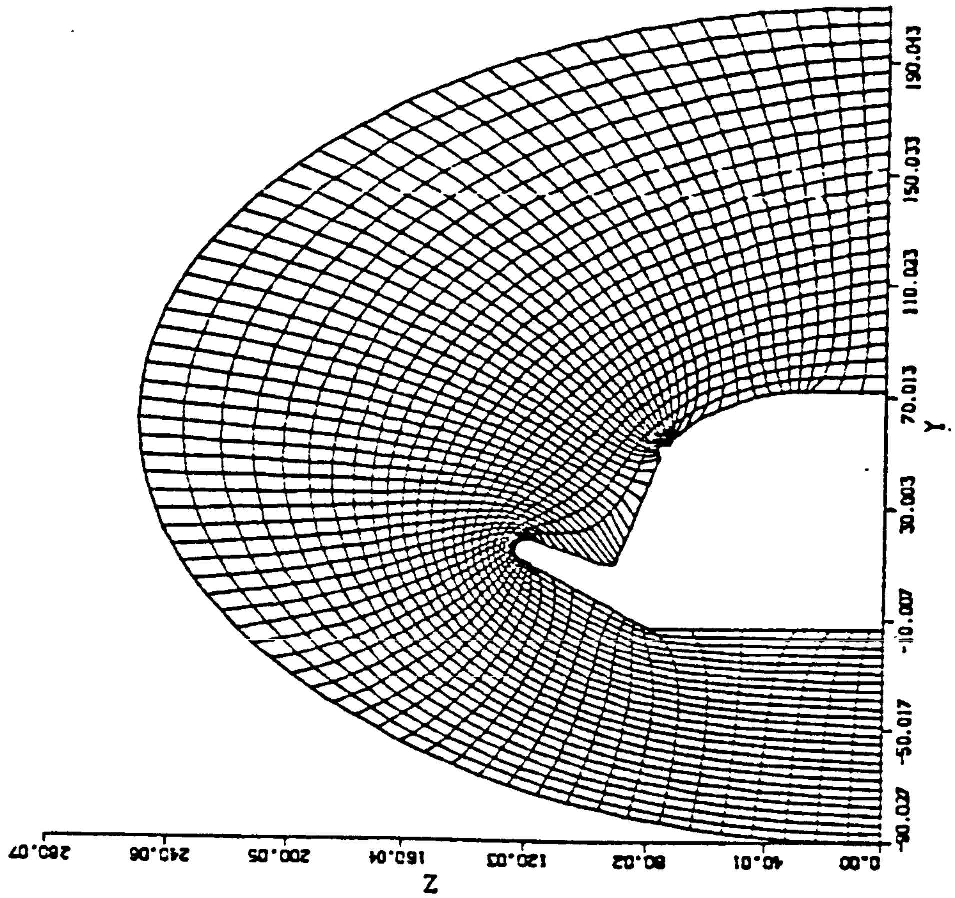

Figure 6: Body Profile and Elliptic Grid at Axial Station X=500.

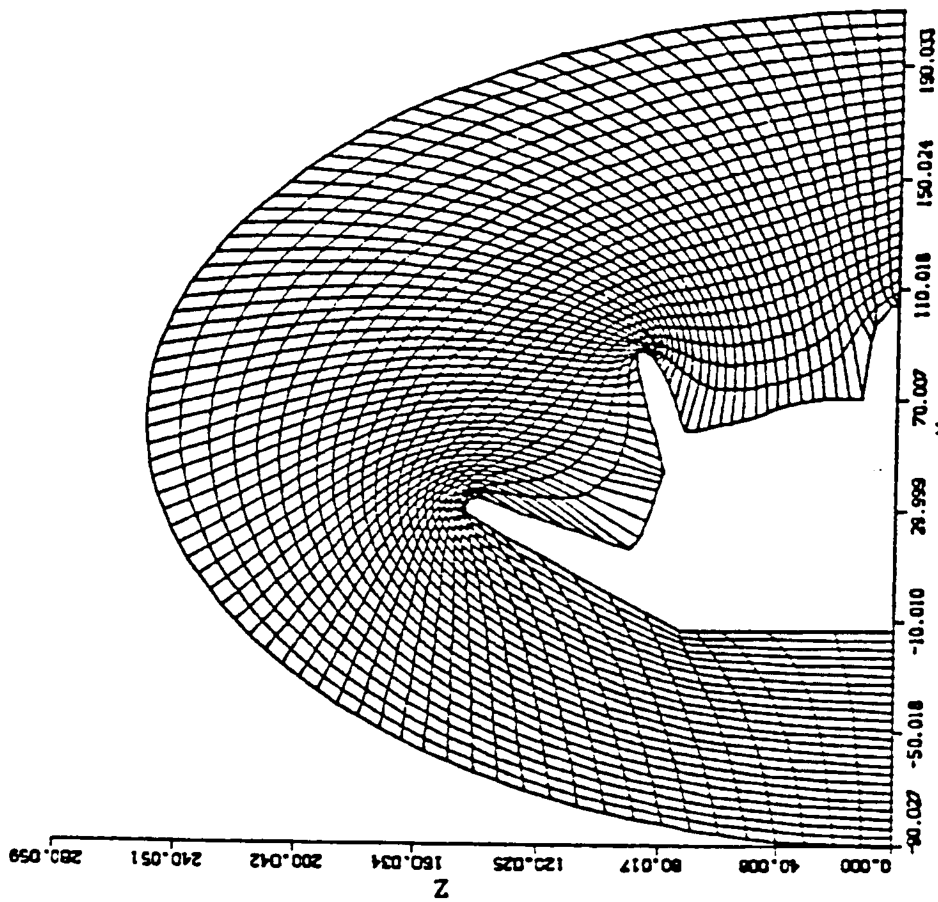

Figure 7: Body Profile and Elliptic Grid at Axial Station X=550.

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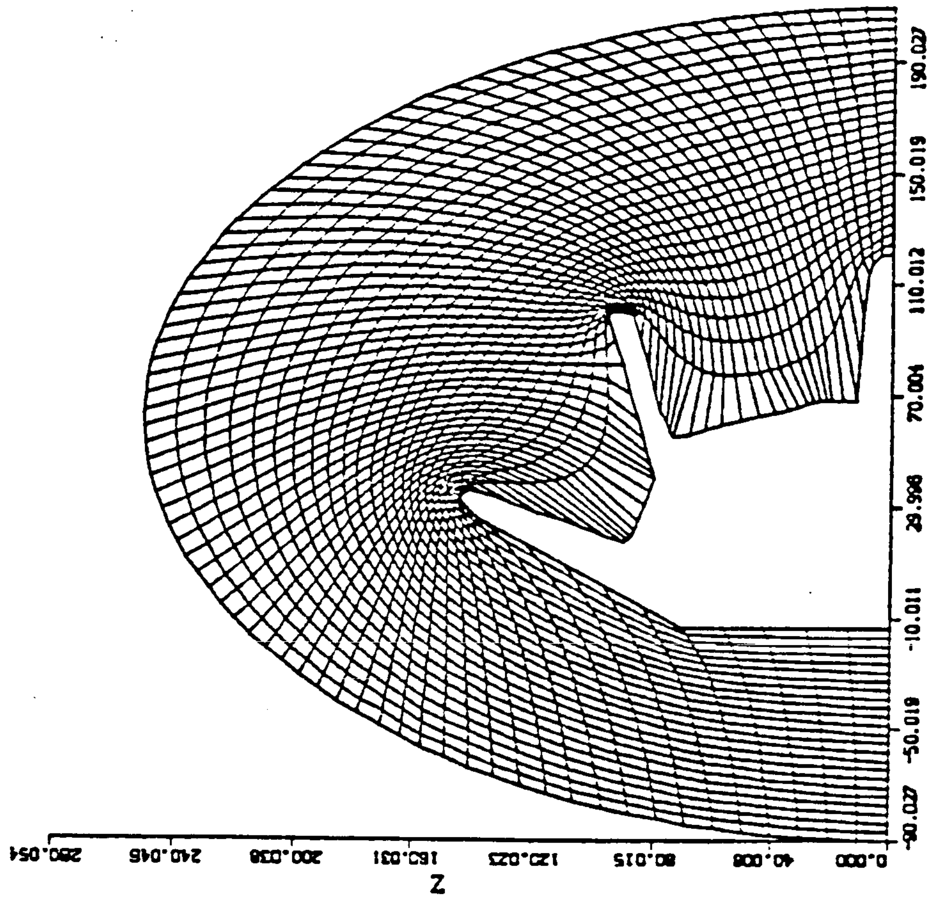

Figure 8: Body Profile and Elliptic Grid at Axial Station X=575.

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ACKNOWLEDGEMENT

The author would like to thank NASA, American Society for Engineering Education, and University of Houston for providing him with the opportunity to spend a very worthwhile and interesting summer at the

Johnson Space Center, Houston, Texas. He would like to acknowledge the center, in particular, the Aeroscience Branch of Advanced Programs Office, for its hospitality and excellent working conditions.

Finally, he would like to thank Dr. Chen-Peng Li for suggesting this area of research.