INSTRUCTIONS FOR PROGRAM STAGEN

Original version STAGEN-17.1 .

Latest version STAGEN-17.2 has one minor change as detailed on page 3.

STAGEN is a blade geometry generation package that generates a data set for the 3D, multistage, turbomachinery flow calculation program MULTALL. It is intended to be very easy to use so that once the initial data file has been generated the blade geometry can be changed and a new 3D calculation started in a matter of seconds. The program is written in FORTRAN77 and should run on any machine with a FORTRAN compiler. The only exception to this is the option to plot out the blade profiles generated. This uses the graphics program HGRAPH, which is no longer available. If the program will compile without HGRAPH then it may be run without plotting the profiles, simply answer "N" when asked if you would like to plot the blade profiles. If it will not compile without HGRAPH delete lines 1448 to 1538 of the program, the lines to be deleted are clearly marked by comment cards. It should be easily possible to replace the HGRAPH plots with a different plotting package.
An executable version of STAGEN, which will plot out the blade profiles, is supplied in the folder entitled "PLOTTING PROGRAMS" but this may not work on all systems.

The blade geometry is defined using as few parameters as possible so that changes can be made quickly and easily. The program contains many comments that may explain the use of the input variables in more detail than these instructions.

Not all the options available in MULTALL may be set by STAGEN since, for simplicity, most parameters are set by default. Less common flow features, such as shroud leakage, coolant flows, surface roughness, bleed flows, etc, which can be computed by MULTALL, are not included and must be added to the output data set ("**stage_new.dat**" or "**stage_old.dat**") manually if required. However, it would be easy to modify STAGEN to output such features. Details of the data required are in the MULTALL manual. STAGEN will produce output files for throughflow or for quasi-3D blade-to-blade calculations if either IM or KM is set equal to 2 .

Two different data sets are written by STAGEN. One, "**stage_new.dat**", is for the new free format input data used in MULTALL_OPEN if the file "intype" is set to "N". The other, "**stage_old.dat**", is formatted data, similar to that used in older versions of MULTALL, it can be used with MULTALL_OPEN if the file "intype" is set to "O" .

The program produces an output file for a machine with a smooth annulus with tip clearances allowed for by the pinched tip model. It can generate data sets for axial, mixed or radial flow machines. The blades are first generated in two dimensions on a plane surface and are then projected onto stream surfaces, which can be for an axial, radial or mixed flow machine. The stream surfaces need not be true stream surfaces of the flow but can be any convenient axisymmetric surface, e.g. a cylinder or a cone. When projected onto the stream surface the 'x' coordinate on the plane surface becomes the meridional distance and the 'y' coordinate on the plane surface is transformed to the cylindrical angle, θ, using

$$\theta - \theta_1 = \int_{r1}^{r} dy / r$$

so that a flat plate transforms into a log spiral. Hence, if the stream surface has a change of radius the blade shape on the developed stream surface is not exactly the same as seen on the plane surface but the loading should be similar to that of a two-dimensional blade with the original profile.

At least two stream surfaces must be used to define a blade row but as many stream surfaces as required can be used. The first stream surface must coincide with the hub of the machine and the last must be the casing of the machine. STAGEN cannot handle the option to read in the hub and casing surfaces separately from the stream surfaces, which is available in MULTALL.

Multiple blade rows can be generated with the limits only imposed by the dimensioning of MULTALL.

The blade geometry and flow conditions must be provided in a data file. When the program is started the user is asked for the name of this input file with an option to select **"stagen.dat"** as a default, however any other file name can be used if required. Two output files are written for different versions of MULTALL. "**stage_new.dat**" is for the newer input data format used in MULTALL-OPEN and "**stage_old.dat**" is for the older input format which can also be used on MULTALL_OPEN and is almost, but not quite, compatible with previous versions of MULTALL, e.g. MULTALL_15. In addition a file called **"out"** is written to FORTRAN unit 8. File **"out"** is not used by the flow calculation program but contains blade coordinates and other useful information, which may be useful for finding any mistakes in the input data file.

The names of the variables used in STAGEN are mainly the same as in MULTALL and are defined in the MULTALL user manual and so the present manual should be read in conjunction with the MULTALL manual. However, most of the default variables are defined in the Appendix to this manual, they are also defined by comments in the code.

In order to plot the blade profiles generated, STAGEN must be compiled and linked with the graphics library HGRAPH. If HGRAPH is not available then delete lines 1448 to 1538 of the program, it will then run but not plot out the blade profiles generated. It should be easy to change the program to use a different plotting package. Alternatively an executable version of STAGEN, which will plot out the blade profiles, is supplied in the folder entitled "PLOTTING PROGRAMS", but this may not work on all systems. Having compiled the program, simply type the name of the executable and you will then be asked for the name of the input file, which is usually **stagen.dat** .

Most of the control parameters of the program and the gas properties are set by defaults within the program, these are used if the input variable "IFDEF" is set to 0. However, if IFDEF is set to 1 then the values of most control parameters may be read in as part of the data set. It is usually easier to edit the program and recompile it to change the default settings rather than to make small changes to the data in the input file.

All data input is in free format so a value **must be input for every variable**, even if it is not used. Blank lines are left in order to help the layout of the input data file and these **must** be included where indicated.

All the input data must be in SI units. i.e. lengths in metres, velocities in m/s, pressures in N/m^2 , temperatures in K.

STAGEN 17.2

STAGEN 17.2 differs from 17.1 only by reading in the gas constant and gas specific heat ratio as the first line of input data. Previously these were set by default. Old stagen data sets do not have this input and their first line of data is Card 1A, " IM , KM " , they should be corrected by adding a new first line, containing the values of the gas constant, RGAS, and gas specific heat ratio, GAMMA, before using with STAGEN-17.2 or later.

DETAILS OF THE INPUT FILE REQUIRED BY STAGEN

The data input is in a series of lines of data, which will be referred to as "CARDS" . Some "CARDS" are blank lines which are just there to space out the data, but they must still be input.

All data is in Free Format .

On starting the program you will be asked for the name of the data input file with an option to choose "stagen.dat" as a default.

****

CARD 1

This is new to version 17.2

RGAS, GAMMA

RGAS	The gas constant in J/kg K. A typical value for air is 287.5
GAMMA	The gas specific heat ratio. The value for air is 1.4.

****

CARD 1A

IM, KM

IM	Is the number of grid points in the pitchwise direction. Typically in the range 19 -> 64
KM	Is the number of grid points in the spanwise direction. Typically in the range 19 -> 64 .

****

CARD 2
FPRAT, FPMAX

FPRAT Is the grid expansion ratio in the pitchwise direction. This should be less than 1.4. A typical value is 1.25 .

FPMAX Is the ratio of the maximum grid spacing in the pitchwise direction to that of the first two grid points. Typically in the range 5 -> 25 .

****

CARD 3
FRRAT, FRMAX

FRRAT Is the grid expansion ratio in the spanwise direction. Less than 1.4. Typical value = 1.25

FRMAX Is the ratio of the maximum grid spacing in the spanwise direction to that at the first two grid points. Typically in the range 5 -> 25.

****

CARD 3A
IFDEF

If IFDEF = 0 the default control parameters are set within the program. If IFDEF is not zero then these parameters must be read in from the next 11 cards, 3B to 3L .

****

CARDS 3B to 3L ARE ONLY NEEDED IF “IFDEF” IS NOT ZERO
SEE THE MAIN 3D PROGRAM (MULTALL) INSTRUCTIONS FOR THE MEANING OF THE PROGRAM CONTROL PARAMETERS SET BY THEM.

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CARD 3B
NMAX, NCHANGE
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CARD 3C
IN_VTAN, IN_PRESS, INPUT, INVR, ITIMST, ISMTH, IPOUT, INFLOW, NLOS, ILOS, IF_RESTART, IOUTST, IBOUND, ISHIFT
****

CARD 3D
IR, JR, KR, IRBB, JRBB, KRBB, NSBUP, NSBON, NSBDN, IFMIX, NEWGRID
****

CARD 3E
JTRANS, JTRANP, JTRANH, JTRANT
****

CARD 3F
IF_CUSP, ICUSP, LCUSP, LCUSPUP, IFANGLES, IF_DESIGN
****

CARD 3G
CP, GA, CFL, SFT, SFX, FAC_4TH, MACHLIM
****

CARD 3H
DAMP, FBLK1, FBLK2, FBLK3, SFEX, CLIM, RFIN
****

CARD 3I
IFMIX, RFMIX, FSMTHB, FEXTRAP, FANGLE, NEXTRAP_LE, NEXTRAP_TE
****

CARD 3J
FSTURB, TURBVIS_DAMP, TURBVIS_LIM, REYNO, PRANDTL, FR_VIS, FTRANS, YPLUSWALL, YPLAM, YPTURB
****

CARD 3K

FAC_STMIX, FAC_ST0, FAC_ST1, FAC_ST2, FAC_ST3, FAC_SFVIS

****

CARD 3L

FRACPB, FRACPW, FRACPUP, FRACPIN, FRACPLE, FRACPTE, FRACPDWN

****

****

END OF NON_DEFAULT DATA INPUT FOR MAIN PROGRAM CONTROL PARAMETERS

****

CARD 4
NROWS, NOSECT

NROWS Is the number of blade rows to be designed.

NOSECT Is the number of blade sections to be designed per row. This must be the same for all rows.

****

CARD 5
FAC_SCALE

FAC_SCALE Is a scaling factor that will be used to multiply all blade coordinates. Set = 1.0 if the blade is to be generated at full scale.

****

REPEAT ALL CARDS 6 TO 28 FOR EACH BLADE ROW

CARD 6
Blank Line

CARD 7
Title of the blade row, any alphanumeric characters in rows 1 to 72.

CARD 8
Blank Line

****

CARD 9
NINTUP, NINTON, NINTDN

NINTUP	Number of grid spacings requested upstream of the leading edge.
NINTON	Number of grid spacings requested on the blade surface.
NINTDN	Number of grid spacings requested downstream of the trailing edge.

Note: These are the number of grid spacings which = number of grid points -1

****

CARDS 10
XFRAC(I), RELSPCE(I)

A table of I values of the ***relative*** meridional spacings of the *final grid* as a function of the meridional chord.

XFRAC(I)   Fraction of meridional chord.
RELSPCE(I) Relative grid spacing at this x value.

The table is read until a value of XFRAC(I) greater than 0.99999 is found so the meridional chord must vary from 0.0 to 1.0. The relative spacings can be in any units as long as they are all relative not absolute values. Typically about 5 values of XFRAC and RELSPCE are sufficient to define the final grid spacings on the blade.
****

CARD 11
NBLADE

NBLADE   Is the number of blades in the current blade row.
****

CARD 12
RPMROW, PUPROW, PLEROW, PTEROW, PDROW

RPMROW Is the rotational speed of the blade row. Positive if the rotation is in the theta direction. It may be negative.

PUPROW Is a guess of the static pressure at mid-span upstream of the blade row, in N/m^2.

PLEROW Is a guess of the static pressure at mid-span at the leading edge of the blade row, in N/m^2.

PTEROW Is a guess of the static pressure at mid-span at the trailing edge of the blade row, in N/m^2.

PDROW Is a guess of the static pressure at mid-span at exit from the blade row, in N/m^2.

Note: These pressures are only used for the initial guess. They should not influence the final solution but a better guess will give faster convergence.
****

CARD 13
KTIPS, KTIPE, JROTHS, JROTHE, JROTTS, JROTTE FRACTIP, RPMHUB

KTIPS	Is the K value at which tip clearance starts. Set = 1 for hub clearance.
KTIPE	Is the K value at which tip clearance ends. Set = KM for tip clearance.
JROTHS	Is the J value at which the hub starts to rotate at RPMHUB.
JROTHE	Is the J value at which the hub stops rotating at RPMHUB.
JROTTS	Is the J value at which the casing starts rotating at RPMROW.
JROTTE	Is the J value at which the casing stops rotating at RPMROW.
FRACTIP	Is the tip or hub clearance as a fraction of the blade span.
RPMHUB	Is the rotational speed of the hub in between the J points JROTHS, JROTHE. in RPM .

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Note only a singe value of tip clearance can be used. To vary the clearance from leading edge to trailing edge, edit the final data set.

****
REPEAT CARDS 14 TO 28 for each of the NOSECT blade sections on the current blade row.
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CARD 14 Blank line
CARD 15 Title of the current blade section. Any alphanumeric characters in columns 1 to 72.
CARD 16 Blank line
****

CARD 16A
INTYPE

INTYPE = 0. Means that the blade section is specified by a set of (x,y) coordinates going around the blade surface. These are input as data in CARD 16C.

INTYPE =1. Means that the blade section is generated by specifying its centre line slope and a mathematically generated thickness distribution. This is the most usual type of input,

INTYPE = 2. Means that the blade section is generated by specifying its centre line slope and its tangential thickness above and below the centre line at as many points as required along the axial chord.

INTYPE = 3. Means that the blade is section specified by the surface slopes of its upper and lower surfaces at as many points as required along the axial chord.
****

CARD 16B THIS IS ONLY NEEDED IF INTYPE = 0
NPOINTS , NXPTS, IFCLOCK, IFREV

NPOINTS Is the number of points around the blade at which coordinates will be given when INTYPE = 0.

NXPTS Is the number of points on the camber line that will be used to generate the final blade. This should be far more than the number of grid points. Typically 200 points should be enough.

IFCLOCK The points to be input go clockwise round the blade if IFCLOCK = 0, anticlockwise if IFCLOCK = 1.

IFREV The upper and lower surfaces are inverted if IFREV = 1, no changes if IFREV = 0 .
****

CARD 16 C THIS IS ONLY NEEDED IF INTYPE = 0

A table of NPOINTS values of XIN , YIN

XIN(N), YIN(N) The x,y coordinates of points on the blade surface. Typically 100 points are needed to define a blade accurately with close clustering around the leading and trailing edges.
****

IF INTYPE IS NOT = 0 READ IN CARDS 17- 20 .
JUMP TO CARD 21 IF INTYPE = 0.

****

CARD 17

NPIN, NXPTS, NSMOOTH

NPIN	Is the number of points in the table of camber line slopes , blade thicknesses, etc, input in the next card. Typically = 5 ->10 points are sufficient.
NXPTS	Is the number of points on the camber line that will be used to generate the blade. Typically 200 points should be enough.
NSMOOTH	Is the number of times that the input camber line slope, blade thickness or surface slope input above will be smoothed. Typically = 2.

****

IF INTYPE = 1 READ CARD 18

CARD 18

FRAC(N), SLOPE(N), N= 1, NPIN

FRAC(N)	Is the fraction of meridional chord at which the camber line slope is input. The first value must be 0.0 and the last value 1.0 .
SLOPE(N)	Is the camber line slope in degrees at FRAC(N). The slope is positive if a vector along the camber line points in (i.e. has a positive component in) the direction of rotation.

****

IF INTYPE = 2 READ CARD 18A

CARD 18A
FRAC(N), SLOPE(N), TKH(N), TKL(N) N= 1, NPIN

FRAC(N)	Is the fraction of meridional chord at which the camber line slope is input. The first value must be 0.0 and the last value 1.0 .
SLOPE(N)	Is the camber line slope in degrees at FRAC(N). The slope is positive if a vector along the camber line points in (i.e. in the direction of increasing meridional distance) has a positive component in the direction of rotation.
TKH(N)	The blade tangential thickness above the centre line as a fraction of the meridional chord.
TKL(N)	The blade tangential thickness below the centre line as a fraction of the meridional chord.

****

IF INTYPE = 3 INPUT CARD 18B

CARD 18B

FRAC(N), SLPUP(N), SLPLOW(N) , N = 1, NPIN

FRAC(N)	Is the fraction of meridional chord at which the camber line slope is input. The first value must be 0.0 and the last value 1.0 .
SLPUP(N)	Is the slope of the upper blade surface in degrees.
SLPLOW(N)	Is the slope of the lower blade surface in degrees.

Note. It is more difficult to generate a good blade shape using this method but it does give most control over the surface curvature.

****

CARD 19 must be input for INTYPE = 1, 2, or 3 but some of the values are not used unless INTYPE = 1.

CARD 19

TKLE, TKTE, TKMAX, XTMAX, XMODLE, XMODTE, TK_TYP

TKLE	Is the leading edge thickness as a fraction of the blade chord. Card 20 decides which chord it is based on.
TKTE	Is the trailing edge thickness as a fraction of the blade chord. Card 20 decides which chord it is based on.
TKMAX	Is the maximum thickness (as a fraction of the blade chord) of the final blade section. Card 20 decides which chord it is based on.
XTMAX	Is the position of maximum thickness as a fraction of the blade axial chord.
XMODLE	Is the fraction of axial chord over which the leading edge will be rounded. Typically = 0.02 .
XMODTE	Is the fraction of the axial chord over which the trailing edge will be rounded. Typically = 0.02 . Set = 0 for a square trailing edge of thickness TKTE.
TK_TYP	Controls the shape of the thickness distribution. Typically = 2.0 . Large values give a "square " thickness distribution. A value 1.0 gives a "triangular" distribution. Non integer values may be used, e.g. TK_TYP = 1.8 is quite common.

****

CARD 20
FCHORD, FPERP, FTKSCALE

FCHORD Determines whether the above thicknesses are fractions of the axial chord or of the true chord. FCHORD = 1 means they are fractions of the true chord. FCHORD = 0 means fractions of the axial chord.

FPERP When INTYPE = 1 this controls whether the thickness distribution is added perpendicular to the camber line or in the tangential direction . FPERP = 1 uses the perpendicular thickness and is most usual. However, for very thick and high camber blades this may cause problems and so it may be necessary to set FPERP = 0 to use a tangential thickness distribution.

FTKSCALE Is used to decide whether to scale the maximum blade thickness to the value TKMAX input above. This is useful if INTYPE = 2 or 3. It is not used if INTYPE = 0. FTKSCALE = 1 means the thicknesses are scaled. FTKSCALE = 0 means the thicknesses are not scaled.

****

CARD 21
ROTN, XROT, YROT

ROTN	Is the angle by which the blade just generated will be rotated in the clockwise sense about the point XROT,YROT. In degrees.
XROT	Is the X coordinate of the point about which the blade will be rotated as a fraction of the axial chord with the origin at the leading edge.
YROT	Is the Y coordinate of the point about which the blade will be rotated as a fraction of the axial chord with the origin at the leading edge.

****

CARD 22
XCUP, XCDWN, BETUP, BETDN

XCUP	The axial extend of the grid upstream of the blade as a fraction of the axial chord. Typically = 0.5 .
XCDWN	The axial extend of the grid downstream of the blade as a fraction of the axial chord. Typically = 0.5 .
BETUP	The angle of the upstream grid extension. Usually the same as the camber line angle at the leading edge. In degrees. May be negative.
BETDN	The angle of the downstream grid extension. Usually the same as the camber line angle at the trailing edge. In degrees. May be –ve .

****

CARD 23 BLANK CARD

****

CARD 24

NSSURF

NSSURF Is the number of points is the table of stream surface coordinates to be input in the next card. The final blade coordinates will be generated on this stream surface. The stream surface used need not be a true stream surface of the flow, any convenient axisymmetric surface (such as a conical surface) can be used. However, in many cases its coordinates may conveniently be taken from a throughflow solution. Typically about 8 points should be sufficient. Preferably one point should coincide with the blade row leading edge and one with the trailing edge.

****

CARD 25

XRIN(N) , N = 1,NSSURF

XRIN(N) Is the axial coordinate of the N th point on the stream surface. Note the first point must be upstream of the leading edge grid point and the last point must be downstream of the trailing edge grid point on the blade section being generated.

****

CARD 25a

RIN(N) , N = 1,NSSURF

RIN(N)	Is the radius of the N th point on the stream surface. See comments on the last card.

****

CARD 26

XLE, XTE, RLE, RTE

XLE	Is the x coordinate of the leading edge of the final blade.
XTE	is the x coordinate of the trailing edge of the final blade.
RLE	Is the radial coordinate of the leading edge of the final blade.
RTE	Is the radial coordinate of the trailing edge of the final blade.

NOTE: All these points must lie on the stream surface input in the last two cards.

****

CARD 27
FCENTROID, FTANG, FLEAN, FSWEEP, FAXIAL

These cards determine the final stacking of the section generated.

FCENTROID	If this = 1 the blade is stacked with its centroid on a radial line through the centroid of the hub section. If FCENTROID = 0.0 the blade is stacked on its leading edge. FTANG, FLEAN, FSWEEP, FAXIAL will then make changes relative to this stacking.
FTANG	The blade section is leaned in the tangential (i.e. circumferential) direction by a distance = FTANG x its meridional chord. FTANG may be positive or negative.
FLEAN	The blade section is leaned in the direction perpendicular to its chord line by a distance FTANG x its meridional chord.
FSWEEP	The blade section is swept along its chord line in the downstream direction by FSWEEP x its meridional chord.
FAXIAL	The blade section is moved in the axial (downstream) direction by FAXIAL x its meridional chord.

NOTE: FTANG, FLEAN, FSWEEP AND FAXIAL should all be set to zero and FCENTROID to 1 to obtain a stacking through the centroids of the blade sections.

The stacking options cannot be used for blades where the radius change between the leading and trailing edge is larger than the axial extent of the blade. To prevent any stacking changes in this case set FCENTROID = 2.0 .

****

CARD 28
FSCALE, FCONST

After stacking the blade can be scaled to increase it local chord. This can also be done by changing the coordinates XLE, XTE in card 26. The blade remains on the stream surface.

FSCALE	The blade meridional chord is multiplied by FSCALE.
FCONST	The scaling is done so that a point at a fraction FCONST of the meridional chord from the leading edge remains fixed.

Note that this can be used to give local sweep to the blade, for example by keeping the trailing edge fixed and increasing the meridional chord.

****

END OF DATA INPUT ON THE CURRENT BLADE SECTION
RETURN TO CARD 14 TO START THE NEXT SECTION OF THE CURRENT BLADE ROW.

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END OF DATA INPUT ON THE CURRENT BLADE ROW
RETURN TO CARD 6 TO START THE NEXT BLADE ROW, UNLESS THIS IS THE LAST ROW, IN WHICH CASE MOVE ON TO CARD 29.

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CARD 29 BLANK LINE
****

CARD 29A
PUPHUB, PUPTIP, PDHUB, PDTIP

PUPHUB Is a guess of the inlet pressure on the hub at the upstream boundary of the whole calculation, in N/m^2.

PUPTIP Is a guess of the inlet pressure on the casing at the upstream boundary of the whole calculation, in N/m^2.

PDHUB Is the static pressure on the hub at the downstream boundary of the whole calculation, in N/m^2. This is a boundary condition whose use is determined by IPOUT.

PDTIP Is the static pressure on the casing at the downstream boundary of the whole calculation, in N/m^2. This is a boundary condition whose use is determined by IPOUT.

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CARD 30 BLANK CARD
****

CARD 31
NINLET

NINLET Is the number of spanwise points at which the inlet flow conditions are to be specified. Also used for the exit pressure profile if requested.
****

CARD 32
FSPAN(I) I = 1,NINLET

FSPAN(I) Is the fraction of the span at which the inlet or exit conditions are specified in the next few cards.

****

CARD 33
POIN(I) I = 1, NINLET

POIN(I) Are the inlet stagnation pressures at the above fractions of the span. In N/m**2

****

CARD 34
TOIN(I) I = 1, NINLET

TOIN(I) Are the inlet stagnation temperature, in K, at the above fractions of the span.

****

CARD 35
VTIN(I) I = 1, NINLET

VTIN(I) Is the inlet swirl velocity at the above fractions of the span. In m/s .

****

CARD 36

VMIN(I) I = 1, NINLET

VMIN(I) Is the inlet meridional velocity at the above fractions of the span. In m/s .

****

CARD 37

B1IN(I)   I = 1, NINLET

B1IN(I)   Is the inlet meridional yaw angle, Tan $^{-1}(V_t/V_m)$, at the above fractions of the span. Positive if the swirl is in the direction of rotation.

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CARD 38

BRIN(I)   I = 1, NINLET

BRIN(I)   Is the inlet meridional pitch angle , Tan $^{-1}(V_r/V_x)$, at the above fractions of the span.

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****

END OF INPUT DATA TO STAGEN

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APPENDIX. LIST OF DEFAULT VALUES SET BY STAGEN

These values can easily be changed by editing and recompiling the program. The meaning of the variables is also described by comments in the code.

INTEGER VARIABLES

NMAX = 9000	Maximum number of time steps.
IN_VTAN = 0	Inlet boundary condition for the flow angle. The absolute flow angle is fixed.
IN_PRESS = 0	The pressure at the inlet boundary is calculated from the computed density.
INPUT = 2	The blade geometry is input on the hub and casing stream surfaces in addition to any other streamwise surfaces.
IN_VR = 0	The radial velocity at inlet is obtained by extrapolation from the interior flow field.
ITIMST = 3	Using the standard “scree” scheme.
IPOUT = 1	Exit boundary uses fixed pressures at the hub and casing with a linear variation between.
INFLOW = 0	Mass flow rate not specified.
ILOS = 10	Simple mixing length turbulence model used.
NLOS = 5	Viscous forces updated every 5 steps.
IF_RESTART=0	Not starting from a restart file.
IOUTST = 1	Writing out a restart file when finished.
IBOUND = 0	Viscous shear on all solid surfaces.
IR,JR,KR = 3	Cell size of the first multigrid blocks.
IRBB,JRBB,KRBB =9	Cell size of the second level multigrid blocks.
NSBUP = 1	One superblock upstream of the leading edge.
NSBON = 2	Three superblocks in the blade row.
NSBDN = 1	One superblock downstream of the trailing edge.
IFMIX = 1	Standard mixing plane treatment.
NEWGRID= 0	No generation of a new grid by the solver.

JTRANS, JTRANP =0	Fully turbulent boundary layers on the blades.
JTRANH, JTRANT=0	Fully turbulent boundary layers on the endwalls.
ISHIFT = 2	Grids are automatically adjusted to be contiguous at the mixing plane.
NCHANGE = 1000	Smoothing and damping factors are increased over the first 1000 steps.
IF_CUSP = 0	No cusp will be generated.
LCUSP = 4	Length of cusp to be generated.
ICUSP = 0	Any cusp is centred on the blade centre line.
LCUSPUP= 0	Cusp starts LCUSPUP points upstream of the trailing edge.
IFANGLES=0	The upstream and downstream grid angles are obtained by extrapolation from the blade centre line.
NEXTRAP_LE = 10	The upstream grid direction is extrapolated using the first 10 points on the blade.
NEXTRAP_TE = 10	The downstream grid direction is extrapolated using the last 10 points on the blade.
IF_DESIGN = 0	The blade shape will not be changed within MULTALL.
IF_RESTAGGER=0	The blade witll not be restaggered within MULTALL.
IF_LEAN = 0	The blade will not be leaned within MULTALL.

GAS PROPERTIES

CP = 1005.	Specific heat capacity is for air at room temperatures.
GA = 1.4	Specific heat ratio is for air.

FLOATING POINT CONTROL VARIABLES

CFL = 0.4	The time step length is set by CFL and a standard safe value is 0.4 .
SFT = 0.005	The smoothing in the pitchwise and spanwise directions is the standard value, 0.005.

SFX = 0.005	The smoothing in the streamwise (meridional) direction is the standard value, 0.005.
FAC_4TH = 0.8	The proportion of 4^{th} order smoothing is 0.8.
MACHLIM = 2	The Mach number limiter is 2.0 .
DAMP = 10	The damping factor is 10, a standard value.
FBLK1 = 0.4	The changes for the first level of multigrid blocks are reduced by 0.4 .
FBLK1 = 0.2	The changes for the second level of multigrid blocks are reduced by 0.2 .
FBLK3 = 0.1	The changes for the superblocks are reduced by 0.1.
SFEX = 0.0	No exit flow smoothing.
CLIM = 0.001	Convergence limit on the percentage change in the average residuals.
RFIN = 0.5	Relaxation factor on the changes in inlet flow conditions.
RFMIX = 0.025	Relaxation factor on the isentropic forcing of the flow downstream of the mixing plane.
FSMTHB = 1.0	Factor for increasing the smoothing at the inlet and exit boundaries and at the mixing plane.
FEXTRAP = 0.8	Flux extrapolation factor at the mixing plane. Also used to extrapolate the pressure to the exit boundary.
FANGLE = 0.8	Angle extrapolation factor downstream of the mixing plane.

VISCOUS MODEL PARAMETERS

FSTURB = 1.0	The free stream turbulent viscosity is the laminar viscosity x FSTURB .
TURBVISDAMP= 0.5	The pitchwise average turbulent viscosity is halved across a mixing plane.
TURBVISLIM = 1000.	The maximum accepted value of turbulent viscosity = TURBVISLIM x laminar viscosity .

REYNO = 800000.	The Reynolds number of the first blade row based on the axial chord and the exit flow velocity of the first blade row. This is used to set the level of laminar viscosity.
PRANDTL = 1.0	The Prandtl number of the fluid, about 1.0 for air.
RF_VIS = 0.5	Changes in turbulent viscosity are relaxed by 0.5.
FTRANS = 0.001	Transition occurs whenever the ratio of turbulent to laminar viscosity exceeds this value.
YPLUSWALL = 0.0	The skin friction is calculated from the specified YPLUSWALL only if YPLUSWALL is greater than 5.0, otherwise use the standard wall functions.
YPLAM = 5.0	No turbulent viscosity is allowed for YPLUS less than YPLAM .
YPTURB = 25.0	Turbulent viscosity is damped between YPLUS = YPLAM and YPTURB.
FACMIXUP = 2.0	The turbulent viscosity is increased by this over the first NMIXUP steps.
NMIXUP = 1000	The number of time steps over which the turbulent viscosity is increased.
FRACPB = 0.03	The mixing length limit in the blade row if using ILOS = 10.
FRACPW = 0.03	The mixing length limit downstream of the blades if using ILOS = 10.
FRACPUP = 0.03	The mixing length limit upstream of the blades if using ILOS = 10.
FRACPIN = 0.02	The mixing length limit at the inlet boundary if using ILOS = 100.
FRACPLE = 0.03	The mixing length limit at blade leading edge if using ILOS = 100.
FRACPTE = 0.03	The mixing length limit at blade trailing edge if using ILOS = 100.
FRACPDWN= 0.04	The mixing length limit at the downstream boundary or mixing plane if using ILOS = 100.
FAC_STMIX = 0.0	The S-A model is used without trying to match the mixing length turbulent viscosity.

FAC_ST0 = 1.0	Factor scaling the first source term in the S-A model.
FAC_ST1 = 1.0	Factor scaling the second source term in the S-A model.
FAC_ST2 = 1.0	Factor scaling the third source term in the S-A model.
FAC_ST3 = 1.0	Factor scaling the fourth source term in the S-A model.
FAC_SFVIS = 2.0	The smoothing of the turbulent viscosity calculated by the S-A model is multiplied by this factor.