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User's Guide for MSAP2D: A Program for Unsteady Aerodynamic and Aeroelastic (Flutter and Forced Response) Analysis of Multistage Compressors and Turbines

Version 1.0

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User's Guide for MSAP2D : A Program for Unsteady Aerodynamic and Aeroelastic (Flutter and Forced Response) Analysis of Multistage Compressors and Turbines

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SUMMARY

This guide describes the input data required for using MSAP2D (Multi Stage Aeroelastic analysis Program - Two Dimensional) computer code. MSAP2D can be used for steady, unsteady aerodynamic, and aeroelastic (flutter and forced response) analysis of bladed disks arranged in multiple blade rows such as those found in compressors, turbines, counter rotating propellers or propfans. The code can also be run for single blade row. MSAP2D code is an extension of the original NPHASE code for multiblade row aerodynamic and aeroelastic analysis.

Euler equations are used to obtain aerodynamic forces. The structural dynamic equations are written for a rigid typical section undergoing pitching(torsion) and plunging (bending) motion. The aeroelastic equations are solved in time domain. For single blade row analysis, frequency domain analysis is also provided to obtain unsteady aerodynamic coefficients required in an eigen analysis for flutter.

In this manual, sample input and output are provided for a single blade row example, two blade row example with equal and unequal number of blades in the blade rows.

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1. INTRODUCTION

During the period of 1982-1992 several aeroelastic analyses for turbomachines and propfans were developed at NASA Lewis Research Center. This development resulted in individual codes with differences in the aerodynamic and structural models used, Ref. 1. However, these codes can be used for only single blade row analysis. In 1993, effort to develop codes that can handle more than one blade row was started. A code, named MSAP2D (Multi Stage Aeroelastic analysis Program - Two Dimensional) has been developed under this initiative. MSAP2D can be used for steady, unsteady aerodynamic, and aeroelastic (flutter and forced response) analysis of bladed disks arranged in multiple blade rows such as those found in compressors, turbines, counter rotating propellers or propfans. The code can also be run for single blade row analysis. MSAP2D code is an extension of the original NPHASE code, Ref. 2, for multiblade row aerodynamic and aeroelastic analysis. An exclusively single blade row aerodynamic and aeroelastic analysis program, ECAP2D, is available in Ref. 3.

This guide will help the user in the preparation of the input data file required for the MSAP2D code. Detailed explanations of the aerodynamic analysis, the numerical algorithms, and the aeroelastic analysis are not given in this guide. Instead, the reader is directed to specific references that deal with each of these items. In the following sections, first a brief description of the analysis is given. This is followed by two sections describing the input and output to the program. A job run stream for Cray YMP is given next followed by input and output files for three examples. The guide ends with a listing of the program calling tree for MSAP2D and references.

The MSAP2D code was developed with the support of the Structural Dynamics Branch at NASA Lewis Research Center. It is made available strictly as a research tool. Neither NASA Lewis Research Center, nor any individuals who have contributed to the development of the code, assume any liability resulting from the use of this code beyond research needs.

2. ANALYSIS

The aerodynamic analysis used in this code is based on the two-dimensional unsteady Euler equations. These equations are solved for a cascade of blades. A finite volume approach is used to solve the Euler equations. A hybrid approach of flux vector splitting scheme (FVS) on left-hand-side, and flux difference splitting scheme (FDS) on right-hand-side terms is used. The coordinate system used is shown in Fig. 1a for a single blade row configuration and in Fig. 1b for a two blade row configuration. The transformation of the equations to the computational plane and the subsequent discretization and solution of these equations is described in Refs. 2 and 4. The interface boundary between the blade rows is handled using the procedure described in Ref. 5. The detailed description of the aerodynamic analysis and grid motion can be found in these references. The references also contain the full description of the formulation including the governing equations and boundary conditions.

The aeroelastic analysis is described in Refs. 6-10. The structural model for each blade is a rigid typical section model with two degrees of freedom, pitching and plunging, as shown in Fig. 2. The aeroelastic equations, for all blades in all rows, are integrated in time using Newmark's method. A response with growing amplitude indicates flutter or a forced response condition at resonance. When, a single blade row is analyzed, a frequency domain aeroelastic analysis is also provided (as in Ref. 6). For frequency domain aeroelastic analysis, the blades are oscillated harmonically. The time history of the forces (lift and moment) from this harmonic oscillation is Fourier analyzed to obtain unsteady aerodynamic harmonic coefficients. These unsteady aerodynamic coefficients are then used in an eigen analysis. The eigen values determine the flutter condition. The examples given here can be found in Refs. 6-10.

3. DESCRIPTION OF INPUT DATA

The MSAP2D code is written in FORTRAN. It was developed and is operational on the Cray YMP computer at NASA Lewis Research Center under the UNICOS operating system. The source code is designated as *msap2d.f*, and the input data for the code is provided in the input file *msap2d.in.*

3.1 Dimension Statement for the Program

The source code contains two parameter cards. The first parameter card defines the maximum number of blade rows and the maximum number of blades (blocks) for calculation. The second parameter card defines the grid size i.e. the number of grid points in the axial and circumferential direction which are *same* for all blade rows at this time. For required number of blade rows, required blocks, and for the grid size for computation that are larger than defined by the parameter cards, the parameter cards should be changed **globally** in the source code and the source code should be then compiled. The parameter cards are as follows (defined for two blade rows, three blades (blocks) in each row, and 91x41 grid for each block):

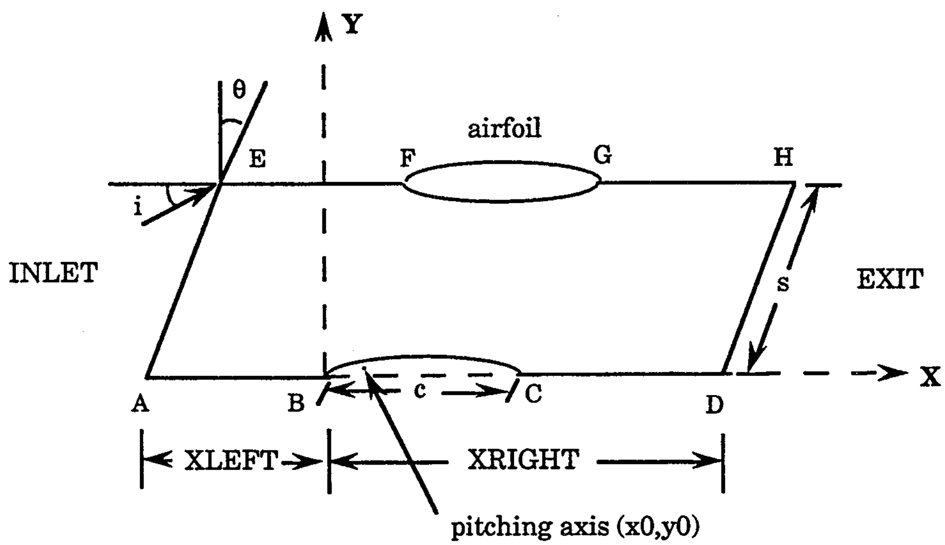

Figure 1a: Cascade geometry showing stagger angle (θ), chord length (c), incidence angle (i) and gap (s).

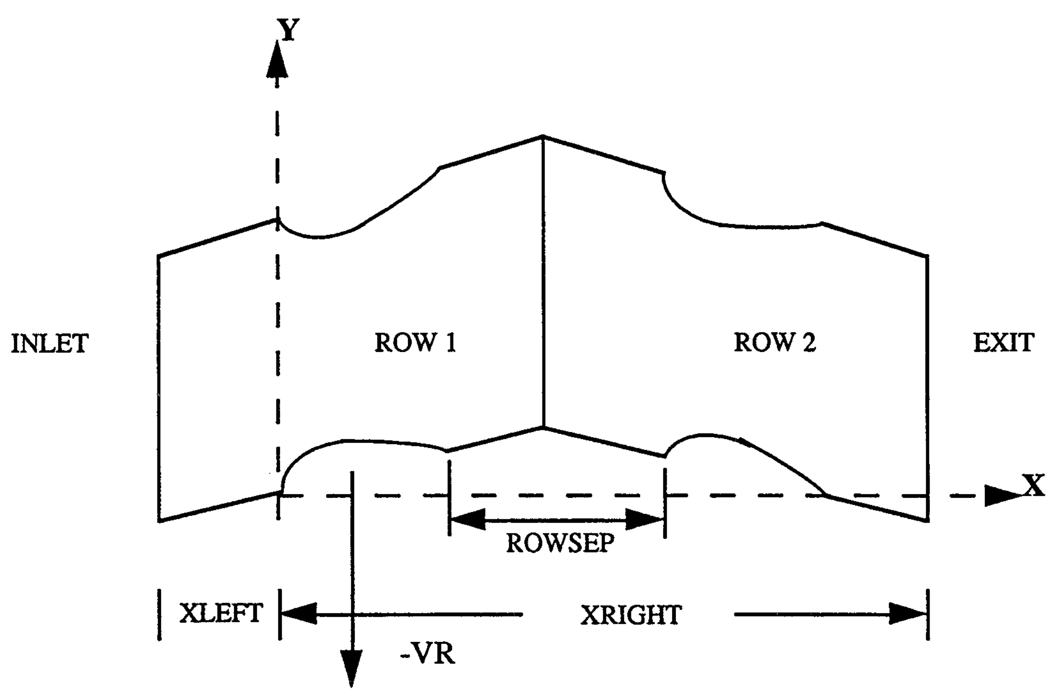

Figure 1b: Cascade geometry for two blade rows showing XLEFT, XRIGHT and ROWSEP

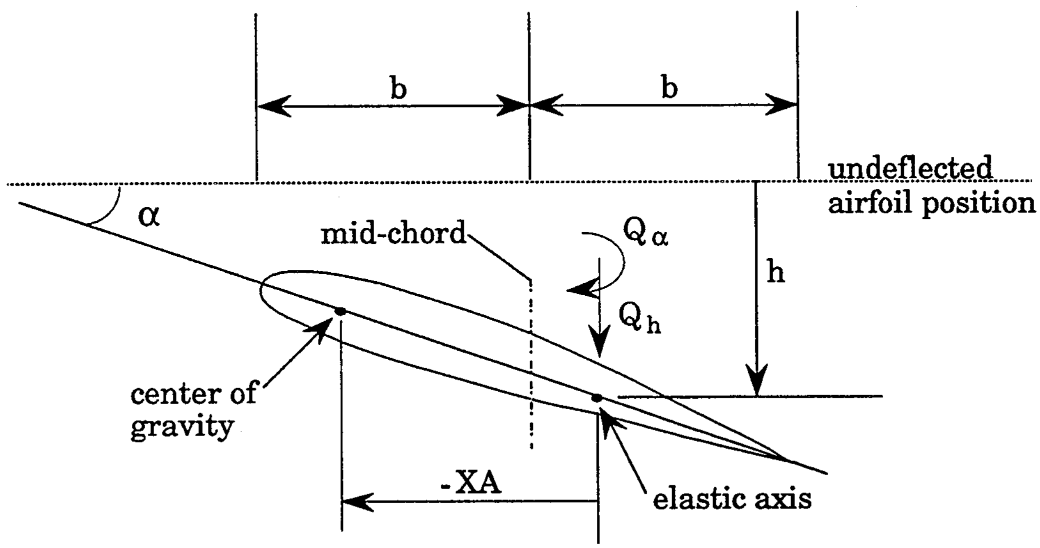

Figure 2: Typical section blade model showing plunging (h), pitching (α), degrees of freedom, lift (Qh), moment (Qα), distance between center of gravity and elastic axis (XA)

```
parameter(nrmx=2, nbsx=3)
parameter(ni=91, nj=41)
```

where

nrmx = maximum number of blade rows; Due to coding reasons, nrmx must be dimensioned a minimum of two (nrmx=2) even when single blade row is used.

nbsx = number of passages/blocks/blades for computation from the blade row having the highest number of blades; can be dimensioned for one block (nbsx =1) when one block is used for analysis.

ni = number of grid points in the axial (streamwise) direction; must be same for all blade rows.

nj = number of grid points in the circumferential direction; must be same for all blade rows.

It should be noted that the number of blade rows and blocks actually used can be less than the one defined in the parameter card, but the values of ni and nj should match actual grid size used.

It should also be noted that the computational grid, if read as input from outside the code, is required for only one block for each blade row. The code, while executing, arranges the grid for the required number of blocks for computation. If the grid is generated outside of this code, the values of 'ni' and 'nj' should be set for that grid size before compiling the code.

3.2 Description of Input Variables

The input is given through a data file named **msap2d.in** . This file contains the standard (unit 5) input that the MSAP2D code requires. In the input file, the values of each set of input variables is preceded by an informational line containing the names of the variables. This line is read in 8A10 format. Following this line, the values of the variables are read. Real values are read in 8F10.4 format and integer values are read in 8I10 format.

For clarity, the flow variables, algorithm variables, and structural variables are sometimes separated by an extra line denoted as "spacer".

description: spacer

```
*.........*.........*.........*.........*.........*.
```

The input variables are described below in the order in which they appear in the input data file (see section 7.1 for sample input file).

variable: `INDBC`
type: integer variable
description: `INDBC=0` use characteristic variable boundary conditions

variable: `MIRROR`
type: integer variable
description: `MIRROR=0` first row is moving down, second row moving up
`MIRROR=1` make a mirror reflection of the grid to suit the above pattern

variable: `IORIG`
type: integer variable
description: `IORIG=0` for future use

variable: `ISYST`
type: integer variable
description: `ISYST=0`, for future use

variable: `MOTION`
type: integer variable
description: defines type of solution method
`MOTION = 0` steady
`MOTION = 1` harmonic oscillation method
`MOTION =-1` time domain method

variable: `INEW`
type: integer variable
description: control for future use
`INEW = 0` presently

variable: `FSMACH`
type: real variable
description: Mach number of flow at inlet

variable: `PHASE`
type: real variable
description: interblade phase angle in degrees. Used only for harmonic oscillation method. No meaning for time domain method.

variable: REDFRE
type: real variable
description: reduced frequency of oscillation, non-dimensionalized with airfoil semi-chord and inlet (free-stream) velocity. No meaning for time domain method.

variable: ALPHA
type: real variable
description: incidence angle (i) in degrees. See Fig. 1a.

variable: H0/C
type: real variable
description: plunging amplitude of oscillation, non-dimensionalized with airfoil chord, c. Required for calculations with plunging motion (see Fig.2). Used for harmonic oscillation method (MOTION=1).

variable: ALFA0D
type: real variable
description: pitching amplitude of oscillation in degrees. Required for calculations with pitching motion (see Fig.2). Used in harmonic oscillation method (MOTION=1).

variable: CFL
type: real variable
description: maximum value of the CFL number. The time step used in the solution is determined by the maximum value of the CFL. For a given grid cell size, a small value of CFL will give small time step, and a large value will give large time step. CFL number is proportional to time step and grid cell size.

variable: PRAT
type: real variable
description: exit pressure ratio, ratio of pressure at the exit plane to the total pressure. Used in subsonic flow and supersonic flow with subsonic axial component velocity. Not required for supersonic through-flow cases.

variable: PSI
type: real variable
description: algorithm control, depends on ORDER and LIMIT (see below)

variable: ORDER
type: real variable
description: order of the solution method
ORDER = 2 use second order spatial accuracy
ORDER = 3 use third order spatial accuracy

variable: LIMIT
type: real variable
description: flux limiter
LIMIT = 0 use no flux limiters
LIMIT = 1 use minmod flux limiter (see MINMOD routine)
LIMIT = 2 use superbee flux limiter (see SUPBEE routine)
LIMIT = 3 use van Leer flux limiter (see VL routine)

variable: X0
type: real variable
description: x-location of pitching (elastic) axis, in units of chord, referenced from leading edge, see Fig.1a.

variable: Y0
type: real variable
description: y-location of pitching (elastic) axis, in units of chord, referenced from leading edge, see Fig.1a.

variable: NCYC
type: integer variable
description: number of cycles of oscillation of the airfoils (MOTION=1).
Not used for or for time domain method (MOTION=-1)

variable: NTSS
type: integer variable
description: number of time steps for which the airfoils remain steady. Used for initializing the flow before blade oscillation begins.

variable: NTTOT
type: integer variable
description: total number of time steps in the calculation (MOTION =0,-1), for MOTION =1, this value is not used.

variable: NTPRNT
type: integer variable
description: the number of time steps after which information is written to standard output (unit 6) in routine FORCE.

variable: IGB
type: integer variable
description: indicator to determine how the grid is generated.
IGB=0 grid generated with in the code
IGB=-1 read externally generated grid (read (2) x(ni,nj),y(ni,nj))
IGB=-2 generates a uniform grid with in the code
IGB=1 read grid generated by grid generator of Ref. 11

variable: XLEFT
type: real variable
description: inlet (left) boundary location of the computational grid in units of chord; see figure 1.

variable: XRIGHT
type: real variable
description: exit (right) boundary location of the computational grid in units of chord; see figure 1.

variable: NROW
type: integer variable
description: number of blade rows for the current analysis

variable: NRFLBC
type: integer variable
description: control to make any blade row in a two blade row configuration have no blades i.e.solid boundaries; useful for debugging
NRFLBC=0 both rows have blades
NRFLBC=1 front blade row has no blades
NRFLBC=2 second blade row has no blades

variable: ROWSEP
type: real variable
description: distance between two blade rows in units of chord, see Fig. 1b

variable: KIN
type: integer variable
description: restart unit number
KIN=0 for first run
KIN=8 if solution starts from previous run

variable: KOUT
type: integer variable
description: unit to save output for restart

KOUT=0 do not save for restart run
KOUT=9 save for restart run

variable: MOOVEE
type: integer variable
description: unit to write files for movie making
MOOVEE=0 do not save solution for movie
MOOVEE=1 save solution for movie

variable: IMODE
type: integer variable
description: mode of airfoil oscillation
IMODE=0 for plunging
IMODE=1 for pitching
IMODE=2 for combined plunging-pitching motion

variable: IFLTR
type: integer variable
description: flag for flutter calculation
IFLTR = 0 steady analysis (MOTION=0)
IFLTR =1 single degree freedom, harmonic oscillation method (MOTION=1)
IFLTR =1 two degrees of freedom, harmonic oscillation method (MOTION=1)
IFLTR=-1 single degree freedom, time domain method, (MOTION=-1)
IFLTR=-2 two degrees of freedom, time domain method, (MOTION=-1)

variable: IFREE
type: integer variable
description: to enable for free vibration analysis only of the structural model, and to check the code with user supplied example

IFREE=0 do aeroelastic analysis

IFREE=1 do free vibration analysis with the present structural model

IFREE=2 do forced response analysis for a two degrees freedom system (IMODE=2) without damping, example from K.J. Bathe, Finite Element Method, pp. 513;. User can change the data in routines STRDAT and INICON to set up his own example.

IFREE=3 do forced response analysis for a single degree freedom system with viscous damping, example given from : Structural Dynamics, An Introduction to Computer Methods, Roy R. Craig, Jr., pp. 150. Give IMODE=2 to test the example without damping and with viscous damping in the same run. User can change the data in routines STRDAT and INICON to set up his own example.

variable: VSTAR
type: real variable
description: reduced velocity non-dimensionalized with airfoil semi-chord and natural frequency in torsion (pitching) for MOTION=-1

variable: SBYC
type: real variable
description: cascade gap (s) -to-chord (c) ratio for the first blade row, see Fig.1a.

variable: STAG
type: real variable
description: cascade stagger angle (theta) in degrees for the first blade row, see Fig.1a.

variable: IAFOIL
type: integer variable
description: airfoil type
IAFOIL=0 (flat plate)
IAFOIL=1 NACA 0012
IAFOIL=2 Biconvex(thickness to chord ratio defined in routine GRIDGEN)
IAFOIL=3 NACA 66006
IAFOIL=4 (left open)
IAFOIL=5 read upper surface and lower surface coordinates of any given airfoil. y values available at x values given by 1.0/number of points on the airfoil (see GRIDGEN subroutine).

variable: NBS
type: integer variable
description: number of blades in the first blade row

variable: ILE
type: integer variable
description: airfoil leading edge grid i - index number

variable: ITE
type: integer variable
description: airfoil trailing edge grid i - index number

variable: PERCJ
type: real variable
description: percentage of the grid that follows grid motion
PERCJ=100 at present

variable: VR
type: real variable
description: blade row speed in terms of Mach number; the first blade row is moving in the negative y-direction, see Fig. 1b.

variable: CHORD
type: real variable
description: non-dimensional chord value; always equal to 1.0

variable: GHS
type: real variable
description: natural frequency in bending (plunging) in cycles per second.

variable: GAS
type: real variable
description: natural frequency in torsion (pitching) in cycles per second.

variable: ZHS
type: real variable
description: ratio of damping in bending (plunging) to critical damping (non-dimensional)

variable: ZAS
type: real variable
description: ratio of damping in torsion (pitching) to critical damping (non-dimensional)

variable: XMU
type: real variable
description: mass ratio, ratio, XMU = m/ (π ρ b**2), where m is the airfoil mass, ρ is the air density and b is the semichord.

variable: XRA
type: real variable
description: radius of gyration of typical section about pitching (elastic) axis in semi-chord units

variable: XA
type: real variable
description: static imbalance of typical section, distance of center of gravity (c.g.) from the elastic axis in semi-chord units; positive for c.g. aft of elastic axis, see Fig. 2.

variable: HD0
type: real variable
description: initial condition on plunging velocity (plunging displacement per unit time; plunging displacement is non-dimensionalized by chord and time by chord and speed of sound) (MOTION=-1)

variable: ALFAD0
type: real variable
description: initial condition on pitching velocity (degree per unit time; time is non-dimensionalized by chord and speed of sound) (MOTION=-1)

variable: H0
type: real variable
description: initial condition on plunging displacement (non-dimensionalized with chord) (MOTION=-1)

variable: ALFA0
type: real variable
description: initial condition on pitching displacement (degrees), (MOTION=-1)

variable: SMOTION
type: real variable
description: indicator for inclusion of blade vibration in the aerodynamic force calculation;
=0 do not include (forced response)
=1 include (flutter plus forced response)

NOTE 1: The lines containing the names and variables GHS, GAS, ZHS, ZAS, XMU, XRA, XA and HD0, ALFAD0, H0 and ALFA0 are repeated **for each block** / passage/ blade **with in the number of blade row loop.**

NOTE 2: The lines containing the names SBYC, STAG, IAFOIL, NBS, ILE, ITE, PERCJ, VR, CHORD are repeated **for each blade row**.

variable: IGSTOP
type: integer variable
description: indicator to stop after setting up the grid;useful for debugging.
>0 stop after setting up the grid
=0 proceed for numerical calculations

variable: GUSTUA
type: real variable
description: amplitude of the gust velocity in x-direction
=0.0 at present (no gust response capability)

variable: PHASE
type: real variable
description: phase of the gust velocity in x-direction
=0.0 at present (no gust response capability)

variable: GUSTVA
type: real variable
description: amplitude of the gust velocity in y-direction
=0.0 at present (no gust response capability)

variable: PHASE
type: real variable
description: phase of the gust velocity in y-direction
=0.0 at present (no gust response capability)

variable: NTINT
type: integer variable
description: number of time steps for checking the program before real case; useful for debugging.
>0 run the code only for this many steps
=0 run the code for final case

variable: DTGIV
type: real variable
description: user input time step, useful for debugging
>0.0 run the code for this time step
=0 run the code for the time step calculated in the code

3.3 Additional Input Files

If the option IGB= - 1 or 1 is used, the grid is read as input. For IGB= - 1 option, the grid file should be available in binary format and the file should be linked to unit 2 (For Cray compilers, the file is named fort.2). As mentioned earlier, it is read as read(2) xin, yin. The xin and yin arrays are of (ni,nj) length. For the IGB =1 option, the grid file should be named 'grid'. The sdblib.a package, which is available at NASA Lewis Research Center, is used to read this file. It is sufficient that grid is available for only one block. The grid should be available in the coordinate system shown in Fig. 1a.

For the first run, the program creates a unit 9 file (fort.9 file on Cray). This file contains all the data necessary for restart option. This file becomes input file for subsequent runs, and has to be linked to unit 8 (renamed fort.8 for Cray) before running the code for the same case.

4. DESCRIPTION OF OUTPUT FILES

The code creates the following output files:

(1) Unit 6 output: This output contains an echo of the input for verification. It is also used for verifying that the stagger angle, and gap-to-chord ratio calculated from input grid file is same as the input value. The calculated time step used in the computation is also printed. In addition, for the harmonic oscillation method, it shows the unsteady aerodynamic coefficients of lift and moment for each cycle of oscillation. Additionally, it contains the eigen values from the flutter analysis. For steady solution (not given in this manual), and for the time domain method it shows the rms values of residuals, for checking the convergence of the solution.

(2) FORT.7: a formatted file of the grid. See MAIN program for the format description. Useful to check the grid before calculations begin. Can be read by PLOT3D program.

(3) FORT.9: binary file for restart run. For first run KIN=0; for restart run KIN=8 and fort.9 is renamed fort.8.

(4) FORT.50+i, i =1,nbs*NROW. From time domain analysis it has seven columns, which are index, plunging displacement, pitching displacement, unsteady lift, unsteady moment, total lift and total moment. (Note: total lift and total moment include the contributions from steady and unsteady motion; unsteady lift and unsteady moment include contributions due to unsteady motion only.). For the multiblade row case, first 50+i,i=1,nbs1, next 50+nbs1+i=1,nbs2, etc , are created, where nbs1 is the number of blades in the first row, and nbs2 is the number of blades in the second row.

(5) FORT.80+nr, nr=1,NROW: an intermediate file when the code is run for multiblade row.

(6) FORT.90 (OUT.DCP): file containing the real and imaginary components of unsteady pressures for harmonic oscillation method. It has six columns which are index, chord distance, real component, imaginary component, magnitude and phase.

(7) FORT.90+nr, nr=1,NROW (OUT.HIST1, OUT.HIST2, etc.) : file containing the information on force coefficients versus time. It has five columns which are time step number, time, lift, moment and drag coefficients. Used for frequency domain time history solution.

(8) FORT.95+nr, nr=1,NROW (OUT.CP1, OUT.CP2, etc.): file containing the pressure distribution on the airfoil surface. It has eight columns which are upper surface coordinate, Mach number, isentropic Mach number, pressure coefficient, lower surface coordinate, Mach number, isentropic Mach number, pressure coefficient.

(9) GRID.BIN, FLOW.BIN: binary grid (airfoil coordinates) and flow files (values of density, two velocity components and energy at each grid point), respectively, created at the end of the calculations for plotting. These are printed using routines in sdblib.a package. See the routine GROUT subroutine in MSAP2D program for format description. Can be read by PLOT3D plotting program.

5. ADDITIONAL NOTES

The code requires the IMSL (International Mathematical and Scientific Library) routine FFTRF for obtaining the harmonic components of the time history. Also, at present the code is compiled with sdblib.a which is a package to transfer binary files independent of machines. PLOT3D is required for graphical visualization of grid and flow data. The existing grid generation routine within the code may be good for flat plate cases only. For other cases, grid can be generated outside and read through unit 2.

For the example given in section 7.1, with a 91x41 grid for two blocks, and for Mach number = 2.61, reduced frequency =1.0, with a CFL number of 4.0, the calculated time step was 0.00443. About 272 time steps per cycle were required, and for three cycles, the cpu time is 307 seconds on Cray YMP. The cpu time included the time required for SSD (about 84 seconds). The code required 3.73 MW memory. The memory can be considerably reduced by doing the Fourier transform outside the program.

6. JOB RUN STREAM ON CRAY YMP

A sample Cray job stream to run MSAP2D at NASA Lewis Research Center is given in this section. For this case there are no additional input data files to be linked. The source code, msap2d.f, is compiled using cft77 with standard options. Two solid state devices (ssd) are touched to store and retrieve intermediate data, since two blocks (nbs=2) are used for computations. The compiled code is loaded and linked with sdblib.a, a package for reading binary files, and with IMSL (version 10) library. The input is contained in the file named msap2d.in. The standard unit 6 output is written to a file named msap2d.out. The rest of the file contains UNICOS and Cray related commands.

```
#! /bin/csh
# QSUB -r plate
# QSUB -lM 4.0 Mw
# QSUB
ja
cd /wrk/smreddy/pltpi
#
touch ssd.11 ; env FILENV=sss assign -s u -a ssd.11 fort.11
touch ssd.12 ; env FILENV=sss assign -s u -a ssd.11 fort.12
#
cft77 -V -a static msap2d.f
segldr -o e2d msap2d.o sdblib.a /tpsw/imsl/imslib.a
env FILENV = sss time e2d <msap2d.in> msap2d.out
rm ssd.1* sss
js -st
```

7. EXAMPLE CASES:

The input and output for three examples are given in the following sections. The first example is for the calculation of unsteady aerodynamic coefficients for a single blade row. The second example is for the calculation of unsteady aerodynamic and structural response of two blade row configuration with both the blade rows having equal number of blades. The third example is again for two blade rows, but with unequal number of blades in the blade rows. The harmonic oscillation (frequency domain) method is used for single blade row analysis, and time domain method for two blade row examples. For all the three cases, the grid is generated within the code, and pitching motion only is considered. In addition to the usual unit 6 output, a list of additional files of interest, created by the code, is also given. These cases are provided so that the user can verify the correct installation and operation of the code. The single blade row case is provided as a check for single blade version for the MSAP2D code, and to check with those presented in the literature (for example in Refs. 3, 6-10).

7.1 Unsteady Aerodynamics of a Flat-Plate Cascade Oscillating in Pitch, Single Blade Row, Harmonic Oscillation Method

A flat plate cascade at zero angle of attack (ALPHA=0.0) is considered for the single blade row (NROW=1) example. The cascade stagger angle (STAG) is 28 degrees, and the gap-to-chord ratio (SBYC) is 0.311. The Mach number at the inlet (FSMACH) is 2.61. The pitching axis is located at about 30% of chord from the leading edge (X0 = 0.3, Y0=0.0). The following structural properties are used: the mass ratio (XMU) is 456, the radius of gyration (XRA) is 0.588, natural frequencies in bending and torsion in cycles per second respectively are 0.567 and 1.0 i.e. GAS=0.567 and GHS=1.0, and the offset (XA) between elastic axis and center of gravity is zero, with no structural damping (ZHS, ZAS = 0.0). The elastic axis and the pitching axis are assumed identical in the code, and for all the examples presented here.

The grid is generated within the code (IGB=0) for the flat plate geometry (IAFOIL=0). The grid has 91 points in the streamwise direction (ni=91) and 41 points in the circumferential direction (nj=41). There are 51 points on the airfoil, and 19 points between inlet and leading edge (ILE=20, ITE=70). Two blocks (passages) are used in the calculations i.e. NBS=2. The source code is compiled with the following parameter statements.

```
parameter(nrmx=2, nbsx=2)
parameter(ni=91, nj=41)
```

It should be noted that the code is compiled with nrmx=2 instead of nrmx=1, because of the coding restrictions for multiblade row.

The unsteady aerodynamic coefficients are calculated for pitching about 30% of chord from leading edge (X0 = 0.3, Y0=0.0) at a reduced frequency (REDFREQ) of 1.0. The unsteady aerodynamic coefficients are calculated by harmonically oscillating (MOTION=1) the blades in 180 degrees phase angle (PHASE=180.) in pitch (IMODE=1). A pitching amplitude (ALFA0D) of 0.15 degrees is used. A CFL number of 4.0 is used to give a time step (dtmin) of 0.00442. This value of the time step, for the given value of reduced frequency, yields 272 steps per cycle (nperiod=272). Calculations are performed for 3 cycles (NCYC=3) of oscillation. At the end of calculations for each cycle of oscillation, the forces (lift followed by moment) are Fourier analyzed and harmonics are printed.

Input file (msap2d.in)

```
      INDBC     MIRROR
          0          0
      IORIG      ISYST
          0          0
     MOTION       INEW
          1          0
     FSMACH      PHASE    REDFREQ      ALPHA
      2.610    180.000     1.0000       0.00
       H0/C     ALFA0D
     0.0000     0.1500
.........*.........*.........*.........*.........*
        CFL       PRAT        PSI      ORDER      LIMIT
        4.0     0.7320     0.3333        3.0        1.0
         X0         Y0
     0.3000     0.0000
.........*.........*.........*.........*
       NCYC       NTSS      NTTOT    NTPRNT
          3         10        250        50
        IGB
          0
.........*.........*
      XLEFT     XRIGHT
    -0.3000        1.5
.........*.........*.........*.........*.........*
       NROW     NRFLBC     ROWSEP
          1          0     1.0000
.........*.........*.........*.........*.........*
        KIN       KOUT     MOOVEE
          0          9          0
      IMODE      IFLTR      IFREE
          1          1          0
.........*
      VSTAR
       0.12
.........*.........*.........*.........*
       SBYC       STAG     IAFOIL        NBS
     0.3110      28.00          0          2
        ILE        ITE      PERCJ         VR      CHORD
         20         70      100.0     -0.000        1.0
        GHS        GAS        ZHS        ZAS        XMU        XRA         XA
      0.286        1.0      0.000      0.000      162.7      0.588      0.000
        HD0     ALFAD0         H0      ALFA0
      0.000      0.000        0.0        0.0
    SMOTION
      1.000
        GHS        GAS        ZHS        ZAS        XMU        XRA         XA
      0.286        1.0      0.000      0.000      162.7      0.588      0.000
        HD0     ALFAD0         H0      ALFA0
      0.000  -0.000000        0.0        0.0
    SMOTION
      1.000
---IGSTOP: stop after grid set up(=0 no stop)----
0
     GUSTUA      PHASE
        0.0        0.0
```

```
   GUSTVA      PHASE
      0.0        0.0
---NTINT: number of steps for debugging----
0
--DTGIV: user input time step--
0.0
```

Unit 6 output file (msap2d.out)

```
  indbc = 0mirror = 0
  iorig = 0isyst = 0
  motion = 1inew= 0

 *****************************************************
                          HARMONIC MOTION
 *****************************************************

     factors for vibration =      1.0000      1.0000
   FSMACH      PHASE   REDFREQ     ALPHA
   2.6100  180.0000    1.0000    0.0000
     H0/C     ALFA0D
   0.0000     0.1500
      CFL       PRAT       PSI     ORDER     LIMIT
   4.0000     0.7320    0.3333    3.0000    1.0000
       X0         Y0
   0.3000     0.0000
     NCYC       NTSS     NTTOT    NTPRNT
        3         10       250        50
      IGB
        0
    XLEFT     XRIGHT
  -0.3000     1.5000
     NROW     NRFLBC    ROWSEP
        1          0     1.000
    KMODE       KFFT     LIMIT
        1          1         1
      KIN       KOUT    MOOVEE
        0          9         0

  ****** Oscillating Cascade Analysis ******
  input run stream:

  number of blocks =    3 where each block has dimensions of:
                ni =   91
                nj =   41
                nk =    2

  freestream mach number   =  2.6100
  inlet incidence angle    =  0.0000 (degrees)
  exit pressure ratio      =  0.7320 (p/ptot)
  inter-blade phase angle =180.0000 (degrees)
  reduced frequency        =  1.0000 (based on semichord)
  reduced frequency        =  5.2200 (in terms of omega)
  amplitude of plunge      =  0.0000 (percent chord)
  amplitude of pitch       =  0.1500 (degrees)
  airfoil moment center    =  0.3000 (x0, percent chord)
  airfoil moment center    =  0.0000 (y0, percent chord)
```

```
nb       =    3 (total number of cycles)
kin      =    0 (restart input number -if 0 not used)
kout     =    9 (restart output number -if 0 not used)
kfft     =    1 (no fft analysis if kfft=0)
moovee   =    0 (save certain steps for animation)
kmode    =    1 (stationary or oscillating cascade)

a fft analysis will be done at the end of each cycle

      flux limiter input information:

            limit =    1
            psi   = 0.333
            order =   3.0

note with limit=1, MINMOD limiter has been invoked

    grid generated now , igb =     0
    IMODE      IFLTR      IFREE
       1          1          0
    PITCHING MOTION
    FLUTTER IN FREQ. DOMAIN: SINGLE DEGREE OF FREEDOM

    **** PRINT INTERVAL, NTPRNT **** =   50

 number of rows =1
 for row =1
     SBYC       STAG     IAFOIL       NBS
   0.3110   28.0000          0          2
      ILE        ITE      PERCJ        VR      CHORD
       20         70    100.000     0.000      1.000
    motion indicator for blade    1:   1.0000
    GAMA H =      0.28600     GAMA ALPHA =      1.00000
    ZETA H =      0.00000     ZETA ALPHA =      0.00000
    MASS RATIO(XMU)                       =   162.70000
    RADIUS OF GYRATION(XRA)               =     0.58800
    DT. BETWEEN E.A. AND C.G.(XALFA)      =     0.00000
    initial plunging velocity             =     0.00000
    initial pitching velocity             =     0.00000
    initial plunging displacement         =     0.00000
    initial pitching displacemnet         =     0.00000
    SELF VIBRATION INDICATOR              =     1.00000

    motion indicator for blade    2:   1.0000
    GAMA H =      0.28600     GAMA ALPHA =      1.00000
    ZETA H =      0.00000     ZETA ALPHA =      0.00000
    MASS RATIO(XMU)                       =   162.70000
    RADIUS OF GYRATION(XRA)               =     0.58800
    DT. BETWEEN E.A. AND C.G.(XALFA)      =     0.00000
    initial plunging velocity             =     0.00000
    initial pitching velocity             =     0.00000
    initial plunging displacement         =     0.00000
    initial pitching displacemnet         =     0.00000
    SELF VIBRATION INDICATOR              =     1.00000

 xminb=-0.3xmaxb=1.5rowsep=1.
 GRID FOR ROW =1
```

```
nr =1 ile =20 ite =70chord=1.
 xleft=-0.3 xright=1.5
 igb = 0
 calling gridgen
    IN ROUTINE GRIDGEN:STAG,SC,CHORD,X1,X4,NIF,NIB,IRUN
   28.00000      0.31100      1.00000     -0.30000      1.50000   20   70    0
 stagger angle (deg.) from input file =
                              28.0000000000
 stagger angle (deg.) from grid file =
                              28.0000000000
 stagger angle (deg.) used in the cal. =
                              28.0000000000
 gap-to-chord ratio from input file =
                               0.3110000000
 gap-to-chord ratio from grid file =
                               0.3110000000
 gap-to-chord ratio used in the calculation =
                               0.3110000000
    finished reading grid coordinates in routine RDGRID
    *** x coordinates at 0,ile,ite,last
        -0.30000      0.00000      1.00000      1.50000
         0.00000      0.00000      0.00000      0.00000
        -0.15399      0.14601      1.14601      1.64601
         0.27460      0.27460      0.27460      0.27460
 chord along the x-axis
nr, xadd(nr)= 1,  0.
nr, yadd(nr)= 1,  0.
xminb=-0.3xmaxb=1.5rowsep=1.
 before calling STRTRS
    *** x coordinates at 0,ile,ite,last
        -0.30000      0.00000      1.00000      1.50000
         0.00000      0.00000      0.00000      0.00000
        -0.15399      0.14601      1.14601      1.64601
         0.27460      0.27460      0.27460      0.27460
xlenth,ylenth,chord= 1.,  0.,  1.
nr, angdeg in main  = 1,  0.
 in routine STRTRS***
 height and xshift for row= 0.2745967013791,  0.1460056560264,  1

Starting the initial grid calculation in STRTRS
 nr, angdeg in gridp= 1,  0.
 nr, coss,sins = 1,  1.,  0.
 KMODE in STRTRS= 0
 KMODE IN ICRS 0
  For block  1:
    dtmin (as computed in eigenv) at cfl =  4.0 is      0.00442
 dtmin1=4.4236861250468E-3dtmin = 4.4236861250468E-3nr=1
 nssd=11 y1=0. nr=1 n=1 at grid generation
    corresponding to alfa=     0.1500 degrees
 KMODE in STRTRS= 0
 KMODE IN ICRS 0
  For block  2:
    dtmin (as computed in eigenv) at cfl =  4.0 is      0.00442
 dtmin1=4.4236861250468E-3dtmin = 4.4236861250468E-3nr=1
 nssd=12 y1=0.2745967013791 nr=1 n=2 at grid generation
    corresponding to alfa=    -0.1500 degrees
Successful completion of grid generation in STRTRS
```

```
The flow solution will use dtmin= 0.00443 and nperiod=   272
to give a maximum cfl close to   4.000

*** distance between t.e. to l.e. ***-1.
  axial chord       actual chord      setting angle
2*1.,  0.
3*0.

gust parameters
 U velocity and Phase(radians)
2*0.
 V velocity and Phase(radians)
2*0.
reading input nt
ntinpt,nt,nperiod= 0,  2*272
nperd2= 544
 height=0.2745967013791 ymin=-0.296811180188 ymax=0.6864917534478
KMODE= 1KFFT= 1
 ile=20 ite=70 height=0.2745967013791
stag in perf = 0.4886921905584
x0, y0 in perf = 0.3,  0.
nr, angdeg in perf = 1,  0.
nr, coss,sins = 1,  1.,  0.
 ile=20 ite=70 height=0.2745967013791

 nrow1 nrow2 =2*1
 h0,alfa0,nr =0.,  -2.6179938779915E-3,  1
value of L in pvar= 1
xlenth,ylenth,chord=0.9999965731347, -2.6179607744297E-3,  0.9999965731347
```

Surface Mach Number, Isentropic Mach Number and CP; block = 1 and ncyc =   272

x/c	machu	imachu	cpu	x/c	machl	imachl	cpl
-0.2878	2.6100	2.6100	0.0000	-0.1418	2.6100	2.6100	0.0000
-0.2753	2.6100	2.6100	0.0000	-0.1293	2.6100	2.6100	0.0000
-0.2624	2.6100	2.6100	0.0000	-0.1164	2.6100	2.6100	0.0000
-0.2492	2.6100	2.6100	0.0000	-0.1032	2.6100	2.6100	0.0000
-0.2356	2.6100	2.6100	0.0000	-0.0896	2.6100	2.6100	0.0000
-0.2216	2.6100	2.6100	0.0000	-0.0756	2.6100	2.6100	0.0000
-0.2072	2.6100	2.6100	0.0000	-0.0612	2.6100	2.6100	0.0000
-0.1924	2.6100	2.6100	0.0000	-0.0464	2.6100	2.6100	0.0000
-0.1773	2.6100	2.6100	0.0000	-0.0312	2.6100	2.6100	0.0000
-0.1616	2.6100	2.6100	0.0000	-0.0156	2.6100	2.6100	0.0000
-0.1456	2.6100	2.6100	0.0000	0.0004	2.6100	2.6100	0.0000
-0.1291	2.6100	2.6100	0.0000	0.0169	2.6100	2.6100	0.0000
-0.1121	2.6100	2.6100	0.0000	0.0339	2.6100	2.6100	0.0000
-0.0947	2.6100	2.6100	0.0000	0.0513	2.6100	2.6100	0.0000
-0.0768	2.6100	2.6100	0.0000	0.0692	2.6100	2.6100	0.0000
-0.0584	2.6100	2.6100	0.0000	0.0876	2.6100	2.6100	0.0000
-0.0395	2.6100	2.6100	0.0000	0.1065	2.6100	2.6100	0.0000
-0.0200	2.6100	2.6100	0.0000	0.1260	2.6100	2.6100	0.0000
0.0000	2.6100	2.6100	0.0000	0.1460	2.6100	2.6100	0.0000
0.0200	2.6133	2.6160	0.0019	0.1660	2.6133	2.6156	0.0018
0.0400	2.6124	2.6165	0.0021	0.1860	2.6124	2.6166	0.0021
0.0600	2.6121	2.6165	0.0021	0.2060	2.6120	2.6166	0.0021
0.0800	2.6118	2.6165	0.0021	0.2260	2.6116	2.6165	0.0021
0.1000	2.6115	2.6165	0.0021	0.2460	2.6111	2.6165	0.0021
0.1200	2.6112	2.6165	0.0021	0.2660	2.6107	2.6165	0.0021
0.1400	2.6109	2.6164	0.0021	0.2860	2.6102	2.6164	0.0021

0.1600	2.6107	2.6164	0.0021	0.3060	2.6097	2.6164	0.0021
0.1800	2.6104	2.6164	0.0021	0.3260	2.6093	2.6164	0.0021
0.2000	2.6102	2.6163	0.0020	0.3460	2.6090	2.6163	0.0020
0.2200	2.6100	2.6163	0.0020	0.3660	2.6088	2.6163	0.0020
0.2400	2.6098	2.6163	0.0020	0.3860	2.6088	2.6163	0.0020
0.2600	2.6097	2.6163	0.0020	0.4060	2.6088	2.6163	0.0020
0.2800	2.6096	2.6162	0.0020	0.4260	2.6088	2.6163	0.0020
0.3000	2.6096	2.6162	0.0020	0.4460	2.6088	2.6162	0.0020
0.3200	2.6096	2.6162	0.0020	0.4660	2.6088	2.6162	0.0020
0.3400	2.6096	2.6162	0.0020	0.4860	2.6089	2.6162	0.0020
0.3600	2.6097	2.6161	0.0020	0.5060	2.6090	2.6162	0.0020
0.3800	2.6097	2.6161	0.0020	0.5260	2.6092	2.6161	0.0020
0.4000	2.6098	2.6161	0.0020	0.5460	2.6095	2.6162	0.0020
0.4200	2.6099	2.6161	0.0020	0.5660	2.6097	2.6162	0.0020
0.4400	2.6100	2.6161	0.0020	0.5860	2.6101	2.6162	0.0020
0.4600	2.6101	2.6160	0.0019	0.6060	2.6102	2.6161	0.0020
0.4800	2.6102	2.6160	0.0019	0.6260	2.6103	2.6155	0.0018
0.5000	2.6102	2.6160	0.0019	0.6460	2.6098	2.6143	0.0014
0.5200	2.6103	2.6160	0.0019	0.6660	2.6090	2.6129	0.0010
0.5400	2.6103	2.6160	0.0019	0.6860	2.6082	2.6116	0.0005
0.5600	2.6104	2.6160	0.0019	0.7060	2.6074	2.6105	0.0002
0.5800	2.6104	2.6160	0.0019	0.7260	2.6067	2.6098	-0.0001
0.6000	2.6105	2.6160	0.0019	0.7460	2.6061	2.6094	-0.0002
0.6200	2.6105	2.6160	0.0019	0.7660	2.6061	2.6096	-0.0001
0.6400	2.6105	2.6160	0.0019	0.7860	2.6062	2.6100	0.0000
0.6600	2.6106	2.6161	0.0020	0.8060	2.6064	2.6106	0.0002
0.6800	2.6107	2.6162	0.0020	0.8260	2.6069	2.6113	0.0004
0.7000	2.6108	2.6162	0.0020	0.8460	2.6074	2.6120	0.0007
0.7200	2.6108	2.6162	0.0020	0.8660	2.6079	2.6127	0.0009
0.7400	2.6107	2.6159	0.0019	0.8860	2.6086	2.6133	0.0011
0.7600	2.6105	2.6153	0.0017	0.9060	2.6092	2.6138	0.0012
0.7800	2.6100	2.6145	0.0014	0.9260	2.6099	2.6143	0.0014
0.8000	2.6095	2.6135	0.0011	0.9460	2.6106	2.6148	0.0016
0.8200	2.6089	2.6126	0.0008	0.9660	2.6112	2.6153	0.0017
0.8400	2.6083	2.6118	0.0006	0.9860	2.6117	2.6159	0.0019
0.8600	2.6078	2.6113	0.0004	1.0060	2.6121	2.6164	0.0021
0.8800	2.6073	2.6109	0.0003	1.0260	2.6124	2.6170	0.0023
0.9000	2.6070	2.6106	0.0002	1.0460	2.6126	2.6175	0.0024
0.9200	2.6068	2.6105	0.0002	1.0660	2.6127	2.6181	0.0026
0.9400	2.6067	2.6106	0.0002	1.0860	2.6127	2.6187	0.0028
0.9600	2.6068	2.6109	0.0003	1.1060	2.6126	2.6192	0.0030
0.9800	2.6070	2.6113	0.0004	1.1260	2.6126	2.6198	0.0031
1.0000	2.6074	2.6122	0.0007	1.1460	2.6123	2.6206	0.0034
1.0200	2.6046	2.6053	-0.0015	1.1660	2.6092	2.6143	0.0014
1.0403	2.6054	2.6056	-0.0014	1.1863	2.6094	2.6140	0.0013
1.0610	2.6058	2.6056	-0.0014	1.2070	2.6094	2.6139	0.0013
1.0821	2.6062	2.6057	-0.0014	1.2281	2.6092	2.6138	0.0012
1.1035	2.6065	2.6058	-0.0014	1.2495	2.6092	2.6137	0.0012
1.1252	2.6069	2.6059	-0.0013	1.2712	2.6092	2.6136	0.0012
1.1474	2.6073	2.6059	-0.0013	1.2934	2.6093	2.6135	0.0011
1.1699	2.6076	2.6059	-0.0013	1.3159	2.6094	2.6136	0.0012
1.1928	2.6080	2.6058	-0.0014	1.3388	2.6095	2.6137	0.0012
1.2161	2.6084	2.6058	-0.0014	1.3621	2.6097	2.6139	0.0013
1.2398	2.6087	2.6058	-0.0014	1.3858	2.6098	2.6140	0.0013
1.2638	2.6091	2.6058	-0.0014	1.4099	2.6099	2.6140	0.0013
1.2883	2.6093	2.6059	-0.0013	1.4344	2.6100	2.6140	0.0013
1.3133	2.6095	2.6060	-0.0013	1.4593	2.6100	2.6139	0.0013
1.3386	2.6096	2.6060	-0.0013	1.4846	2.6100	2.6139	0.0012

1.3644	2.6097	2.6061	-0.0013	1.5104	2.6101	2.6138	0.0012
1.3906	2.6098	2.6061	-0.0013	1.5366	2.6101	2.6137	0.0012
1.4173	2.6100	2.6062	-0.0012	1.5633	2.6101	2.6135	0.0011
1.4444	2.6100	2.6062	-0.0012	1.5904	2.6101	2.6135	0.0011
1.4720	2.6101	2.6061	-0.0013	1.6180	2.6101	2.6136	0.0012
1.5000	2.6098	2.6055	-0.0015	1.6460	2.6105	2.6143	0.0014

******** inlet conditions ********

j	u	v	mach	angle	p/pt
2	2.610	0.000	2.610	0.000	0.0493
3	2.610	0.000	2.610	0.000	0.0493
4	2.610	0.000	2.610	0.000	0.0493
5	2.610	0.000	2.610	0.000	0.0493
6	2.610	0.000	2.610	0.000	0.0493
7	2.610	0.000	2.610	0.000	0.0493
8	2.610	0.000	2.610	0.000	0.0493
9	2.610	0.000	2.610	0.000	0.0493
10	2.610	0.000	2.610	0.000	0.0493
11	2.610	0.000	2.610	0.000	0.0493
12	2.610	0.000	2.610	0.000	0.0493
13	2.610	0.000	2.610	0.000	0.0493
14	2.610	0.000	2.610	0.000	0.0493
15	2.610	0.000	2.610	0.000	0.0493
16	2.610	0.000	2.610	0.000	0.0493
17	2.610	0.000	2.610	0.000	0.0493
18	2.610	0.000	2.610	0.000	0.0493
19	2.610	0.000	2.610	0.000	0.0493
20	2.610	0.000	2.610	0.000	0.0493
21	2.610	0.000	2.610	0.000	0.0493
22	2.610	0.000	2.610	0.000	0.0493
23	2.610	0.000	2.610	0.000	0.0493
24	2.610	0.000	2.610	0.000	0.0493
25	2.610	0.000	2.610	0.000	0.0493
26	2.610	0.000	2.610	0.000	0.0493
27	2.610	0.000	2.610	0.000	0.0493
28	2.610	0.000	2.610	0.000	0.0493
29	2.610	0.000	2.610	0.000	0.0493
30	2.610	0.000	2.610	0.000	0.0493
31	2.610	0.000	2.610	0.000	0.0493
32	2.610	0.000	2.610	0.000	0.0493
33	2.610	0.000	2.610	0.000	0.0493
34	2.610	0.000	2.610	0.000	0.0493
35	2.610	0.000	2.610	0.000	0.0493
36	2.610	0.000	2.610	0.000	0.0493
37	2.610	0.000	2.610	0.000	0.0493
38	2.610	0.000	2.610	0.000	0.0493
39	2.610	0.000	2.610	0.000	0.0493
40	2.610	0.000	2.610	0.000	0.0493
41	2.610	0.000	2.610	0.000	0.0493

The average inlet Mach number is: 2.6100

******** exit conditions ********

j	u	v	mach	angle	p/pt
2	2.608	0.004	2.599	0.092	0.0497
3	2.607	0.004	2.599	0.093	0.0497

```
  4  2.606  0.004  2.598  0.092  0.0496
  5  2.606  0.004  2.599  0.092  0.0496
  6  2.606  0.004  2.600  0.093  0.0496
  7  2.606  0.004  2.601  0.094  0.0496
  8  2.607  0.004  2.602  0.095  0.0495
  9  2.607  0.004  2.603  0.097  0.0495
 10  2.607  0.005  2.604  0.101  0.0494
 11  2.607  0.005  2.606  0.106  0.0494
 12  2.607  0.005  2.607  0.112  0.0493
 13  2.608  0.005  2.609  0.119  0.0493
 14  2.608  0.006  2.611  0.129  0.0492
 15  2.608  0.006  2.612  0.142  0.0492
 16  2.608  0.007  2.614  0.156  0.0491
 17  2.608  0.008  2.616  0.171  0.0491
 18  2.609  0.008  2.618  0.182  0.0490
 19  2.609  0.008  2.619  0.181  0.0490
 20  2.609  0.008  2.620  0.168  0.0489
 21  2.609  0.006  2.620  0.139  0.0489
 22  2.608  0.004  2.620  0.090  0.0489
 23  2.608  0.002  2.618  0.036  0.0490
 24  2.608  0.000  2.618 -0.004  0.0490
 25  2.608 -0.002  2.619 -0.033  0.0489
 26  2.609 -0.003  2.620 -0.055  0.0489
 27  2.609 -0.003  2.621 -0.069  0.0489
 28  2.609 -0.004  2.622 -0.077  0.0489
 29  2.609 -0.004  2.622 -0.082  0.0488
 30  2.609 -0.004  2.623 -0.086  0.0488
 31  2.609 -0.004  2.623 -0.088  0.0488
 32  2.609 -0.004  2.622 -0.090  0.0489
 33  2.609 -0.004  2.622 -0.091  0.0489
 34  2.609 -0.004  2.622 -0.092  0.0489
 35  2.609 -0.004  2.621 -0.091  0.0489
 36  2.608 -0.004  2.620 -0.090  0.0489
 37  2.608 -0.004  2.619 -0.089  0.0489
 38  2.609 -0.004  2.620 -0.090  0.0489
 39  2.610 -0.004  2.620 -0.089  0.0490
 40  2.610 -0.004  2.620 -0.090  0.0490
 41  2.610 -0.004  2.619 -0.087  0.0490

 The average exit Mach number is:     2.6142
 xlenth,ylenth,chord=0.9999965730657,  2.6179871306358E-3,  0.9999965730657

Surface Mach Number, Isentropic Mach Number and CP; block =  2 and ncyc =    272
                  ****
                  ****
```

***** The output for block 2, similar to block 1, is deleted for brevity ****
****** until it prints average exit Mach number ****.

```
                  ****
                  ****
 The average exit Mach number is:     2.6142

    FOURIER COEFFICIENTS FOR CYCLE      1
     ZERO TH HARMONIC =      0.1195
      higher HARMONICS = 1,2,3,4
        0.5660     0.0546     0.5686     5.5091
        0.0456    -0.0651     0.0795   -54.9680
        0.0164     0.0189     0.0251    49.0880
       -0.0483     0.0186     0.0518   158.9463
```

FOURIER COEFFICIENTS FOR CYCLE 1
ZERO TH HARMONIC = 0.0492
higher HARMONICS = 1,2,3,4

0.0810	-0.0209	0.0837	-14.4356
0.0339	-0.0275	0.0436	-39.0198
0.0221	0.0130	0.0256	30.5599
-0.0105	0.0164	0.0195	122.6215

Unsteady Pressure Distribution, First Harmonic of dcp:
FOURIER COEFFICIENTS FOR CYCLE 1

i	x/c	Real	Imag	Mag	Phase
272					
21	0.0100	0.6344	0.4138	0.7575	33.1123
22	0.0300	0.7426	0.4515	0.8691	31.3033
23	0.0500	0.7450	0.4231	0.8568	29.5940
24	0.0700	0.7401	0.3919	0.8374	27.9024
25	0.0900	0.7357	0.3617	0.8198	26.1802
26	0.1100	0.7317	0.3318	0.8034	24.3909
27	0.1300	0.7277	0.3012	0.7876	22.4850
28	0.1500	0.7240	0.2697	0.7726	20.4305
29	0.1700	0.7206	0.2381	0.7589	18.2804
30	0.1900	0.7173	0.2068	0.7465	16.0805
31	0.2100	0.7140	0.1756	0.7353	13.8135
32	0.2300	0.7109	0.1438	0.7253	11.4370
33	0.2500	0.7080	0.1115	0.7167	8.9508
34	0.2700	0.7053	0.0790	0.7097	6.3923
35	0.2900	0.7028	0.0464	0.7043	3.7793
36	0.3100	0.7005	0.0137	0.7006	1.1203
37	0.3300	0.6981	-0.0188	0.6983	-1.5405
38	0.3500	0.6957	-0.0514	0.6976	-4.2294
39	0.3700	0.6945	-0.0862	0.6998	-7.0729
40	0.3900	0.6954	-0.1233	0.7063	-10.0516
41	0.4100	0.6974	-0.1585	0.7151	-12.8047
42	0.4300	0.6973	-0.1849	0.7214	-14.8554
43	0.4500	0.6873	-0.1955	0.7146	-15.8739
44	0.4700	0.6499	-0.1710	0.6720	-14.7453
45	0.4900	0.5814	-0.1128	0.5922	-10.9782
46	0.5100	0.4986	-0.0392	0.5002	-4.5001
47	0.5300	0.4181	0.0302	0.4192	4.1312
48	0.5500	0.3556	0.0789	0.3642	12.5060
49	0.5700	0.3178	0.1017	0.3337	17.7447
50	0.5900	0.3020	0.1001	0.3181	18.3426
51	0.6100	0.3125	0.0775	0.3219	13.9358
52	0.6300	0.3370	0.0437	0.3398	7.3956
53	0.6500	0.3716	0.0039	0.3716	0.6064
54	0.6700	0.4106	-0.0352	0.4122	-4.8935
55	0.6900	0.4469	-0.0677	0.4520	-8.6136
56	0.7100	0.4735	-0.0884	0.4817	-10.5726
57	0.7300	0.4847	-0.0926	0.4935	-10.8131
58	0.7500	0.4790	-0.0813	0.4859	-9.6324
59	0.7700	0.4606	-0.0583	0.4643	-7.2156
60	0.7900	0.4350	-0.0290	0.4359	-3.8084
61	0.8100	0.4095	0.0009	0.4095	0.1239
62	0.8300	0.3915	0.0252	0.3923	3.6879
63	0.8500	0.3855	0.0398	0.3875	5.8959
64	0.8700	0.3913	0.0430	0.3936	6.2779
65	0.8900	0.4091	0.0348	0.4106	4.8681
66	0.9100	0.4381	0.0164	0.4384	2.1468
67	0.9300	0.4753	-0.0088	0.4754	-1.0571

```
  68     0.9500     0.5214    -0.0388     0.5229    -4.2578
  69     0.9700     0.5679    -0.0735     0.5726    -7.3729
  70     0.9900     0.6494    -0.1113     0.6589    -9.7221
****
****
```

***** Output of surface Mach number, etc., for cycle 2, for ****
****blocks 1 and 2 are deleted for brevity****

```
****
****
     FOURIER COEFFICIENTS FOR CYCLE      2
     ZERO TH HARMONIC =      0.0037
      higher HARMONICS = 1,2,3,4
         0.6397     0.2134     0.6744    18.4493
         0.0005    -0.0011     0.0012   -65.3642
         0.0008    -0.0016     0.0018   -65.2791
         0.0004     0.0001     0.0004     9.7595
     FOURIER COEFFICIENTS FOR CYCLE      2
     ZERO TH HARMONIC =      0.0011
      higher HARMONICS = 1,2,3,4
         0.1000     0.0530     0.1132    27.8942
        -0.0008    -0.0009     0.0012  -132.6405
         0.0000    -0.0011     0.0011   -90.7289
         0.0001    -0.0001     0.0001   -68.0409
 Unsteady Pressure Distribution, First Harmonic of dcp:
     FOURIER COEFFICIENTS FOR CYCLE      2
   i       x/c        Real       Imag       Mag       Phase
 272
   21     0.0100     0.7215     0.4373     0.8437    31.2188
   22     0.0300     0.8147     0.4627     0.9370    29.5949
   23     0.0500     0.8135     0.4335     0.9218    28.0535
   24     0.0700     0.8082     0.4025     0.9029    26.4751
   25     0.0900     0.8041     0.3730     0.8864    24.8889
   26     0.1100     0.8000     0.3440     0.8709    23.2673
   27     0.1300     0.7960     0.3142     0.8558    21.5408
   28     0.1500     0.7923     0.2833     0.8415    19.6728
   29     0.1700     0.7888     0.2522     0.8282    17.7316
   30     0.1900     0.7853     0.2218     0.8160    15.7702
   31     0.2100     0.7817     0.1915     0.8048    13.7679
   32     0.2300     0.7781     0.1608     0.7945    11.6761
   33     0.2500     0.7747     0.1294     0.7854     9.4856
   34     0.2700     0.7713     0.0978     0.7775     7.2275
   35     0.2900     0.7680     0.0661     0.7708     4.9205
   36     0.3100     0.7648     0.0343     0.7655     2.5715
   37     0.3300     0.7613     0.0031     0.7613     0.2335
   38     0.3500     0.7575    -0.0282     0.7580    -2.1294
   39     0.3700     0.7545    -0.0620     0.7570    -4.6988
   40     0.3900     0.7535    -0.0993     0.7601    -7.5090
   41     0.4100     0.7544    -0.1347     0.7664   -10.1244
   42     0.4300     0.7549    -0.1591     0.7715   -11.9020
   43     0.4500     0.7462    -0.1638     0.7640   -12.3820
   44     0.4700     0.7093    -0.1223     0.7197    -9.7812
   45     0.4900     0.6383    -0.0360     0.6393    -3.2286
   46     0.5100     0.5506     0.0720     0.5553     7.4502
   47     0.5300     0.4635     0.1765     0.4959    20.8453
   48     0.5500     0.3945     0.2552     0.4698    32.8941
   49     0.5700     0.3528     0.3001     0.4632    40.3880
   50     0.5900     0.3334     0.3159     0.4593    43.4543
   51     0.6100     0.3483     0.3008     0.4602    40.8195
```

```
  52    0.6300    0.3774    0.2710    0.4646   35.6838
  53    0.6500    0.4193    0.2319    0.4791   28.9438
  54    0.6700    0.4674    0.1933    0.5058   22.4656
  55    0.6900    0.5125    0.1620    0.5375   17.5397
  56    0.7100    0.5477    0.1461    0.5668   14.9373
  57    0.7300    0.5658    0.1527    0.5861   15.0979
  58    0.7500    0.5646    0.1816    0.5930   17.8311
  59    0.7700    0.5482    0.2276    0.5935   22.5435
  60    0.7900    0.5231    0.2833    0.5949   28.4378
  61    0.8100    0.4980    0.3403    0.6032   34.3450
  62    0.8300    0.4819    0.3902    0.6201   38.9977
  63    0.8500    0.4793    0.4265    0.6415   41.6639
  64    0.8700    0.4905    0.4461    0.6630   42.2865
  65    0.8900    0.5142    0.4504    0.6835   41.2143
  66    0.9100    0.5517    0.4395    0.7054   38.5375
  67    0.9300    0.6005    0.4196    0.7326   34.9470
  68    0.9500    0.6604    0.3936    0.7688   30.7970
  69    0.9700    0.7209    0.3615    0.8065   26.6293
  70    0.9900    0.8276    0.3314    0.8915   21.8228
****
****
```

***** Output of surface Mach number, etc., for cycle 3, for ****
****blocks 1 and 2 are deleted for brevity****

```
****
****
    FOURIER COEFFICIENTS FOR CYCLE      3
     ZERO TH HARMONIC =      0.0036
      higher HARMONICS = 1,2,3,4
        0.6399     0.2135     0.6745    18.4532
        0.0005    -0.0010     0.0012   -62.4648
        0.0008    -0.0016     0.0018   -63.9458
        0.0004     0.0001     0.0005    15.6683
     FOURIER COEFFICIENTS FOR CYCLE      3
     ZERO TH HARMONIC =      0.0010
      higher HARMONICS = 1,2,3,4
        0.1001     0.0530     0.1133    27.9017
       -0.0008    -0.0008     0.0011  -133.8403
        0.0000    -0.0010     0.0010   -90.3718
        0.0001    -0.0001     0.0001   -62.4420
Unsteady Pressure Distribution, First Harmonic of dcp:
     FOURIER COEFFICIENTS FOR CYCLE      3
   i      x/c       Real      Imag       Mag       Phase
 272
  21    0.0100    0.7215    0.4373    0.8437   31.2188
  22    0.0300    0.8147    0.4627    0.9370   29.5949
  23    0.0500    0.8135    0.4335    0.9218   28.0535
  24    0.0700    0.8082    0.4025    0.9029   26.4751
  25    0.0900    0.8041    0.3730    0.8864   24.8889
  26    0.1100    0.8000    0.3440    0.8709   23.2673
  27    0.1300    0.7960    0.3142    0.8558   21.5408
  28    0.1500    0.7923    0.2833    0.8415   19.6728
  29    0.1700    0.7888    0.2522    0.8282   17.7316
  30    0.1900    0.7853    0.2218    0.8160   15.7702
  31    0.2100    0.7817    0.1915    0.8048   13.7680
  32    0.2300    0.7781    0.1608    0.7945   11.6762
  33    0.2500    0.7747    0.1294    0.7854    9.4856
  34    0.2700    0.7713    0.0978    0.7775    7.2275
  35    0.2900    0.7680    0.0661    0.7708    4.9205
```

36	0.3100	0.7648	0.0343	0.7655	2.5715
37	0.3300	0.7613	0.0031	0.7613	0.2335
38	0.3500	0.7575	-0.0282	0.7580	-2.1292
39	0.3700	0.7545	-0.0620	0.7570	-4.6984
40	0.3900	0.7535	-0.0993	0.7601	-7.5084
41	0.4100	0.7545	-0.1347	0.7664	-10.1220
42	0.4300	0.7549	-0.1591	0.7715	-11.9018
43	0.4500	0.7462	-0.1638	0.7640	-12.3809
44	0.4700	0.7093	-0.1222	0.7198	-9.7789
45	0.4900	0.6384	-0.0360	0.6394	-3.2257
46	0.5100	0.5506	0.0720	0.5553	7.4530
47	0.5300	0.4635	0.1765	0.4960	20.8479
48	0.5500	0.3946	0.2552	0.4699	32.8966
49	0.5700	0.3528	0.3002	0.4632	40.3931
50	0.5900	0.3334	0.3159	0.4593	43.4536
51	0.6100	0.3482	0.3009	0.4602	40.8275
52	0.6300	0.3773	0.2711	0.4646	35.6916
53	0.6500	0.4192	0.2319	0.4790	28.9505
54	0.6700	0.4673	0.1932	0.5057	22.4675
55	0.6900	0.5124	0.1620	0.5373	17.5418
56	0.7100	0.5476	0.1461	0.5667	14.9349
57	0.7300	0.5657	0.1526	0.5859	15.0925
58	0.7500	0.5645	0.1814	0.5929	17.8199
59	0.7700	0.5481	0.2274	0.5934	22.5305
60	0.7900	0.5231	0.2831	0.5948	28.4246
61	0.8100	0.4981	0.3402	0.6032	34.3320
62	0.8300	0.4821	0.3901	0.6202	38.9810
63	0.8500	0.4796	0.4265	0.6418	41.6432
64	0.8700	0.4910	0.4462	0.6635	42.2643
65	0.8900	0.5149	0.4505	0.6842	41.1806
66	0.9100	0.5527	0.4399	0.7064	38.5198
67	0.9300	0.6015	0.4203	0.7338	34.9466
68	0.9500	0.6614	0.3946	0.7702	30.8184
69	0.9700	0.7219	0.3626	0.8079	26.6698
70	0.9900	0.8284	0.3328	0.8927	21.8865

```
  block  1 of row  1 written on unit  9 ncyc =    816
  block  2 of row  1 written on unit  9 ncyc =    816

Job Accounting - Summary Report
===============================
Operating System                : sn1030 lercymp 8.0.2.3 8.0.14 CRAY Y-MP
User CPU Time                   :          307.4754 Seconds
System CPU Time                 :           83.0533 Seconds
Maximum memory used             :            3.2344 MWords
```

Additional Output of Interest:

OUT.HIST1: A file containing the time history of force coefficients versus time of the center blade. It has five columns which are time step number, time, lift, moment and drag coefficients.

7.2 Unsteady Aerodynamics and Structural Response of a Supersonic Compressor Stage with Two blades in each row, Time Domain Analysis

In this example, two blade rows (NROW=2) are considered. Each row has two blades, i.e. NBS=2 for both the rows. The airfoils in the blade rows are double circular arc airfoils (IAFOIL=2) with 1% thickness to chord ratio. The axial gap between the blade rows (ROWSEP) is 20% of the chord length. The gap to chord ratio (SBYC) is 0.5 and stagger angle (STAG) is zero for both the blade rows. The front row is designated as rotor and moves with a velocity of Mach 0.1 in the negative Y-direction, Fig. 1b (VR=-0.1 in the input for this blade row). The flow enters the front blade row parallel to X-axis i.e. at zero angle of attack (ALPHA=0.0). The Mach number at the inlet (FSMACH) is 1.5. The aft row is stationary (VR=0.0) and is designated as stator. The pitching axis is located at about 30% of chord from the leading edge (X0 = 0.3, Y0=0.0).

The structural properties used are as follows: The mass ratio (XMU) is 456, the radius of gyration (XRA) is 0.588, natural frequencies in bending and torsion in cycles per second respectively are 0.567 and 1.0 (GAS=0.567 and GHS=1.0), with no structural damping (ZHS, ZAS = 0.0). The offset (XA) between elastic axis and center of gravity is zero. The elastic axis is assumed to be same as the pitching axis i.e. X0 = 0.3, Y0=0.0.

The grid is generated within the code (IGB=-2) for the double circular arc airfoil geometry (IAFOIL=2). The thickness of the airfoil (1%) is given in the subroutine GRIDGEN. A 41x41 (streamwise by pitchwise) grid for each block in each row is used in the solution i.e. ni=41, nj=41. There are 30 points on each airfoil, 10 points in the interface region, five points each in upstream of the boundary and downstream of the boundary. The inlet boundary is located 0.1667 chords upstream of the front row (XLEFT=0.1667). The exit boundary is located at 2.3667 chords downstream from the leading edge of the front row airfoil (XRIGHT=2.3667). The blade rows are separated by 0.2 chord lengths (ROWSEP=0.2). Therefore, the exit boundary is located at 0.1667 chord lengths from the trailing edge of the second blade row (stator) airfoil (for unit chord lengths of airfoils in each row).

The aeroelastic equations are integrated in time (MOTION=-1). The input values for PHASE, REDFRE, H0/C and ALFA0D are not used in the computation. A CFL number of 5.0 is used giving a time step (dtmin) of 0.02336. Calculations are performed for NTTOT =1050 time steps. The calculations start running the code in steady mode for NTSS =88 steps. A reduced velocity parameter (VSTAR) of 1.2 is used. Two blocks are used for computation. Non-zero initial conditions are selected for the stator blade row (ALFAD0 = 0.01 for both blade 1 and blade 2). The source code is compiled with the following parameter statements.

```
parameter(nrmx=2, nbsx=2)
parameter(ni=41, nj=41)
```

Input file (msap2d.in)

```
    INDBC    MIRROR
        0         0
    IORIG     ISYST
        0         0
   MOTION      INEW
       -1         0
   FSMACH     PHASE   REDFREQ     ALPHA
     1.50     0.000    1.0000      0.00
     H0/C    ALFA0D
   0.0000    0.0000
.........*.........*.........*.........*.........*
      CFL      PRAT       PSI     ORDER     LIMIT
      5.0    0.7320    0.3333       3.0       1.0
       X0        Y0
   0.3000       0.0
.........*.........*.........*.........*
     NCYC      NTSS     NTTOT    NTPRNT
        1        88      1050       100
      IGB
       -2
.........*.........*
    XLEFT    XRIGHT
  -0.1667    2.3667
.........*.........*.........*.........*.........*
     NROW    NRFLBC    ROWSEP
        2         0    0.2000
.........*.........*.........*
      KIN      KOUT    MOOVEE
        0         9         0
    IMODE    IFLTR     IFREE
        1        -1         0
.........*
    VSTAR
     1.20
.........*.........*.........*.........*
     SBYC      STAG    IAFOIL       NBS
    0.500     00.00         2         2
      ILE       ITE     PERCJ        VR     CHORD
        6        36     100.0     -0.10       1.0
      GHS       GAS       ZHS       ZAS       XMU       XRA        XA
    0.567       1.0     0.000     0.000     456.2     0.588     0.000
      HD0    ALFAD0        H0    ALFA0
    0.000     0.000       0.0       0.0
  SMOTION
    0.000
      GHS       GAS       ZHS       ZAS       XMU       XRA        XA
    0.567       1.0     0.000     0.000     456.2     0.588     0.000
      HD0    ALFAD0        H0    ALFA0
    0.000 -0.000000       0.0       0.0
  SMOTION
    0.000
.........*.........*.........*.........*
```

```
     SBYC       STAG     IAFOIL        NBS
    0.500      00.00          2          2
      ILE        ITE      PERCJ         VR      CHORD
        6         36      100.0       0.00        1.0
      GHS        GAS        ZHS        ZAS        XMU        XRA         XA
    0.567        1.0      0.000      0.000      456.2      0.588      0.000
      HD0     ALFAD0         H0     ALFA0
    0.000      0.010        0.0        0.0
  SMOTION
    0.000
      GHS        GAS        ZHS        ZAS        XMU        XRA         XA
    0.567        1.0      0.000      0.000      456.2      0.588      0.000
      HD0     ALFAD0         H0     ALFA0
    0.000   0.010000        0.0        0.0
  SMOTION
    0.000
---IGSTOP: stop after grid set up(=0 no stop)----
0
   GUSTUA      PHASE
     0.00      0.000
   GUSTVA      PHASE
     0.00      0.000
---NTINT: number of steps for debugging----
0
--DTGIV: user input time step--
0.0
```

Unit 6 output file (msap2d.out)

```
  indbc = 0mirror = 0
  iorig = 0isyst = 0
  motion = -1inew= 0

 ****************************************************
                       TIME DOMAIN SOLUTION
 ****************************************************

    factors for vibration =       0.0000      0.0000
   FSMACH      PHASE    REDFREQ      ALPHA
   1.5000     0.0000     1.0000     0.0000
     H0/C     ALFA0D
   0.0000     0.0000
      CFL       PRAT        PSI      ORDER      LIMIT
   5.0000     0.7320     0.3333     3.0000     1.0000
       X0         Y0
   0.3000     0.0000
     NCYC       NTSS      NTTOT     NTPRNT
        1         88       1050         50
      IGB
       -2
    XLEFT     XRIGHT
  -0.1667     2.3667
     NROW     NRFLBC     ROWSEP
        2          0      0.200
    KMODE       KFFT      LIMIT
        1          1          1
```

```
     KIN        KOUT     MOOVEE
       0           9          0

 ****** Oscillating Cascade Analysis ******
 input run stream:

 number of blocks =     3 where each block has dimensions of:
               ni =    41
               nj =    41
               nk =     2

 freestream mach number   =  1.5000
 inlet incidence angle    =  0.0000 (degrees)
 exit pressure ratio      =  0.7320 (p/ptot)
 inter-blade phase angle  =  0.0000 (degrees)
 reduced frequency        =  1.0000 (based on semichord)
 reduced frequency        =  3.0000 (in terms of omega)
 amplitude of plunge      =  0.0000 (percent chord)
 amplitude of pitch       =  0.0000 (degrees)
 airfoil moment center    =  0.3000 (x0, percent chord)
 airfoil moment center    =  0.0000 (y0, % chord )

 nb       =     1 (total number of cycles)
 kin      =     0 (restart input number -if 0 not used)
 kout     =     9 (restart output number -if 0 not used)
 kfft     =     1 (no fft analysis if kfft=0)
 moovee   =     0 (save certain steps for animation)
 kmode    =     1 (stationary or oscillating cascade)

a fft analysis will be done at the end of each cycle

      flux limiter input information:

            limit =    1
            psi   = 0.333
            order =   3.0

note with limit=1, MINMOD limiter has been invoked

    IMODE      IFLTR      IFREE
        1         -1          0
    PITCHING MOTION
    **** PRINT INTERVAL, NTPRNT **** =   100

  number of rows =2
  for row =1
     SBYC        STAG     IAFOIL        NBS
   0.5000    0.0000          2          2
      ILE         ITE      PERCJ         VR      CHORD
        6          36   100.000     -0.100      1.000
    motion indicator for blade    1:   0.0000
    GAMA H =       0.56700     GAMA ALPHA =     1.00000
    ZETA H =       0.00000     ZETA ALPHA =     0.00000
    MASS RATIO(XMU)                      =   456.20000
    RADIUS OF GYRATION(XRA)              =     0.58800
    DT. BETWEEN E.A. AND C.G.(XALFA)     =     0.00000
    initial plunging velocity            =     0.00000
    initial pitching velocity            =     0.00000
```

```
   initial plunging displacement      =      0.00000
   initial pitching displacemnet      =      0.00000
   SELF VIBRATION INDICATOR           =      0.00000

   motion indicator for blade     2:   0.0000
   GAMA H =       0.56700      GAMA ALPHA =      1.00000
   ZETA H =       0.00000      ZETA ALPHA =      0.00000
   MASS RATIO(XMU)                    =    456.20000
   RADIUS OF GYRATION(XRA)            =      0.58800
   DT. BETWEEN E.A. AND C.G.(XALFA)   =      0.00000
   initial plunging velocity          =      0.00000
   initial pitching velocity          =      0.00000
   initial plunging displacement      =      0.00000
   initial pitching displacemnet      =      0.00000
   SELF VIBRATION INDICATOR           =      0.00000

for row =2
    SBYC       STAG     IAFOIL       NBS
  0.5000     0.0000          2         2
     ILE        ITE      PERCJ        VR      CHORD
       6         36    100.000     0.000      1.000
   motion indicator for blade     1:   0.0000
   GAMA H =       0.56700      GAMA ALPHA =      1.00000
   ZETA H =       0.00000      ZETA ALPHA =      0.00000
   MASS RATIO(XMU)                    =    456.20000
   RADIUS OF GYRATION(XRA)            =      0.58800
   DT. BETWEEN E.A. AND C.G.(XALFA)   =      0.00000
   initial plunging velocity          =      0.00000
   initial pitching velocity          =      0.01000
   initial plunging displacement      =      0.00000
   initial pitching displacemnet      =      0.00000
   SELF VIBRATION INDICATOR           =      0.00000

   motion indicator for blade     2:   0.0000
   GAMA H =       0.56700      GAMA ALPHA =      1.00000
   ZETA H =       0.00000      ZETA ALPHA =      0.00000
   MASS RATIO(XMU)                    =    456.20000
   RADIUS OF GYRATION(XRA)            =      0.58800
   DT. BETWEEN E.A. AND C.G.(XALFA)   =      0.00000
   initial plunging velocity          =      0.00000
   initial pitching velocity          =      0.01000
   initial plunging displacement      =      0.00000
   initial pitching displacemnet      =      0.00000
   SELF VIBRATION INDICATOR           =      0.00000

   VELOCITY PARAMETER FOR TIME DOMAIN ANALYSIS      1.20000

    TIME DOMAIN: pitching motion only

   no. of time steps for steady solution, ntss  =   88
   no. of total time steps,               nttot = 1050
 NI IS LESS THAN THE REQUIRED
NDIMI, NI = 43,  41
xminb=-0.1667xmaxb=2.3667rowsep=0.2
GRID FOR ROW =1
nr =1 ile =6 ite =36chord=1.
 xleft=-0.1667 xright=1.1
 igb = -2
```

```
 calling grdunf
 entered grdunf
grid for DCA a.f. of t/c  1.E-2
  IN ROUTINE GRDUNF:STAG,SC,CHORD,X1,X4,NIF,NIB,IRUN
    0.00000      0.50000      1.00000     -0.16670     1.10000     6   36    2
 finished setting the front part
 dx at the bottom line3.3333333333333E-2
x(nif,1,1)= -8.8817841970013E-16
 finished defining bottom line
 finished defining top line
 finished defining in between
 finished the end part
 stagger angle (deg.) from input file =
                              0.0000000000
 stagger angle (deg.) from grid file =
                              0.0000000000
 stagger angle (deg.) used in the cal. =
                              0.0000000000
 gap-to-chord ratio from input file =
                              0.5000000000
 gap-to-chord ratio from grid file =
                              0.5000000000
 gap-to-chord ratio used in the calculation =
                              0.5000000000
    finished reading grid coordinates in routine RDGRID
    *** x coordinates at 0,ile,ite,last
        -0.16670     0.00000     1.00000     1.10000
         0.00000     0.00000     0.00000     0.00000
        -0.16670     0.00000     1.00000     1.10000
         0.50000     0.50000     0.50000     0.50000
 chord along the x-axis
nr, xadd(nr)= 1,  0.
nr, yadd(nr)= 1,  0.
xminb=-0.1667xmaxb=2.3667rowsep=0.2
 before calling STRTRS
    *** x coordinates at 0,ile,ite,last
        -0.16670     0.00000     1.00000     1.10000
         0.00000     0.00000     0.00000     0.00000
        -0.16670     0.00000     1.00000     1.10000
         0.50000     0.50000     0.50000     0.50000
xlenth,ylenth,chord= 1.,  0.,  1.
nr, angdeg in main  = 1,  0.
 in routine STRTRS***
 height and xshift for row= 0.5,  0.,  1

Starting the initial grid calculation in STRTRS
nr, angdeg in gridp= 1,  0.
nr, coss,sins = 1,  1.,  0.
KMODE in STRTRS= 0
KMODE IN ICRS 0
 For block  1:
    dtmin (as computed in eigenv) at cfl =  5.0 is      0.02336
dtmin1=2.3364485981303E-2dtmin = 2.3364485981303E-2nr=1
nssd=11 y1=0. nr=1 n=1 at grid generation
    corresponding to alfa=    0.0000 degrees
KMODE in STRTRS= 0
KMODE IN ICRS 0
 For block  2:
```

```
    dtmin (as computed in eigenv) at cfl =  5.0 is      0.02336
 dtmin1=2.3364485981298E-2dtmin = 2.3364485981298E-2nr=1
 nssd=12 y1=0.5 nr=1 n=2 at grid generation
    corresponding to alfa=     0.0000 degrees
Successful completion of grid generation in STRTRS

 The flow solution will use dtmin= 0.02380 and nperiod=    88
 to give a maximum cfl close to   5.000

    Newmark constants for dt =       0.02380
   0.70617E+04    0.84034E+02    0.16807E+03    0.10000E+01    0.10000E+01
0.00000E+00   0.11900E-01   0.11900E-01
   0.10000E+01 0.00000E+00 0.00000E+00 0.34574E+00
   0.10000E+01 0.00000E+00 0.00000E+00 0.28923E+01
   0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00
   0.20093E+01 0.00000E+00 0.00000E+00 0.21609E+01
   0.70637E+04 0.00000E+00 0.00000E+00 0.24437E+04
   0.14157E-03 0.00000E+00 0.00000E+00 0.40922E-03
   0.10000E+01 0.00000E+00 0.00000E+00 0.34574E+00
   0.10000E+01 0.00000E+00 0.00000E+00 0.28923E+01
   0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00
   0.20093E+01 0.00000E+00 0.00000E+00 0.21609E+01
   0.70637E+04 0.00000E+00 0.00000E+00 0.24437E+04
   0.14157E-03 0.00000E+00 0.00000E+00 0.40922E-03
      finished job in routine strdat
 xminb=-0.1667xmaxb=2.3667rowsep=0.2
 GRID FOR ROW =2
 nr =2 ile =6 ite =36chord=1.
  xleft=-0.1 xright=1.1667
  igb = -2
  calling grdunf
  entered grdunf
 grid for DCA a.f. of t/c  1.E-2
    IN ROUTINE GRDUNF:STAG,SC,CHORD,X1,X4,NIF,NIB,IRUN
    0.00000      0.50000      1.00000     -0.10000      1.16670     6   36    2
  finished setting the front part
  dx at the bottom line3.3333333333333E-2
 x(nif,1,1)= -4.4408920985006E-16
  finished defining bottom line
  finished defining top line
  finished defining in between
  finished the end part
  stagger angle (deg.) from input file =
                               0.0000000000
  stagger angle (deg.) from grid file =
                               0.0000000000
  stagger angle (deg.) used in the cal. =
                               0.0000000000
  gap-to-chord ratio from input file =
                               0.5000000000
  gap-to-chord ratio from grid file =
                               0.5000000000
  gap-to-chord ratio used in the calculation =
                               0.5000000000
    finished reading grid coordinates in routine RDGRID
    *** x coordinates at 0,ile,ite,last
        -0.10000      0.00000      1.00000      1.16670
         0.00000      0.00000      0.00000      0.00000
```

```
        -0.10000     0.00000     1.00000     1.16670
         0.50000     0.50000     0.50000     0.50000
  chord along the x-axis
 nr, xadd(nr)= 2,  1.2
 nr, yadd(nr)= 2,  0.
 xminb=-0.1667xmaxb=2.3667rowsep=0.2
  before calling STRTRS
     *** x coordinates at 0,ile,ite,last
         1.10000     1.20000     2.20000     2.36670
         0.00000     0.00000     0.00000     0.00000
         1.10000     1.20000     2.20000     2.36670
         0.50000     0.50000     0.50000     0.50000
 xlenth,ylenth,chord= 1.,  0.,  1.
 nr, angdeg in main  = 2,  0.
  in routine STRTRS***
  height and xshift for row= 0.5,  0.,  2

Starting the initial grid calculation in STRTRS
 KMODE in STRTRS= 0
 KMODE IN ICRS 0
  For block  1:
     dtmin (as computed in eigenv) at cfl =  5.0 is      0.02427
 dtmin1=2.3364485981298E-2dtmin = 2.3364485981298E-2nr=2
 nssd=13 y1=0.5 nr=2 n=1 at grid generation
     corresponding to alfa=     0.0000 degrees
 KMODE in STRTRS= 0
 KMODE IN ICRS 0
  For block  2:
     dtmin (as computed in eigenv) at cfl =  5.0 is      0.02336
 dtmin1=2.3364485981298E-2dtmin = 2.3364485981298E-2nr=2
 nssd=14 y1=0. nr=2 n=2 at grid generation
     corresponding to alfa=     0.0000 degrees
Successful completion of grid generation in STRTRS

 The flow solution will use dtmin= 0.02380 and nperiod=    88
 to give a maximum cfl close to   5.000

     Newmark constants for dt =       0.02380
    0.70617E+04    0.84034E+02    0.16807E+03    0.10000E+01    0.10000E+01
0.00000E+00    0.11900E-01    0.11900E-01
   0.10000E+01 0.00000E+00 0.00000E+00 0.34574E+00
   0.10000E+01 0.00000E+00 0.00000E+00 0.28923E+01
   0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00
   0.20093E+01 0.00000E+00 0.00000E+00 0.21609E+01
   0.70637E+04 0.00000E+00 0.00000E+00 0.24437E+04
   0.14157E-03 0.00000E+00 0.00000E+00 0.40922E-03
   0.10000E+01 0.00000E+00 0.00000E+00 0.34574E+00
   0.10000E+01 0.00000E+00 0.00000E+00 0.28923E+01
   0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00
   0.20093E+01 0.00000E+00 0.00000E+00 0.21609E+01
   0.70637E+04 0.00000E+00 0.00000E+00 0.24437E+04
   0.14157E-03 0.00000E+00 0.00000E+00 0.40922E-03
      finished job in routine strdat
 *** distance between t.e. to l.e. ***0.2
   axial chord      actual chord      setting angle
 1.,  1.,  0.
 2*1.,  0.
                        residual information
```

```
gust parameters
 U velocity and Phase(radians)
2*0.
 V velocity and Phase(radians)
2*0.
reading input nt
ntinpt,nt,nperiod= 0,  1050,  88
 vr1, vr2, nperd2 = -0.1,  0.,  176
 height=0.5 ymin=-0.25 ymax=1.25
KMODE= 0KFFT= 0
 ile=6 ite=36 height=0.5
vr = 0.
   1    1  5.47399E-01  2.25000E+00 -1.32408E+01 -3.31334E-14 -1.26762E+01
   2    1  5.47399E-01  2.25000E+00 -1.37312E+01  7.68444E-15 -1.30028E+01
stag in perf = 0.
x0, y0 in perf = 0.3,  0.
nr, angdeg in perf = 1,  0.
nr, coss,sins = 1,  1.,  0.
 ile=6 ite=36 height=0.5
vr = 0.
   1    1  5.47399E-01  2.25000E+00 -1.37325E+01  7.68444E-15 -1.30051E+01
   2    1  5.47399E-01  2.25000E+00 -1.32579E+01 -3.31334E-14 -1.26914E+01
stag in perf = 0.
x0, y0 in perf = 0.3,  0.
nr, angdeg in perf = 2,  0.
nr, coss,sins = 2,  1.,  0.
 ile=6 ite=36 height=0.5
vr = 0.
   1    2  5.71199E-01  2.25025E+00 -2.71640E+00 -5.72336E-04 -2.21075E+00
   2    2  5.71199E-01  2.25025E+00 -2.71678E+00 -5.72336E-04 -2.21098E+00
 ile=6 ite=36 height=0.5
vr = 0.
   1    2  5.71199E-01  2.25025E+00 -2.71949E+00 -5.72336E-04 -2.21494E+00
   2    2  5.71199E-01  2.25025E+00 -2.71948E+00 -5.72336E-04 -2.21493E+00
 ile=6 ite=36 height=0.5
vr = 0.
   1    3  5.94999E-01  2.25085E+00 -2.33727E+00 -1.46455E-03 -1.83010E+00
   2    3  5.94999E-01  2.25085E+00 -2.33723E+00 -1.46458E-03 -1.83007E+00
 ile=6 ite=36 height=0.5
vr = 0.
   1    3  5.94999E-01  2.25085E+00 -2.34135E+00 -1.46451E-03 -1.83600E+00
   2    3  5.94999E-01  2.25085E+00 -2.34136E+00 -1.46437E-03 -1.83600E+00
 ile=6 ite=36 height=0.5
vr = 0.
   1    4  6.18799E-01  2.25185E+00 -2.10643E+00 -2.56224E-03 -1.59635E+00
   2    4  6.18799E-01  2.25185E+00 -2.10641E+00 -2.56225E-03 -1.59633E+00
 ile=6 ite=36 height=0.5
vr = 0.
   1    4  6.18799E-01  2.25185E+00 -2.11152E+00 -2.56228E-03 -1.60383E+00
   2    4  6.18799E-01  2.25185E+00 -2.11152E+00 -2.56232E-03 -1.60383E+00
 ile=6 ite=36 height=0.5
vr = 0.
   1    5  6.42598E-01  2.25330E+00 -1.94285E+00 -3.86730E-03 -1.42873E+00
   2    5  6.42598E-01  2.25330E+00 -1.94285E+00 -3.86729E-03 -1.42873E+00
 ile=6 ite=36 height=0.5
vr = 0.
   1    5  6.42598E-01  2.25330E+00 -1.94903E+00 -3.86742E-03 -1.43753E+00
   2    5  6.42598E-01  2.25330E+00 -1.94903E+00 -3.86747E-03 -1.43753E+00
```

```
 ile=6 ite=36 height=0.5
vr = 0.
   1    6  6.66398E-01  2.25519E+00 -1.81865E+00 -5.19185E-03 -1.30118E+00
   2    6  6.66398E-01  2.25519E+00 -1.81865E+00 -5.19182E-03 -1.30118E+00
 ile=6 ite=36 height=0.5
vr = 0.
   1   85  2.54659E+00  2.41806E+00 -1.86473E+00  2.97520E-03 -1.51902E+00
   2   85  2.54659E+00  2.41806E+00 -1.86473E+00  2.97520E-03 -1.51902E+00
vr = 0.
   1   85  2.54659E+00  2.39417E+00 -1.54248E+00  5.24065E-03 -1.13215E+00
   2   85  2.54659E+00  2.39417E+00 -1.54248E+00  5.24067E-03 -1.13215E+00
vr = 0.
   1   86  2.57039E+00  2.41584E+00 -1.87151E+00  2.96612E-03 -1.52673E+00
   2   86  2.57039E+00  2.41584E+00 -1.87151E+00  2.96612E-03 -1.52673E+00
vr = 0.
   1   86  2.57039E+00  2.39894E+00 -1.55436E+00  4.68276E-03 -1.15090E+00
   2   86  2.57039E+00  2.39894E+00 -1.55436E+00  4.68278E-03 -1.15090E+00
vr = 0.
   1   87  2.59419E+00  2.41351E+00 -1.87867E+00  2.94418E-03 -1.53494E+00
   2   87  2.59419E+00  2.41351E+00 -1.87867E+00  2.94418E-03 -1.53494E+00
vr = 0.
   1   87  2.59419E+00  2.40354E+00 -1.56368E+00 -4.92801E-03 -1.16602E+00
   2   87  2.59419E+00  2.40354E+00 -1.56368E+00 -4.92801E-03 -1.16602E+00
vr = 0.
     INITIAL CONDITIONS ON BLADE      1 ROW      1
   0.00000E+00    0.00000E+00    0.00000E+00    0.00000E+00   -0.33520E-04
0.19218E-03
  -0.33520E-04   0.66445E-04
     INITIAL CONDITIONS ON BLADE      2 ROW      1
   0.00000E+00    0.00000E+00    0.00000E+00    0.00000E+00   -0.33520E-04
0.18248E-04
  -0.33520E-04   0.63093E-05
     done in routine struct
   1   88  2.61799E+00  2.41108E+00 -1.88641E+00  2.90664E-03 -1.54379E+00
   2   88  2.61799E+00  2.41108E+00 -1.88641E+00  2.90664E-03 -1.54379E+00
vr = 0.
     INITIAL CONDITIONS ON BLADE      1 ROW      2
   0.00000E+00    0.00000E+00    0.00000E+00    0.43633E-03    0.13348E-03
0.20764E-03
   0.13348E-03   0.71790E-04
     INITIAL CONDITIONS ON BLADE      2 ROW      2
   0.00000E+00    0.00000E+00    0.00000E+00    0.43633E-03    0.13348E-03
0.20765E-03
   0.13348E-03   0.71793E-04
     done in routine struct
   1   88  2.61799E+00  2.40796E+00 -1.57067E+00 -5.23656E-03 -1.17731E+00
   2   88  2.61799E+00  2.40796E+00 -1.57067E+00 -5.23657E-03 -1.17731E+00
vr = -0.1
     done in routine struct
   1   89  2.64179E+00  2.41456E+00 -2.12430E-01 -1.00567E-01  2.81083E-01
   2   89  2.64179E+00  2.41456E+00 -2.12430E-01 -1.00567E-01  2.81083E-01
vr = 0.
     done in routine struct
   1   89  2.64179E+00  2.41219E+00 -1.57494E+00 -5.37419E-03 -1.18443E+00
   2   89  2.64179E+00  2.41219E+00 -1.57494E+00 -5.37418E-03 -1.18443E+00
vr = -0.1
     done in routine struct
   1   90  2.66559E+00  2.45953E+00 -1.89764E-01  1.37941E-01  3.07044E-01
```

```
  2   90  2.66559E+00  2.45953E+00 -1.89764E-01  1.37941E-01  3.07044E-01
vr = 0.
   done in routine struct
  1   90  2.66559E+00  2.41622E+00 -1.57165E+00  1.07183E-02 -1.17549E+00
  2   90  2.66559E+00  2.41622E+00 -1.57165E+00  1.07183E-02 -1.17549E+00
vr = -0.1
   done in routine struct
  1   91  2.68939E+00  2.52276E+00 -2.50597E-01  1.54490E-01  2.69124E-01
  2   91  2.68939E+00  2.52276E+00 -2.50597E-01  1.54490E-01  2.69124E-01
vr = 0.
   done in routine struct
  1   91  2.68939E+00  2.42006E+00 -1.52535E+00  2.38086E-02 -1.06029E+00
  2   91  2.68939E+00  2.42006E+00 -1.52535E+00  2.38086E-02 -1.06029E+00
vr = -0.1
   done in routine struct
  1   92  2.71319E+00  2.55157E+00 -2.61710E-01  1.35793E-01  2.66593E-01
  2   92  2.71319E+00  2.55157E+00 -2.61710E-01  1.35793E-01  2.66593E-01
vr = 0.
   done in routine struct
  1   92  2.71319E+00  2.42372E+00 -1.40022E+00  3.58534E-02 -8.28929E-01
  2   92  2.71319E+00  2.42372E+00 -1.40022E+00  3.58534E-02 -8.28929E-01
vr = -0.1
   done in routine struct
  1   93  2.73699E+00  2.55978E+00 -3.00811E-01  1.16881E-01  2.39544E-01
  2   93  2.73699E+00  2.55978E+00 -3.00811E-01  1.16881E-01  2.39544E-01
vr = 0.
   done in routine struct
  1   93  2.73699E+00  2.42725E+00 -1.24186E+00  4.99547E-02 -6.12387E-01
  2   93  2.73699E+00  2.42725E+00 -1.24186E+00  4.99547E-02 -6.12387E-01
vr = -0.1
   done in routine struct
  1   94  2.76079E+00  2.57941E+00 -3.21219E-01  1.04026E-01  2.20665E-01
  2   94  2.76079E+00  2.57941E+00 -3.21219E-01  1.04026E-01  2.20665E-01
vr = 0.
   done in routine struct
  1   94  2.76079E+00  2.43076E+00 -1.10161E+00  6.52241E-02 -4.52168E-01
  2   94  2.76079E+00  2.43076E+00 -1.10161E+00  6.52241E-02 -4.52168E-01
vr = -0.1
   done in routine struct
  1   95  2.78459E+00  2.58660E+00 -3.41577E-01  9.76224E-02  2.00283E-01
  2   95  2.78459E+00  2.58660E+00 -3.41577E-01  9.76224E-02  2.00283E-01
vr = 0.
   done in routine struct
  1   95  2.78459E+00  2.43438E+00 -9.90235E-01  7.70125E-02 -3.40896E-01
  2   95  2.78459E+00  2.43438E+00 -9.90235E-01  7.70125E-02 -3.40896E-01
vr = -0.1
   done in routine struct
  1   96  2.80839E+00  2.58719E+00 -3.64059E-01  9.57222E-02  1.76756E-01
  2   96  2.80839E+00  2.58719E+00 -3.64059E-01  9.57222E-02  1.76756E-01
vr = 0.
   done in routine struct
  1   96  2.80839E+00  2.43832E+00 -9.10465E-01  8.33872E-02 -2.69120E-01
  2   96  2.80839E+00  2.43832E+00 -9.10465E-01  8.33872E-02 -2.69120E-01
vr = -0.1
   done in routine struct
  1   97  2.83219E+00  2.58449E+00 -3.98675E-01  9.11682E-02  1.40369E-01
  2   97  2.83219E+00  2.58449E+00 -3.98675E-01  9.11682E-02  1.40369E-01
vr = 0.
```

```
    done in routine struct
  1   97  2.83219E+00  2.44280E+00 -8.59496E-01  8.18995E-02 -2.28231E-01
  2   97  2.83219E+00  2.44280E+00 -8.59496E-01  8.18995E-02 -2.28231E-01
vr = -0.1
    done in routine struct
  1   98  2.85599E+00  2.58194E+00 -4.54576E-01  8.28057E-02  8.25705E-02
  2   98  2.85599E+00  2.58194E+00 -4.54576E-01  8.28057E-02  8.25705E-02
vr = 0.
    done in routine struct
  1   98  2.85599E+00  2.44800E+00 -8.31668E-01  7.54289E-02 -2.13735E-01
  2   98  2.85599E+00  2.44800E+00 -8.31668E-01  7.54289E-02 -2.13735E-01
vr = -0.1
    done in routine struct
  1   99  2.87979E+00  2.57746E+00 -5.37727E-01  6.98502E-02 -1.62765E-03
  2   99  2.87979E+00  2.57746E+00 -5.37727E-01  6.98502E-02 -1.62765E-03
vr = 0.
    done in routine struct
  1   99  2.87979E+00  2.45398E+00 -8.33228E-01  7.14466E-02 -2.27893E-01
  2   99  2.87979E+00  2.45398E+00 -8.33228E-01  7.14466E-02 -2.27893E-01
vr = -0.1
    DONE IN ROUTINE CPINT
    DONE IN ROUTINE CPINT
    DONE IN ROUTINE FORCE
    done in routine struct
  1  100  2.90359E+00  2.57315E+00 -6.27422E-01 -6.12596E-02 -8.71772E-02
  2  100  2.90359E+00  2.57315E+00 -6.27422E-01 -6.12596E-02 -8.71772E-02
vr = 0.
    DONE IN ROUTINE CPINT
    DONE IN ROUTINE CPINT
    DONE IN ROUTINE FORCE
    done in routine struct
  1  100  2.90359E+00  2.46054E+00 -8.69303E-01  6.12245E-02 -2.75045E-01
  2  100  2.90359E+00  2.46054E+00 -8.69303E-01  6.12245E-02 -2.75045E-01
vr = -0.1
    DONE IN ROUTINE CPINT
    DONE IN ROUTINE CPINT
    DONE IN ROUTINE FORCE
    done in routine struct
  1 1000  2.43235E+01  2.70437E+00 -5.98427E+00 -3.44220E-06 -5.32887E+00
  2 1000  2.43235E+01  2.70437E+00 -5.98247E+00 -3.44220E-06 -5.32876E+00
vr = 0.
    DONE IN ROUTINE CPINT
    DONE IN ROUTINE CPINT
    DONE IN ROUTINE FORCE
    done in routine struct
  1 1000  2.43235E+01  2.60516E+00 -1.23846E+00  1.54080E-02 -8.16867E-01
  2 1000  2.43235E+01  2.60516E+00 -1.23846E+00  1.54080E-02 -8.16867E-01

vr = -0.1
    done in routine struct
  1 1050  2.55135E+01  2.70437E+00 -5.91592E+00 -3.44933E-06 -5.32826E+00
  2 1050  2.55135E+01  2.70437E+00 -5.91616E+00 -3.44933E-06 -5.32827E+00
vr = 0.
    done in routine struct
  1 1050  2.55135E+01  2.56779E+00 -1.23740E+00  1.50456E-02 -8.16905E-01
  2 1050  2.55135E+01  2.56779E+00 -1.23740E+00  1.50456E-02 -8.16905E-01
 nrow1 nrow2 =1,  2
 h0,alfa0,nr =2*0.,  1
```

```
value of L in pvar= 1
xlenth,ylenth,chord= 1.,   0.,   1.
```

Surface Mach Number, Isentropic Mach Number and CP; block = 1 and ncyc = 1050

x/c	machu	imachu	cpu	x/c	machl	imachl	cpl
-0.1334	1.5000	1.5000	0.0000	-0.1334	1.5000	1.5000	0.0000
-0.1000	1.5000	1.5000	0.0000	-0.1000	1.5000	1.5000	0.0000
-0.0667	1.5000	1.5000	0.0000	-0.0667	1.5000	1.5000	0.0000
-0.0333	1.5000	1.5000	0.0000	-0.0333	1.5000	1.5000	0.0000
0.0000	1.5000	1.5000	0.0000	0.0000	1.5000	1.5000	0.0000
0.0333	1.5646	1.5675	0.0596	0.0333	1.3597	1.3599	-0.1398
0.0667	1.5715	1.5937	0.0814	0.0667	1.3677	1.3303	-0.1721
0.1000	1.5663	1.5974	0.0844	0.1000	1.3768	1.3334	-0.1687
0.1333	1.5669	1.5986	0.0854	0.1333	1.3802	1.3368	-0.1649
0.1667	1.5689	1.6011	0.0874	0.1667	1.3818	1.3394	-0.1621
0.2000	1.5711	1.6040	0.0898	0.2000	1.3839	1.3424	-0.1588
0.2333	1.5728	1.6064	0.0917	0.2333	1.3860	1.3452	-0.1557
0.2667	1.5745	1.6091	0.0939	0.2667	1.3878	1.3478	-0.1529
0.3000	1.5768	1.6121	0.0963	0.3000	1.3900	1.3507	-0.1497
0.3333	1.5784	1.6142	0.0980	0.3333	1.3917	1.3530	-0.1473
0.3667	1.5790	1.6155	0.0990	0.3667	1.3925	1.3545	-0.1456
0.4000	1.5807	1.6186	0.1014	0.4000	1.3942	1.3576	-0.1422
0.4333	1.5861	1.6262	0.1075	0.4333	1.3995	1.3663	-0.1329
0.4667	1.5915	1.6295	0.1101	0.4667	1.4126	1.3853	-0.1128
0.5000	1.5834	1.6061	0.0915	0.5000	1.4325	1.4130	-0.0842
0.5333	1.5105	1.5011	0.0010	0.5333	1.4560	1.4459	-0.0514
0.5667	1.4031	1.3760	-0.1225	0.5667	1.4808	1.4804	-0.0183
0.6000	1.3593	1.3137	-0.1907	0.6000	1.5038	1.5127	0.0116
0.6333	1.3639	1.3164	-0.1877	0.6333	1.5236	1.5408	0.0366
0.6667	1.3728	1.3265	-0.1764	0.6667	1.5397	1.5635	0.0562
0.7000	1.3832	1.3390	-0.1625	0.7000	1.5511	1.5798	0.0699
0.7333	1.3904	1.3481	-0.1525	0.7333	1.5580	1.5901	0.0785
0.7667	1.3952	1.3547	-0.1454	0.7667	1.5623	1.5971	0.0842
0.8000	1.3997	1.3606	-0.1390	0.8000	1.5662	1.6033	0.0893
0.8333	1.4053	1.3681	-0.1309	0.8333	1.5697	1.6087	0.0936
0.8667	1.4127	1.3782	-0.1203	0.8667	1.5721	1.6131	0.0971
0.9000	1.4222	1.3910	-0.1068	0.9000	1.5758	1.6200	0.1026
0.9333	1.4343	1.4077	-0.0897	0.9333	1.5805	1.6286	0.1094
0.9667	1.4495	1.4285	-0.0686	0.9667	1.5955	1.6489	0.1250
1.0000	1.4598	1.4448	-0.0525	1.0000	1.5959	1.6459	0.1228
1.0200	1.5228	1.5323	0.0291	1.0200	1.5152	1.5323	0.0291
1.0400	1.5034	1.5041	0.0037	1.0400	1.5007	1.5041	0.0037
1.0600	1.4771	1.4778	-0.0207	1.0600	1.4963	1.4778	-0.0207
1.0800	1.4358	1.4422	-0.0550	1.0800	1.4676	1.4422	-0.0550
1.1000	1.4245	1.4222	-0.0749	1.1000	1.4373	1.4222	-0.0749

******** inlet conditions ********

j	u	v	mach	angle	p/pt
2	1.500	0.000	1.500	0.000	0.2724
3	1.500	0.000	1.500	0.000	0.2724
4	1.500	0.000	1.500	0.000	0.2724
5	1.500	0.000	1.500	0.000	0.2724
6	1.500	0.000	1.500	0.000	0.2724
7	1.500	0.000	1.500	0.000	0.2724
8	1.500	0.000	1.500	0.000	0.2724
9	1.500	0.000	1.500	0.000	0.2724
10	1.500	0.000	1.500	0.000	0.2724

11	1.500	0.000	1.500	0.000	0.2724
12	1.500	0.000	1.500	0.000	0.2724
13	1.500	0.000	1.500	0.000	0.2724
14	1.500	0.000	1.500	0.000	0.2724
15	1.500	0.000	1.500	0.000	0.2724
16	1.500	0.000	1.500	0.000	0.2724
17	1.500	0.000	1.500	0.000	0.2724
18	1.500	0.000	1.500	0.000	0.2724
19	1.500	0.000	1.500	0.000	0.2724
20	1.500	0.000	1.500	0.000	0.2724
21	1.500	0.000	1.500	0.000	0.2724
22	1.500	0.000	1.500	0.000	0.2724
23	1.500	0.000	1.500	0.000	0.2724
24	1.500	0.000	1.500	0.000	0.2724
25	1.500	0.000	1.500	0.000	0.2724
26	1.500	0.000	1.500	0.000	0.2724
27	1.500	0.000	1.500	0.000	0.2724
28	1.500	0.000	1.500	0.000	0.2724
29	1.500	0.000	1.500	0.000	0.2724
30	1.500	0.000	1.500	0.000	0.2724
31	1.500	0.000	1.500	0.000	0.2724
32	1.500	0.000	1.500	0.000	0.2724
33	1.500	0.000	1.500	0.000	0.2724
34	1.500	0.000	1.500	0.000	0.2724
35	1.500	0.000	1.500	0.000	0.2724
36	1.500	0.000	1.500	0.000	0.2724
37	1.500	0.000	1.500	0.000	0.2724
38	1.500	0.000	1.500	0.000	0.2724
39	1.500	0.000	1.500	0.000	0.2724
40	1.500	0.000	1.500	0.000	0.2724
41	1.500	0.000	1.500	0.000	0.2724

The average inlet Mach number is: 1.5000

******** exit conditions ********

j	u	v	mach	angle	p/pt
2	1.445	-0.055	1.372	-2.172	0.3027
3	1.466	-0.057	1.416	-2.209	0.2924
4	1.484	-0.071	1.459	-2.736	0.2824
5	1.503	-0.086	1.508	-3.269	0.2715
6	1.517	-0.095	1.544	-3.577	0.2640
7	1.527	-0.097	1.571	-3.637	0.2584
8	1.529	-0.092	1.577	-3.446	0.2571
9	1.529	-0.085	1.575	-3.199	0.2574
10	1.526	-0.077	1.568	-2.875	0.2586
11	1.523	-0.067	1.560	-2.521	0.2601
12	1.521	-0.058	1.553	-2.203	0.2615
13	1.519	-0.051	1.548	-1.937	0.2626
14	1.517	-0.045	1.544	-1.712	0.2633
15	1.516	-0.040	1.542	-1.517	0.2637
16	1.516	-0.036	1.540	-1.344	0.2640
17	1.515	-0.031	1.539	-1.185	0.2642
18	1.515	-0.027	1.538	-1.039	0.2644
19	1.514	-0.024	1.536	-0.902	0.2647
20	1.513	-0.020	1.535	-0.771	0.2649
21	1.513	-0.017	1.533	-0.645	0.2653
22	1.512	-0.014	1.531	-0.526	0.2655

```
  23  1.511 -0.011  1.530 -0.413  0.2658
  24  1.511 -0.008  1.529 -0.302  0.2659
  25  1.511 -0.005  1.529 -0.195  0.2659
  26  1.511 -0.002  1.530 -0.086  0.2657
  27  1.511  0.001  1.531  0.030  0.2654
  28  1.512  0.004  1.534  0.163  0.2648
  29  1.513  0.008  1.536  0.308  0.2642
  30  1.514  0.012  1.539  0.438  0.2636
  31  1.513  0.014  1.538  0.519  0.2637
  32  1.510  0.013  1.529  0.510  0.2656
  33  1.503  0.008  1.510  0.310  0.2698
  34  1.489 -0.005  1.474 -0.208  0.2779
  35  1.468 -0.027  1.422 -1.060  0.2905
  36  1.448 -0.045  1.374 -1.787  0.3029
  37  1.436 -0.055  1.345 -2.175  0.3107
  38  1.432 -0.056  1.337 -2.242  0.3129
  39  1.430 -0.055  1.334 -2.202  0.3136
  40  1.432 -0.051  1.340 -2.019  0.3115
  41  1.434 -0.054  1.353 -2.137  0.3064

The average exit Mach number is:    1.4976
xlenth,ylenth,chord= 1.,  0.,  1.

Surface Mach Number, Isentropic Mach Number and CP; block =  2 and ncyc =  1050
                ****
                ****
                ****
```

***** The output for block 2, similar to block 1, is deleted for brevity ****
****** until it prints average exit Mach number ****.

```
                ****
                ****
                ****
The average exit Mach number is:    1.4976
 h0,alfa0,nr =2*0.,  2
value of L in pvar= 1
xlenth,ylenth,chord= 1.,  0.,  1.

Surface Mach Number, Isentropic Mach Number and CP; block =  1 and ncyc =  1050
```

x/c	machu	imachu	cpu	x/c	machl	imachl	cpl
1.1200	1.5129	1.5198	0.0180	1.1200	1.5126	1.5198	0.0180
1.1400	1.5163	1.5252	0.0228	1.1400	1.5161	1.5252	0.0228
1.1600	1.5207	1.5314	0.0283	1.1600	1.5202	1.5313	0.0283
1.1800	1.5264	1.5374	0.0336	1.1800	1.5250	1.5375	0.0337
1.2000	1.5299	1.5408	0.0366	1.2000	1.5273	1.5409	0.0367
1.2333	1.4889	1.4906	-0.0087	1.2333	1.5205	1.5392	0.0352
1.2667	1.4618	1.4343	-0.0628	1.2667	1.5420	1.5626	0.0555
1.3000	1.4204	1.3716	-0.1273	1.3000	1.5745	1.5937	0.0814
1.3333	1.3857	1.3258	-0.1771	1.3333	1.5764	1.5883	0.0770
1.3667	1.3851	1.3226	-0.1807	1.3667	1.5428	1.5458	0.0410
1.4000	1.3995	1.3437	-0.1574	1.4000	1.4880	1.4937	-0.0058
1.4333	1.4251	1.3774	-0.1211	1.4333	1.4559	1.4660	-0.0319
1.4667	1.4477	1.4077	-0.0896	1.4667	1.4556	1.4674	-0.0305
1.5000	1.4580	1.4263	-0.0708	1.5000	1.4627	1.4762	-0.0222
1.5333	1.4633	1.4387	-0.0585	1.5333	1.4716	1.4867	-0.0124
1.5667	1.4668	1.4477	-0.0496	1.5667	1.4802	1.4974	-0.0024
1.6000	1.4723	1.4589	-0.0387	1.6000	1.4898	1.5099	0.0090
1.6333	1.4811	1.4740	-0.0243	1.6333	1.5016	1.5244	0.0221
1.6667	1.4956	1.4949	-0.0047	1.6667	1.5138	1.5405	0.0363

1.7000	1.5181	1.5214	0.0195	1.7000	1.5306	1.5551	0.0490
1.7333	1.5157	1.5277	0.0251	1.7333	1.5322	1.5521	0.0464
1.7667	1.5106	1.5238	0.0216	1.7667	1.5269	1.5327	0.0295
1.8000	1.4885	1.5040	0.0037	1.8000	1.4927	1.4784	-0.0201
1.8333	1.4630	1.4808	-0.0179	1.8333	1.4548	1.4210	-0.0761
1.8667	1.4476	1.4654	-0.0325	1.8667	1.4238	1.3737	-0.1251
1.9000	1.4464	1.4647	-0.0331	1.9000	1.4084	1.3471	-0.1537
1.9333	1.4499	1.4685	-0.0296	1.9333	1.4083	1.3444	-0.1567
1.9667	1.4594	1.4782	-0.0203	1.9667	1.4156	1.3567	-0.1433
2.0000	1.4703	1.4894	-0.0099	2.0000	1.4315	1.3826	-0.1156
2.0333	1.4810	1.5005	0.0005	2.0333	1.4474	1.4101	-0.0871
2.0667	1.4918	1.5127	0.0116	2.0667	1.4622	1.4363	-0.0608
2.1000	1.5038	1.5269	0.0244	2.1000	1.4745	1.4584	-0.0392
2.1333	1.5193	1.5464	0.0415	2.1333	1.4834	1.4752	-0.0231
2.1667	1.5342	1.5652	0.0576	2.1667	1.4871	1.4860	-0.0130
2.2000	1.5638	1.6021	0.0883	2.2000	1.4883	1.4897	-0.0095
2.2333	1.4961	1.5246	0.0223	2.2333	1.5056	1.5249	0.0225
2.2667	1.5029	1.5169	0.0154	2.2667	1.5029	1.5169	0.0154
2.3000	1.5048	1.5064	0.0059	2.3000	1.4927	1.5064	0.0059
2.3334	1.4946	1.4911	-0.0083	2.3334	1.4776	1.4911	-0.0082
2.3667	1.4782	1.4735	-0.0248	2.3667	1.4627	1.4736	-0.0247

******** inlet conditions ********

j	u	v	mach	angle	p/pt
2	1.512	-0.005	1.532	-0.208	0.2652
3	1.512	-0.002	1.533	-0.081	0.2650
4	1.512	0.001	1.534	0.041	0.2647
5	1.513	0.005	1.537	0.174	0.2642
6	1.514	0.008	1.539	0.304	0.2637
7	1.514	0.011	1.539	0.401	0.2636
8	1.512	0.012	1.536	0.436	0.2642
9	1.508	0.009	1.523	0.334	0.2670
10	1.499	0.001	1.499	0.025	0.2724
11	1.483	-0.014	1.459	-0.558	0.2816
12	1.463	-0.035	1.410	-1.356	0.2936
13	1.445	-0.050	1.368	-1.980	0.3045
14	1.436	-0.056	1.346	-2.239	0.3104
15	1.433	-0.056	1.340	-2.240	0.3121
16	1.432	-0.054	1.338	-2.162	0.3124
17	1.434	-0.049	1.344	-1.962	0.3105
18	1.435	-0.050	1.354	-1.988	0.3064
19	1.444	-0.050	1.370	-1.987	0.3029
20	1.462	-0.051	1.406	-1.995	0.2948
21	1.478	-0.062	1.444	-2.396	0.2859
22	1.496	-0.076	1.489	-2.903	0.2756
23	1.512	-0.087	1.531	-3.280	0.2666
24	1.525	-0.092	1.565	-3.468	0.2594
25	1.530	-0.091	1.580	-3.394	0.2565
26	1.531	-0.085	1.583	-3.192	0.2559
27	1.530	-0.078	1.578	-2.930	0.2567
28	1.527	-0.069	1.570	-2.598	0.2581
29	1.524	-0.060	1.562	-2.262	0.2597
30	1.521	-0.053	1.555	-1.978	0.2611
31	1.519	-0.046	1.550	-1.739	0.2621
32	1.518	-0.041	1.546	-1.533	0.2628
33	1.517	-0.036	1.544	-1.354	0.2631
34	1.517	-0.032	1.543	-1.195	0.2634

35	1.516	-0.028	1.541	-1.051	0.2637
36	1.515	-0.024	1.540	-0.916	0.2639
37	1.515	-0.021	1.538	-0.786	0.2642
38	1.514	-0.017	1.536	-0.660	0.2646
39	1.513	-0.014	1.535	-0.540	0.2649
40	1.512	-0.011	1.533	-0.425	0.2651
41	1.512	-0.008	1.532	-0.306	0.2653

The average inlet Mach number is: 1.4975

******** exit conditions ********

j	u	v	mach	angle	p/pt
2	1.473	0.002	1.442	0.096	0.2841
3	1.468	-0.004	1.427	-0.157	0.2884
4	1.467	-0.005	1.419	-0.210	0.2911
5	1.463	-0.008	1.407	-0.320	0.2945
6	1.458	-0.010	1.394	-0.400	0.2978
7	1.454	-0.014	1.385	-0.559	0.3002
8	1.452	-0.019	1.381	-0.745	0.3013
9	1.453	-0.024	1.383	-0.957	0.3009
10	1.456	-0.031	1.390	-1.236	0.2991
11	1.461	-0.040	1.403	-1.569	0.2959
12	1.469	-0.051	1.422	-2.001	0.2912
13	1.480	-0.060	1.450	-2.315	0.2846
14	1.490	-0.067	1.473	-2.560	0.2793
15	1.496	-0.070	1.490	-2.673	0.2752
16	1.502	-0.070	1.505	-2.659	0.2719
17	1.506	-0.068	1.517	-2.578	0.2692
18	1.509	-0.063	1.524	-2.399	0.2676
19	1.511	-0.058	1.529	-2.187	0.2665
20	1.512	-0.051	1.531	-1.951	0.2657
21	1.512	-0.045	1.533	-1.689	0.2652
22	1.512	-0.037	1.535	-1.419	0.2647
23	1.512	-0.031	1.536	-1.157	0.2643
24	1.513	-0.024	1.538	-0.904	0.2638
25	1.514	-0.017	1.540	-0.661	0.2631
26	1.515	-0.011	1.544	-0.426	0.2623
27	1.516	-0.005	1.548	-0.197	0.2614
28	1.518	0.001	1.552	0.020	0.2605
29	1.520	0.006	1.557	0.225	0.2596
30	1.521	0.011	1.561	0.413	0.2589
31	1.523	0.015	1.563	0.574	0.2585
32	1.524	0.018	1.565	0.690	0.2584
33	1.524	0.021	1.563	0.784	0.2589
34	1.522	0.022	1.557	0.831	0.2601
35	1.517	0.023	1.546	0.851	0.2623
36	1.511	0.021	1.533	0.813	0.2648
37	1.505	0.018	1.519	0.682	0.2676
38	1.500	0.013	1.504	0.501	0.2709
39	1.494	0.009	1.488	0.355	0.2748
40	1.490	0.005	1.476	0.195	0.2778
41	1.476	0.005	1.451	0.182	0.2819

The average exit Mach number is: 1.4920
xlenth,ylenth,chord= 1., 0., 1.

Surface Mach Number, Isentropic Mach Number and CP; block = 2 and ncyc = 1050

```
                    ****
                    ****
                    ****
```

***** The output for block 2, similar to block 1, is deleted for brevity ****
****** until it prints average exit Mach number ****.

```
                    ****
                    ****
                    ****
 The average exit Mach number is:    1.4920

  done outputting binary grid file***
 ** finished writing binary flow file ***

  block  1 of row  1 written on unit  9 ncyc =   1050
  block  2 of row  1 written on unit  9 ncyc =   1050

  block  1 of row  2 written on unit  9 ncyc =   1050
  block  2 of row  2 written on unit  9 ncyc =   1050

Job Accounting - Summary Report
===============================
Operating System               : sn1030 lercymp 8.0.2.3 8.0.14 CRAY Y-MP
User CPU Time                  :          364.0790 Seconds
System CPU Time                :          188.7850 Seconds
Maximum memory used            :            2.5996 MWords
```

Additional Outputs of Interest:

(1) FORT.50+i, i =1,nbs is produced giving the time history of pitching and plunging motion for each blade for both the rows. It has seven columns, which are index, plunging displacement, pitching displacement, unsteady lift, unsteady moment, total lift and total moment.

FORT.51 output:

For blade 1 of the first row (rotor in this case), the variation of pitching amplitude is given in the third column. Only selected output is shown for brevity.

88	0.0000000E+00	0.0000000E+00	-0.3351969E-04	0.6644482E-04	-0.3351969E-04	0.6644482E-04
89	0.0000000E+00	0.2753180E-07	-0.3597917E-04	0.4210713E-05	-0.3597917E-04	0.4210713E-05
90	0.0000000E+00	0.8286117E-07	0.4888123E-01	0.9966607E-02	0.4888123E-01	0.9966607E-02
91	0.0000000E+00	0.1895055E-06	0.1393826E+00	0.2858334E-01	0.1393826E+00	0.2858334E-01
92	0.0000000E+00	0.5448518E-06	0.1996672E+00	0.4117623E-01	0.1996672E+00	0.4117623E-01
93	0.0000000E+00	0.1454927E-05	0.2156745E+00	0.4437046E-01	0.2156745E+00	0.4437046E-01
94	0.0000000E+00	0.3158052E-05	0.2057149E+00	0.4194500E-01	0.2057149E+00	0.4194500E-01
95	0.0000000E+00	0.5733290E-05	0.1903534E+00	0.3829664E-01	0.1903534E+00	0.3829664E-01
96	0.0000000E+00	0.9144269E-05	0.1773857E+00	0.3504313E-01	0.1773857E+00	0.3504313E-01
97	0.0000000E+00	0.1331223E-04	0.1716148E+00	0.3340288E-01	0.1716148E+00	0.3340288E-01
98	0.0000000E+00	0.1816182E-04	0.1721755E+00	0.3322768E-01	0.1721755E+00	0.3322768E-01
99	0.0000000E+00	0.2364139E-04	0.1758480E+00	0.3375014E-01	0.1758480E+00	0.3375014E-01
100	0.0000000E+00	0.2972402E-04	0.1796655E+00	0.3424339E-01	0.1796655E+00	0.3424339E-01

101	0.0000000E+00	0.3639519E-04	0.1815370E+00	0.3412128E-01	0.1815370E+00	0.3412128E-01
102	0.0000000E+00	0.4363845E-04	0.1812418E+00	0.3333624E-01	0.1812418E+00	0.3333624E-01
103	0.0000000E+00	0.5142541E-04	0.1795870E+00	0.3211897E-01	0.1795870E+00	0.3211897E-01
104	0.0000000E+00	0.5971357E-04	0.1772049E+00	0.3058902E-01	0.1772049E+00	0.3058902E-01
105	0.0000000E+00	0.6844922E-04	0.1745753E+00	0.2883956E-01	0.1745753E+00	0.2883956E-01
106	0.0000000E+00	0.7757047E-04	0.1717635E+00	0.2684824E-01	0.1717635E+00	0.2684824E-01
107	0.0000000E+00	0.8700899E-04	0.1684449E+00	0.2448648E-01	0.1684449E+00	0.2448648E-01
108	0.0000000E+00	0.9668980E-04	0.1641323E+00	0.2157891E-01	0.1641323E+00	0.2157891E-01
109	0.0000000E+00	0.1065292E-03	0.1584100E+00	0.1797489E-01	0.1584100E+00	0.1797489E-01
110	0.0000000E+00	0.1164318E-03	0.1510364E+00	0.1358787E-01	0.1510364E+00	0.1358787E-01
111	0.0000000E+00	0.1262881E-03	0.1420482E+00	0.8437907E-02	0.1420482E+00	0.8437907E-02
112	0.0000000E+00	0.1359731E-03	0.1317944E+00	0.2686885E-02	0.1317944E+00	0.2686885E-02
113	0.0000000E+00	0.1453476E-03	0.1208787E+00	-0.3359516E-02	0.1208787E+00	-0.3359516E-02
114	0.0000000E+00	0.1542616E-03	0.1099674E+00	-0.9342073E-02	0.1099674E+00	-0.9342073E-02
115	0.0000000E+00	0.1625613E-03	0.9961283E-01	-0.1495092E-01	0.9961283E-01	-0.1495092E-01
116	0.0000000E+00	0.1700958E-03	0.9023267E-01	-0.1994133E-01	0.9023267E-01	-0.1994133E-01
117	0.0000000E+00	0.1767246E-03	0.8209724E-01	-0.2415411E-01	0.8209724E-01	-0.2415411E-01
118	0.0000000E+00	0.1823222E-03	0.7528256E-01	-0.2755538E-01	0.7528256E-01	-0.2755538E-01
119	0.0000000E+00	0.1867826E-03	0.6977575E-01	-0.3016747E-01	0.6977575E-01	-0.3016747E-01
120	0.0000000E+00	0.1900199E-03	0.6555967E-01	-0.3202101E-01	0.6555967E-01	-0.3202101E-01
121	0.0000000E+00	0.1919688E-03	0.6252747E-01	-0.3320702E-01	0.6252747E-01	-0.3320702E-01
122	0.0000000E+00	0.1925838E-03	0.6049888E-01	-0.3385285E-01	0.6049888E-01	-0.3385285E-01
123	0.0000000E+00	0.1918378E-03	0.5922712E-01	-0.3411678E-01	0.5922712E-01	-0.3411678E-01
124	0.0000000E+00	0.1897192E-03	0.5843558E-01	-0.3416485E-01	0.5843558E-01	-0.3416485E-01
125	0.0000000E+00	0.1862292E-03	0.5789178E-01	-0.3412710E-01	0.5789178E-01	-0.3412710E-01
126	0.0000000E+00	0.1813787E-03	0.5740284E-01	-0.3410687E-01	0.5740284E-01	-0.3410687E-01
127	0.0000000E+00	0.1751849E-03	0.5683664E-01	-0.3417606E-01	0.5683664E-01	-0.3417606E-01
128	0.0000000E+00	0.1676699E-03	0.5613643E-01	-0.3436657E-01	0.5613643E-01	-0.3436657E-01
129	0.0000000E+00	0.1588585E-03	0.5527886E-01	-0.3468637E-01	0.5527886E-01	-0.3468637E-01
130	0.0000000E+00	0.1487781E-03	0.5426649E-01	-0.3512514E-01	0.5426649E-01	-0.3512514E-01
131	0.0000000E+00	0.1374578E-03	0.5312574E-01	-0.3566177E-01	0.5312574E-01	-0.3566177E-01
132	0.0000000E+00	0.1249287E-03	0.5188378E-01	-0.3627628E-01	0.5188378E-01	-0.3627628E-01
133	0.0000000E+00	0.1112241E-03	0.5056657E-01	-0.3694882E-01	0.5056657E-01	-0.3694882E-01
134	0.0000000E+00	0.9638005E-04	0.4921066E-01	-0.3765287E-01	0.4921066E-01	-0.3765287E-01
135	0.0000000E+00	0.8043535E-04	0.4786335E-01	-0.3835719E-01	0.4786335E-01	-0.3835719E-01
136	0.0000000E+00	0.6343207E-04	0.4656448E-01	-0.3903732E-01	0.4656448E-01	-0.3903732E-01
137	0.0000000E+00	0.4541600E-04	0.4534368E-01	-0.3967459E-01	0.4534368E-01	-0.3967459E-01
138	0.0000000E+00	0.2643699E-04	0.4420875E-01	-0.4026211E-01	0.4420875E-01	-0.4026211E-01
139	0.0000000E+00	0.6549088E-05	0.4316207E-01	-0.4079687E-01	0.4316207E-01	-0.4079687E-01
140	0.0000000E+00	-0.1418941E-04	0.4220684E-01	-0.4127791E-01	0.4220684E-01	-0.4127791E-01
141	0.0000000E+00	-0.3571615E-04	0.4132805E-01	-0.4171538E-01	0.4132805E-01	-0.4171538E-01
142	0.0000000E+00	-0.5796492E-04	0.4049998E-01	-0.4212533E-01	0.4049998E-01	-0.4212533E-01
143	0.0000000E+00	-0.8086610E-04	0.3971108E-01	-0.4251549E-01	0.3971108E-01	-0.4251549E-01
144	0.0000000E+00	-0.1043472E-03	0.3896429E-01	-0.4288572E-01	0.3896429E-01	-0.4288572E-01
145	0.0000000E+00	-0.1283331E-03	0.3826007E-01	-0.4323739E-01	0.3826007E-01	-0.4323739E-01
146	0.0000000E+00	-0.1527466E-03	0.3759707E-01	-0.4357155E-01	0.3759707E-01	-0.4357155E-01
147	0.0000000E+00	-0.1775086E-03	0.3696619E-01	-0.4389271E-01	0.3696619E-01	-0.4389271E-01
148	0.0000000E+00	-0.2025385E-03	0.3635315E-01	-0.4420880E-01	0.3635315E-01	-0.4420880E-01
149	0.0000000E+00	-0.2277542E-03	0.3575009E-01	-0.4452470E-01	0.3575009E-01	-0.4452470E-01
150	0.0000000E+00	-0.2530732E-03	0.3515425E-01	-0.4484183E-01	0.3515425E-01	-0.4484183E-01
151	0.0000000E+00	-0.2784125E-03	0.3456556E-01	-0.4515958E-01	0.3456556E-01	-0.4515958E-01
152	0.0000000E+00	-0.3036888E-03	0.3398710E-01	-0.4547578E-01	0.3398710E-01	-0.4547578E-01
153	0.0000000E+00	-0.3288193E-03	0.3342140E-01	-0.4578897E-01	0.3342140E-01	-0.4578897E-01
154	0.0000000E+00	-0.3537216E-03	0.3286903E-01	-0.4609886E-01	0.3286903E-01	-0.4609886E-01

155	0.0000000E+00	-0.3783140E-03	0.3232994E-01	-0.4640508E-01	0.3232994E-01	-0.4640508E-01
156	0.0000000E+00	-0.4025160E-03	0.3180580E-01	-0.4670602E-01	0.3180580E-01	-0.4670602E-01
157	0.0000000E+00	-0.4262483E-03	0.3129957E-01	-0.4699926E-01	0.3129957E-01	-0.4699926E-01
158	0.0000000E+00	-0.4494330E-03	0.3081529E-01	-0.4728183E-01	0.3081529E-01	-0.4728183E-01
159	0.0000000E+00	-0.4719941E-03	0.3035609E-01	-0.4755112E-01	0.3035609E-01	-0.4755112E-01
160	0.0000000E+00	-0.4938578E-03	0.2992221E-01	-0.4780657E-01	0.2992221E-01	-0.4780657E-01
161	0.0000000E+00	-0.5149520E-03	0.2951219E-01	-0.4804920E-01	0.2951219E-01	-0.4804920E-01
162	0.0000000E+00	-0.5352076E-03	0.2912371E-01	-0.4828026E-01	0.2912371E-01	-0.4828026E-01
163	0.0000000E+00	-0.5545579E-03	0.2875657E-01	-0.4849936E-01	0.2875657E-01	-0.4849936E-01
164	0.0000000E+00	-0.5729391E-03	0.2841290E-01	-0.4870481E-01	0.2841290E-01	-0.4870481E-01
165	0.0000000E+00	-0.5902907E-03	0.2809423E-01	-0.4889556E-01	0.2809423E-01	-0.4889556E-01
166	0.0000000E+00	-0.6065556E-03	0.2780049E-01	-0.4907158E-01	0.2780049E-01	-0.4907158E-01
167	0.0000000E+00	-0.6216801E-03	0.2753047E-01	-0.4923356E-01	0.2753047E-01	-0.4923356E-01
168	0.0000000E+00	-0.6356145E-03	0.2728205E-01	-0.4938252E-01	0.2728205E-01	-0.4938252E-01
169	0.0000000E+00	-0.6483127E-03	0.2705316E-01	-0.4951945E-01	0.2705316E-01	-0.4951945E-01
170	0.0000000E+00	-0.6597329E-03	0.2684249E-01	-0.4964507E-01	0.2684249E-01	-0.4964507E-01
171	0.0000000E+00	-0.6698375E-03	0.2664943E-01	-0.4975980E-01	0.2664943E-01	-0.4975980E-01
172	0.0000000E+00	-0.6785934E-03	0.2647362E-01	-0.4986390E-01	0.2647362E-01	-0.4986390E-01
173	0.0000000E+00	-0.6859719E-03	0.2631441E-01	-0.4995765E-01	0.2631441E-01	-0.4995765E-01
174	0.0000000E+00	-0.6919491E-03	0.2617048E-01	-0.5004171E-01	0.2617048E-01	-0.5004171E-01
175	0.0000000E+00	-0.6965059E-03	0.2603985E-01	-0.5011717E-01	0.2603985E-01	-0.5011717E-01
176	0.0000000E+00	-0.6996277E-03	0.2592033E-01	-0.5018537E-01	0.2592033E-01	-0.5018537E-01
177	0.0000000E+00	-0.7013051E-03	0.2580987E-01	-0.5024776E-01	0.2580987E-01	-0.5024776E-01
178	0.0000000E+00	-0.7015336E-03	0.2570698E-01	-0.5030542E-01	0.2570698E-01	-0.5030542E-01
179	0.0000000E+00	-0.7003137E-03	0.2561115E-01	-0.5035880E-01	0.2561115E-01	-0.5035880E-01
180	0.0000000E+00	-0.6976508E-03	0.2552220E-01	-0.5040808E-01	0.2552220E-01	-0.5040808E-01
181	0.0000000E+00	-0.6935556E-03	0.2543919E-01	-0.5045381E-01	0.2543919E-01	-0.5045381E-01
182	0.0000000E+00	-0.6880434E-03	0.2536061E-01	-0.5049683E-01	0.2536061E-01	-0.5049683E-01
183	0.0000000E+00	-0.6811348E-03	0.2528551E-01	-0.5053764E-01	0.2528551E-01	-0.5053764E-01
184	0.0000000E+00	-0.6728550E-03	0.2521270E-01	-0.5057712E-01	0.2521270E-01	-0.5057712E-01
185	0.0000000E+00	-0.6632343E-03	0.2514077E-01	-0.5061633E-01	0.2514077E-01	-0.5061633E-01
186	0.0000000E+00	-0.6523073E-03	0.2506915E-01	-0.5065568E-01	0.2506915E-01	-0.5065568E-01
187	0.0000000E+00	-0.6401137E-03	0.2499788E-01	-0.5069533E-01	0.2499788E-01	-0.5069533E-01
188	0.0000000E+00	-0.6266972E-03	0.2492676E-01	-0.5073562E-01	0.2492676E-01	-0.5073562E-01
189	0.0000000E+00	-0.6121063E-03	0.2485465E-01	-0.5077744E-01	0.2485465E-01	-0.5077744E-01
190	0.0000000E+00	-0.5963934E-03	0.2478264E-01	-0.5081990E-01	0.2478264E-01	-0.5081990E-01
191	0.0000000E+00	-0.5796148E-03	0.2471276E-01	-0.5086140E-01	0.2471276E-01	-0.5086140E-01
192	0.0000000E+00	-0.5618308E-03	0.2464443E-01	-0.5090224E-01	0.2464443E-01	-0.5090224E-01
193	0.0000000E+00	-0.5431051E-03	0.2457715E-01	-0.5094281E-01	0.2457715E-01	-0.5094281E-01
194	0.0000000E+00	-0.5235049E-03	0.2451165E-01	-0.5098271E-01	0.2451165E-01	-0.5098271E-01
195	0.0000000E+00	-0.5031003E-03	0.2442870E-01	-0.5103131E-01	0.2442870E-01	-0.5103131E-01
196	0.0000000E+00	-0.4819643E-03	0.2438695E-01	-0.5106006E-01	0.2438695E-01	-0.5106006E-01
197	0.0000000E+00	-0.4601725E-03	0.2432750E-01	-0.5109762E-01	0.2432750E-01	-0.5109762E-01
198	0.0000000E+00	-0.4378028E-03	0.2427046E-01	-0.5113408E-01	0.2427046E-01	-0.5113408E-01
199	0.0000000E+00	-0.4149350E-03	0.2421611E-01	-0.5116920E-01	0.2421611E-01	-0.5116920E-01
200	0.0000000E+00	-0.3916507E-03	0.2416449E-01	-0.5120284E-01	0.2416449E-01	-0.5120284E-01
250	0.0000000E+00	-0.1420576E-03	0.2383049E-01	-0.5145642E-01	0.2383049E-01	-0.5145642E-01
300	0.0000000E+00	-0.5161379E-03	0.2384871E-01	-0.5144558E-01	0.2384871E-01	-0.5144558E-01
350	0.0000000E+00	-0.2778384E-04	0.2384948E-01	-0.5144515E-01	0.2384948E-01	-0.5144515E-01
400	0.0000000E+00	-0.6167220E-03	0.2384920E-01	-0.5144532E-01	0.2384920E-01	-0.5144532E-01
450	0.0000000E+00	0.5631749E-04	0.2384914E-01	-0.5144537E-01	0.2384914E-01	-0.5144537E-01
500	0.0000000E+00	-0.6819912E-03	0.2384915E-01	-0.5144537E-01	0.2384915E-01	-0.5144537E-01
550	0.0000000E+00	0.1009265E-03	0.2384916E-01	-0.5144536E-01	0.2384916E-01	-0.5144536E-01
600	0.0000000E+00	-0.7046918E-03	0.2384919E-01	-0.5144535E-01	0.2384919E-01	-0.5144535E-01

650	0.0000000E+00	0.1010837E-03	0.2384921E-01	-0.5144533E-01	0.2384921E-01	-0.5144533E-01
700	0.0000000E+00	-0.6823005E-03	0.2384921E-01	-0.5144532E-01	0.2384921E-01	-0.5144532E-01
750	0.0000000E+00	0.5677146E-04	0.2384919E-01	-0.5144531E-01	0.2384919E-01	-0.5144531E-01
800	0.0000000E+00	-0.6173066E-03	0.2384919E-01	-0.5144530E-01	0.2384919E-01	-0.5144530E-01
850	0.0000000E+00	-0.2708498E-04	0.2384920E-01	-0.5144527E-01	0.2384920E-01	-0.5144527E-01
900	0.0000000E+00	-0.5169333E-03	0.2384928E-01	-0.5144523E-01	0.2384928E-01	-0.5144523E-01
950	0.0000000E+00	-0.1411649E-03	0.2384931E-01	-0.5144521E-01	0.2384931E-01	-0.5144521E-01
1000	0.0000000E+00	-0.3923378E-03	0.2384933E-01	-0.5144519E-01	0.2384933E-01	-0.5144519E-01
1050	0.0000000E+00	-0.2727885E-03	0.2384934E-01	-0.5144517E-01	0.2384934E-01	-0.5144517E-01

Note: The aerodynamic forces (lift and moment) given in the last two columns, converge to a constant value. This is due the fact that in supersonic through flow, the aft row (stator in this case) will not have influence on the front blade row (rotor in this case) (Ref.9).

FORT.53 output:

For blade 1 of the second row (stator in this case), the variation of pitching amplitude is given in the third column. Only selected output is shown for brevity.

88	0.0000000E+00	0.0000000E+00	0.1334763E-03	0.7179038E-04	0.1334763E-03	0.7179038E-04
89	0.0000000E+00	0.1040525E-04	0.1255046E-03	0.6713205E-04	0.1255046E-03	0.6713205E-04
90	0.0000000E+00	0.2080415E-04	0.1266639E-03	0.6596567E-04	0.1266639E-03	0.6596567E-04
91	0.0000000E+00	0.3113087E-04	0.1391829E-03	0.6658873E-04	0.1391829E-03	0.6658873E-04
92	0.0000000E+00	0.4134884E-04	0.1709839E-03	0.6527812E-04	0.1709839E-03	0.6527812E-04
93	0.0000000E+00	0.5142191E-04	0.2385446E-03	0.5606816E-04	0.2385446E-03	0.5606816E-04
94	0.0000000E+00	0.6131440E-04	0.3744820E-03	0.2909874E-04	0.3744820E-03	0.2909874E-04
95	0.0000000E+00	0.7099108E-04	0.6356646E-03	-0.2827818E-04	0.6356646E-03	-0.2827818E-04
96	0.0000000E+00	0.8041709E-04	0.1101821E-02	-0.1271549E-03	0.1101821E-02	-0.1271549E-03
97	0.0000000E+00	0.8955787E-04	0.1846218E-02	-0.2744813E-03	0.1846218E-02	-0.2744813E-03
98	0.0000000E+00	0.9837901E-04	0.2903115E-02	-0.4651048E-03	0.2903115E-02	-0.4651048E-03
99	0.0000000E+00	0.1068463E-03	0.4230372E-02	-0.6735705E-03	0.4230372E-02	-0.6735705E-03
100	0.0000000E+00	0.1149260E-03	0.5691532E-02	-0.8531548E-03	0.5691532E-02	-0.8531548E-03
101	0.0000000E+00	0.1225855E-03	0.7086930E-02	-0.9450668E-03	0.7086930E-02	-0.9450668E-03
102	0.0000000E+00	0.1297944E-03	0.8192719E-02	-0.8940888E-03	0.8192719E-02	-0.8940888E-03
103	0.0000000E+00	0.1365254E-03	0.8794159E-02	-0.6592093E-03	0.8794159E-02	-0.6592093E-03
104	0.0000000E+00	0.1427561E-03	0.8696996E-02	-0.2183267E-03	0.8696996E-02	-0.2183267E-03
105	0.0000000E+00	0.1484693E-03	0.7749775E-02	0.4183319E-03	0.7749775E-02	0.4183319E-03
106	0.0000000E+00	0.1536540E-03	0.5768278E-02	0.1220320E-02	0.5768278E-02	0.1220320E-02
107	0.0000000E+00	0.1583046E-03	0.2450246E-02	0.2156369E-02	0.2450246E-02	0.2156369E-02
108	0.0000000E+00	0.1624210E-03	-0.2656712E-02	0.3188706E-02	-0.2656712E-02	0.3188706E-02
109	0.0000000E+00	0.1660077E-03	-0.1017327E-01	0.4266480E-02	-0.1017327E-01	0.4266480E-02
110	0.0000000E+00	0.1690731E-03	-0.2078926E-01	0.5320242E-02	-0.2078926E-01	0.5320242E-02
111	0.0000000E+00	0.1716280E-03	-0.3507771E-01	0.6254483E-02	-0.3507771E-01	0.6254483E-02
112	0.0000000E+00	0.1736846E-03	-0.5328736E-01	0.6938268E-02	-0.5328736E-01	0.6938268E-02
113	0.0000000E+00	0.1752541E-03	-0.7510029E-01	0.7214758E-02	-0.7510029E-01	0.7214758E-02
114	0.0000000E+00	0.1763443E-03	-0.9948598E-01	0.6937424E-02	-0.9948598E-01	0.6937424E-02
115	0.0000000E+00	0.1769563E-03	-0.1247305E+00	0.6015286E-02	-0.1247305E+00	0.6015286E-02
116	0.0000000E+00	0.1770816E-03	-0.1486920E+00	0.4475840E-02	-0.1486920E+00	0.4475840E-02
117	0.0000000E+00	0.1767011E-03	-0.1691015E+00	0.2496979E-02	-0.1691015E+00	0.2496979E-02

118	0.0000000E+00	0.1757853E-03	-0.1841203E+00	0.3742846E-03	-0.1841203E+00	0.3742846E-03
119	0.0000000E+00	0.1742983E-03	-0.1934980E+00	-0.1547221E-02	-0.1934980E+00	-0.1547221E-02
120	0.0000000E+00	0.1722035E-03	-0.1978038E+00	-0.2935988E-02	-0.1978038E+00	-0.2935988E-02
121	0.0000000E+00	0.1694706E-03	-0.1977793E+00	-0.3566074E-02	-0.1977793E+00	-0.3566074E-02
122	0.0000000E+00	0.1660818E-03	-0.1947708E+00	-0.3370091E-02	-0.1947708E+00	-0.3370091E-02
123	0.0000000E+00	0.1620364E-03	-0.1901532E+00	-0.2410988E-02	-0.1901532E+00	-0.2410988E-02
124	0.0000000E+00	0.1573526E-03	-0.1849304E+00	-0.8437848E-03	-0.1849304E+00	-0.8437848E-03
125	0.0000000E+00	0.1520658E-03	-0.1799283E+00	0.1046916E-02	-0.1799283E+00	0.1046916E-02
126	0.0000000E+00	0.1462254E-03	-0.1755305E+00	0.2926598E-02	-0.1755305E+00	0.2926598E-02
127	0.0000000E+00	0.1398892E-03	-0.1713024E+00	0.4574844E-02	-0.1713024E+00	0.4574844E-02
128	0.0000000E+00	0.1331172E-03	-0.1663824E+00	0.5957644E-02	-0.1663824E+00	0.5957644E-02
129	0.0000000E+00	0.1259671E-03	-0.1600951E+00	0.7200284E-02	-0.1600951E+00	0.7200284E-02
130	0.0000000E+00	0.1184931E-03	-0.1522568E+00	0.8460268E-02	-0.1522568E+00	0.8460268E-02
131	0.0000000E+00	0.1107482E-03	-0.1430385E+00	0.9892498E-02	-0.1430385E+00	0.9892498E-02
132	0.0000000E+00	0.1027863E-03	-0.1329369E+00	0.1162944E-01	-0.1329369E+00	0.1162944E-01
133	0.0000000E+00	0.9466581E-04	-0.1226241E+00	0.1375357E-01	-0.1226241E+00	0.1375357E-01
134	0.0000000E+00	0.8645153E-04	-0.1127865E+00	0.1628201E-01	-0.1127865E+00	0.1628201E-01
135	0.0000000E+00	0.7821629E-04	-0.1038887E+00	0.1917240E-01	-0.1038887E+00	0.1917240E-01
136	0.0000000E+00	0.7004098E-04	-0.9595208E-01	0.2235012E-01	-0.9595208E-01	0.2235012E-01
137	0.0000000E+00	0.6201354E-04	-0.8862853E-01	0.2572114E-01	-0.8862853E-01	0.2572114E-01
138	0.0000000E+00	0.5422723E-04	-0.8145000E-01	0.2919082E-01	-0.8145000E-01	0.2919082E-01
139	0.0000000E+00	0.4677839E-04	-0.7392228E-01	0.3268672E-01	-0.7392228E-01	0.3268672E-01
140	0.0000000E+00	0.3976433E-04	-0.6570539E-01	0.3612912E-01	-0.6570539E-01	0.3612912E-01
141	0.0000000E+00	0.3328131E-04	-0.5691444E-01	0.3935471E-01	-0.5691444E-01	0.3935471E-01
142	0.0000000E+00	0.2742220E-04	-0.4777666E-01	0.4231753E-01	-0.4777666E-01	0.4231753E-01
143	0.0000000E+00	0.2227380E-04	-0.3854046E-01	0.4503215E-01	-0.3854046E-01	0.4503215E-01
144	0.0000000E+00	0.1791531E-04	-0.2974563E-01	0.4738274E-01	-0.2974563E-01	0.4738274E-01
145	0.0000000E+00	0.1441734E-04	-0.2194570E-01	0.4927356E-01	-0.2194570E-01	0.4927356E-01
146	0.0000000E+00	0.1184011E-04	-0.1551605E-01	0.5064974E-01	-0.1551605E-01	0.5064974E-01
147	0.0000000E+00	0.1023132E-04	-0.1072133E-01	0.5146465E-01	-0.1072133E-01	0.5146465E-01
148	0.0000000E+00	0.9624710E-05	-0.7690900E-02	0.5170683E-01	-0.7690900E-02	0.5170683E-01
149	0.0000000E+00	0.1003912E-04	-0.6165633E-02	0.5146299E-01	-0.6165633E-02	0.5146299E-01
150	0.0000000E+00	0.1147852E-04	-0.5635702E-02	0.5087515E-01	-0.5635702E-02	0.5087515E-01
151	0.0000000E+00	0.1393352E-04	-0.5642464E-02	0.5007957E-01	-0.5642464E-02	0.5007957E-01
152	0.0000000E+00	0.1738405E-04	-0.5750567E-02	0.4922616E-01	-0.5750567E-02	0.4922616E-01
153	0.0000000E+00	0.2180234E-04	-0.5640080E-02	0.4842124E-01	-0.5640080E-02	0.4842124E-01
154	0.0000000E+00	0.2715575E-04	-0.5221245E-02	0.4768473E-01	-0.5221245E-02	0.4768473E-01
155	0.0000000E+00	0.3340890E-04	-0.4561314E-02	0.4700194E-01	-0.4561314E-02	0.4700194E-01
156	0.0000000E+00	0.4052446E-04	-0.3727105E-02	0.4638102E-01	-0.3727105E-02	0.4638102E-01
157	0.0000000E+00	0.4846326E-04	-0.2755404E-02	0.4585186E-01	-0.2755404E-02	0.4585186E-01
158	0.0000000E+00	0.5718461E-04	-0.1649897E-02	0.4546137E-01	-0.1649897E-02	0.4546137E-01
159	0.0000000E+00	0.6664703E-04	-0.3230038E-03	0.4528710E-01	-0.3230038E-03	0.4528710E-01
160	0.0000000E+00	0.7680942E-04	0.1309635E-02	0.4537735E-01	0.1309635E-02	0.4537735E-01
161	0.0000000E+00	0.8763249E-04	0.3264032E-02	0.4571565E-01	0.3264032E-02	0.4571565E-01
162	0.0000000E+00	0.9907974E-04	0.5528258E-02	0.4626556E-01	0.5528258E-02	0.4626556E-01
163	0.0000000E+00	0.1111174E-03	0.8084314E-02	0.4698782E-01	0.8084314E-02	0.4698782E-01
164	0.0000000E+00	0.1237141E-03	0.1085307E-01	0.4781775E-01	0.1085307E-01	0.4781775E-01
165	0.0000000E+00	0.1368398E-03	0.1368645E-01	0.4867113E-01	0.1368645E-01	0.4867113E-01
166	0.0000000E+00	0.1504645E-03	0.1646545E-01	0.4948188E-01	0.1646545E-01	0.4948188E-01
167	0.0000000E+00	0.1645574E-03	0.1911240E-01	0.5020610E-01	0.1911240E-01	0.5020610E-01
168	0.0000000E+00	0.1790851E-03	0.2153939E-01	0.5080135E-01	0.2153939E-01	0.5080135E-01
169	0.0000000E+00	0.1940108E-03	0.2367798E-01	0.5123621E-01	0.2367798E-01	0.5123621E-01
170	0.0000000E+00	0.2092938E-03	0.2551433E-01	0.5150979E-01	0.2551433E-01	0.5150979E-01
171	0.0000000E+00	0.2248890E-03	0.2704650E-01	0.5162847E-01	0.2704650E-01	0.5162847E-01

172	0.0000000E+00	0.2407469E-03	0.2825864E-01	0.5158545E-01	0.2825864E-01	0.5158545E-01
173	0.0000000E+00	0.2568137E-03	0.2913614E-01	0.5137423E-01	0.2913614E-01	0.5137423E-01
174	0.0000000E+00	0.2730319E-03	0.2966045E-01	0.5099147E-01	0.2966045E-01	0.5099147E-01
175	0.0000000E+00	0.2893395E-03	0.2983142E-01	0.5044166E-01	0.2983142E-01	0.5044166E-01
176	0.0000000E+00	0.3056712E-03	0.2967348E-01	0.4974205E-01	0.2967348E-01	0.4974205E-01
177	0.0000000E+00	0.3219578E-03	0.2920965E-01	0.4891520E-01	0.2920965E-01	0.4891520E-01
178	0.0000000E+00	0.3381277E-03	0.2846076E-01	0.4798508E-01	0.2846076E-01	0.4798508E-01
179	0.0000000E+00	0.3541066E-03	0.2747725E-01	0.4698240E-01	0.2747725E-01	0.4698240E-01
180	0.0000000E+00	0.3698190E-03	0.2630186E-01	0.4592798E-01	0.2630186E-01	0.4592798E-01
181	0.0000000E+00	0.3851890E-03	0.2497344E-01	0.4484475E-01	0.2497344E-01	0.4484475E-01
182	0.0000000E+00	0.4001406E-03	0.2355491E-01	0.4376657E-01	0.2355491E-01	0.4376657E-01
183	0.0000000E+00	0.4145988E-03	0.2209653E-01	0.4271760E-01	0.2209653E-01	0.4271760E-01
184	0.0000000E+00	0.4284904E-03	0.2063638E-01	0.4171649E-01	0.2063638E-01	0.4171649E-01
185	0.0000000E+00	0.4417448E-03	0.1920354E-01	0.4077671E-01	0.1920354E-01	0.4077671E-01
186	0.0000000E+00	0.4542947E-03	0.1782241E-01	0.3990488E-01	0.1782241E-01	0.3990488E-01
187	0.0000000E+00	0.4660763E-03	0.1650560E-01	0.3910661E-01	0.1650560E-01	0.3910661E-01
188	0.0000000E+00	0.4770301E-03	0.1526774E-01	0.3838548E-01	0.1526774E-01	0.3838548E-01
189	0.0000000E+00	0.4871009E-03	0.1411203E-01	0.3773682E-01	0.1411203E-01	0.3773682E-01
190	0.0000000E+00	0.4962383E-03	0.1301768E-01	0.3715095E-01	0.1301768E-01	0.3715095E-01
191	0.0000000E+00	0.5043966E-03	0.1196985E-01	0.3661620E-01	0.1196985E-01	0.3661620E-01
192	0.0000000E+00	0.5115347E-03	0.1097153E-01	0.3611915E-01	0.1097153E-01	0.3611915E-01
193	0.0000000E+00	0.5176165E-03	0.1003414E-01	0.3565174E-01	0.1003414E-01	0.3565174E-01
194	0.0000000E+00	0.5226101E-03	0.9160297E-02	0.3521233E-01	0.9160297E-02	0.3521233E-01
195	0.0000000E+00	0.5264883E-03	0.8344865E-02	0.3480355E-01	0.8344865E-02	0.3480355E-01
196	0.0000000E+00	0.5292282E-03	0.7586986E-02	0.3443050E-01	0.7586986E-02	0.3443050E-01
197	0.0000000E+00	0.5308119E-03	0.6889088E-02	0.3409383E-01	0.6889088E-02	0.3409383E-01
198	0.0000000E+00	0.5312261E-03	0.6257005E-02	0.3379069E-01	0.6257005E-02	0.3379069E-01
199	0.0000000E+00	0.5304623E-03	0.5702296E-02	0.3351854E-01	0.5702296E-02	0.3351854E-01
200	0.0000000E+00	0.5285171E-03	0.5211333E-02	0.3327510E-01	0.5211333E-02	0.3327510E-01
250	0.0000000E+00	-0.1775220E-03	0.3579984E-02	0.2580078E-01	0.3579984E-02	0.2580078E-01
300	0.0000000E+00	0.3908373E-03	-0.9602320E-02	0.1262133E-01	-0.9602320E-02	0.1262133E-01
350	0.0000000E+00	-0.2220359E-03	-0.7137840E-02	0.1842336E-01	-0.7137840E-02	0.1842336E-01
400	0.0000000E+00	0.4430725E-03	-0.1376280E-01	0.2259962E-01	-0.1376280E-01	0.2259962E-01
450	0.0000000E+00	-0.1422492E-03	-0.3758597E-02	0.2472675E-01	-0.3758597E-02	0.2472675E-01
500	0.0000000E+00	0.3563650E-03	-0.5978018E-02	0.1412002E-01	-0.5978018E-02	0.1412002E-01
550	0.0000000E+00	-0.1746384E-03	-0.8150222E-02	0.1670708E-01	-0.8150222E-02	0.1670708E-01
600	0.0000000E+00	0.3617251E-03	-0.1391514E-01	0.2181302E-01	-0.1391514E-01	0.2181302E-01
650	0.0000000E+00	-0.4387718E-04	-0.8684810E-02	0.2429904E-01	-0.8684810E-02	0.2429904E-01
700	0.0000000E+00	0.2604030E-03	-0.1544448E-02	0.1658023E-01	-0.1544448E-02	0.1658023E-01
750	0.0000000E+00	-0.5778216E-04	-0.1008419E-01	0.1450880E-01	-0.1008419E-01	0.1450880E-01
800	0.0000000E+00	0.2132489E-03	-0.1305406E-01	0.2083686E-01	-0.1305406E-01	0.2083686E-01
850	0.0000000E+00	0.1141025E-03	-0.1135036E-01	0.2382314E-01	-0.1135036E-01	0.2382314E-01
900	0.0000000E+00	0.1025094E-03	0.2783995E-02	0.1965863E-01	0.2783995E-02	0.1965863E-01
950	0.0000000E+00	0.1238276E-03	-0.1200745E-01	0.1249734E-01	-0.1200745E-01	0.1249734E-01
1000	0.0000000E+00	0.7186149E-05	-0.1034214E-01	0.2013406E-01	-0.1034214E-01	0.2013406E-01
1050	0.0000000E+00	0.3148271E-03	-0.1260987E-01	0.2340267E-01	-0.1260987E-01	0.2340267E-01

Note: A plot of the pitching amplitudes (3rd column) showed that the amplitudes are increasing with time. This is due the fact that for V*=1.2, the natural frequency of the aeroelastic system is close to the forcing function frequency, (Ref.9).

7.3 Unsteady Aerodynamics and Structural Response of a Supersonic Compressor Stage with Three blades in the front row and two blades in the aft row, Time Domain Analysis

In this example, as in section 7.2, again two blade rows (NROW=2) are considered. However, now the front row has three blades, and aft row has two blades. This is indicated in the input file by bold. The airfoils in the blade rows are double circular arc airfoils (IAFOIL=2) with 1% thickness to chord ratio. The axial gap between the blade rows (ROWSEP) is 20% of the chord length. The gap to chord ratio (SBYC) is 0.3333 for the front blade row, and 0.5 for the aft blade row. Stagger angle (STAGGER) is zero for both the blade rows. The front row is designated as rotor and moves with a velocity of Mach 0.1 in the negative Y-direction, see Fig. 1b (VR=-0.1 in the input for this blade row). The flow enters the front blade row parallel to X-axis i.e. at zero angle of attack (ALPHA=0.0). The Mach number at the inlet (FSMACH) is 1.5. The aft row is stationary (VR=0.0) and is designated as stator. The pitching axis is located at about 30% of chord from the leading edge (X0 = 0.3, Y0=0.0).

The structural properties used are as follows: the mass ratio (XMU) is 456. The radius of gyration (XRA) is 0.588, natural frequencies in bending and torsion in cycles per second respectively are 0.567 and 1.0 (GAS=0.567 and GHS=1.0), with no structural damping (ZHS, ZAS = 0.0). The offset (XA) between elastic axis and center of gravity is zero. The elastic axis is assumed to be same as the pitching axis i.e. X0 = 0.3, Y0=0.0.

The grid is generated within the code (IGB=-2) for the double circular arc airfoil geometry (IAFOIL=2). The thickness of the airfoil (1%) is given in the subroutine GRIDGEN. A 41x41 (streamwise by pitchwise) grid for each block in each row is used in the solution i.e. ni=41, nj=41. There are 30 points on each airfoil, 10 points in the interface region, five points each in upstream of the boundary and downstream of the boundary. The inlet boundary is located 0.1667 chords upstream of the front row (XLEFT=0.1667). The exit boundary is located at 2.3667 chords downstream from the leading edge of the front row airfoil (XRIGHT=2.3667). The blade rows are separated by 0.2 chord lengths (ROWSEP=0.2). Therefore, the exit boundary is located at 0.1667 chord lengths from the trailing edge of the second blade row (stator) airfoil (for unit chord lengths of airfoils in each row).

The aeroelastic equations are integrated in time (MOTION=-1). The input values for PHASE, REDFRE, H0/C and ALFA0D are not used in the computation. A CFL number of 5.0 is used giving a time step (dtmin) of 0.01938. Calculations are performed for NTTOT =1050 time steps. The calculations start running the code in steady mode for NTSS =88 steps. A reduced velocity parameter (VSTAR) of

1.2 is used. The source file is compiled with *nbsx=3* since maximum of three blocks are used for this case. In the data file, NBS=3 for the first row and NBS=2 for the second row. Non-zero initial conditions are selected for the stator blade row (ALFADO = 0.01 for both blade 1 and blade 2). The source code is compiled with the following parameter statements.

```
parameter(nrmx=2, nbsx=3)
parameter(ni=41, nj=41)
```

input file (msap2d.in)

```
    INDBC     MIRROR
        0          0
    IORIG      ISYST
        0          0
   MOTION       INEW
       -1          0
   FSMACH      PHASE    REDFREQ      ALPHA
     1.50      0.000     1.0000       0.00
     H0/C     ALFA0D
   0.0000     0.0000
.........*.........*.........*.........*.........*
      CFL       PRAT        PSI      ORDER      LIMIT
      5.0     0.7320     0.3333        3.0        1.0
       X0         Y0
   0.3000        0.0
.........*.........*.........*.........*
     NCYC       NTSS      NTTOT    NTPRNT
        1         88       1050        50
      IGB
       -2
.........*.........*
    XLEFT     XRIGHT
  -0.1667     2.3667
.........*.........*.........*.........*.........*
     NROW     NRFLBC     ROWSEP
        2          0     0.2000
.........*.........*.........*
      KIN       KOUT     MOOVEE
        0          9          0
    IMODE      IFLTR      IFREE
        1         -1          0
.........*
    VSTAR
     1.20
.........*.........*.........*.........*
     SBYC       STAG     IAFOIL        NBS
.333333333     00.00          2          3
      ILE        ITE      PERCJ         VR      CHORD
        6         36      100.0      -0.10        1.0
      GHS        GAS        ZHS        ZAS        XMU        XRA         XA
    0.567        1.0      0.000      0.000      456.2      0.588      0.000
      HD0     ALFAD0         H0      ALFA0
    0.000      0.000        0.0        0.0
```

```
  SMOTION
    0.000
      GHS         GAS         ZHS         ZAS         XMU         XRA          XA
    0.567         1.0       0.000       0.000       456.2       0.588       0.000
      HD0      ALFAD0          H0       ALFA0
    0.000   -0.000000         0.0         0.0
  SMOTION
    0.000
      GHS         GAS         ZHS         ZAS         XMU         XRA          XA
    0.567         1.0       0.000       0.000       456.2       0.588       0.000
      HD0      ALFAD0          H0       ALFA0
    0.000       0.000         0.0         0.0
  SMOTION
    0.000
.........*.........*.........*.........*
     SBYC        STAG      IAFOIL         NBS
    0.500       00.00           2           2
      ILE         ITE       PERCJ          VR       CHORD
        6          36       100.0        0.00         1.0
      GHS         GAS         ZHS         ZAS         XMU         XRA          XA
    0.567         1.0       0.000       0.000       456.2       0.588       0.000
      HD0      ALFAD0          H0       ALFA0
    0.000       0.010         0.0         0.0
  SMOTION
    0.000
      GHS         GAS         ZHS         ZAS         XMU         XRA          XA
    0.567         1.0       0.000       0.000       456.2       0.588       0.000
      HD0      ALFAD0          H0       ALFA0
    0.000    0.010000         0.0         0.0
  SMOTION
    0.000
---IGSTOP: stop after grid set up(=0 no stop)----
0
    GUSTUA      PHASE
      0.00      0.000
    GUSTVA      PHASE
      0.00      0.000
----NTINT number of steps for initial debugging----
0
--DTGIV: user input time step--
0.0
```

Unit 6 output file (msap2d.out)

```
  indbc = 0mirror = 0
  iorig = 0isyst = 0
  motion = -1inew= 0

 *****************************************************
                         TIME DOMAIN SOLUTION
 *****************************************************

     factors for vibration =        0.0000        0.0000        0.0000
    FSMACH      PHASE    REDFREQ     ALPHA
    1.5000     0.0000     1.0000    0.0000
      H0/C     ALFA0D
    0.0000     0.0000
```

```
     CFL       PRAT        PSI      ORDER      LIMIT
  5.0000     0.7320     0.3333     3.0000     1.0000
      X0         Y0
  0.3000     0.0000
    NCYC       NTSS      NTTOT     NTPRNT
       1         88       1050         50
     IGB
      -2
   XLEFT     XRIGHT
 -0.1667     2.3667
    NROW     NRFLBC     ROWSEP
       2          0      0.200
   KMODE       KFFT      LIMIT
       1          1          1
     KIN       KOUT     MOOVEE
       0          9          0

****** Oscillating Cascade Analysis ******
input run stream:

number of blocks =    3 where each block has dimensions of:
              ni =   41
              nj =   41
              nk =    2

freestream mach number   =  1.5000
inlet incidence angle    =  0.0000 (degrees)
exit pressure ratio      =  0.7320 (p/ptot)
inter-blade phase angle  =  0.0000 (degrees)
reduced frequency        =  1.0000 (based on semichord)
reduced frequency        =  3.0000 (in terms of omega)
amplitude of plunge      =  0.0000 (percent chord)
amplitude of pitch       =  0.0000 (degrees)
airfoil moment center    =  0.3000 (x0, percent chord)
airfoil moment center    =  0.0000 (y0, % chord )


nb       =    1 (total number of cycles)
kin      =    0 (restart input number -if 0 not used)
kout     =    9 (restart output number -if 0 not used)
kfft     =    1 (no fft analysis if kfft=0)
moovee   =    0 (save certain steps for animation)
kmode    =    1 (stationary or oscillating cascade)

a fft analysis will be done at the end of each cycle

      flux limiter input information:

            limit =    1
            psi   = 0.333
            order =   3.0

note with limit=1, MINMOD limiter has been invoked

    IMODE      IFLTR      IFREE
        1         -1          0
    PITCHING MOTION
    **** PRINT INTERVAL, NTPRNT **** =    50
```

```
number of rows =2
for row =1
   SBYC      STAG    IAFOIL      NBS
  0.3333    0.0000        2        3
    ILE        ITE     PERCJ       VR      CHORD
      6        36   100.000    -0.100      1.000
   motion indicator for blade    1:   0.0000
   GAMA H =      0.56700     GAMA ALPHA =      1.00000
   ZETA H =      0.00000     ZETA ALPHA =      0.00000
   MASS RATIO(XMU)                      =   456.20000
   RADIUS OF GYRATION(XRA)              =     0.58800
   DT. BETWEEN E.A. AND C.G.(XALFA)     =     0.00000
   initial plunging velocity            =     0.00000
   initial pitching velocity            =     0.00000
   initial plunging displacement        =     0.00000
   initial pitching displacemnet        =     0.00000
   SELF VIBRATION INDICATOR             =     0.00000

   motion indicator for blade    2:   0.0000
   GAMA H =      0.56700     GAMA ALPHA =      1.00000
   ZETA H =      0.00000     ZETA ALPHA =      0.00000
   MASS RATIO(XMU)                      =   456.20000
   RADIUS OF GYRATION(XRA)              =     0.58800
   DT. BETWEEN E.A. AND C.G.(XALFA)     =     0.00000
   initial plunging velocity            =     0.00000
   initial pitching velocity            =     0.00000
   initial plunging displacement        =     0.00000
   initial pitching displacemnet        =     0.00000
   SELF VIBRATION INDICATOR             =     0.00000

   motion indicator for blade    3:   0.0000
   GAMA H =      0.56700     GAMA ALPHA =      1.00000
   ZETA H =      0.00000     ZETA ALPHA =      0.00000
   MASS RATIO(XMU)                      =   456.20000
   RADIUS OF GYRATION(XRA)              =     0.58800
   DT. BETWEEN E.A. AND C.G.(XALFA)     =     0.00000
   initial plunging velocity            =     0.00000
   initial pitching velocity            =     0.00000
   initial plunging displacement        =     0.00000
   initial pitching displacemnet        =     0.00000
   SELF VIBRATION INDICATOR             =     0.00000

 for row =2
   SBYC      STAG    IAFOIL      NBS
  0.5000    0.0000        2        2
    ILE        ITE     PERCJ       VR      CHORD
      6        36   100.000     0.000      1.000
   motion indicator for blade    1:   0.0000
   GAMA H =      0.56700     GAMA ALPHA =      1.00000
   ZETA H =      0.00000     ZETA ALPHA =      0.00000
   MASS RATIO(XMU)                      =   456.20000
   RADIUS OF GYRATION(XRA)              =     0.58800
   DT. BETWEEN E.A. AND C.G.(XALFA)     =     0.00000
   initial plunging velocity            =     0.00000
   initial pitching velocity            =     0.01000
   initial plunging displacement        =     0.00000
   initial pitching displacemnet        =     0.00000
```

```
   SELF VIBRATION INDICATOR           =     0.00000

   motion indicator for blade    2:  0.0000
   GAMA H =      0.56700     GAMA ALPHA =     1.00000
   ZETA H =      0.00000     ZETA ALPHA =     0.00000
   MASS RATIO(XMU)                    =   456.20000
   RADIUS OF GYRATION(XRA)            =     0.58800
   DT. BETWEEN E.A. AND C.G.(XALFA)   =     0.00000
   initial plunging velocity          =     0.00000
   initial pitching velocity          =     0.01000
   initial plunging displacement      =     0.00000
   initial pitching displacemnet      =     0.00000
   SELF VIBRATION INDICATOR           =     0.00000

   VELOCITY PARAMETER FOR TIME DOMAIN ANALYSIS      1.20000

    TIME DOMAIN: pitching motion only

   no. of time steps for steady solution, ntss  =   88
   no. of total time steps,               nttot = 1050
 NI IS LESS THAN THE REQUIRED
NDIMI, NI = 43,  41
xminb=-0.1667xmaxb=2.3667rowsep=0.2
GRID FOR ROW =1
nr =1 ile =6 ite =36chord=1.
 xleft=-0.1667 xright=1.1
 igb = -2
 calling grdunf
 entered grdunf
grid for DCA a.f. of t/c  1.E-2
   IN ROUTINE GRDUNF:STAG,SC,CHORD,X1,X4,NIF,NIB,IRUN
   0.00000     0.33333     1.00000    -0.16670     1.10000     6    36     2
 finished setting the front part
 dx at the bottom line3.3333333333333E-2
x(nif,1,1)= -8.8817841970013E-16
 finished defining bottom line
 finished defining top line
 finished defining in between
 finished the end part
 stagger angle (deg.) from input file =
                              0.0000000000
 stagger angle (deg.) from grid file =
                              0.0000000000
 stagger angle (deg.) used in the cal. =
                              0.0000000000
 gap-to-chord ratio from input file =
                              0.3333333330
 gap-to-chord ratio from grid file =
                              0.3333333330
 gap-to-chord ratio used in the calculation =
                              0.3333333330
   finished reading grid coordinates in routine RDGRID
   *** x coordinates at 0,ile,ite,last
       -0.16670     0.00000     1.00000     1.10000
        0.00000     0.00000     0.00000     0.00000
       -0.16670     0.00000     1.00000     1.10000
        0.33333     0.33333     0.33333     0.33333
 chord along the x-axis
```

```
nr, xadd(nr)= 1,  0.
nr, yadd(nr)= 1,  0.
xminb=-0.1667xmaxb=2.3667rowsep=0.2
 before calling STRTRS
    *** x coordinates at 0,ile,ite,last
        -0.16670      0.00000     1.00000     1.10000
         0.00000      0.00000     0.00000     0.00000
        -0.16670      0.00000     1.00000     1.10000
         0.33333      0.33333     0.33333     0.33333
xlenth,ylenth,chord= 1.,  0.,  1.
nr, angdeg in main  = 1,  0.
 in routine STRTRS***
 height and xshift for row= 0.333333333,  0.,  1

Starting the initial grid calculation in STRTRS
 nr, angdeg in gridp= 1,  0.
 nr, coss,sins = 1,  1.,  0.
 KMODE in STRTRS= 0
 KMODE IN ICRS 0
  For block  1:
     dtmin (as computed in eigenv) at cfl =  5.0 is      0.01938
 dtmin1=1.937984495132E-2dtmin = 1.937984495132E-2nr=1
 nssd=11 y1=0. nr=1 n=1 at grid generation
     corresponding to alfa=     0.0000 degrees
 KMODE in STRTRS= 0
 KMODE IN ICRS 0
  For block  2:
     dtmin (as computed in eigenv) at cfl =  5.0 is      0.01938
 dtmin1=1.9379844951319E-2dtmin = 1.9379844951319E-2nr=1
 nssd=12 y1=0.333333333 nr=1 n=2 at grid generation
     corresponding to alfa=     0.0000 degrees
 KMODE in STRTRS= 0
 KMODE IN ICRS 0
  For block  3:
     dtmin (as computed in eigenv) at cfl =  5.0 is      0.01938
 dtmin1=1.9379844951316E-2dtmin = 1.9379844951316E-2nr=1
 nssd=13 y1=0.666666666 nr=1 n=3 at grid generation
     corresponding to alfa=     0.0000 degrees
Successful completion of grid generation in STRTRS

 The flow solution will use dtmin= 0.01939 and nperiod=   108
 to give a maximum cfl close to   5.000

     Newmark constants for dt =       0.01939
    0.10636E+05    0.10313E+03    0.20626E+03    0.10000E+01    0.10000E+01
0.00000E+00   0.96963E-02   0.96963E-02
   0.10000E+01 0.00000E+00 0.00000E+00 0.34574E+00
   0.10000E+01 0.00000E+00 0.00000E+00 0.28923E+01
   0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00
   0.20093E+01 0.00000E+00 0.00000E+00 0.21609E+01
   0.10638E+05 0.00000E+00 0.00000E+00 0.36796E+04
   0.94000E-04 0.00000E+00 0.00000E+00 0.27177E-03
   0.10000E+01 0.00000E+00 0.00000E+00 0.34574E+00
   0.10000E+01 0.00000E+00 0.00000E+00 0.28923E+01
   0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00
   0.20093E+01 0.00000E+00 0.00000E+00 0.21609E+01
   0.10638E+05 0.00000E+00 0.00000E+00 0.36796E+04
   0.94000E-04 0.00000E+00 0.00000E+00 0.27177E-03
```

```
  0.10000E+01 0.00000E+00 0.00000E+00 0.34574E+00
  0.10000E+01 0.00000E+00 0.00000E+00 0.28923E+01
  0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00
  0.20093E+01 0.00000E+00 0.00000E+00 0.21609E+01
  0.10638E+05 0.00000E+00 0.00000E+00 0.36796E+04
  0.94000E-04 0.00000E+00 0.00000E+00 0.27177E-03
     finished job in routine strdat
xminb=-0.1667xmaxb=2.3667rowsep=0.2
GRID FOR ROW =2
nr =2 ile =6 ite =36chord=1.
 xleft=-0.1 xright=1.1667
 igb = -2
 calling grdunf
 entered grdunf
grid for DCA a.f. of t/c  1.E-2
    IN ROUTINE GRDUNF:STAG,SC,CHORD,X1,X4,NIF,NIB,IRUN
    0.00000     0.50000     1.00000    -0.10000     1.16670    6   36    2
 finished setting the front part
 dx at the bottom line3.3333333333333E-2
x(nif,1,1)= -4.4408920985006E-16
 finished defining bottom line
 finished defining top line
 finished defining in between
 finished the end part
 stagger angle (deg.) from input file =
                              0.0000000000
 stagger angle (deg.) from grid file =
                              0.0000000000
 stagger angle (deg.) used in the cal. =
                              0.0000000000
 gap-to-chord ratio from input file =
                              0.5000000000
 gap-to-chord ratio from grid file =
                              0.5000000000
 gap-to-chord ratio used in the calculation =
                              0.5000000000
    finished reading grid coordinates in routine RDGRID
    *** x coordinates at 0,ile,ite,last
        -0.10000     0.00000     1.00000     1.16670
         0.00000     0.00000     0.00000     0.00000
        -0.10000     0.00000     1.00000     1.16670
         0.50000     0.50000     0.50000     0.50000
 chord along the x-axis
nr, xadd(nr)= 2,  1.2
nr, yadd(nr)= 2,  0.
xminb=-0.1667xmaxb=2.3667rowsep=0.2
 before calling STRTRS
    *** x coordinates at 0,ile,ite,last
         1.10000     1.20000     2.20000     2.36670
         0.00000     0.00000     0.00000     0.00000
         1.10000     1.20000     2.20000     2.36670
         0.50000     0.50000     0.50000     0.50000
xlenth,ylenth,chord= 1.,  0.,  1.
nr, angdeg in main  = 2,  0.
 in routine STRTRS***
 height and xshift for row= 0.5,  0.,  2

Starting the initial grid calculation in STRTRS
```

```
KMODE in STRTRS= 0
KMODE IN ICRS 0
 For block  1:
    dtmin (as computed in eigenv) at cfl =  5.0 is      0.02427
dtmin1=1.9379844951316E-2dtmin = 1.9379844951316E-2nr=2
nssd=14 y1=0.5 nr=2 n=1 at grid generation
    corresponding to alfa=     0.0000 degrees
KMODE in STRTRS= 0
KMODE IN ICRS 0
 For block  2:
    dtmin (as computed in eigenv) at cfl =  5.0 is      0.01938
dtmin1=1.9379844951316E-2dtmin = 1.9379844951316E-2nr=2
nssd=15 y1=0. nr=2 n=2 at grid generation
    corresponding to alfa=     0.0000 degrees
Successful completion of grid generation in STRTRS

The flow solution will use dtmin= 0.01939 and nperiod=   108
to give a maximum cfl close to   5.000

    Newmark constants for dt =        0.01939
   0.10636E+05    0.10313E+03    0.20626E+03    0.10000E+01    0.10000E+01
0.00000E+00    0.96963E-02    0.96963E-02
  0.10000E+01 0.00000E+00 0.00000E+00 0.34574E+00
  0.10000E+01 0.00000E+00 0.00000E+00 0.28923E+01
  0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00
  0.20093E+01 0.00000E+00 0.00000E+00 0.21609E+01
  0.10638E+05 0.00000E+00 0.00000E+00 0.36796E+04
  0.94000E-04 0.00000E+00 0.00000E+00 0.27177E-03
  0.10000E+01 0.00000E+00 0.00000E+00 0.34574E+00
  0.10000E+01 0.00000E+00 0.00000E+00 0.28923E+01
  0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00
  0.20093E+01 0.00000E+00 0.00000E+00 0.21609E+01
  0.10638E+05 0.00000E+00 0.00000E+00 0.36796E+04
  0.94000E-04 0.00000E+00 0.00000E+00 0.27177E-03
     finished job in routine strdat
*** distance between t.e. to l.e. ***0.2
  axial chord      actual chord      setting angle
1.,  1.,  0.
2*1.,  0.

                        residual information

gustua = 0. gustup(degrees) = 0.
gustva = 0. gustvp(degrees) = 0.
gust parameters
 U velocity and Phase(radians)
2*0.
 V velocity and Phase(radians)
2*0.
reading input nt
ntinpt,nt,nperiod= 0,  1050,  108
 vr1, vr2, nperd2 = -0.1,  0.,  216
 height=0.333333333 ymin=-0.1666666665 ymax=1.1666666655
KMODE= 0KFFT= 0
 ile=6 ite=36 height=0.333333333
vr = 0.
   1    1  5.42991E-01  2.25000E+00 -1.33740E+01  3.46608E-14 -1.28161E+01
   2    1  5.42991E-01  2.25000E+00 -1.39812E+01 -5.88169E-15 -1.32075E+01
```

```
   3    1  5.42991E-01  2.25000E+00 -1.38873E+01  2.46427E-15 -1.35029E+01
stag in perf = 0.
x0, y0 in perf = 0.3,  0.
nr, angdeg in perf = 1,  0.
nr, coss,sins = 1,  1.,  0.
 ile=6 ite=36 height=0.5
vr = 0.
   1    1  5.42991E-01  2.25000E+00 -1.38362E+01  6.99094E-15 -1.30564E+01
   2    1  5.42991E-01  2.25000E+00 -1.33043E+01 -3.11985E-14 -1.27286E+01
stag in perf = 0.
x0, y0 in perf = 0.3,  0.
nr, angdeg in perf = 2,  0.
nr, coss,sins = 2,  1.,  0.
 ile=6 ite=36 height=0.333333333
vr = 0.
   1    2  5.62384E-01  2.25026E+00 -2.65305E+00 -6.75163E-04 -2.15285E+00
   2    2  5.62384E-01  2.25026E+00 -2.65444E+00 -6.75163E-04 -2.15368E+00
   3    2  5.62384E-01  2.25026E+00 -2.65449E+00 -6.75163E-04 -2.15372E+00
 ile=6 ite=36 height=0.5
vr = 0.
   1    2  5.62384E-01  2.25024E+00 -2.77888E+00 -4.84961E-04 -2.26819E+00
   2    2  5.62384E-01  2.25024E+00 -2.77872E+00 -4.84961E-04 -2.26810E+00
 ile=6 ite=36 height=0.333333333
vr = 0.
   1    3  5.81776E-01  2.25085E+00 -2.27478E+00 -1.70519E-03 -1.77150E+00
   2    3  5.81776E-01  2.25085E+00 -2.27464E+00 -1.70541E-03 -1.77135E+00
   3    3  5.81776E-01  2.25085E+00 -2.27470E+00 -1.70519E-03 -1.77142E+00
 ile=6 ite=36 height=0.5
vr = 0.
   1    3  5.81776E-01  2.25079E+00 -2.39831E+00 -1.26500E-03 -1.88751E+00
   2    3  5.81776E-01  2.25079E+00 -2.39832E+00 -1.26513E-03 -1.88752E+00
 ile=6 ite=36 height=0.333333333
vr = 0.
   1    4  6.01169E-01  2.25185E+00 -2.04334E+00 -2.95555E-03 -1.53553E+00
   2    4  6.01169E-01  2.25185E+00 -2.04324E+00 -2.95549E-03 -1.53546E+00
   3    4  6.01169E-01  2.25185E+00 -2.04325E+00 -2.95555E-03 -1.53547E+00
 ile=6 ite=36 height=0.5
vr = 0.
   1    4  6.01169E-01  2.25173E+00 -2.16671E+00 -2.25015E-03 -1.65423E+00
   2    4  6.01169E-01  2.25173E+00 -2.16672E+00 -2.25012E-03 -1.65424E+00
 ile=6 ite=36 height=0.333333333
vr = 0.
   1    5  6.20562E-01  2.25328E+00 -1.87719E+00 -4.37997E-03 -1.36409E+00
   2    5  6.20562E-01  2.25328E+00 -1.87715E+00 -4.37988E-03 -1.36408E+00
   3    5  6.20562E-01  2.25328E+00 -1.87715E+00 -4.37998E-03 -1.36407E+00
 ile=6 ite=36 height=0.5
vr = 0.
   1    5  6.20562E-01  2.25308E+00 -2.00396E+00 -3.48671E-03 -1.48786E+00
   2    5  6.20562E-01  2.25308E+00 -2.00397E+00 -3.48666E-03 -1.48787E+00
 ile=6 ite=36 height=0.333333333
vr = 0.
   1   80  2.07500E+00  2.48982E+00 -1.71354E+00  3.31516E-03 -1.36069E+00
   2   80  2.07500E+00  2.48982E+00 -1.71354E+00  3.31516E-03 -1.36069E+00
   3   80  2.07500E+00  2.48982E+00 -1.71354E+00  3.31516E-03 -1.36069E+00
vr = 0.
   1   80  2.07500E+00  2.43543E+00 -1.47191E+00  5.47747E-03 -1.05359E+00
   2   80  2.07500E+00  2.48068E+00 -1.47722E+00  5.51911E-03 -1.06037E+00
vr = 0.
```

```
   1   81  2.09440E+00  2.49127E+00 -1.71669E+00  3.28697E-03 -1.36510E+00
   2   81  2.09440E+00  2.49127E+00 -1.71669E+00  3.28697E-03 -1.36510E+00
   3   81  2.09440E+00  2.49127E+00 -1.71669E+00  3.28697E-03 -1.36510E+00
vr = 0.
   1   81  2.09440E+00  2.43610E+00 -1.47724E+00 -5.27637E-03 -1.06349E+00
   2   81  2.09440E+00  2.48136E+00 -1.48273E+00 -5.45300E-03 -1.07120E+00
vr = 0.
   1   82  2.11379E+00  2.49252E+00 -1.71952E+00  3.21907E-03 -1.36887E+00
   2   82  2.11379E+00  2.49252E+00 -1.71952E+00  3.21907E-03 -1.36887E+00
   3   82  2.11379E+00  2.49252E+00 -1.71952E+00  3.21907E-03 -1.36887E+00
vr = 0.
   1   82  2.11379E+00  2.43693E+00 -1.48233E+00 -5.56560E-03 -1.07222E+00
   2   82  2.11379E+00  2.48216E+00 -1.48831E+00 -5.51343E-03 -1.08102E+00
vr = 0.
   1   83  2.13318E+00  2.49357E+00 -1.72239E+00  3.14353E-03 -1.37244E+00
   2   83  2.13318E+00  2.49357E+00 -1.72239E+00  3.14353E-03 -1.37244E+00
   3   83  2.13318E+00  2.49357E+00 -1.72239E+00  3.14353E-03 -1.37244E+00
vr = 0.
   1   83  2.13318E+00  2.43759E+00 -1.48471E+00 -5.67081E-03 -1.07506E+00
   2   83  2.13318E+00  2.48303E+00 -1.49110E+00 -5.47581E-03 -1.08465E+00
vr = 0.
   1   84  2.15257E+00  2.49440E+00 -1.72491E+00  3.13654E-03 -1.37584E+00
   2   84  2.15257E+00  2.49440E+00 -1.72491E+00  3.13654E-03 -1.37584E+00
   3   84  2.15257E+00  2.49440E+00 -1.72491E+00  3.13654E-03 -1.37584E+00
vr = 0.
   1   84  2.15257E+00  2.43809E+00 -1.48355E+00 -5.62024E-03 -1.07026E+00
   2   84  2.15257E+00  2.48396E+00 -1.48949E+00 -5.40150E-03 -1.07980E+00
vr = 0.
   1   85  2.17197E+00  2.49502E+00 -1.72735E+00  3.07880E-03 -1.37922E+00
   2   85  2.17197E+00  2.49502E+00 -1.72735E+00  3.07880E-03 -1.37922E+00
   3   85  2.17197E+00  2.49502E+00 -1.72735E+00  3.07880E-03 -1.37922E+00
vr = 0.
   1   85  2.17197E+00  2.43844E+00 -1.47958E+00  5.99363E-03 -1.06027E+00
   2   85  2.17197E+00  2.48491E+00 -1.48456E+00  5.70338E-03 -1.06876E+00
vr = 0.
   1   86  2.19136E+00  2.49542E+00 -1.72959E+00  3.09561E-03 -1.38221E+00
   2   86  2.19136E+00  2.49542E+00 -1.72959E+00  3.09561E-03 -1.38221E+00
   3   86  2.19136E+00  2.49542E+00 -1.72959E+00  3.09561E-03 -1.38221E+00
vr = 0.
   1   86  2.19136E+00  2.43864E+00 -1.47496E+00  6.36630E-03 -1.04952E+00
   2   86  2.19136E+00  2.48587E+00 -1.47887E+00  6.13566E-03 -1.05658E+00
vr = 0.
   1   87  2.21075E+00  2.49562E+00 -1.73176E+00  3.09151E-03 -1.38486E+00
   2   87  2.21075E+00  2.49562E+00 -1.73176E+00  3.09151E-03 -1.38486E+00
   3   87  2.21075E+00  2.49562E+00 -1.73176E+00  3.09151E-03 -1.38486E+00
vr = 0.
   1   87  2.21075E+00  2.43870E+00 -1.47275E+00  6.59937E-03 -1.04305E+00
   2   87  2.21075E+00  2.48680E+00 -1.47540E+00  6.28392E-03 -1.04860E+00
vr = 0.
     INITIAL CONDITIONS ON BLADE      1 ROW      1
   0.00000E+00    0.00000E+00    0.00000E+00    0.00000E+00   -0.76283E-04
0.16308E-03
  -0.76283E-04   0.56385E-04
     INITIAL CONDITIONS ON BLADE      2 ROW      1
   0.00000E+00    0.00000E+00    0.00000E+00    0.00000E+00   -0.76283E-04   -
0.18183E-04
  -0.76283E-04  -0.62865E-05
     INITIAL CONDITIONS ON BLADE      3 ROW      1
```

```
   0.00000E+00    0.00000E+00    0.00000E+00    0.00000E+00   -0.76283E-04   -
0.18183E-04
  -0.76283E-04  -0.62865E-05
    done in routine struct
   1   88  2.23014E+00  2.49562E+00 -1.73400E+00  3.06536E-03 -1.38726E+00
   2   88  2.23014E+00  2.49562E+00 -1.73400E+00  3.06536E-03 -1.38726E+00
   3   88  2.23014E+00  2.49562E+00 -1.73400E+00  3.06536E-03 -1.38726E+00
 vr = 0.
    INITIAL CONDITIONS ON BLADE      1 ROW      2
   0.00000E+00    0.00000E+00    0.00000E+00    0.43633E-03    0.53680E-03
0.22252E-03
   0.53680E-03   0.76935E-04
    INITIAL CONDITIONS ON BLADE      2 ROW      2
   0.00000E+00    0.00000E+00    0.00000E+00    0.43633E-03    0.12140E-03
0.38253E-03
   0.12140E-03   0.13226E-03
    done in routine struct
   1   88  2.23014E+00  2.43858E+00 -1.47492E+00  6.54989E-03 -1.04407E+00
   2   88  2.23014E+00  2.48770E+00 -1.47646E+00  6.31099E-03 -1.04852E+00
 vr = 0.
    done in routine struct
   1   89  2.24954E+00  2.49542E+00 -1.73635E+00  3.02782E-03 -1.38956E+00
   2   89  2.24954E+00  2.49542E+00 -1.73635E+00  3.02782E-03 -1.38956E+00
   3   89  2.24954E+00  2.49542E+00 -1.73635E+00  3.02782E-03 -1.38956E+00
 vr = 0.
    done in routine struct
   1   89  2.24954E+00  2.43830E+00 -1.48207E+00  6.30121E-03 -1.05379E+00
   2   89  2.24954E+00  2.48854E+00 -1.48271E+00  6.08475E-03 -1.05738E+00
 vr = 0.
    done in routine struct
   1   90  2.26893E+00  2.49502E+00 -1.73877E+00  3.02285E-03 -1.39180E+00
   2   90  2.26893E+00  2.49502E+00 -1.73877E+00  3.02285E-03 -1.39180E+00
   3   90  2.26893E+00  2.49502E+00 -1.73877E+00  3.02285E-03 -1.39180E+00
 vr = 0.
    done in routine struct
   1   90  2.26893E+00  2.43786E+00 -1.49351E+00  5.76163E-03 -1.07136E+00
   2   90  2.26893E+00  2.48928E+00 -1.49303E+00  5.63388E-03 -1.07393E+00
 vr = 0.
    done in routine struct
   1   91  2.28832E+00  2.49443E+00 -1.74126E+00  3.02733E-03 -1.39419E+00
   2   91  2.28832E+00  2.49443E+00 -1.74126E+00  3.02733E-03 -1.39419E+00
   3   91  2.28832E+00  2.49443E+00 -1.74126E+00  3.02733E-03 -1.39419E+00
 vr = 0.
    done in routine struct
   1   91  2.28832E+00  2.43728E+00 -1.50692E+00  5.03306E-03 -1.09356E+00
   2   91  2.28832E+00  2.48988E+00 -1.50579E+00  5.11856E-03 -1.09559E+00
 vr = 0.
    done in routine struct
   1   92  2.30771E+00  2.49364E+00 -1.74394E+00  2.99485E-03 -1.39711E+00
   2   92  2.30771E+00  2.49364E+00 -1.74394E+00  2.99485E-03 -1.39711E+00
   3   92  2.30771E+00  2.49364E+00 -1.74394E+00  2.99485E-03 -1.39711E+00
 vr = 0.
    done in routine struct
   1   92  2.30771E+00  2.43657E+00 -1.51926E+00  4.80805E-03 -1.11553E+00
   2   92  2.30771E+00  2.49034E+00 -1.51760E+00 -4.48254E-03 -1.11710E+00
 vr = 0.
    done in routine struct
   1   93  2.32711E+00  2.49267E+00 -1.74679E+00  3.00898E-03 -1.40031E+00
```

```
   2    93   2.32711E+00   2.49267E+00 -1.74679E+00  3.00898E-03 -1.40031E+00
   3    93   2.32711E+00   2.49267E+00 -1.74679E+00  3.00898E-03 -1.40031E+00
vr = 0.
    done in routine struct
   1    93   2.32711E+00   2.43573E+00 -1.52742E+00  5.38496E-03 -1.13136E+00
   2    93   2.32711E+00   2.49063E+00 -1.52557E+00 -4.79710E-03 -1.13286E+00
vr = 0.
    done in routine struct
   1    94   2.34650E+00   2.49155E+00 -1.74971E+00  3.04370E-03 -1.40350E+00
   2    94   2.34650E+00   2.49155E+00 -1.74971E+00  3.04370E-03 -1.40350E+00
   3    94   2.34650E+00   2.49155E+00 -1.74971E+00  3.04370E-03 -1.40350E+00
vr = 0.
    done in routine struct
   1    94   2.34650E+00   2.43476E+00 -1.52995E+00  5.89267E-03 -1.13737E+00
   2    94   2.34650E+00   2.49077E+00 -1.52789E+00 -5.16436E-03 -1.13868E+00
vr = 0.
    done in routine struct
   1    95   2.36589E+00   2.49025E+00 -1.75291E+00  3.02198E-03 -1.40693E+00
   2    95   2.36589E+00   2.49025E+00 -1.75291E+00  3.02198E-03 -1.40693E+00
   3    95   2.36589E+00   2.49025E+00 -1.75291E+00  3.02198E-03 -1.40693E+00
vr = 0.
    done in routine struct
   1    95   2.36589E+00   2.43368E+00 -1.52708E+00  6.30691E-03 -1.13376E+00
   2    95   2.36589E+00   2.49074E+00 -1.52514E+00  5.47181E-03 -1.13485E+00
vr = 0.
    done in routine struct
   1    96   2.38528E+00   2.48878E+00 -1.75616E+00  2.95650E-03 -1.41050E+00
   2    96   2.38528E+00   2.48878E+00 -1.75616E+00  2.95650E-03 -1.41050E+00
   3    96   2.38528E+00   2.48878E+00 -1.75616E+00  2.95650E-03 -1.41050E+00
vr = 0.
    done in routine struct
   1    96   2.38528E+00   2.43252E+00 -1.52102E+00  6.60364E-03 -1.12476E+00
   2    96   2.38528E+00   2.49053E+00 -1.51932E+00  5.63225E-03 -1.12555E+00
vr = 0.
    done in routine struct
   1    97   2.40468E+00   2.48715E+00 -1.75969E+00  2.97101E-03 -1.41461E+00
   2    97   2.40468E+00   2.48715E+00 -1.75969E+00  2.97101E-03 -1.41461E+00
   3    97   2.40468E+00   2.48715E+00 -1.75969E+00  2.97101E-03 -1.41461E+00
vr = 0.
    done in routine struct
   1    97   2.40468E+00   2.43127E+00 -1.51467E+00  6.83267E-03 -1.11547E+00
   2    97   2.40468E+00   2.49013E+00 -1.51324E+00  5.86501E-03 -1.11607E+00
vr = 0.
    done in routine struct
   1    98   2.42407E+00   2.48535E+00 -1.76341E+00  2.98924E-03 -1.41919E+00
   2    98   2.42407E+00   2.48535E+00 -1.76341E+00  2.98924E-03 -1.41919E+00
   3    98   2.42407E+00   2.48535E+00 -1.76341E+00  2.98924E-03 -1.41919E+00
vr = 0.
    done in routine struct
   1    98   2.42407E+00   2.42994E+00 -1.51050E+00  6.86067E-03 -1.10992E+00
   2    98   2.42407E+00   2.48958E+00 -1.50921E+00  5.91815E-03 -1.11036E+00
vr = 0.
    done in routine struct
   1    99   2.44346E+00   2.48340E+00 -1.76728E+00  2.96835E-03 -1.42391E+00
   2    99   2.44346E+00   2.48340E+00 -1.76728E+00  2.96835E-03 -1.42391E+00
   3    99   2.44346E+00   2.48340E+00 -1.76728E+00  2.96835E-03 -1.42391E+00
vr = 0.
    done in routine struct
```

```
    1   99  2.44346E+00  2.43093E+00 -1.50986E+00  6.57929E-03 -1.11024E+00
    2   99  2.44346E+00  2.48888E+00 -1.50883E+00  5.71528E-03 -1.11090E+00
vr = 0.
     DONE IN ROUTINE CPINT
     DONE IN ROUTINE CPINT
     DONE IN ROUTINE CPINT
     DONE IN ROUTINE FORCE
     done in routine struct
    1  100  2.46285E+00  2.48129E+00 -1.77118E+00  2.97599E-03 -1.42854E+00
    2  100  2.46285E+00  2.48129E+00 -1.77118E+00  2.97599E-03 -1.42854E+00
    3  100  2.46285E+00  2.48129E+00 -1.77118E+00  2.97599E-03 -1.42854E+00
vr = 0.
     DONE IN ROUTINE CPINT
     DONE IN ROUTINE CPINT
     DONE IN ROUTINE FORCE
     done in routine struct
    1  100  2.46285E+00  2.43390E+00 -1.51303E+00  6.00801E-03 -1.11704E+00
    2  100  2.46285E+00  2.48806E+00 -1.51216E+00 -5.42729E-03 -1.11791E+00
vr = 0.
     done in routine struct
    1  101  2.48225E+00  2.47899E+00 -1.77516E+00  2.93619E-03 -1.43302E+00
    2  101  2.48225E+00  2.47899E+00 -1.77516E+00  2.93619E-03 -1.43302E+00
    3  101  2.48225E+00  2.47899E+00 -1.77516E+00  2.93619E-03 -1.43302E+00
vr = 0.
     done in routine struct
    1  101  2.48225E+00  2.43667E+00 -1.51918E+00 -5.56244E-03 -1.12882E+00
    2  101  2.48225E+00  2.48717E+00 -1.51841E+00 -5.32976E-03 -1.12977E+00
vr = 0.
     done in routine struct
    1  102  2.50164E+00  2.47653E+00 -1.77938E+00  2.93385E-03 -1.43762E+00
    2  102  2.50164E+00  2.47653E+00 -1.77938E+00  2.93385E-03 -1.43762E+00
    3  102  2.50164E+00  2.47653E+00 -1.77938E+00  2.93385E-03 -1.43762E+00
vr = 0.
     done in routine struct
    1  102  2.50164E+00  2.43921E+00 -1.52705E+00 -5.39536E-03 -1.14344E+00
    2  102  2.50164E+00  2.48614E+00 -1.52627E+00 -5.16898E-03 -1.14421E+00
vr = 0.
     done in routine struct
    1  103  2.52103E+00  2.47392E+00 -1.78378E+00  2.92603E-03 -1.44209E+00
    2  103  2.52103E+00  2.47392E+00 -1.78378E+00  2.92603E-03 -1.44209E+00
    3  103  2.52103E+00  2.47392E+00 -1.78378E+00  2.92603E-03 -1.44209E+00
vr = 0.
     done in routine struct
    1  103  2.52103E+00  2.44150E+00 -1.53506E+00 -5.19607E-03 -1.15790E+00
    2  103  2.52103E+00  2.48500E+00 -1.53399E+00 -5.03140E-03 -1.15794E+00
vr = 0.
     done in routine struct
    1  104  2.54042E+00  2.47121E+00 -1.78851E+00  2.90030E-03 -1.44665E+00
    2  104  2.54042E+00  2.47121E+00 -1.78851E+00  2.90030E-03 -1.44665E+00
    3  104  2.54042E+00  2.47121E+00 -1.78851E+00  2.90030E-03 -1.44665E+00
vr = 0.
     done in routine struct
    1  104  2.54042E+00  2.44355E+00 -1.54134E+00 -5.58714E-03 -1.16911E+00
    2  104  2.54042E+00  2.48375E+00 -1.54010E+00 -5.03716E-03 -1.16837E+00
vr = 0.
     done in routine struct
    1  105  2.55982E+00  2.46840E+00 -1.79371E+00  2.85009E-03 -1.45177E+00
    2  105  2.55982E+00  2.46840E+00 -1.79371E+00  2.85009E-03 -1.45177E+00
```

```
   3  105   2.55982E+00  2.46840E+00 -1.79371E+00  2.85009E-03 -1.45177E+00
vr = 0.
    done in routine struct
   1  105   2.55982E+00  2.44534E+00 -1.54480E+00 -5.93361E-03 -1.17517E+00
   2  105   2.55982E+00  2.48237E+00 -1.54343E+00 -5.37536E-03 -1.17351E+00
vr = 0.
    done in routine struct
   1  106   2.57921E+00  2.46550E+00 -1.79941E+00  2.79183E-03 -1.45768E+00
   2  106   2.57921E+00  2.46550E+00 -1.79941E+00  2.79183E-03 -1.45768E+00
   3  106   2.57921E+00  2.46550E+00 -1.79941E+00  2.79183E-03 -1.45768E+00
vr = 0.
    done in routine struct
   1  106   2.57921E+00  2.44687E+00 -1.54546E+00 -6.22913E-03 -1.17612E+00
   2  106   2.57921E+00  2.48069E+00 -1.54370E+00 -5.66507E-03 -1.17334E+00
vr = 0.
    done in routine struct
   1  107   2.59860E+00  2.46251E+00 -1.80560E+00  2.75780E-03 -1.46438E+00
   2  107   2.59860E+00  2.46251E+00 -1.80560E+00  2.75780E-03 -1.46438E+00
   3  107   2.59860E+00  2.46251E+00 -1.80560E+00  2.75780E-03 -1.46438E+00
vr = 0.
    done in routine struct
   1  107   2.59860E+00  2.44814E+00 -1.54405E+00 -6.41129E-03 -1.17355E+00
   2  107   2.59860E+00  2.47889E+00 -1.54186E+00 -5.91918E-03 -1.16969E+00
vr = 0.
    done in routine struct
   1  108   2.61799E+00  2.45960E+00 -1.81181E+00  2.74454E-03 -1.47129E+00
   2  108   2.61799E+00  2.45960E+00 -1.81181E+00  2.74454E-03 -1.47129E+00
   3  108   2.61799E+00  2.45960E+00 -1.81181E+00  2.74454E-03 -1.47129E+00
vr = 0.
    done in routine struct
   1  108   2.61799E+00  2.44917E+00 -1.54132E+00 -6.93965E-03 -1.16899E+00
   2  108   2.61799E+00  2.47701E+00 -1.53893E+00 -6.15672E-03 -1.16470E+00
vr = -0.1
    done in routine struct
   1  109   2.63739E+00  2.47051E+00 -1.42154E-01 -1.19899E-01  3.43187E-01
   2  109   2.63739E+00  2.47051E+00 -1.42154E-01 -1.19899E-01  3.43187E-01
   3  109   2.63739E+00  2.47051E+00 -1.42154E-01 -1.19899E-01  3.43187E-01
vr = 0.
    done in routine struct
   1  109   2.63739E+00  2.44996E+00 -1.53882E+00 -7.58596E-03 -1.16452E+00
   2  109   2.63739E+00  2.47504E+00 -1.53580E+00 -6.58476E-03 -1.15986E+00
vr = -0.1
    done in routine struct
   1  110   2.65678E+00  2.50981E+00 -1.20827E-01  1.57485E-01  3.68329E-01
   2  110   2.65678E+00  2.50981E+00 -1.20827E-01  1.57485E-01  3.68329E-01
   3  110   2.65678E+00  2.50981E+00 -1.20827E-01  1.57485E-01  3.68329E-01
vr = 0.
    done in routine struct
   1  110   2.65678E+00  2.45053E+00 -1.53141E+00  9.72239E-03 -1.15285E+00
   2  110   2.65678E+00  2.47302E+00 -1.53408E+00  7.79612E-03 -1.15656E+00
   1 1000   1.99161E+01  2.56178E+00 -4.26574E+00 -7.33954E-05 -3.66298E+00
   2 1000   1.99161E+01  2.56178E+00 -4.26574E+00 -7.33954E-05 -3.66298E+00
   3 1000   1.99161E+01  2.56178E+00 -4.26574E+00 -7.33954E-05 -3.66298E+00
vr = 0.
    DONE IN ROUTINE CPINT
    DONE IN ROUTINE CPINT
    DONE IN ROUTINE FORCE
    done in routine struct
```

```
   1 1000  1.99161E+01  3.07773E+00 -1.35502E+00 -1.27887E-02 -9.36101E-01
   2 1000  1.99161E+01  3.06714E+00 -1.34347E+00 -1.27552E-02 -9.26568E-01
vr = -0.1
    done in routine struct
   1 1050  2.08858E+01  2.56178E+00 -4.34146E+00  8.32938E-05 -3.64260E+00
   2 1050  2.08858E+01  2.56178E+00 -4.34146E+00  8.32938E-05 -3.64260E+00
   3 1050  2.08858E+01  2.56178E+00 -4.34146E+00  8.32938E-05 -3.64260E+00
vr = 0.
    done in routine struct
   1 1050  2.08858E+01  3.09765E+00 -1.36790E+00 -1.27276E-02 -9.49860E-01
   2 1050  2.08858E+01  3.06630E+00 -1.35823E+00 -1.24631E-02 -9.35077E-01
 nrow1 nrow2 =1,  2
 h0,alfa0,nr =2*0.,  1
value of L in pvar= 1
xlenth,ylenth,chord= 1.,  0.,  1.
```

Surface Mach Number, Isentropic Mach Number and CP; block = 2 and ncyc = 1050

x/c	machu	imachu	cpu	x/c	machl	imachl	cpl
-0.1334	1.5000	1.5000	0.0000	-0.1334	1.5000	1.5000	0.0000
-0.1000	1.5000	1.5000	0.0000	-0.1000	1.5000	1.5000	0.0000
-0.0667	1.5000	1.5000	0.0000	-0.0667	1.5000	1.5000	0.0000
-0.0333	1.5000	1.5000	0.0000	-0.0333	1.5000	1.5000	0.0000
0.0000	1.5000	1.5000	0.0000	0.0000	1.5000	1.5000	0.0000
0.0333	1.5631	1.5751	0.0660	0.0333	1.3552	1.3449	-0.1560
0.0667	1.5670	1.5944	0.0820	0.0667	1.3747	1.3353	-0.1667
0.1000	1.5655	1.5959	0.0832	0.1000	1.3744	1.3313	-0.1710
0.1333	1.5682	1.5999	0.0864	0.1333	1.3770	1.3356	-0.1663
0.1667	1.5697	1.6016	0.0878	0.1667	1.3836	1.3434	-0.1577
0.2000	1.5701	1.6025	0.0886	0.2000	1.3823	1.3416	-0.1596
0.2333	1.5724	1.6064	0.0917	0.2333	1.3819	1.3420	-0.1592
0.2667	1.5791	1.6160	0.0994	0.2667	1.3860	1.3488	-0.1518
0.3000	1.5804	1.6149	0.0986	0.3000	1.4011	1.3698	-0.1292
0.3333	1.5497	1.5584	0.0518	0.3333	1.4249	1.4028	-0.0946
0.3667	1.4587	1.4374	-0.0597	0.3667	1.4545	1.4438	-0.0534
0.4000	1.3749	1.3334	-0.1687	0.4000	1.4853	1.4867	-0.0124
0.4333	1.3451	1.2921	-0.2154	0.4333	1.5115	1.5233	0.0211
0.4667	1.3515	1.2991	-0.2074	0.4667	1.5313	1.5505	0.0451
0.5000	1.3605	1.3100	-0.1949	0.5000	1.5391	1.5616	0.0546
0.5333	1.3699	1.3223	-0.1811	0.5333	1.5439	1.5696	0.0613
0.5667	1.3816	1.3377	-0.1640	0.5667	1.5495	1.5812	0.0711
0.6000	1.3974	1.3587	-0.1411	0.6000	1.5694	1.6041	0.0899
0.6333	1.4169	1.3847	-0.1135	0.6333	1.5696	1.6051	0.0906
0.6667	1.4387	1.4143	-0.0829	0.6667	1.5411	1.5516	0.0460
0.7000	1.4619	1.4464	-0.0509	0.7000	1.4594	1.4440	-0.0532
0.7333	1.4856	1.4795	-0.0191	0.7333	1.3844	1.3522	-0.1482
0.7667	1.5076	1.5106	0.0096	0.7667	1.3553	1.3145	-0.1898
0.8000	1.5263	1.5373	0.0335	0.8000	1.3641	1.3263	-0.1765
0.8333	1.5404	1.5578	0.0514	0.8333	1.3805	1.3472	-0.1535
0.8667	1.5510	1.5739	0.0650	0.8667	1.3972	1.3695	-0.1295
0.9000	1.5630	1.5926	0.0805	0.9000	1.4133	1.3912	-0.1067
0.9333	1.5775	1.6150	0.0986	0.9333	1.4296	1.4134	-0.0838
0.9667	1.5983	1.6433	0.1208	0.9667	1.4458	1.4360	-0.0611
1.0000	1.5889	1.6265	0.1077	1.0000	1.4635	1.4610	-0.0367
1.0200	1.4923	1.5062	0.0056	1.0200	1.4891	1.5062	0.0056
1.0400	1.4783	1.4696	-0.0285	1.0400	1.4637	1.4696	-0.0285
1.0600	1.4658	1.4453	-0.0520	1.0600	1.4449	1.4453	-0.0520
1.0800	1.4528	1.4280	-0.0691	1.0800	1.4352	1.4280	-0.0691
1.1000	1.4539	1.4317	-0.0654	1.1000	1.4469	1.4317	-0.0654

******** inlet conditions ********

j	u	v	mach	angle	p/pt
2	1.500	0.000	1.500	0.000	0.2724
3	1.500	0.000	1.500	0.000	0.2724
4	1.500	0.000	1.500	0.000	0.2724
5	1.500	0.000	1.500	0.000	0.2724
6	1.500	0.000	1.500	0.000	0.2724
7	1.500	0.000	1.500	0.000	0.2724
8	1.500	0.000	1.500	0.000	0.2724
9	1.500	0.000	1.500	0.000	0.2724
10	1.500	0.000	1.500	0.000	0.2724
11	1.500	0.000	1.500	0.000	0.2724
12	1.500	0.000	1.500	0.000	0.2724
13	1.500	0.000	1.500	0.000	0.2724
14	1.500	0.000	1.500	0.000	0.2724
15	1.500	0.000	1.500	0.000	0.2724
16	1.500	0.000	1.500	0.000	0.2724
17	1.500	0.000	1.500	0.000	0.2724
18	1.500	0.000	1.500	0.000	0.2724
19	1.500	0.000	1.500	0.000	0.2724
20	1.500	0.000	1.500	0.000	0.2724
21	1.500	0.000	1.500	0.000	0.2724
22	1.500	0.000	1.500	0.000	0.2724
23	1.500	0.000	1.500	0.000	0.2724
24	1.500	0.000	1.500	0.000	0.2724
25	1.500	0.000	1.500	0.000	0.2724
26	1.500	0.000	1.500	0.000	0.2724
27	1.500	0.000	1.500	0.000	0.2724
28	1.500	0.000	1.500	0.000	0.2724
29	1.500	0.000	1.500	0.000	0.2724
30	1.500	0.000	1.500	0.000	0.2724
31	1.500	0.000	1.500	0.000	0.2724
32	1.500	0.000	1.500	0.000	0.2724
33	1.500	0.000	1.500	0.000	0.2724
34	1.500	0.000	1.500	0.000	0.2724
35	1.500	0.000	1.500	0.000	0.2724
36	1.500	0.000	1.500	0.000	0.2724
37	1.500	0.000	1.500	0.000	0.2724
38	1.500	0.000	1.500	0.000	0.2724
39	1.500	0.000	1.500	0.000	0.2724
40	1.500	0.000	1.500	0.000	0.2724
41	1.500	0.000	1.500	0.000	0.2724

The average inlet Mach number is: 1.5000

******** exit conditions ********

j	u	v	mach	angle	p/pt
2	1.446	-0.157	1.383	-6.180	0.3012
3	1.447	-0.155	1.380	-6.122	0.3031
4	1.445	-0.150	1.375	-5.913	0.3043
5	1.445	-0.145	1.372	-5.730	0.3050
6	1.445	-0.139	1.371	-5.500	0.3052
7	1.447	-0.136	1.376	-5.379	0.3039
8	1.450	-0.135	1.383	-5.324	0.3021
9	1.456	-0.137	1.397	-5.372	0.2987

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 10  1.466 -0.143  1.420 -5.566  0.2929
 11  1.478 -0.153  1.451 -5.895  0.2854
 12  1.493 -0.167  1.491 -6.367  0.2765
 13  1.506 -0.180  1.527 -6.817  0.2688
 14  1.516 -0.189  1.556 -7.107  0.2628
 15  1.523 -0.192  1.575 -7.201  0.2587
 16  1.529 -0.194  1.591 -7.223  0.2557
 17  1.531 -0.191  1.595 -7.121  0.2549
 18  1.531 -0.188  1.596 -6.990  0.2546
 19  1.531 -0.183  1.593 -6.824  0.2549
 20  1.530 -0.178  1.590 -6.630  0.2554
 21  1.529 -0.172  1.588 -6.425  0.2559
 22  1.529 -0.167  1.585 -6.221  0.2564
 23  1.528 -0.161  1.583 -6.028  0.2566
 24  1.528 -0.156  1.583 -5.836  0.2567
 25  1.529 -0.151  1.583 -5.648  0.2566
 26  1.530 -0.146  1.584 -5.467  0.2563
 27  1.530 -0.142  1.585 -5.295  0.2561
 28  1.530 -0.138  1.585 -5.137  0.2559
 29  1.530 -0.134  1.585 -5.002  0.2560
 30  1.530 -0.131  1.582 -4.894  0.2566
 31  1.528 -0.128  1.577 -4.805  0.2575
 32  1.523 -0.128  1.564 -4.819  0.2602
 33  1.518 -0.129  1.549 -4.872  0.2632
 34  1.510 -0.134  1.530 -5.073  0.2674
 35  1.500 -0.141  1.507 -5.375  0.2725
 36  1.490 -0.149  1.481 -5.707  0.2784
 37  1.479 -0.155  1.455 -5.971  0.2845
 38  1.470 -0.159  1.434 -6.163  0.2895
 39  1.462 -0.160  1.416 -6.253  0.2938
 40  1.453 -0.161  1.401 -6.320  0.2966
 41  1.446 -0.157  1.386 -6.214  0.2997

The average exit Mach number is:     1.5042
 h0,alfa0,nr =2*0.,  2
value of L in pvar= 1
xlenth,ylenth,chord= 1.,  0.,  1.

Surface Mach Number, Isentropic Mach Number and CP; block =  1 and ncyc =  1050
   x/c          machu     imachu        cpu     x/c         machl     imachl        cpl
   1.1200      1.4657     1.4448    -0.0524    1.1200      1.5468     1.5529     0.0471
   1.1400      1.4713     1.4513    -0.0461    1.1400      1.5608     1.5613     0.0543
   1.1600      1.4778     1.4605    -0.0372    1.1600      1.5679     1.5560     0.0498
   1.1800      1.4865     1.4716    -0.0266    1.1800      1.5398     1.5315     0.0285
   1.2000      1.4953     1.4833    -0.0155    1.2000      1.5088     1.5109     0.0100
   1.2333      1.2296     1.2581    -0.2552    1.2333      1.5470     1.5606     0.0537
   1.2667      1.2861     1.2538    -0.2604    1.2667      1.5493     1.5891     0.0776
   1.3000      1.3071     1.2786    -0.2311    1.3000      1.5652     1.6149     0.0986
   1.3333      1.3257     1.3006    -0.2056    1.3333      1.5839     1.6360     0.1151
   1.3667      1.3351     1.3112    -0.1936    1.3667      1.5983     1.6531     0.1282
   1.4000      1.3289     1.2995    -0.2069    1.4000      1.6121     1.6725     0.1427
   1.4333      1.2948     1.2565    -0.2571    1.4333      1.6294     1.6965     0.1602
   1.4667      1.2629     1.2179    -0.3040    1.4667      1.6590     1.7337     0.1862
   1.5000      1.2594     1.2107    -0.3130    1.5000      1.6757     1.7497     0.1969
   1.5333      1.2717     1.2265    -0.2934    1.5333      1.6710     1.7373     0.1886
   1.5667      1.2940     1.2560    -0.2577    1.5667      1.6430     1.7002     0.1629
   1.6000      1.3193     1.2896    -0.2182    1.6000      1.6105     1.6661     0.1380
   1.6333      1.3482     1.3270    -0.1758    1.6333      1.6021     1.6598     0.1333
```

1.6667	1.3788	1.3666	-0.1326	1.6667	1.6039	1.6496	0.1256
1.7000	1.4102	1.4075	-0.0898	1.7000	1.5521	1.5539	0.0480
1.7333	1.4411	1.4480	-0.0493	1.7333	1.4010	1.3831	-0.1151
1.7667	1.4703	1.4871	-0.0119	1.7667	1.3211	1.2755	-0.2347
1.8000	1.4974	1.5241	0.0219	1.8000	1.3191	1.2677	-0.2438
1.8333	1.5226	1.5589	0.0523	1.8333	1.3280	1.2791	-0.2304
1.8667	1.5460	1.5915	0.0796	1.8667	1.3425	1.2902	-0.2175
1.9000	1.5688	1.6227	0.1047	1.9000	1.3347	1.2781	-0.2316
1.9333	1.5915	1.6540	0.1289	1.9333	1.3239	1.2623	-0.2502
1.9667	1.6137	1.6838	0.1510	1.9667	1.3196	1.2567	-0.2569
2.0000	1.6409	1.7173	0.1749	2.0000	1.3249	1.2649	-0.2472
2.0333	1.6503	1.7274	0.1819	2.0333	1.3412	1.2880	-0.2201
2.0667	1.6461	1.7211	0.1775	2.0667	1.3617	1.3179	-0.1860
2.1000	1.6355	1.7055	0.1666	2.1000	1.3824	1.3498	-0.1508
2.1333	1.6237	1.6970	0.1606	2.1333	1.4027	1.3813	-0.1170
2.1667	1.6218	1.6947	0.1589	2.1667	1.4241	1.4142	-0.0830
2.2000	1.6099	1.6681	0.1395	2.2000	1.4361	1.4347	-0.0624
2.2333	1.4807	1.4907	-0.0086	2.2333	1.4905	1.5196	0.0178
2.2667	1.4286	1.4150	-0.0822	2.2667	1.4040	1.4200	-0.0772
2.3000	1.4002	1.3882	-0.1098	2.3000	1.3571	1.3711	-0.1278
2.3334	1.4043	1.3955	-0.1022	2.3334	1.3839	1.3772	-0.1213
2.3667	1.4273	1.4235	-0.0736	2.3667	1.4154	1.4135	-0.0837

******** inlet conditions ********

j	u	v	mach	angle	p/pt
2	1.450	-0.161	1.396	-6.319	0.2975
3	1.449	-0.158	1.388	-6.214	0.3001
4	1.449	-0.152	1.383	-5.982	0.3021
5	1.449	-0.144	1.381	-5.660	0.3028
6	1.450	-0.136	1.382	-5.379	0.3025
7	1.453	-0.133	1.389	-5.241	0.3007
8	1.462	-0.136	1.409	-5.324	0.2957
9	1.476	-0.147	1.446	-5.699	0.2867
10	1.495	-0.166	1.497	-6.317	0.2750
11	1.513	-0.181	1.547	-6.824	0.2645
12	1.527	-0.189	1.584	-7.069	0.2570
13	1.533	-0.189	1.599	-7.035	0.2540
14	1.534	-0.184	1.602	-6.843	0.2533
15	1.532	-0.177	1.598	-6.597	0.2539
16	1.532	-0.169	1.594	-6.284	0.2546
17	1.531	-0.160	1.591	-5.968	0.2551
18	1.531	-0.152	1.590	-5.677	0.2552
19	1.532	-0.145	1.590	-5.412	0.2551
20	1.532	-0.139	1.589	-5.190	0.2552
21	1.531	-0.135	1.586	-5.033	0.2558
22	1.527	-0.132	1.576	-4.953	0.2577
23	1.519	-0.134	1.555	-5.039	0.2621
24	1.508	-0.140	1.525	-5.293	0.2685
25	1.493	-0.150	1.490	-5.731	0.2765
26	1.478	-0.159	1.454	-6.130	0.2847
27	1.467	-0.163	1.427	-6.343	0.2912
28	1.456	-0.163	1.407	-6.408	0.2954
29	1.448	-0.159	1.391	-6.281	0.2989
30	1.449	-0.156	1.386	-6.156	0.3012
31	1.449	-0.149	1.382	-5.873	0.3025
32	1.449	-0.141	1.380	-5.542	0.3030
33	1.450	-0.135	1.383	-5.316	0.3021

34	1.455	-0.134	1.394	-5.248	0.2994
35	1.466	-0.139	1.419	-5.409	0.2933
36	1.482	-0.153	1.462	-5.897	0.2828
37	1.501	-0.172	1.514	-6.518	0.2712
38	1.518	-0.184	1.560	-6.922	0.2618
39	1.529	-0.190	1.591	-7.086	0.2556
40	1.534	-0.188	1.602	-6.992	0.2534
41	1.533	-0.182	1.600	-6.770	0.2536

The average inlet Mach number is: 1.4910

******** exit conditions ********

j	u	v	mach	angle	p/pt
2	1.433	-0.082	1.359	-3.255	0.3040
3	1.441	-0.076	1.366	-3.023	0.3043
4	1.440	-0.071	1.361	-2.833	0.3059
5	1.439	-0.066	1.354	-2.630	0.3082
6	1.437	-0.062	1.348	-2.460	0.3101
7	1.434	-0.057	1.343	-2.283	0.3111
8	1.436	-0.057	1.345	-2.265	0.3109
9	1.435	-0.058	1.345	-2.329	0.3106
10	1.441	-0.063	1.357	-2.485	0.3076
11	1.451	-0.072	1.379	-2.839	0.3020
12	1.464	-0.085	1.411	-3.323	0.2941
13	1.482	-0.102	1.454	-3.930	0.2843
14	1.498	-0.117	1.494	-4.463	0.2753
15	1.510	-0.127	1.526	-4.812	0.2685
16	1.518	-0.132	1.549	-4.981	0.2636
17	1.525	-0.134	1.567	-5.023	0.2599
18	1.530	-0.134	1.582	-4.990	0.2568
19	1.535	-0.132	1.595	-4.924	0.2541
20	1.540	-0.130	1.608	-4.841	0.2515
21	1.546	-0.128	1.623	-4.740	0.2488
22	1.552	-0.125	1.638	-4.609	0.2460
23	1.557	-0.121	1.652	-4.447	0.2434
24	1.562	-0.117	1.664	-4.270	0.2414
25	1.564	-0.111	1.671	-4.076	0.2400
26	1.565	-0.106	1.674	-3.889	0.2393
27	1.566	-0.102	1.674	-3.724	0.2394
28	1.564	-0.098	1.668	-3.577	0.2404
29	1.558	-0.095	1.652	-3.497	0.2432
30	1.549	-0.093	1.627	-3.454	0.2477
31	1.538	-0.095	1.598	-3.551	0.2533
32	1.525	-0.102	1.564	-3.814	0.2602
33	1.509	-0.111	1.525	-4.209	0.2681
34	1.492	-0.119	1.484	-4.580	0.2771
35	1.476	-0.125	1.444	-4.823	0.2864
36	1.463	-0.127	1.415	-4.965	0.2938
37	1.454	-0.127	1.393	-5.004	0.2991
38	1.450	-0.125	1.381	-4.940	0.3025
39	1.445	-0.120	1.369	-4.729	0.3055
40	1.435	-0.112	1.356	-4.450	0.3069
41	1.424	-0.100	1.341	-4.018	0.3085

The average exit Mach number is: 1.4940
xlenth,ylenth,chord= 1., 0., 1.

Surface Mach Number, Isentropic Mach Number and CP; block = 2 and ncyc = 1050

x/c	machu	imachu	cpu	x/c	machl	imachl	cpl
1.1200	1.5474	1.5529	0.0471	1.1200	1.4599	1.4449	-0.0524
1.1400	1.5502	1.5609	0.0540	1.1400	1.4689	1.4513	-0.0461
1.1600	1.5410	1.5554	0.0493	1.1600	1.4775	1.4604	-0.0372
1.1800	1.5129	1.5315	0.0284	1.1800	1.4867	1.4716	-0.0266
1.2000	1.4952	1.5112	0.0102	1.2000	1.4951	1.4833	-0.0155
1.2333	1.3168	1.3335	-0.1686	1.2333	1.6099	1.6275	0.1085
1.2667	1.2920	1.2430	-0.2733	1.2667	1.6370	1.6990	0.1620
1.3000	1.2628	1.1929	-0.3351	1.3000	1.6616	1.7465	0.1948
1.3333	1.2608	1.1916	-0.3368	1.3333	1.6642	1.7416	0.1915
1.3667	1.2789	1.2143	-0.3084	1.3667	1.6364	1.7010	0.1635
1.4000	1.3041	1.2471	-0.2684	1.4000	1.5872	1.6474	0.1239
1.4333	1.3249	1.2752	-0.2350	1.4333	1.5575	1.6186	0.1015
1.4667	1.3411	1.2970	-0.2097	1.4667	1.5578	1.6213	0.1036
1.5000	1.3529	1.3119	-0.1927	1.5000	1.5670	1.6347	0.1141
1.5333	1.3521	1.3129	-0.1916	1.5333	1.5781	1.6507	0.1264
1.5667	1.3501	1.3106	-0.1943	1.5667	1.5895	1.6678	0.1393
1.6000	1.3530	1.3149	-0.1893	1.6000	1.6026	1.6883	0.1543
1.6333	1.3684	1.3324	-0.1698	1.6333	1.6218	1.7176	0.1751
1.6667	1.3922	1.3619	-0.1376	1.6667	1.6553	1.7505	0.1975
1.7000	1.4213	1.3997	-0.0978	1.7000	1.6453	1.7108	0.1704
1.7333	1.4532	1.4437	-0.0536	1.7333	1.5028	1.5069	0.0063
1.7667	1.4830	1.4864	-0.0126	1.7667	1.2589	1.2497	-0.2653
1.8000	1.5083	1.5252	0.0228	1.8000	1.2074	1.1675	-0.3676
1.8333	1.5282	1.5576	0.0511	1.8333	1.2375	1.1980	-0.3288
1.8667	1.5423	1.5821	0.0719	1.8667	1.2666	1.2315	-0.2873
1.9000	1.5508	1.5985	0.0853	1.9000	1.2890	1.2592	-0.2539
1.9333	1.5547	1.6082	0.0932	1.9333	1.3084	1.2826	-0.2264
1.9667	1.5572	1.6149	0.0985	1.9667	1.3259	1.3035	-0.2023
2.0000	1.5613	1.6220	0.1041	2.0000	1.3420	1.3232	-0.1801
2.0333	1.5681	1.6314	0.1116	2.0333	1.3577	1.3425	-0.1587
2.0667	1.5769	1.6431	0.1206	2.0667	1.3738	1.3625	-0.1370
2.1000	1.5888	1.6597	0.1332	2.1000	1.3909	1.3838	-0.1144
2.1333	1.6033	1.6812	0.1492	2.1333	1.4089	1.4063	-0.0910
2.1667	1.6392	1.7245	0.1799	2.1667	1.4283	1.4305	-0.0666
2.2000	1.6428	1.7168	0.1745	2.2000	1.4446	1.4526	-0.0449
2.2333	1.5110	1.5195	0.0177	2.2333	1.4656	1.4908	-0.0085
2.2667	1.4313	1.4200	-0.0771	2.2667	1.4056	1.4150	-0.0822
2.3000	1.3869	1.3711	-0.1278	2.3000	1.3834	1.3882	-0.1098
2.3334	1.3902	1.3772	-0.1213	2.3334	1.4027	1.3955	-0.1022
2.3667	1.4173	1.4135	-0.0837	2.3667	1.4276	1.4235	-0.0736

******** inlet conditions ********

j	u	v	mach	angle	p/pt
2	1.533	-0.175	1.597	-6.525	0.2541
3	1.532	-0.166	1.594	-6.189	0.2547
4	1.531	-0.158	1.591	-5.876	0.2551
5	1.532	-0.150	1.590	-5.586	0.2552
6	1.532	-0.143	1.590	-5.333	0.2551
7	1.531	-0.138	1.588	-5.131	0.2554
8	1.530	-0.134	1.583	-4.990	0.2563
9	1.525	-0.132	1.570	-4.964	0.2589
10	1.516	-0.135	1.546	-5.096	0.2640
11	1.503	-0.143	1.514	-5.428	0.2710
12	1.488	-0.153	1.477	-5.883	0.2793
13	1.474	-0.161	1.444	-6.223	0.2871

14	1.463	-0.163	1.419	-6.365	0.2930
15	1.452	-0.162	1.400	-6.377	0.2967
16	1.448	-0.158	1.389	-6.244	0.2995
17	1.449	-0.154	1.385	-6.080	0.3018
18	1.449	-0.146	1.382	-5.773	0.3026
19	1.449	-0.138	1.381	-5.449	0.3028
20	1.451	-0.134	1.385	-5.264	0.3016
21	1.458	-0.135	1.401	-5.272	0.2977
22	1.470	-0.142	1.431	-5.533	0.2902
23	1.488	-0.159	1.480	-6.106	0.2788
24	1.508	-0.177	1.531	-6.693	0.2676
25	1.523	-0.187	1.573	-7.006	0.2592
26	1.531	-0.190	1.595	-7.062	0.2547
27	1.534	-0.186	1.602	-6.922	0.2533
28	1.533	-0.180	1.599	-6.688	0.2537
29	1.532	-0.172	1.595	-6.390	0.2544
30	1.531	-0.163	1.592	-6.070	0.2550
31	1.531	-0.155	1.590	-5.771	0.2552
32	1.532	-0.147	1.590	-5.497	0.2552
33	1.532	-0.141	1.590	-5.258	0.2551
34	1.531	-0.136	1.587	-5.082	0.2555
35	1.529	-0.133	1.580	-4.962	0.2569
36	1.522	-0.133	1.563	-4.997	0.2605
37	1.512	-0.137	1.536	-5.181	0.2662
38	1.498	-0.146	1.502	-5.575	0.2737
39	1.483	-0.156	1.466	-6.016	0.2820
40	1.471	-0.162	1.436	-6.297	0.2891
41	1.460	-0.163	1.413	-6.364	0.2944

The average inlet Mach number is: 1.5169

******** exit conditions ********

j	u	v	mach	angle	p/pt
2	1.427	-0.096	1.344	-3.841	0.3081
3	1.440	-0.088	1.358	-3.484	0.3072
4	1.443	-0.081	1.358	-3.194	0.3083
5	1.441	-0.072	1.352	-2.881	0.3099
6	1.439	-0.064	1.349	-2.546	0.3105
7	1.438	-0.055	1.348	-2.183	0.3106
8	1.440	-0.052	1.353	-2.082	0.3090
9	1.446	-0.053	1.364	-2.101	0.3064
10	1.456	-0.059	1.388	-2.313	0.3002
11	1.471	-0.070	1.424	-2.724	0.2911
12	1.490	-0.088	1.473	-3.381	0.2798
13	1.506	-0.107	1.518	-4.051	0.2694
14	1.520	-0.119	1.558	-4.477	0.2610
15	1.530	-0.125	1.586	-4.661	0.2552
16	1.537	-0.126	1.606	-4.695	0.2513
17	1.540	-0.124	1.614	-4.595	0.2497
18	1.541	-0.119	1.617	-4.427	0.2489
19	1.541	-0.113	1.616	-4.205	0.2488
20	1.540	-0.107	1.614	-3.965	0.2489
21	1.539	-0.100	1.613	-3.715	0.2492
22	1.538	-0.093	1.611	-3.469	0.2494
23	1.538	-0.087	1.610	-3.232	0.2495
24	1.538	-0.081	1.610	-3.013	0.2496
25	1.539	-0.076	1.609	-2.818	0.2497

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  26  1.539 -0.071  1.608 -2.655  0.2502
  27  1.539 -0.068  1.604 -2.532  0.2511
  28  1.536 -0.067  1.596 -2.482  0.2529
  29  1.531 -0.066  1.581 -2.475  0.2559
  30  1.524 -0.068  1.562 -2.553  0.2596
  31  1.514 -0.073  1.538 -2.773  0.2645
  32  1.502 -0.081  1.510 -3.106  0.2702
  33  1.489 -0.090  1.480 -3.464  0.2768
  34  1.476 -0.097  1.448 -3.757  0.2843
  35  1.465 -0.101  1.423 -3.936  0.2902
  36  1.457 -0.103  1.404 -4.054  0.2948
  37  1.451 -0.103  1.391 -4.069  0.2981
  38  1.447 -0.101  1.382 -4.004  0.3002
  39  1.442 -0.097  1.372 -3.852  0.3022
  40  1.436 -0.092  1.365 -3.648  0.3027
  41  1.431 -0.084  1.357 -3.355  0.3039

 The average exit Mach number is:    1.4878

  done outputting binary grid file***
 ** finished writing binary flow file ***

  block  1 of row  1 written on unit  9 ncyc =    1050
  block  2 of row  1 written on unit  9 ncyc =    1050
  block  3 of row  1 written on unit  9 ncyc =    1050

  block  1 of row  2 written on unit  9 ncyc =    1050
  block  2 of row  2 written on unit  9 ncyc =    1050

Job Accounting - Summary Report
===============================

Operating System                : sn1030 lercymp 8.0.2.3 8.0.14 CRAY Y-MP
User CPU Time                   :          447.1922 Seconds
System CPU Time                 :          244.9529 Seconds
Maximum memory used             :            2.6094 MWords
```

Additional Outputs of Interest:

(1) FORT.50+i, i =1,nbs. A series of output files are produced giving the time history of pitching and plunging motion for each blade for both the rows. Each file has seven columns, which are index, plunging displacement, pitching displacement, unsteady lift, unsteady moment, total lift and total moment.

FORT.51 output:

For blade 1 of the first row (rotor in this case), the variation of pitching amplitude is given in the third column. Only selected output is shown for brevity.

88	0.0000000E+00	0.0000000E+00	-0.7628305E-04	0.5638474E-04	-0.7628305E-04	0.5638474E-04
89	0.0000000E+00	0.1551608E-07	-0.7777890E-04	-0.8207072E-05	-0.7777890E-04	-0.8207072E-05
90	0.0000000E+00	0.4667623E-07	-0.7878274E-04	-0.9744856E-05	-0.7878274E-04	-0.9744856E-05

91	0.0000000E+00	0.7782991E-07	-0.8062464E-04	-0.1156687E-04	-0.8062464E-04	-0.1156687E-04
92	0.0000000E+00	0.1086667E-06	-0.8376576E-04	-0.1396367E-04	-0.8376576E-04	-0.1396367E-04
93	0.0000000E+00	0.1390884E-06	-0.8743256E-04	-0.1661992E-04	-0.8743256E-04	-0.1661992E-04
94	0.0000000E+00	0.1689918E-06	-0.9052533E-04	-0.1902701E-04	-0.9052533E-04	-0.1902701E-04
95	0.0000000E+00	0.1982722E-06	-0.9259275E-04	-0.2095757E-04	-0.9259275E-04	-0.2095757E-04
96	0.0000000E+00	0.2268287E-06	-0.9384496E-04	-0.2251892E-04	-0.9384496E-04	-0.2251892E-04
97	0.0000000E+00	0.2545675E-06	-0.9497480E-04	-0.2404019E-04	-0.9497480E-04	-0.2404019E-04
98	0.0000000E+00	0.2814010E-06	-0.9674220E-04	-0.2583238E-04	-0.9674220E-04	-0.2583238E-04
99	0.0000000E+00	0.3072443E-06	-0.9939801E-04	-0.2801743E-04	-0.9939801E-04	-0.2801743E-04
100	0.0000000E+00	0.3320118E-06	-0.1025328E-03	-0.3044098E-04	-0.1025328E-03	-0.3044098E-04
101	0.0000000E+00	0.3556161E-06	-0.1056900E-03	-0.3290217E-04	-0.1056900E-03	-0.3290217E-04
102	0.0000000E+00	0.3779693E-06	-0.1086746E-03	-0.3529000E-04	-0.1086746E-03	-0.3529000E-04
103	0.0000000E+00	0.3989856E-06	-0.1112290E-03	-0.3741756E-04	-0.1112290E-03	-0.3741756E-04
104	0.0000000E+00	0.4185838E-06	-0.1131066E-03	-0.3909991E-04	-0.1131066E-03	-0.3909991E-04
105	0.0000000E+00	0.4366893E-06	-0.1142945E-03	-0.4031191E-04	-0.1142945E-03	-0.4031191E-04
106	0.0000000E+00	0.4532368E-06	-0.1148179E-03	-0.4112230E-04	-0.1148179E-03	-0.4112230E-04
107	0.0000000E+00	0.4681707E-06	-0.1149383E-03	-0.4173110E-04	-0.1149383E-03	-0.4173110E-04
108	0.0000000E+00	0.4814440E-06	-0.1149227E-03	-0.4229147E-04	-0.1149227E-03	-0.4229147E-04
109	0.0000000E+00	0.4930168E-06	-0.1145971E-03	-0.4267434E-04	-0.1145971E-03	-0.4267434E-04
110	0.0000000E+00	0.5028546E-06	0.5466811E-01	0.1107317E-01	0.5466811E-01	0.1107317E-01
111	0.0000000E+00	0.5488710E-06	0.1540125E+00	0.3136893E-01	0.1540125E+00	0.3136893E-01
112	0.0000000E+00	0.7761130E-06	0.2162303E+00	0.4420170E-01	0.2162303E+00	0.4420170E-01
113	0.0000000E+00	0.1404338E-05	0.2288554E+00	0.4671193E-01	0.2288554E+00	0.4671193E-01
114	0.0000000E+00	0.2597516E-05	0.2131871E+00	0.4317704E-01	0.2131871E+00	0.4317704E-01
115	0.0000000E+00	0.4401715E-05	0.1926790E+00	0.3850215E-01	0.1926790E+00	0.3850215E-01
116	0.0000000E+00	0.6781178E-05	0.1781882E+00	0.3509126E-01	0.1781882E+00	0.3509126E-01
117	0.0000000E+00	0.9674695E-05	0.1732998E+00	0.3384262E-01	0.1732998E+00	0.3384262E-01
118	0.0000000E+00	0.1303197E-04	0.1753820E+00	0.3413682E-01	0.1753820E+00	0.3413682E-01
119	0.0000000E+00	0.1682594E-04	0.1801430E+00	0.3493088E-01	0.1801430E+00	0.3493088E-01
120	0.0000000E+00	0.2104817E-04	0.1833084E+00	0.3517351E-01	0.1833084E+00	0.3517351E-01
121	0.0000000E+00	0.2569598E-04	0.1825913E+00	0.3427381E-01	0.1825913E+00	0.3427381E-01
122	0.0000000E+00	0.3075976E-04	0.1780370E+00	0.3221008E-01	0.1780370E+00	0.3221008E-01
123	0.0000000E+00	0.3621524E-04	0.1705099E+00	0.2908535E-01	0.1705099E+00	0.2908535E-01
124	0.0000000E+00	0.4202179E-04	0.1604360E+00	0.2490251E-01	0.1604360E+00	0.2490251E-01
125	0.0000000E+00	0.4812313E-04	0.1478888E+00	0.1955456E-01	0.1478888E+00	0.1955456E-01
126	0.0000000E+00	0.5444743E-04	0.1324396E+00	0.1281912E-01	0.1324396E+00	0.1281912E-01
127	0.0000000E+00	0.6090608E-04	0.1135574E+00	0.4491351E-02	0.1135574E+00	0.4491351E-02
128	0.0000000E+00	0.6739123E-04	0.9118368E-01	-0.5429736E-02	0.9118368E-01	-0.5429736E-02
129	0.0000000E+00	0.7377397E-04	0.6612280E-01	-0.1656951E-01	0.6612280E-01	-0.1656951E-01
130	0.0000000E+00	0.7990511E-04	0.4011232E-01	-0.2813317E-01	0.4011232E-01	-0.2813317E-01
131	0.0000000E+00	0.8562088E-04	0.1546794E-01	-0.3905402E-01	0.1546794E-01	-0.3905402E-01
132	0.0000000E+00	0.9075361E-04	-0.5552437E-02	-0.4827689E-01	-0.5552437E-02	-0.4827689E-01
133	0.0000000E+00	0.9514575E-04	-0.2121496E-01	-0.5495613E-01	-0.2121496E-01	-0.5495613E-01
134	0.0000000E+00	0.9866395E-04	-0.3049710E-01	-0.5854711E-01	-0.3049710E-01	-0.5854711E-01
135	0.0000000E+00	0.1012106E-03	-0.3378050E-01	-0.5922301E-01	-0.3378050E-01	-0.5922301E-01
136	0.0000000E+00	0.1027301E-03	-0.3223291E-01	-0.5755485E-01	-0.3223291E-01	-0.5755485E-01
137	0.0000000E+00	0.1032077E-03	-0.2708057E-01	-0.5412895E-01	-0.2708057E-01	-0.5412895E-01
138	0.0000000E+00	0.1026631E-03	-0.1990804E-01	-0.4973357E-01	-0.1990804E-01	-0.4973357E-01
139	0.0000000E+00	0.1011416E-03	-0.1218563E-01	-0.4510655E-01	-0.1218563E-01	-0.4510655E-01
140	0.0000000E+00	0.9870434E-04	-0.5087225E-02	-0.4083735E-01	-0.5087225E-02	-0.4083735E-01
141	0.0000000E+00	0.9541812E-04	0.4541490E-03	-0.3741016E-01	0.4541490E-03	-0.3741016E-01
142	0.0000000E+00	0.9134733E-04	0.3878019E-02	-0.3512960E-01	0.3878019E-02	-0.3512960E-01
143	0.0000000E+00	0.8654729E-04	0.5133386E-02	-0.3402050E-01	0.5133386E-02	-0.3402050E-01
144	0.0000000E+00	0.8106032E-04	0.4852683E-02	-0.3374665E-01	0.4852683E-02	-0.3374665E-01

145	0.0000000E+00	0.7491560E-04	0.4051831E-02	-0.3376541E-01	0.4051831E-02	-0.3376541E-01
146	0.0000000E+00	0.6813316E-04	0.3577466E-02	-0.3361165E-01	0.3577466E-02	-0.3361165E-01
147	0.0000000E+00	0.6073027E-04	0.4038305E-02	-0.3294720E-01	0.4038305E-02	-0.3294720E-01
148	0.0000000E+00	0.5272755E-04	0.5737360E-02	-0.3160346E-01	0.5737360E-02	-0.3160346E-01
149	0.0000000E+00	0.4415347E-04	0.8659209E-02	-0.2958684E-01	0.8659209E-02	-0.2958684E-01
150	0.0000000E+00	0.3504649E-04	0.1263547E-01	-0.2699982E-01	0.1263547E-01	-0.2699982E-01
151	0.0000000E+00	0.2545517E-04	0.1733405E-01	-0.2404194E-01	0.1733405E-01	-0.2404194E-01
152	0.0000000E+00	0.1543670E-04	0.2225626E-01	-0.2099936E-01	0.2225626E-01	-0.2099936E-01
153	0.0000000E+00	0.5054014E-05	0.2692438E-01	-0.1814487E-01	0.2692438E-01	-0.1814487E-01
154	0.0000000E+00	-0.5627892E-05	0.3101463E-01	-0.1566298E-01	0.3101463E-01	-0.1566298E-01
155	0.0000000E+00	-0.1654558E-04	0.3437760E-01	-0.1363943E-01	0.3437760E-01	-0.1363943E-01
156	0.0000000E+00	-0.2763981E-04	0.3702110E-01	-0.1207091E-01	0.3702110E-01	-0.1207091E-01
157	0.0000000E+00	-0.3885689E-04	0.3907988E-01	-0.1087535E-01	0.3907988E-01	-0.1087535E-01
158	0.0000000E+00	-0.5014877E-04	0.4075264E-01	-0.9929591E-02	0.4075264E-01	-0.9929591E-02
159	0.0000000E+00	-0.6147218E-04	0.4221420E-01	-0.9124990E-02	0.4221420E-01	-0.9124990E-02
160	0.0000000E+00	-0.7278723E-04	0.4357729E-01	-0.8389615E-02	0.4357729E-01	-0.8389615E-02
161	0.0000000E+00	-0.8405613E-04	0.4488079E-01	-0.7694667E-02	0.4488079E-01	-0.7694667E-02
162	0.0000000E+00	-0.9524225E-04	0.4611150E-01	-0.7043713E-02	0.4611150E-01	-0.7043713E-02
163	0.0000000E+00	-0.1063098E-03	0.4723947E-01	-0.6451116E-02	0.4723947E-01	-0.6451116E-02
164	0.0000000E+00	-0.1172241E-03	0.4823254E-01	-0.5932101E-02	0.4823254E-01	-0.5932101E-02
165	0.0000000E+00	-0.1279513E-03	0.4907268E-01	-0.5495259E-02	0.4907268E-01	-0.5495259E-02
166	0.0000000E+00	-0.1384592E-03	0.4978918E-01	-0.5124561E-02	0.4978918E-01	-0.5124561E-02
167	0.0000000E+00	-0.1487171E-03	0.5043185E-01	-0.4792943E-02	0.5043185E-01	-0.4792943E-02
168	0.0000000E+00	-0.1586957E-03	0.5103256E-01	-0.4482218E-02	0.5103256E-01	-0.4482218E-02
169	0.0000000E+00	-0.1683671E-03	0.5161350E-01	-0.4177583E-02	0.5161350E-01	-0.4177583E-02
170	0.0000000E+00	-0.1777042E-03	0.5219983E-01	-0.3862330E-02	0.5219983E-01	-0.3862330E-02
171	0.0000000E+00	-0.1866809E-03	0.5280213E-01	-0.3530579E-02	0.5280213E-01	-0.3530579E-02
172	0.0000000E+00	-0.1952717E-03	0.5340747E-01	-0.3190946E-02	0.5340747E-01	-0.3190946E-02
173	0.0000000E+00	-0.2034520E-03	0.5400616E-01	-0.2849435E-02	0.5400616E-01	-0.2849435E-02
174	0.0000000E+00	-0.2111979E-03	0.5459529E-01	-0.2508888E-02	0.5459529E-01	-0.2508888E-02
175	0.0000000E+00	-0.2184866E-03	0.5517195E-01	-0.2173141E-02	0.5517195E-01	-0.2173141E-02
176	0.0000000E+00	-0.2252963E-03	0.5572859E-01	-0.1848726E-02	0.5572859E-01	-0.1848726E-02
177	0.0000000E+00	-0.2316065E-03	0.5626241E-01	-0.1538646E-02	0.5626241E-01	-0.1538646E-02
178	0.0000000E+00	-0.2373980E-03	0.5677844E-01	-0.1239408E-02	0.5677844E-01	-0.1239408E-02
179	0.0000000E+00	-0.2426528E-03	0.5727987E-01	-0.9476412E-03	0.5727987E-01	-0.9476412E-03
180	0.0000000E+00	-0.2473545E-03	0.5776453E-01	-0.6639159E-03	0.5776453E-01	-0.6639159E-03
181	0.0000000E+00	-0.2514882E-03	0.5822743E-01	-0.3916521E-03	0.5822743E-01	-0.3916521E-03
182	0.0000000E+00	-0.2550402E-03	0.5866375E-01	-0.1339970E-03	0.5866375E-01	-0.1339970E-03
183	0.0000000E+00	-0.2579985E-03	0.5907385E-01	0.1092295E-03	0.5907385E-01	0.1092295E-03
184	0.0000000E+00	-0.2603527E-03	0.5946286E-01	0.3404598E-03	0.5946286E-01	0.3404598E-03
185	0.0000000E+00	-0.2620938E-03	0.5983742E-01	0.5630806E-03	0.5983742E-01	0.5630806E-03
186	0.0000000E+00	-0.2632146E-03	0.6020463E-01	0.7813739E-03	0.6020463E-01	0.7813739E-03
187	0.0000000E+00	-0.2637094E-03	0.6056662E-01	0.9970291E-03	0.6056662E-01	0.9970291E-03
188	0.0000000E+00	-0.2635741E-03	0.6091974E-01	0.1208362E-02	0.6091974E-01	0.1208362E-02
189	0.0000000E+00	-0.2628061E-03	0.6125914E-01	0.1412613E-02	0.6125914E-01	0.1412613E-02
190	0.0000000E+00	-0.2614042E-03	0.6158333E-01	0.1608561E-02	0.6158333E-01	0.1608561E-02
191	0.0000000E+00	-0.2593690E-03	0.6189370E-01	0.1796759E-02	0.6189370E-01	0.1796759E-02
192	0.0000000E+00	-0.2567026E-03	0.6219255E-01	0.1978335E-02	0.6219255E-01	0.1978335E-02
193	0.0000000E+00	-0.2534087E-03	0.6248226E-01	0.2154517E-02	0.6248226E-01	0.2154517E-02
194	0.0000000E+00	-0.2494925E-03	0.6276461E-01	0.2326278E-02	0.6276461E-01	0.2326278E-02
195	0.0000000E+00	-0.2449608E-03	0.6288459E-01	0.2439125E-02	0.6288459E-01	0.2439125E-02
196	0.0000000E+00	-0.2398222E-03	0.6331063E-01	0.2658334E-02	0.6331063E-01	0.2658334E-02
197	0.0000000E+00	-0.2340865E-03	0.6357241E-01	0.2817703E-02	0.6357241E-01	0.2817703E-02
198	0.0000000E+00	-0.2277649E-03	0.6382244E-01	0.2970402E-02	0.6382244E-01	0.2970402E-02

199	0.0000000E+00	-0.2208698E-03	0.6405885E-01	0.3115362E-02	0.6405885E-01	0.3115362E-02
200	0.0000000E+00	-0.2134153E-03	0.6428265E-01	0.3252874E-02	0.6428265E-01	0.3252874E-02
250	0.0000000E+00	0.3101537E-03	0.6759963E-01	0.5064703E-02	0.6759963E-01	0.5064703E-02
300	0.0000000E+00	-0.1538018E-03	0.6795709E-01	0.5258878E-02	0.6795709E-01	0.5258878E-02
350	0.0000000E+00	0.2852731E-04	0.6802823E-01	0.5296589E-02	0.6802823E-01	0.5296589E-02
400	0.0000000E+00	0.2186892E-03	0.6804118E-01	0.5305697E-02	0.6804118E-01	0.5305697E-02
450	0.0000000E+00	-0.2498279E-03	0.6804233E-01	0.5306683E-02	0.6804233E-01	0.5306683E-02
500	0.0000000E+00	0.2657415E-03	0.6804165E-01	0.5307030E-02	0.6804165E-01	0.5307030E-02
550	0.0000000E+00	-0.4231372E-04	0.6804292E-01	0.5307463E-02	0.6804292E-01	0.5307463E-02
600	0.0000000E+00	-0.9387276E-04	0.6804130E-01	0.5306671E-02	0.6804130E-01	0.5306671E-02
650	0.0000000E+00	0.2918376E-03	0.6804198E-01	0.5306803E-02	0.6804198E-01	0.5306803E-02
700	0.0000000E+00	-0.2375727E-03	0.6804037E-01	0.5305577E-02	0.6804037E-01	0.5305577E-02
750	0.0000000E+00	0.1741348E-03	0.6804148E-01	0.5306301E-02	0.6804148E-01	0.5306301E-02
800	0.0000000E+00	0.8342116E-04	0.6803848E-01	0.5304694E-02	0.6803848E-01	0.5304694E-02
850	0.0000000E+00	-0.1916559E-03	0.6804206E-01	0.5306422E-02	0.6804206E-01	0.5306422E-02
900	0.0000000E+00	0.3134008E-03	0.6803976E-01	0.5305166E-02	0.6803976E-01	0.5305166E-02
950	0.0000000E+00	-0.1722704E-03	0.6804243E-01	0.5306451E-02	0.6804243E-01	0.5306451E-02
1000	0.0000000E+00	0.5421987E-04	0.6804208E-01	0.5305636E-02	0.6804208E-01	0.5305636E-02
1050	0.0000000E+00	0.1987347E-03	0.6804188E-01	0.5306327E-02	0.6804188E-01	0.5306327E-02

Note: The aerodynamic forces (lift and moment) given in the last two columns, converge to a constant value. This is due the fact that in supersonic through flow, the aft row (stator in this case) will not have influence on the front blade row (rotor in this case) (Ref.9). Note that this value is different from the one obtained in section 7.2, since the gap to chord ratio is different.

FORT.54 output:

For blade 1 of the second row (stator in this case), the variation of pitching amplitude is given in the third column. Only selected output is shown for brevity.

88	0.0000000E+00	0.0000000E+00	0.5367982E-03	0.7693453E-04	0.5367982E-03	0.7693453E-04
89	0.0000000E+00	0.8477797E-05	0.4971801E-03	0.4588242E-04	0.4971801E-03	0.4588242E-04
90	0.0000000E+00	0.1695727E-04	0.4522435E-03	0.1564913E-04	0.4522435E-03	0.1564913E-04
91	0.0000000E+00	0.2539754E-04	0.3992372E-03	-0.1247900E-04	0.3992372E-03	-0.1247900E-04
92	0.0000000E+00	0.3377836E-04	0.3414645E-03	-0.3758713E-04	0.3414645E-03	-0.3758713E-04
93	0.0000000E+00	0.4207969E-04	0.2869820E-03	-0.5855424E-04	0.2869820E-03	-0.5855424E-04
94	0.0000000E+00	0.5028166E-04	0.2418554E-03	-0.7361465E-04	0.2418554E-03	-0.7361465E-04
95	0.0000000E+00	0.5836474E-04	0.2083594E-03	-0.8187410E-04	0.2083594E-03	-0.8187410E-04
96	0.0000000E+00	0.6630973E-04	0.1859163E-03	-0.8441188E-04	0.1859163E-03	-0.8441188E-04
97	0.0000000E+00	0.7409787E-04	0.1742443E-03	-0.8289802E-04	0.1742443E-03	-0.8289802E-04
98	0.0000000E+00	0.8171080E-04	0.1728144E-03	-0.7873592E-04	0.1728144E-03	-0.7873592E-04
99	0.0000000E+00	0.8913066E-04	0.1811653E-03	-0.7224538E-04	0.1811653E-03	-0.7224538E-04
100	0.0000000E+00	0.9634009E-04	0.1971179E-03	-0.6354641E-04	0.1971179E-03	-0.6354641E-04
101	0.0000000E+00	0.1033222E-03	0.2161767E-03	-0.5354877E-04	0.2161767E-03	-0.5354877E-04
102	0.0000000E+00	0.1100608E-03	0.2336151E-03	-0.4341567E-04	0.2336151E-03	-0.4341567E-04
103	0.0000000E+00	0.1165401E-03	0.2475518E-03	-0.3380820E-04	0.2475518E-03	-0.3380820E-04
104	0.0000000E+00	0.1227450E-03	0.2590268E-03	-0.2519087E-04	0.2590268E-03	-0.2519087E-04
105	0.0000000E+00	0.1286612E-03	0.2693262E-03	-0.1796201E-04	0.2693262E-03	-0.1796201E-04

106	0.0000000E+00	0.1342747E-03	0.2792942E-03	-0.1249901E-04	0.2792942E-03	-0.1249901E-04
107	0.0000000E+00	0.1395726E-03	0.2900090E-03	-0.9073655E-05	0.2900090E-03	-0.9073655E-05
108	0.0000000E+00	0.1445424E-03	0.3029474E-03	-0.7443762E-05	0.3029474E-03	-0.7443762E-05
109	0.0000000E+00	0.1491726E-03	0.3195052E-03	-0.6702402E-05	0.3195052E-03	-0.6702402E-05
110	0.0000000E+00	0.1534523E-03	0.3413158E-03	-0.5333362E-05	0.3413158E-03	-0.5333362E-05
111	0.0000000E+00	0.1573714E-03	0.3654937E-03	-0.3100946E-05	0.3654937E-03	-0.3100946E-05
112	0.0000000E+00	0.1609207E-03	0.3868269E-03	-0.4371200E-06	0.3868269E-03	-0.4371200E-06
113	0.0000000E+00	0.1640920E-03	0.4005588E-03	0.3298818E-05	0.4005588E-03	0.3298818E-05
114	0.0000000E+00	0.1668778E-03	0.3999209E-03	0.1134839E-04	0.3999209E-03	0.1134839E-04
115	0.0000000E+00	0.1692717E-03	0.3660259E-03	0.3086367E-04	0.3660259E-03	0.3086367E-04
116	0.0000000E+00	0.1712682E-03	0.2438087E-03	0.7415110E-04	0.2438087E-03	0.7415110E-04
117	0.0000000E+00	0.1728628E-03	-0.7689163E-04	0.1640146E-03	-0.7689163E-04	0.1640146E-03
118	0.0000000E+00	0.1740525E-03	-0.7753232E-03	0.3352851E-03	-0.7753232E-03	0.3352851E-03
119	0.0000000E+00	0.1748359E-03	-0.2090045E-02	0.6320980E-03	-0.2090045E-02	0.6320980E-03
120	0.0000000E+00	0.1752136E-03	-0.4298121E-02	0.1104939E-02	-0.4298121E-02	0.1104939E-02
121	0.0000000E+00	0.1751890E-03	-0.7546741E-02	0.1767107E-02	-0.7546741E-02	0.1767107E-02
122	0.0000000E+00	0.1747685E-03	-0.1175884E-01	0.2578800E-02	-0.1175884E-01	0.2578800E-02
123	0.0000000E+00	0.1739622E-03	-0.1660126E-01	0.3454656E-02	-0.1660126E-01	0.3454656E-02
124	0.0000000E+00	0.1727826E-03	-0.2146204E-01	0.4267761E-02	-0.2146204E-01	0.4267761E-02
125	0.0000000E+00	0.1712441E-03	-0.2562975E-01	0.4897441E-02	-0.2562975E-01	0.4897441E-02
126	0.0000000E+00	0.1693610E-03	-0.2845255E-01	0.5252956E-02	-0.2845255E-01	0.5252956E-02
127	0.0000000E+00	0.1671459E-03	-0.2956932E-01	0.5307292E-02	-0.2956932E-01	0.5307292E-02
128	0.0000000E+00	0.1646089E-03	-0.2914485E-01	0.5129670E-02	-0.2914485E-01	0.5129670E-02
129	0.0000000E+00	0.1617569E-03	-0.2770976E-01	0.4828854E-02	-0.2770976E-01	0.4828854E-02
130	0.0000000E+00	0.1585946E-03	-0.2618022E-01	0.4544376E-02	-0.2618022E-01	0.4544376E-02
131	0.0000000E+00	0.1551257E-03	-0.2581393E-01	0.4425499E-02	-0.2581393E-01	0.4425499E-02
132	0.0000000E+00	0.1513549E-03	-0.2762886E-01	0.4538991E-02	-0.2762886E-01	0.4538991E-02
133	0.0000000E+00	0.1472899E-03	-0.3212313E-01	0.4856576E-02	-0.3212313E-01	0.4856576E-02
134	0.0000000E+00	0.1429415E-03	-0.3950124E-01	0.5300536E-02	-0.3950124E-01	0.5300536E-02
135	0.0000000E+00	0.1383241E-03	-0.4987251E-01	0.5779379E-02	-0.4987251E-01	0.5779379E-02
136	0.0000000E+00	0.1334543E-03	-0.6313355E-01	0.6178360E-02	-0.6313355E-01	0.6178360E-02
137	0.0000000E+00	0.1283496E-03	-0.7890119E-01	0.6363423E-02	-0.7890119E-01	0.6363423E-02
138	0.0000000E+00	0.1230270E-03	-0.9654232E-01	0.6211435E-02	-0.9654232E-01	0.6211435E-02
139	0.0000000E+00	0.1175011E-03	-0.1151257E+00	0.5619080E-02	-0.1151257E+00	0.5619080E-02
140	0.0000000E+00	0.1117826E-03	-0.1333949E+00	0.4533812E-02	-0.1333949E+00	0.4533812E-02
141	0.0000000E+00	0.1058764E-03	-0.1497962E+00	0.2979181E-02	-0.1497962E+00	0.2979181E-02
142	0.0000000E+00	0.9978191E-04	-0.1626386E+00	0.1060210E-02	-0.1626386E+00	0.1060210E-02
143	0.0000000E+00	0.9349242E-04	-0.1706046E+00	-0.1030882E-02	-0.1706046E+00	-0.1030882E-02
144	0.0000000E+00	0.8699719E-04	-0.1736268E+00	-0.3033601E-02	-0.1736268E+00	-0.3033601E-02
145	0.0000000E+00	0.8028382E-04	-0.1723807E+00	-0.4660593E-02	-0.1723807E+00	-0.4660593E-02
146	0.0000000E+00	0.7334173E-04	-0.1677378E+00	-0.5686512E-02	-0.1677378E+00	-0.5686512E-02
147	0.0000000E+00	0.6616578E-04	-0.1609723E+00	-0.6013470E-02	-0.1609723E+00	-0.6013470E-02
148	0.0000000E+00	0.5875914E-04	-0.1534471E+00	-0.5656981E-02	-0.1534471E+00	-0.5656981E-02
149	0.0000000E+00	0.5113471E-04	-0.1464550E+00	-0.4749000E-02	-0.1464550E+00	-0.4749000E-02
150	0.0000000E+00	0.4331481E-04	-0.1409406E+00	-0.3528188E-02	-0.1409406E+00	-0.3528188E-02
151	0.0000000E+00	0.3532939E-04	-0.1372331E+00	-0.2245071E-02	-0.1372331E+00	-0.2245071E-02
152	0.0000000E+00	0.2721302E-04	-0.1349028E+00	-0.1056018E-02	-0.1349028E+00	-0.1056018E-02
153	0.0000000E+00	0.1900175E-04	-0.1328921E+00	0.1888645E-04	-0.1328921E+00	0.1888645E-04
154	0.0000000E+00	0.1073103E-04	-0.1299295E+00	0.1074811E-02	-0.1299295E+00	0.1074811E-02
155	0.0000000E+00	0.2435307E-05	-0.1249436E+00	0.2284494E-02	-0.1249436E+00	0.2284494E-02
156	0.0000000E+00	-0.5850942E-05	-0.1172741E+00	0.3856782E-02	-0.1172741E+00	0.3856782E-02
157	0.0000000E+00	-0.1409102E-04	-0.1067286E+00	0.5985609E-02	-0.1067286E+00	0.5985609E-02
158	0.0000000E+00	-0.2224344E-04	-0.9363000E-01	0.8774114E-02	-0.9363000E-01	0.8774114E-02
159	0.0000000E+00	-0.3025963E-04	-0.7866448E-01	0.1220671E-01	-0.7866448E-01	0.1220671E-01

160	0.0000000E+00	-0.3808276E-04	-0.6273092E-01	0.1617788E-01	-0.6273092E-01	0.1617788E-01
161	0.0000000E+00	-0.4564793E-04	-0.4687948E-01	0.2049897E-01	-0.4687948E-01	0.2049897E-01
162	0.0000000E+00	-0.5288379E-04	-0.3211867E-01	0.2493213E-01	-0.3211867E-01	0.2493213E-01
163	0.0000000E+00	-0.5971518E-04	-0.1936919E-01	0.2923561E-01	-0.1936919E-01	0.2923561E-01
164	0.0000000E+00	-0.6606633E-04	-0.9298171E-02	0.3322703E-01	-0.9298171E-02	0.3322703E-01
165	0.0000000E+00	-0.7186421E-04	-0.2207421E-02	0.3675469E-01	-0.2207421E-02	0.3675469E-01
166	0.0000000E+00	-0.7704120E-04	0.1845182E-02	0.3965140E-01	0.1845182E-02	0.3965140E-01
167	0.0000000E+00	-0.8153757E-04	0.3050293E-02	0.4181602E-01	0.3050293E-02	0.4181602E-01
168	0.0000000E+00	-0.8530353E-04	0.1894787E-02	0.4324078E-01	0.1894787E-02	0.4324078E-01
169	0.0000000E+00	-0.8830073E-04	-0.1102034E-02	0.4396458E-01	-0.1102034E-02	0.4396458E-01
170	0.0000000E+00	-0.9050253E-04	-0.5363349E-02	0.4409670E-01	-0.5363349E-02	0.4409670E-01
171	0.0000000E+00	-0.9189350E-04	-0.1022419E-01	0.4382226E-01	-0.1022419E-01	0.4382226E-01
172	0.0000000E+00	-0.9246795E-04	-0.1522116E-01	0.4333403E-01	-0.1522116E-01	0.4333403E-01
173	0.0000000E+00	-0.9222761E-04	-0.1999983E-01	0.4283152E-01	-0.1999983E-01	0.4283152E-01
174	0.0000000E+00	-0.9117903E-04	-0.2428370E-01	0.4249226E-01	-0.2428370E-01	0.4249226E-01
175	0.0000000E+00	-0.8933093E-04	-0.2789299E-01	0.4243723E-01	-0.2789299E-01	0.4243723E-01
176	0.0000000E+00	-0.8669187E-04	-0.3070856E-01	0.4275014E-01	-0.3070856E-01	0.4275014E-01
177	0.0000000E+00	-0.8326852E-04	-0.3269017E-01	0.4345992E-01	-0.3269017E-01	0.4345992E-01
178	0.0000000E+00	-0.7906454E-04	-0.3390563E-01	0.4450547E-01	-0.3390563E-01	0.4450547E-01
179	0.0000000E+00	-0.7408034E-04	-0.3458268E-01	0.4571756E-01	-0.3458268E-01	0.4571756E-01
180	0.0000000E+00	-0.6831391E-04	-0.3509188E-01	0.4686802E-01	-0.3509188E-01	0.4686802E-01
181	0.0000000E+00	-0.6176304E-04	-0.3569386E-01	0.4777205E-01	-0.3569386E-01	0.4777205E-01
182	0.0000000E+00	-0.5442803E-04	-0.3657633E-01	0.4827824E-01	-0.3657633E-01	0.4827824E-01
183	0.0000000E+00	-0.4631430E-04	-0.3803538E-01	0.4824814E-01	-0.3803538E-01	0.4824814E-01
184	0.0000000E+00	-0.3743446E-04	-0.4029990E-01	0.4761364E-01	-0.4029990E-01	0.4761364E-01
185	0.0000000E+00	-0.2781002E-04	-0.4342388E-01	0.4639634E-01	-0.4342388E-01	0.4639634E-01
186	0.0000000E+00	-0.1747217E-04	-0.4734316E-01	0.4469571E-01	-0.4734316E-01	0.4469571E-01
187	0.0000000E+00	-0.6461484E-05	-0.5179091E-01	0.4269040E-01	-0.5179091E-01	0.4269040E-01
188	0.0000000E+00	0.5173574E-05	-0.5643374E-01	0.4058163E-01	-0.5643374E-01	0.4058163E-01
189	0.0000000E+00	0.1737898E-04	-0.6102442E-01	0.3853545E-01	-0.6102442E-01	0.3853545E-01
190	0.0000000E+00	0.3009783E-04	-0.6535200E-01	0.3669043E-01	-0.6535200E-01	0.3669043E-01
191	0.0000000E+00	0.4327279E-04	-0.6928022E-01	0.3513620E-01	-0.6928022E-01	0.3513620E-01
192	0.0000000E+00	0.5684802E-04	-0.7276491E-01	0.3390525E-01	-0.7276491E-01	0.3390525E-01
193	0.0000000E+00	0.7077053E-04	-0.7584325E-01	0.3299675E-01	-0.7584325E-01	0.3299675E-01
194	0.0000000E+00	0.8499081E-04	-0.7855365E-01	0.3239958E-01	-0.7855365E-01	0.3239958E-01
195	0.0000000E+00	0.9946300E-04	-0.8090687E-01	0.3209899E-01	-0.8090687E-01	0.3209899E-01
196	0.0000000E+00	0.1141449E-03	-0.8288291E-01	0.3207594E-01	-0.8288291E-01	0.3207594E-01
197	0.0000000E+00	0.1289979E-03	-0.8449202E-01	0.3230321E-01	-0.8449202E-01	0.3230321E-01
198	0.0000000E+00	0.1439866E-03	-0.8580759E-01	0.3273954E-01	-0.8580759E-01	0.3273954E-01
199	0.0000000E+00	0.1590789E-03	-0.8690144E-01	0.3334187E-01	-0.8690144E-01	0.3334187E-01
200	0.0000000E+00	0.1742450E-03	-0.8784052E-01	0.3406569E-01	-0.8784052E-01	0.3406569E-01
250	0.0000000E+00	0.6001177E-03	-0.5501481E-01	0.6507543E-01	-0.5501481E-01	0.6507543E-01
300	0.0000000E+00	0.2126223E-03	-0.4591552E-01	0.7388886E-01	-0.4591552E-01	0.7388886E-01
350	0.0000000E+00	0.5801313E-03	-0.4328012E-01	0.7659340E-01	-0.4328012E-01	0.7659340E-01
400	0.0000000E+00	0.4636899E-03	-0.4238198E-01	0.7555193E-01	-0.4238198E-01	0.7555193E-01
450	0.0000000E+00	0.2673014E-03	-0.3642823E-01	0.7590162E-01	-0.3642823E-01	0.7590162E-01
500	0.0000000E+00	0.6916686E-03	-0.3967250E-01	0.7780540E-01	-0.3967250E-01	0.7780540E-01
550	0.0000000E+00	0.2606731E-03	-0.4389967E-01	0.7554805E-01	-0.4389967E-01	0.7554805E-01
600	0.0000000E+00	0.4739764E-03	-0.3506366E-01	0.7700071E-01	-0.3506366E-01	0.7700071E-01
650	0.0000000E+00	0.5808855E-03	-0.3987570E-01	0.7670124E-01	-0.3987570E-01	0.7670124E-01
700	0.0000000E+00	0.2164026E-03	-0.4127671E-01	0.7699097E-01	-0.4127671E-01	0.7699097E-01
750	0.0000000E+00	0.6576672E-03	-0.3963243E-01	0.7658227E-01	-0.3963243E-01	0.7658227E-01
800	0.0000000E+00	0.3475908E-03	-0.3737598E-01	0.7579236E-01	-0.3737598E-01	0.7579236E-01
850	0.0000000E+00	0.3797253E-03	-0.3980734E-01	0.7792144E-01	-0.3980734E-01	0.7792144E-01

900	0.0000000E+00	0.6505480E-03	-0.4409571E-01	0.7529952E-01	-0.4409571E-01	0.7529952E-01
950	0.0000000E+00	0.1978506E-03	-0.3493828E-01	0.7662668E-01	-0.3493828E-01	0.7662668E-01
1000	0.0000000E+00	0.6082559E-03	-0.3985437E-01	0.7714426E-01	-0.3985437E-01	0.7714426E-01
1050	0.0000000E+00	0.4529136E-03	-0.4205974E-01	0.7655402E-01	-0.4205974E-01	0.7655402E-01

Note: A plot of the pitching amplitudes (3rd column) showed that a limit cycle response is obtained. This is due the fact that with three blades in the front row, the frequency of the forcing function is not close to the natural frequency of the aeroelastic system for $V^* = 1.2$ (Ref.9).

8. PROGRAM CALLING TREE

The following is the static calling tree for the MSAP2D code:

```
MSAP2D -------FORCE-------CPINT
         |--------GROUT------ASSGN
         |--------INICON------BLDMCK
                          |-INIACC--------GMTMLT
         |--------INPUT-------DPMAP
         |--------INTRPL-----TAINT
         |--------MKGRD3-----GRDSYS3
                          |-RDGRID-------GRDUN2
                                  |---GRDUNF
                                  |---GRIDGEN------VARDXS
         |-------PERF
         |-------PERFDH
         |-------PVAR
         |-------RESTRT
         |-------SAVRST-------ASSGN
         |-------STEPRS--------ASSGN
                          |---------BCNEW
                          |---------BCOLD
                          |---------BCRS
                          |---------DOO
                          |---------FJMAT
                          |---------GJPTRS
                          |---------GRIDP
                          |---------GRIDVRS
                          |---------METRIC1
                          |---------RESIDRS---------MINMOD
                                               |-----RLVECS
                                               |-----SUPBEE
                                               |-----VL
                          |--------EIGENV
                          |--------STORE
                          |--------STPTRS
```

```
|------STRDAT-------BLDDAT
                |--------DINVS

|-------STRTRS-------BCNEW
                |---------BCOLD
                |---------BCRS
                |---------DOO
                |---------EIGENV
                |---------FJMAT
                |---------GJPTRS
                |---------GRIDP
                |---------GRIDVRS
                |---------ICRS
                |---------METRIC

|--------STRUCT-------BLDMCK
                |----------FLTR23--------GMTMLT

|-------STTDRS--------ASSGN
                |---------BCNEW
                |---------BCOLD
                |---------BCRS
                |---------DOO
                |---------FJMAT
                |---------GJPTRS
                |---------GRIDP
                |---------GRIDVRS
                |---------METRIC1
                |---------RESIDRS---------MINMOD
                                       |-----RLVECS
                                       |-----SUPBEE
                                       |-----VL
                |--------EIGENV
                |--------STORE
                |--------STPTRS
```

9. PLANNED EXTENSIONS

The following new capabilities are expected to be included in the next versions: (1) new algorithm to make the solution robust and efficient, (2) viscous capability, (3) gust response capability, and (4) nonlinear damping, for example, friction damper.

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13. ABSTRACT ***(Maximum 200 words)***

This guide describes the input data required for using MSAP2D (Multi Stage Aeroelastic analysis Program - Two Dimensional) computer code. MSAP2D can be used for steady, unsteady aerodynamic, and aeroelastic (flutter and forced response) analysis of bladed disks arranged in multiple blade rows such as those found in compressors, turbines, counter rotating propellers or propfans. The code can also be run for single blade row. MSAP2D code is an extension of the original NPHASE code for multiblade row aerodynamic and aeroelastic analysis. Euler equations are used to obtain aerodynamic forces. The structural dynamic equations are written for a rigid typical section undergoing pitching (torsion) and plunging (bending) motion. The aeroelastic equations are solved in time domain. For single blade row analysis, frequency domain analysis is also provided to obtain unsteady aerodynamic coefficients required in an eigen analysis for flutter. In this manual, sample input and output are provided for a single blade row example, two blade row example with equal and unequal number of blades in the blade rows.

14. SUBJECT TERMS
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