A MULTISTAGE MESH GENERATOR FOR SOLVING THE AVERAGE-PASSAGE EQUATION SYSTEM

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SUMMARY

One means of numerically simulating the three-dimensional flow field within a multistage turbomachine is through the solution of the average-passage equation system. One requirement of a current algorithm used to solve this system of equations has been the ability to generate multiple blade row meshes which satisfy specific geometrical constraints. In addition to meeting this criteria, one desires a mesh generation code which requires minimal user input, utilizes variable mesh control parameters, generates diagnostics helpful to the user, and possesses the capability to handle widely varying geometries. A mesh generation code with these features was written and has been used in solving the inviscid form of the average-passage equation system for both ducted and unducted multiple blade row geometries. This paper serves as a user reference guide, with a description of the mesh generation algorithm, a sample input file, and examples of typical meshes generated.

INTRODUCTION

With the computer resources available today, a rational path to the numerical simulation of the three-dimensional flow field associated with a multistage turbomachine is through the solution of the average-passage equation system outlined by Adamczyk (ref. 1). The flow field description yielded for each blade row is one which is steady with respect to time and spatially periodic from blade passage to blade passage. Based on Adamczyk's closure model for the inviscid form of the average-passage equation system (ref. 2), Celestina and Adamczyk wrote a FORTRAN program to numerically simulate the "average-passage" flow field associated with each blade row of a single stage geometry (ref. 3). Their algorithm imposed several conditions upon the three-dimensional meshes which were to be used by the code. Every blade row required its own H-mesh in cylindrical coordinates which described a full passage from inlet to exit with all the meshes having common axial (z) and radial (r) coordinates. Each blade row's respective mesh had to account for its own blade thickness, while applying zero thickness to the neighboring blade rows. The requirement of a single axisymmetric mesh was due to the body forces and other correlations which must be calculated from each blade row simulation and then communicated to the neighboring blade row simulations via a common set of axisymmetric coordinates.

MULTISTAGE MESH GENERATION STRATEGY

The first step in generating the three-dimensional meshes for each blade row of a multistage geometry is to create the common two-dimensional axisymmetric grid. An approach was taken in which a given geometry is broken up from inlet to exit into "blade" and "nonblade" sections. As an example, the General

Electric Unducted Fan geometry, as shown in figure 1, will be used. This single stage machine is broken up into the various sections in figure 2. Each section is then gridded up two-dimensionally from inlet to exit, with the "blade" sections retaining blade thickness information at each grid point. This is shown in figure 3. When all of the sections have been gridded, they are spliced together to form one two-dimensional axisymmetric surface, as shown in figure 4. A unique three-dimensional mesh is then generated for each blade row using the blade thickness information associated with that blade row and zeroing out the thickness of the neighboring blade rows. Axial and radial cuts are shown for the first and second blade row meshes in figures 5 and 6, respectively.

The two-dimensional grid work was accomplished with the use of two subroutines, SPLINT and INRSCT, which were taken from the MERIDL code of Katsanis and McNally (refs. 4 and 5). These two routines are used to fit cubic spline curves to the blade cut, hub line, tip line, shroud line, inlet plane, and exit plane definitions input to the program. Blade data is required in a form familiar to MERIDL users, constant radial cuts running from hub to tip. Each cut is defined as a series of cylindrical coordinate pairs, either the mean camber line and its associated tangential thickness, or the absolute blade surface coordinates. The hub, tip, and shroud lines are defined as a set of axial and radial coordinate pairs. The inlet and exit planes are set at specific axial locations.

The various "blade" and "nonblade" sections differed in their construction only through the algebraic formula which was used to determine the point distribution in the three directions. Three different packing algorithms were used. The first was a simple geometric progression radiating from a symmetric centerline. This approach was used in both the axial and radial directions on the blades and in the circumferential direction of the entire geometry. Given

D   total projected length of cubic spline curve

RAT   maximum ratio of adjacent cell projected lengths

M   number of points distributed across   D (odd)

the initial cell length of the progression is calculated as

$$DELT = \frac{D/2}{\displaystyle\sum_{i=1}^{(M/2)+1} RAT^i}$$

The point distribution is then given by

$$P(i) = \sum_{j=1}^{i} (DELT)(RAT)^j, \qquad i = 1, (M/2) + 1$$

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In the second method D, RAT, and DELT are given, along with

N total number of parallel cubic spline curves,

leaving M to be calculated. The value of M is calculated by trial and error until it satisfies the two conditions

$$\left(\frac{D}{DELT}\right)_{max} = \sum_{i=1}^{M} RAT^i$$

$$\left(\frac{D}{DELT}\right)_{min} = \sum_{i=1}^{M} RAT^{-i}$$

Where

$$\left(\frac{D}{DELT}\right)_{max} = max \left(\frac{D}{DELT}\right)_{j=1,N}$$

$$\left(\frac{D}{DELT}\right)_{min} = min \left(\frac{D}{DELT}\right)_{j=1,N}$$

These conditions ensure that neither the adjacent cell ratios nor their inverses exceed RAT. The point distribution is then given by

$$P(i) = \sum_{j=1}^{i} (DELT) (RAT)^j, \qquad i = 1,M$$

This approach is used axially in the inlet and exit regions and radially in the tip to shroud region. The most complex packing algorithm is used to calculate the point distribution between blade rows in the axial direction. Given are

D   total projected length of cubic spline curve

RAT   maximum ratio of adjacent cell projected lengths

DELTTE initial cell width (forward blade row trailing edge)

DELTLE initial cell width (aft blade row leading edge)

N   total number of parallel cubic spline curves

Two new distances are calculated by

$$DTE = \left(\frac{DELTTE}{DELTTE + DELTLE} \right) \quad (D)$$

$$DLE = \left(\frac{DELTLE}{DELTTE + DELTLE} \right) \quad (D)$$

The value of M is calculated by trial and error until it satisfies the two conditions

$$\left(\frac{D}{DELT} \right)_{max} \leq \sum_{i=1}^{M} RAT^{i}$$

$$\left(\frac{D}{DELT} \right)_{min} \geq \sum_{i=1}^{M} RAT^{-i}$$

where

$$\left(\frac{D}{DELT} \right)_{max} = max \left(\frac{DTE}{DELTTE} \right), \left(\frac{DLE}{DELTLE} \right), \quad j = 1,N$$

$$\left(\frac{D}{DELT} \right)_{min} = min \left(\frac{DTE}{DELTTE} \right), \left(\frac{DLE}{DELTLE} \right), \quad j = 1,N$$

Again, these conditions ensure that neither the adjacent cell ratios nor their inverses exceed RAT. The point distribution is then given by

$$P(i) = \sum_{j=1}^{i} (DELTTE)(RAT)^{j}, \quad i = 1,M$$

$$P(i) = \sum_{j=1}^{i} (DELTLE)(RAT)^{j}, \quad i = 1,M$$

This combination of packing algorithms allows the user to specify the number of points on each blade, but allows the program to choose the total number of points needed to stay within the packing constraints (maximum ratio of adjacent cell projected lengths) specified by the user. Emphasis was placed on assuring mesh quality, rather than forcing the code to construct a

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mesh to lie within certain preassigned dimension limits. Although the subrou-
tine SPLINT returns information on the first and second derivatives along the
resulting cubic spline curve, orthogonality was not used as a guide in mesh
construction.

A diagram of the static calling tree for the program is shown in figure 7.
All input is read in by the main program MESH and printed out for verification
by the subroutine PRINT. Subroutine ERROR checks for any deviation from the
restrictions placed on parameters in the input file. MESH then makes calls to
the subroutines GENIN, GENBL, GENBB, and GENEX to compute the two-dimensional
axisymmetric grid in the inlet, blade, between blades, and exit regions,
respectively. Each of these routines makes calls to the subroutines SPLINT
and INRSCT to calculate the cubic spline curves which are used to fit the grid
lines to the specific region. In the case of an unducted geometry, one other
subroutine, NUMPTS, is called by MESH to calculate the number of points to be
used radially from blade tip to shroud, with a second pass then made from
inlet to exit to grid that region. The transformation from the common two-
dimensional axisymmetric mesh to the individual three-dimensional meshes is
performed within MESH after all the "blade" and "nonblade" sections have been
gridded. In order to allow for a smooth transition into and out of each blade
passage, a circumferential smoothing factor was added to vary the pitch of the
mesh. This involved an exponentially decaying function which forced the slope
($d\theta/dz$) to zero as the mesh approached the inlet or exit plane. The effect of
this factor is shown in the circumferential cut of figure 8. The code also
allows for constant inlet or exit sections to be added to the meshes by speci-
fying NINPLS and NEXPLS in the input file. Output of the completed three-
dimensional meshes is performed in MESH, with the coordinates being written
out according to the parameter IWRITE. Lastly, subroutine ERROR checks the
completed meshes for problems such as memory overflow, negative blade thick-
ness, adjacent blade rows rotating in the same direction, etc., and PRINT
prints out the output parameters associated with the meshes.

Diagnostics are generated throughout the code to help the user avoid
creating erroneous meshes. Besides the analysis done by ERROR, GENIN, GENBL,
GENBB, GENEX, and NUMPTS detect the failure of the code to fit the mesh to
within the packing tolerance specified by the user and offer suggestions to
alleviate the problem. SPLINT and INRSCT detect errors in the set of points
to be fitted with a cubic spline curve.

The use of an algebraic mesh generation algorithm has allowed the code to
be successfully used over a wide variety of geometries. Although this simplis-
tic approach has yielded few problems in the meshes created, there are several
points which can be looked to for improvement. If one of the cubic spline
curves is highly turned, the resulting interior mesh lines generated could pos-
sibly extend beyond the geometries preassigned domain. In the case of an
unducted geometry, a high degree of skewness sometimes results in the blade tip
region. When dealing with blades which are relatively thick at the leading or
trailing edge, the code cannot yet approximate a rounded or blunt surface there
when relatively few points are used to define the blade surface.

INPUT FILE

An example of a typical input file used by the code is shown in figure 9. In this case the geometry is a two-stage high-pressure fuel turbopump. All input is read from FORTRAN unit 100 in either 20A4, 8I10, or 8F10.5 format, depending on whether the data is character, integer, or real. The first section contains the control parameters to be used in constructing the meshes.

TITLE   description of mesh to be generated

NBLROW   number of blade rows

IGEOM   shrouded (1) or unshrouded (2) geometry

ITHETA   theta input format: mean camber line and tangential thickness (1) surface theta coordinates (2)

IWRITE   mesh write to disk format: unformatted write inside single DO loop (1) unformatted write inside triple DO loop (2)

NINPLS   number of constant inlet planes

NEXPLS   number of constant exit planes

NBLPTZ   number of points on blades in axial direction (odd)

NBLPTR   number of points on blades in radial direction (odd)

NBLPTT   number of points blade to blade in theta direction (odd)

ZINLET   z coordinate at inlet

ZEXIT   z coordinate at exit

RATIN   maximum axial ratio of cells in inlet region

RATEX   maximum axial ratio of cells in exit region

RATBB   maximum axial ratio of cells between blade rows

RATBLZ   maximum axial ratio of cells on blades

RATBLR   maximum radial ratio of cells on blades

RATBLT   maximum circumferential ratio of cells blade to blade

RATTOB   maximum radial ratio of cells from tip to outer boundary
           RATIN, RATEX, RATBB, and RATTOB must be $>$ 1.0
           RATBLZ, RATBLR, and RATBLT must be $\geq$ 1.0
           RATBB must be $\geq$ the ratio of adjacent blade chords

It is important that NX be set greater than or equal to NBLROW in each parameter statement of the code and that PRECIS be set equal to the numerical precision of the computer. The next section contains the hub and tip (or shroud) line coordinates.

NHUB   number of hub points

NTIP   number of tip or shroud points

The axial (z) coordinates are given first, followed by their radial (r) coun-
terparts. The final NBLROW sections are the blade definitions.

NBLD   number of blades in the blade row

NBLCRC number of constant radial cuts describing blade geometry

NPPRC   number of points per radial cut

Each blade cut consists of a series of points each defined by an axial, a
radial, and two angular coordinates. The axial (z) coordinates are given
first, followed by the radial (r) coordinates, followed by the two angular
(θ) coordinates. The angular coordinates may be defined in one of two formats,
depending on the value of the flag ITHETA. The first legal format is the defi-
nition of a mean camber line and an associated tangential thickness. The
second legal format is the definition of the actual blade surface theta
coordinates.

OUTPUT FILES

All mesh data is written out unformatted to FORTRAN units 1 through
NBLROW, with each blade row sequentially assigned its own unit number. The
first record consists of the seven integers IL, JL, KL, ILE, ITE, JTIP, and
NBLD. The value of each of these parameters is also printed out on FORTRAN
unit 101 for each blade row of the geometry, as shown in figure 10. The param-
eter definitions are as follows

IL   number of points in the axial (I) direction

JL   number of points in the radial (J) direction

KL   number of points in the circumferential (K) direction

ILE   I index of blade leading edge

ITE   I index of blade trailing edge

JTIP   J index of blade tip

NBLD   number of blades in the row

The rest of the records consist of the mesh coordinates and can be written out
one of two ways depending on the value of IWRITE. The first option is to
write the coordinates out planewise from hub to tip using an unformatted write
inside a single DO loop. The second option is to write out the coordinates
unformatted using a triple DO loop with the radial index (J) being the outer-
most loop, the circumferential index (K) being the middle loop, and the axial
index (I) being the innermost loop. The first method has the advantage in

that the mesh requires less storage due to the smaller amount of records in
the write.

The next set of figures exhibit views of the resulting four meshes gener-
ated using the example input file. Figure 11 shows the common axisymmetric
grid associated with all four blade rows. The blade-to-blade view of the
first stator, first rotor, second stator, and second rotor meshes is shown in
figures 12 to 15, respectively.

CONCLUSION

An algebraic three-dimensional mesh generator has been developed for use
in solving the average-passage equation system for multistage turbomachinery.
Meshes can be generated for both ducted and unducted geometries consisting of
up to 100 blade rows. The user has access to variable mesh control parameters
and the program attempts to guide the user in their use through diagnostic
messages.

REFERENCES

1. Adamczyk, J.J.: Model Equation for Simulating Flows in Multistage Turboma-
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   of the Inviscid Flow Through a Counterrotating Propeller. J. Turbomachin-
   ery, vol. 108, no. 2, Oct. 1986, pp. 187-193. (NASA TM-87200.)

4. Katsanis, T.; and McNally, W.D.: Revised FORTRAN Program for Calculating
   Velocities and Streamlines on the Hub-Shroud Midchannel Stream Surface of
   an Axial-, Radial-, or Mixed-Flow Turbomachine or Annular Duct: I - User's
   Manual. NASA TN D-8430, 1977.

5. Katsanis, T.; and McNally, W.D.: Revised FORTRAN Program for Calculating
   Velocities and Streamlines on the Hub-Shroud Midchannel Stream Surface of
   an Axial-, Radial-, or Mixed-Flow Turbomachine or Annular Duct:
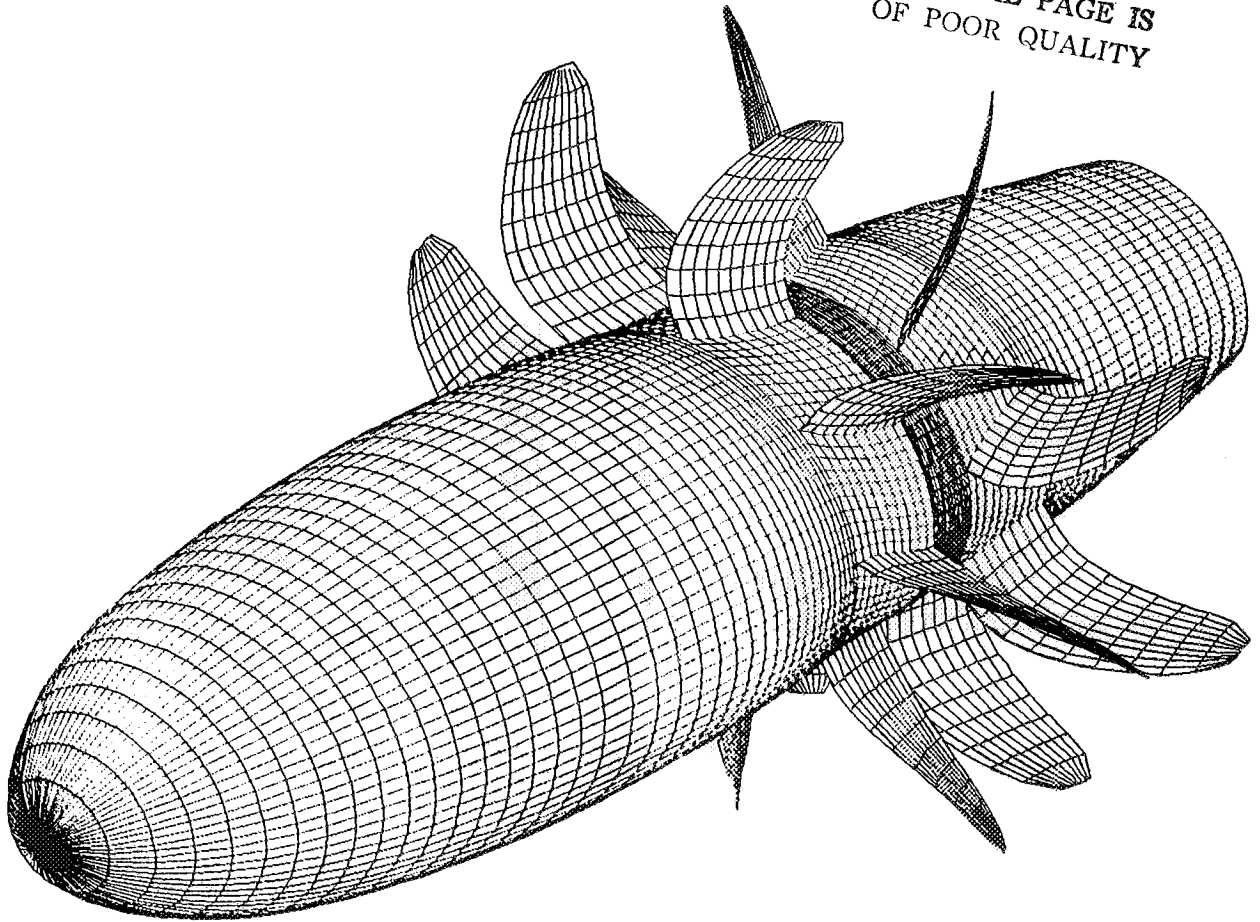   II - Programmer's Manual. NASA TN D-8431, 1977.

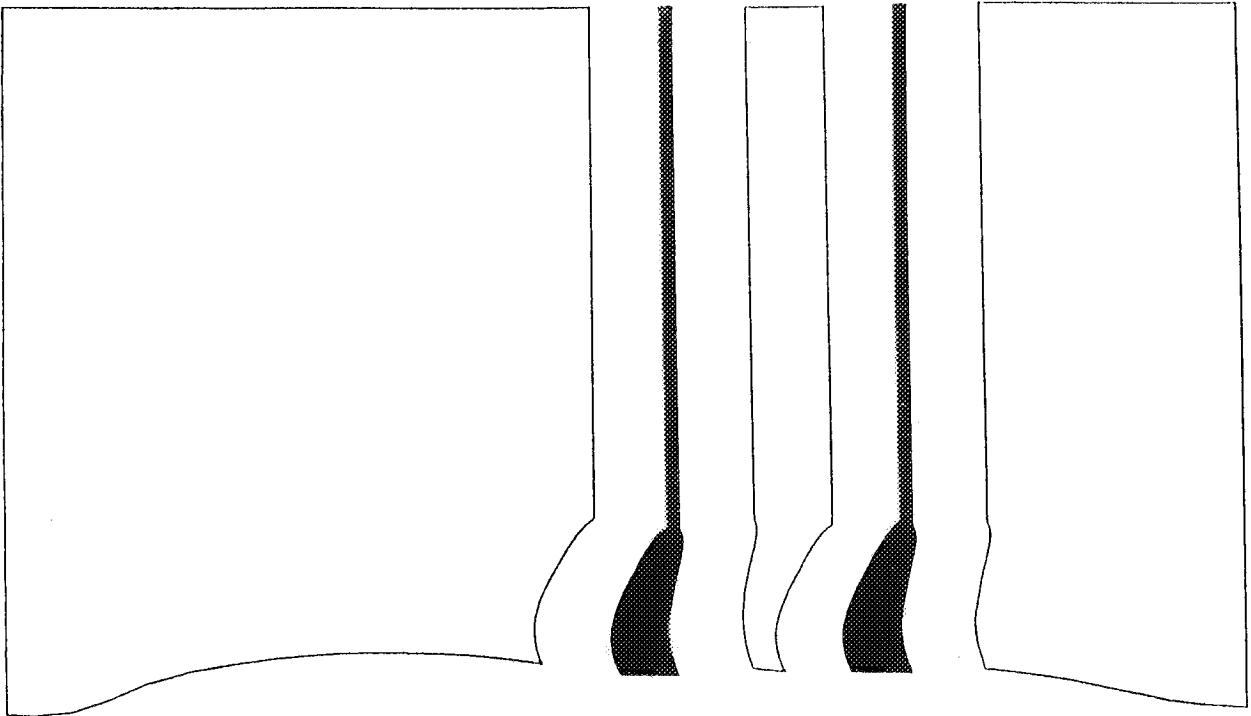FIGURE 1. - GENERAL ELECTRIC UNDUCTED FAN.

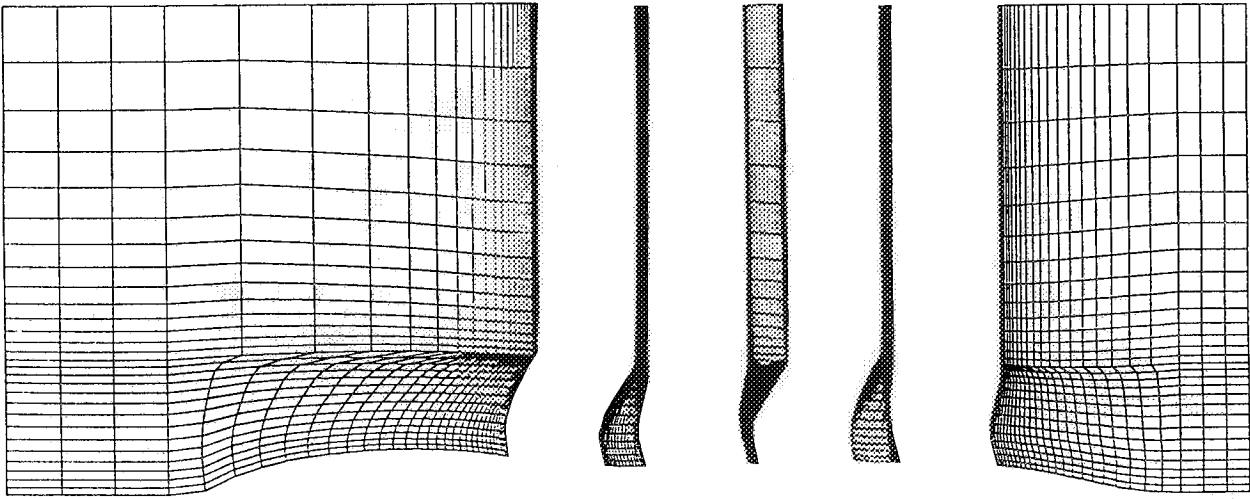FIGURE 2. - GEOMETRY DIVIDED INTO "BLADE" AND "NONBLADE" SECTIONS.
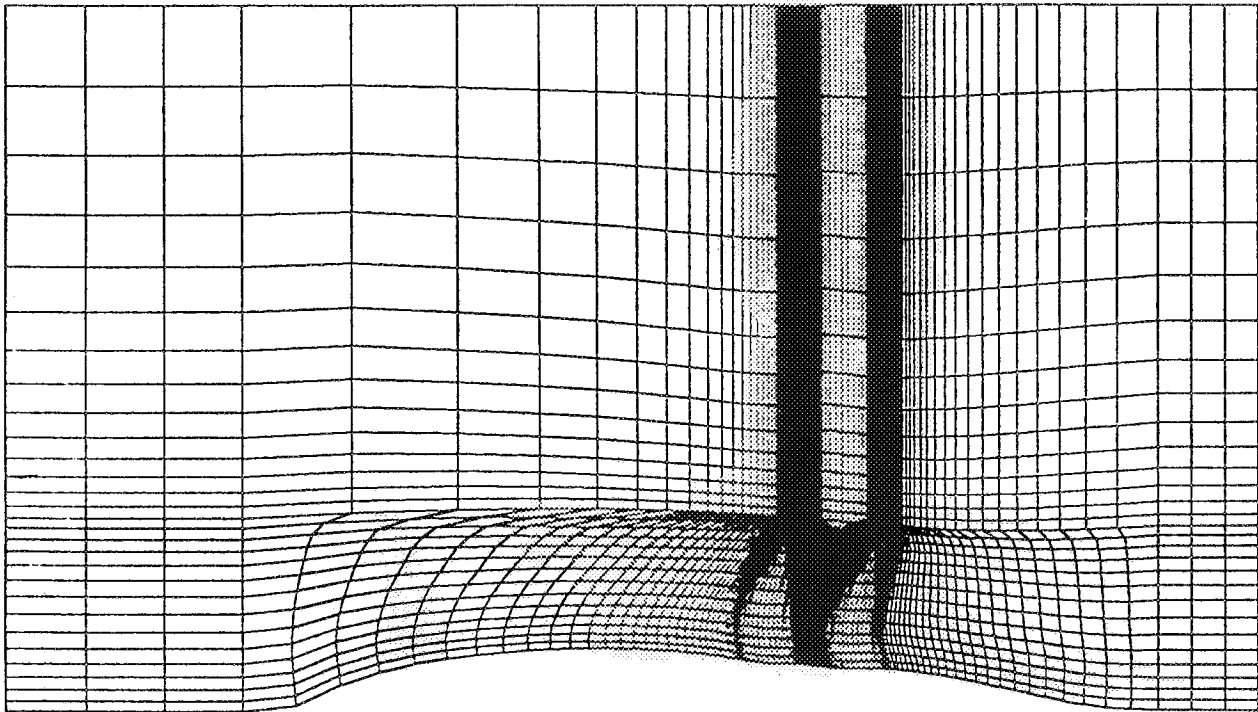
FIGURE 3. - INDIVIDUAL GRIDDED SECTIONS.
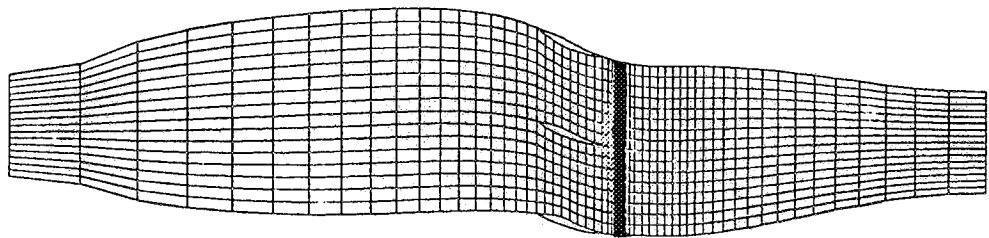

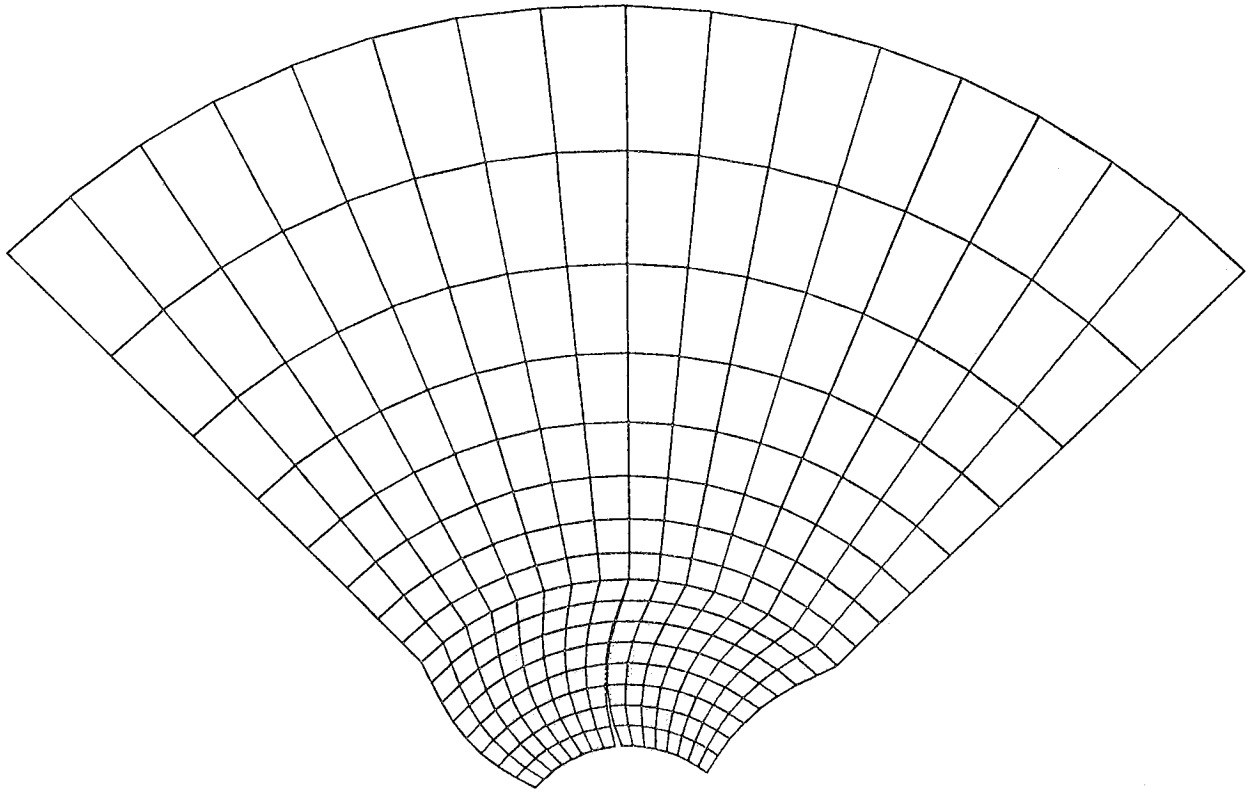FIGURE 4. - COMPOSITE AXISYMMETRIC MESH.

FIGURE 5. - AXIAL AND RADIAL MESH CUTS - 1ST BLADE ROW.

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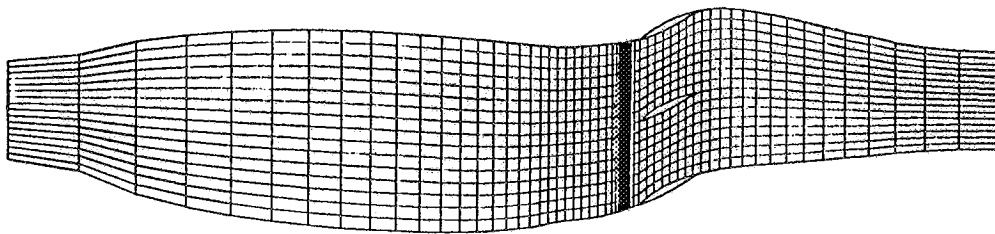
FIGURE 6. – AXIAL AND RADIAL MESH CUTS – 2ND BLADE ROW.
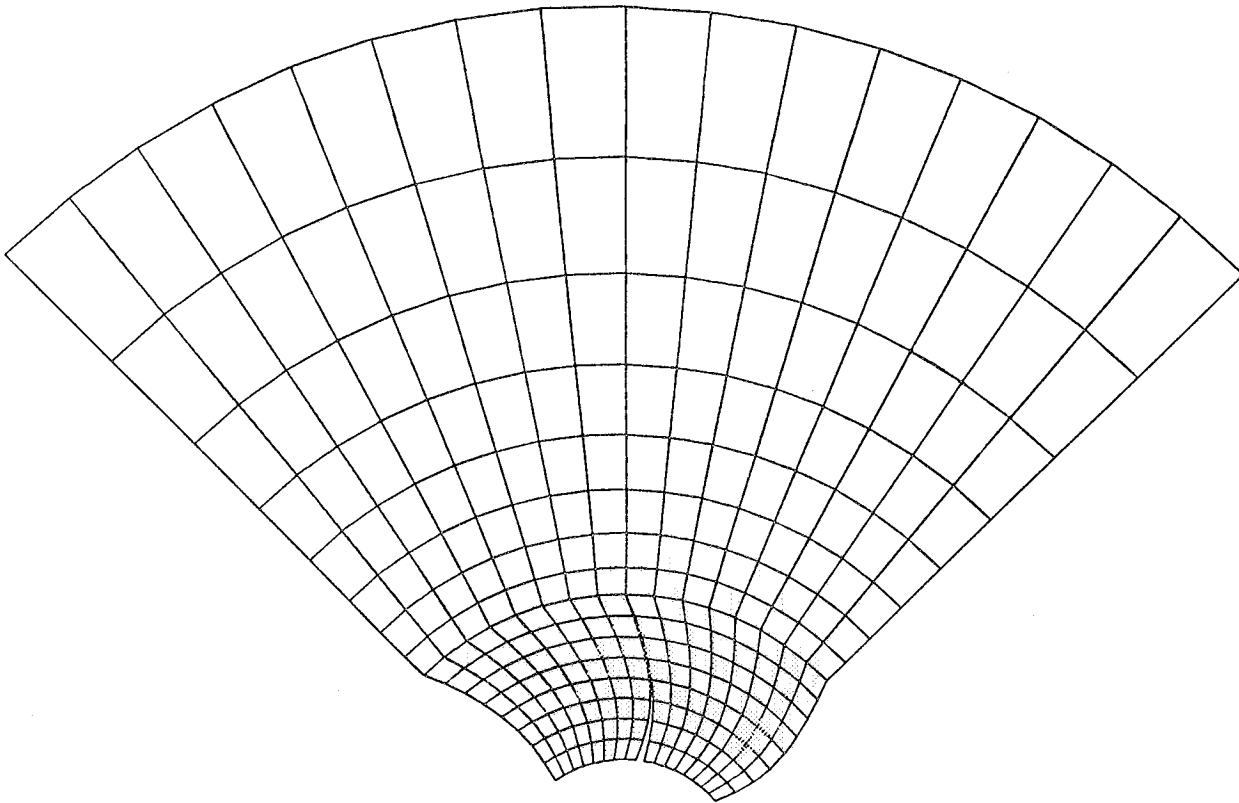
```
MESH
  |  ----- ERROR
  |
  |  ----- PRINT
  |
  |  ----- GENIN
  |            |  ------ INRSCT
  |            |                  |  ------ SPLINT
  |            |
  |            |  ------ SPLINT
  |
  |  ----- GENBL
  |            |  ------ INRSCT
  |            |                  |  ------ SPLINT
  |            |
  |            |  ------ SPLINT
  |
  |  ----- GENBB
  |            |  ------ INRSCT
  |            |                  |  ------ SPLINT
  |            |
  |            |  ------ SPLINT
  |
  |  ----- GENEX
  |            |  ------ INRSCT
  |            |                  |  ------ SPLINT
  |            |
  |            |  ------ SPLINT
  |
  |  ----- NUMPTS
```
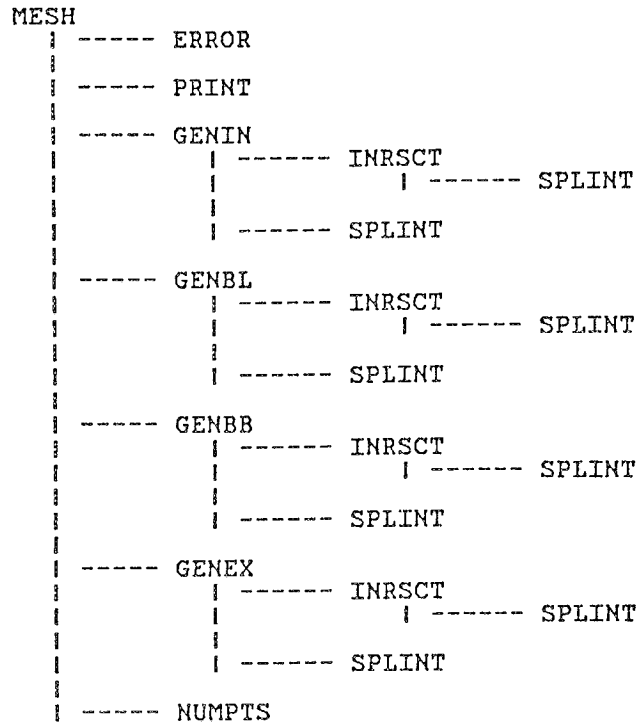
FIGURE 7. - MESH GENERATOR FLOW CHART.
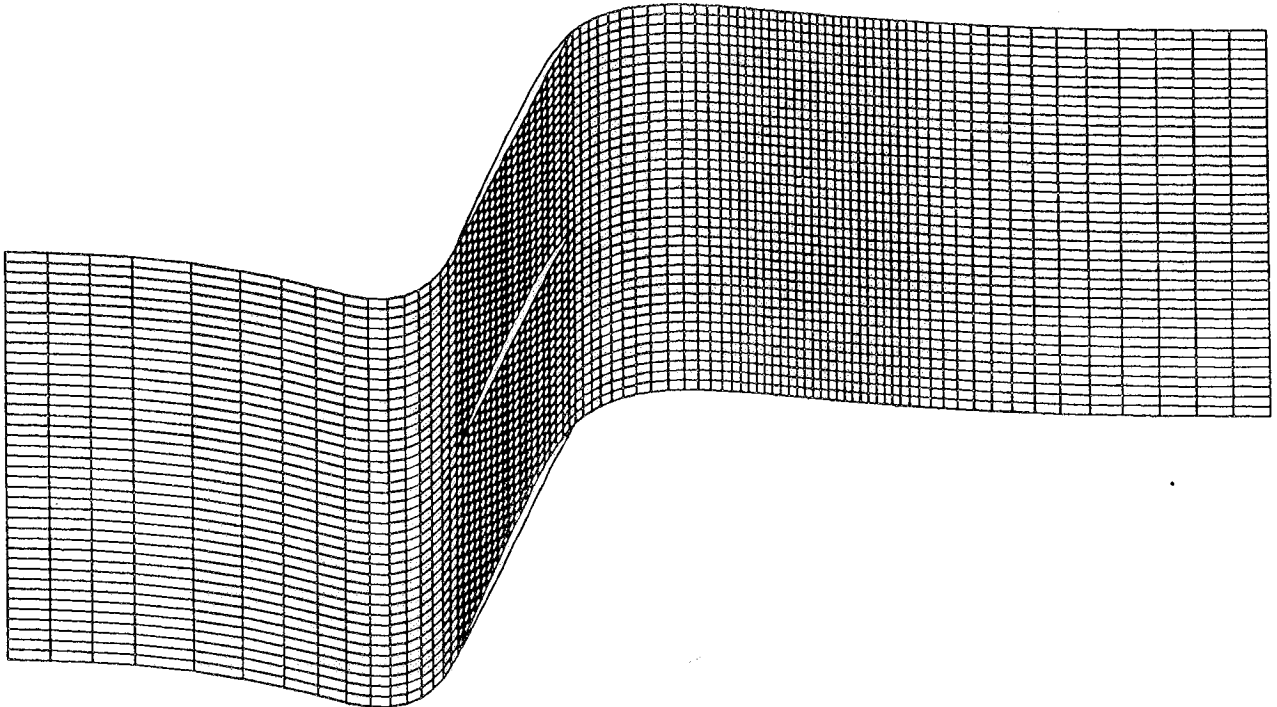
FIGURE 8. - CIRCUMFERENTIAL MESH CUT SHOWING EFFECT OF SMOOTHING FUNCTION.

```
0000001 +TITLE---------------------------------------------------------------------+
0000002  TWO STAGE HIGH PRESSURE FUEL TURBOPUMP
0000003 +NBLROW--++IGEOM----++ITHETA--++IWRITE--++--------++--------++--------++--------+
0000004        4         1         2         1
0000005 +NINPLS--++NEXPLS--++NBLPTZ--++NBLPTR--++NBLPTT--++--------++--------++--------+
0000006        4         4        15        11        11
0000007 +ZINLET--++ZEXIT---++--------++--------++--------++--------++--------++--------+
0000008   -0.10000   0.49500
0000009 +RATIN---++RATEX---++RATBB---++RATBLZ--++RATBLR--++RATBLT--++RATTOB--++--------+
0000010    1.20000   1.20000   1.20000   1.20000   1.00000   1.00000   0.00000
0000011 ***************************************************************************
0000012 +NHUB----++NTIP----++--------++--------++--------++--------++--------++--------+
0000013        2         2
0000014 +--------++--------++--------++--------++--------++--------++--------++--------+
0000015   -0.10000   0.49500
0000016    0.38570   0.38570
0000017 +--------++--------++--------++--------++--------++--------++--------++--------+
0000018   -0.10000   0.49500
0000019    0.46350   0.46350
0000020 ***************************************************************************
0000021 +NBLD----++NBLCRC--++NPPRC---++--------++--------++--------++--------++--------+
0000022       41         2        10
0000023 +--------++--------++--------++--------++--------++--------++--------++--------+
0000024    0.00000   0.00430   0.00830   0.01280   0.02570   0.03760   0.04970   0.06280
0000025    0.07550   0.08470
0000026    0.00000   0.00430   0.00830   0.01280   0.02570   0.03760   0.04970   0.06280
0000027    0.07550   0.08850
0000028    0.39800   0.39800   0.39800   0.39800   0.39800   0.39800   0.39800   0.39800
0000029    0.39800   0.39800
0000030    0.44080   0.44080   0.44080   0.44080   0.44080   0.44080   0.44080   0.44080
0000031    0.44080   0.44080
0000032    0.18530   0.19340   0.19930   0.20330   0.20870   0.20430   0.18700   0.14450
0000033    0.06570   0.00000
0000034    0.17390   0.18000   0.18530   0.18920   0.19530   0.19260   0.17940   0.14140
0000035    0.07620   0.00000
0000036    0.17060   0.16940   0.16730   0.16460   0.15280   0.13840   0.11790   0.08710
0000037    0.04230  -0.01130
0000038    0.16070   0.15800   0.15620   0.15410   0.14310   0.13030   0.11250   0.08600
0000039    0.05010  -0.00930
0000040 ***************************************************************************
0000041 +NBLD----++NBLCRC--++NPPRC---++--------++--------++--------++--------++--------+
0000042       63         2         9
0000043 +--------++--------++--------++--------++--------++--------++--------++--------+
0000044    0.11220   0.11710   0.12210   0.13130   0.14040   0.14960   0.15880   0.16790
0000045    0.17800
0000046    0.12000   0.12330   0.12790   0.13580   0.14380   0.15170   0.15960   0.16750
0000047    0.17520
0000048    0.39950   0.39950   0.39950   0.39950   0.39950   0.39950   0.39950   0.39950
0000049    0.39950
0000050    0.45820   0.45820   0.45820   0.45820   0.45820   0.45820   0.45820   0.45820
0000051    0.45820
0000052   -0.00200  -0.01900  -0.03050  -0.04050  -0.04170  -0.03420  -0.01710   0.01730
0000053    0.06900
0000054   -0.02200  -0.02960  -0.03670  -0.04220  -0.04090  -0.03270  -0.01360   0.01980
0000055    0.05810
0000056    0.01210   0.00480  -0.00150  -0.00630  -0.00500   0.00290   0.01710   0.03980
0000057    0.07680
0000058   -0.01100  -0.01420  -0.01820  -0.02240  -0.02070  -0.01130   0.00690   0.03330
0000059    0.06620
0000060 ***************************************************************************
0000061 +NBLD----++NBLCRC--++NPPRC---++--------++--------++--------++--------++--------+
0000062       39         2        10
0000063 +--------++--------++--------++--------++--------++--------++--------++--------+
0000064    0.20790   0.21160   0.21580   0.22000   0.23160   0.24330   0.25540   0.26710
0000065    0.27830   0.28950
0000066    0.20330   0.20750   0.21160   0.22000   0.23160   0.24330   0.25540   0.26710
0000067    0.27830   0.29410
0000068    0.39420   0.39420   0.39420   0.39420   0.39420   0.39420   0.39420   0.39420
0000069    0.39420   0.39420
0000070    0.44530   0.44530   0.44530   0.44530   0.44530   0.44530   0.44530   0.44530
0000071    0.44530   0.44530
0000072    0.16110   0.17340   0.18310   0.18960   0.19850   0.19560   0.17970   0.14690
0000073    0.07990   0.00250
0000074    0.16320   0.17460   0.18250   0.19240   0.19580   0.18960   0.17160   0.14000
0000075    0.08700   0.00220
0000076    0.14630   0.14760   0.14900   0.15010   0.14630   0.13420   0.11350   0.08520
0000077    0.04710  -0.00760
0000078    0.15010   0.15160   0.15310   0.15220   0.14510   0.13180   0.11160   0.08700
0000079    0.05600  -0.00640
0000080 ***************************************************************************
0000081 +NBLD----++NBLCRC--++NPPRC---++--------++--------++--------++--------++--------+
0000082       59         2        10
0000083 +--------++--------++--------++--------++--------++--------++--------++--------+
0000084    0.32370   0.32640   0.33140   0.33770   0.34610   0.35440   0.36480   0.37520
0000085    0.38360   0.39280
0000086    0.33130   0.33340   0.33560   0.33770   0.34610   0.35440   0.36480   0.37520
0000087    0.38360   0.38780
0000088    0.39530   0.39530   0.39530   0.39530   0.39530   0.39530   0.39530   0.39530
0000089    0.39530   0.39530
0000090    0.46230   0.46230   0.46230   0.46230   0.46230   0.46230   0.46230   0.46230
0000091    0.46230   0.46230
0000092    0.00210  -0.01050  -0.02640  -0.03690  -0.04300  -0.04200  -0.02890  -0.00060
0000093    0.03200   0.07380
0000094   -0.03120  -0.03610  -0.03910  -0.04150  -0.04540  -0.04200  -0.02740   0.00720
0000095    0.04240   0.06110
0000096    0.01480   0.00990   0.00210  -0.00380  -0.00630  -0.00320   0.00780   0.02700
0000097    0.04890   0.08160
0000098   -0.02200  -0.02310  -0.02430  -0.02580  -0.02850  -0.02430  -0.00720   0.02250
0000099    0.05230   0.06850
0000100 /EOF
```

FIGURE 9. - EXAMPLE OF TYPICAL INPUT FILE.

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```
********************************************************************************
 MESH FILE PARAMETERS                        .
********************************************************************************

     IL = 110  JL =   11  KL =   11  JTIP =   11

     BLADE ROW NO.  1   ILE =  14  ITE =  28  NBLD =  41  OMEGA =  +

     BLADE ROW NO.  2   ILE =  36  ITE =  50  NBLD =  63  OMEGA =  -

     BLADE ROW NO.  3   ILE =  58  ITE =  72  NBLD =  39  OMEGA =  +

     BLADE ROW NO.  4   ILE =  80  ITE =  94  NBLD =  59  OMEGA =  -
```

FIGURE 10. - EXAMPLE OF TYPICAL OUTPUT PARAMETERS.
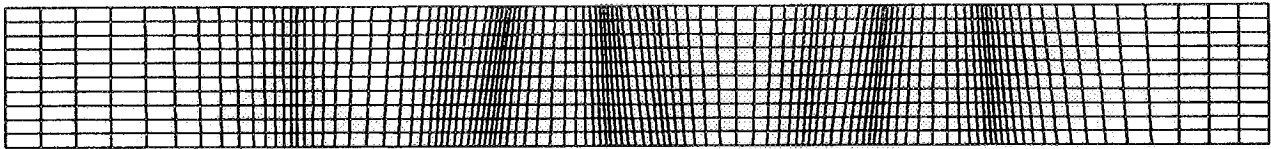
FIGURE 11. - COMMON AXISYMMETRIC MESH.
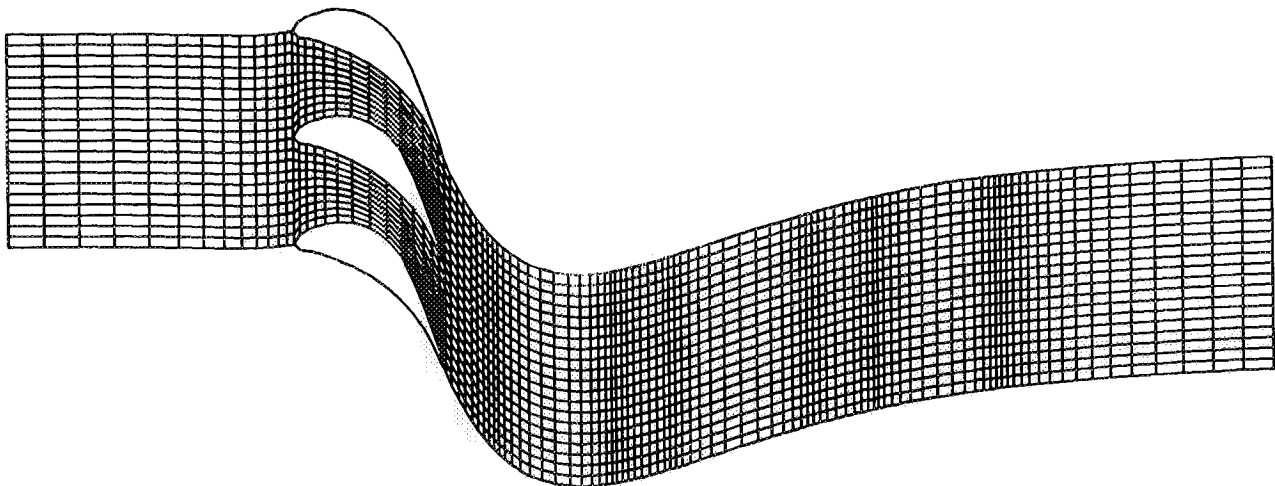
FIGURE 12. - BLADE-TO-BLADE VIEW OF 1st STATOR MESH.
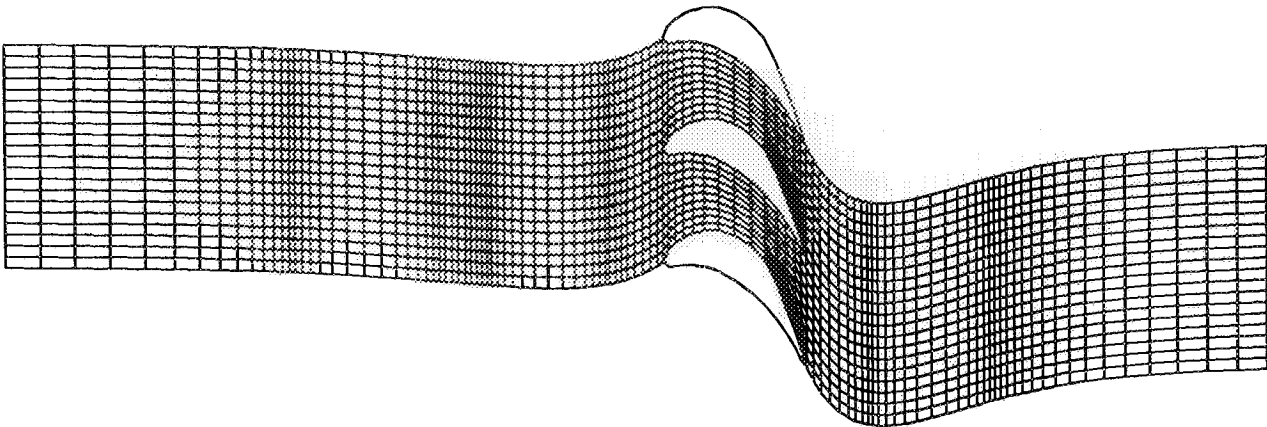
15
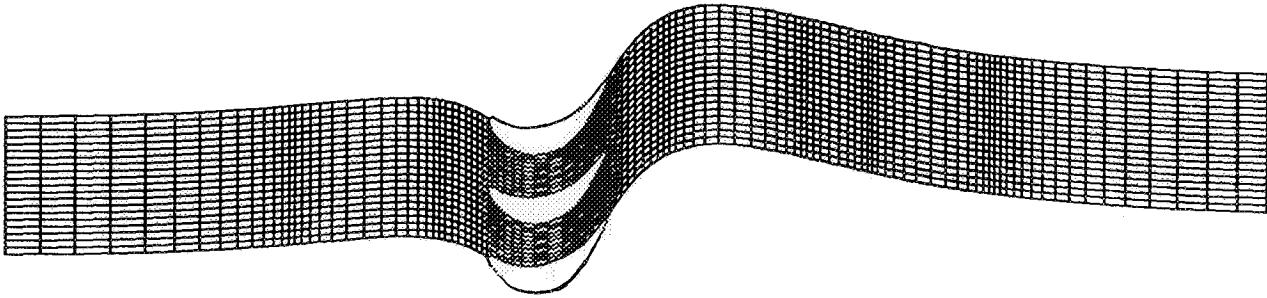
FIGURE 13. - BLADE-TO-BLADE VIEW OF 1ST ROTOR MESH.
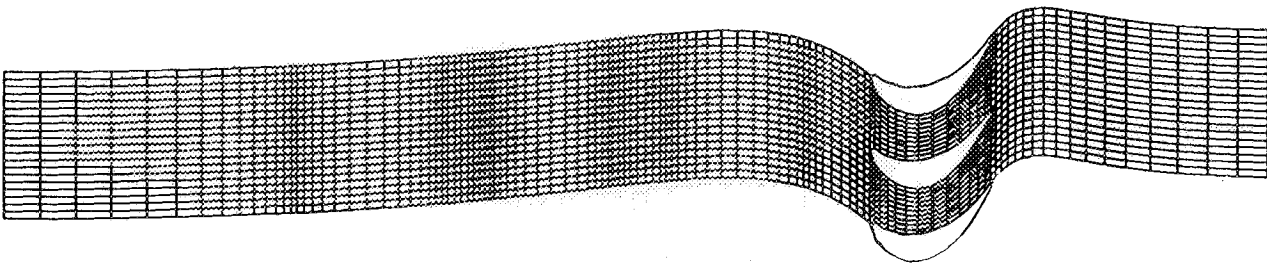
FIGURE 14. - BLADE-TO-BLADE VIEW OF 2ND STATOR MESH.

FIGURE 15. - BLADE-TO-BLADE VIEW OF 2ND ROTOR MESH.

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Report Documentation Page

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16. Abstract

One means of numerically simulating the three-dimensional flow field within a multistage turbomachine is through the solution of the average-passage equation system. One requirement of a current algorithm used to solve this system of equations has been the ability to generate multiple blade row meshes which satisfy specific geometrical constraints. In addition to meeting this criteria, one desires a mesh generation code which requires minimal user input, utilizes variable mesh control parameters, generates diagnostics helpful to the user, and possesses the capability to handle widely varying geometries. A mesh generation code with these features was written and has been used in solving the inviscid form of the average-passage equation system for both ducted and unducted multiple blade row geometries. This paper serves as a user reference guide, with a description of the mesh generation algorithm, a sample input file, and examples of typical meshes generated.

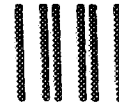| 17. Key Words (Suggested by Author(s)) Mesh generation Turbomachinery	18. Distribution Statement Unclassified - Unlimited Subject Category 02
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