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# FPCAS2D User's Guide

## Version 1.0



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## Abstract

The FPCAS2D computer code has been developed for aeroelastic stability analysis of bladed disks such as those in fans, compressors, turbines, propellers, or propfans. The aerodynamic analysis used in this code is based on the unsteady two-dimensional full potential equation which is solved for a cascade of blades. The structural analysis is based on a two degree-of-freedom rigid typical section model for each blade. Detailed explanations of the aerodynamic analysis, the numerical algorithms, and the aeroelastic analysis are not given in this report. This guide can be used to assist in the preparation of the input data required by the FPCAS2D code. A complete description of the input data is provided in this report. In addition, four test cases, including inputs and outputs, are provided.

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# Table of Contents

## 1. INTRODUCTION

This is a user's guide for the FPCAS2D computer code which was developed for aeroelastic stability analysis of bladed disks such as those found in fans, compressors, turbines, propellers, or propfans. This guide will help the user in the preparation of the input data file required by the FPCAS2D code. Detailed explanations of the aerodynamic analysis, the numerical algorithms, and the aeroelastic analysis will not be given in this guide. Instead, the reader is directed to specific references that deal with each of these items. The FPCAS2D code was developed at the Structural Dynamics Branch at NASA Lewis Research Center. It is made available strictly as a research tool. Neither NASA Lewis Research Center, nor those who have contributed to the development of the code, assume any liability for the use of this code beyond research needs.

The aerodynamic analysis used in this code is based on the unsteady two-dimensional full potential equation. This equation is solved for a cascade of blades. The structural analysis is based on a two degree-of-freedom rigid typical section model for each blade. Either a frequency domain or a time domain flutter analysis is possible.

## 2. ANALYSIS

Detailed descriptions of the aerodynamic analysis can be found in Refs. 1 and 2. The aeroelastic analysis is described in Refs. 3 and 4. Refs. 1 and 2 contain a complete description of the full potential formulation including the governing equation and boundary conditions. The transformation of the equations to the computational plane and the subsequent discretization and solution of these equations is also described in detail. A finite volume approach is adopted and a Newton-iteration method is used to solve the non-linear problem as a series of linear problems at each time step. In Ref. 3, the time domain flutter analysis for cascades is described. In Ref. 4, the pulse response and influence coefficient method for cascades is detailed.

## 3. DESCRIPTION OF INPUT DATA

The FPCAS2D code is written in FORTRAN. It is operational on the Cray YMP computer at NASA Lewis Research Center under the UNICOS operating system. In addition to the source code fpcas2d.f, a parameter definition file para.f is required. This is used to specify the problem-dependent array dimensions. The input data for the code is provided in the input file fpcas2d.input.

### 3.1 Parameter Definition File: para.f

This file contains parameter definitions that are dependent on the size of the problem. These parameters are used to specify dimensions of arrays used within the code. The use of the parameter definition file eliminates the need to edit the source code for the purpose of changing array dimensions. The contents of the parameter definition file are transferred to the source code (at the time of compilation) by INCLUDE statements in the code. The parameter definition file para.f contains a single PARAMETER statement. Nine parameters ID1 through ID9 are specified in the simple form shown below.

```
PARAMETER
& (ID1 = 31000, ID2 = 01000, ID3 = 00085, ID4 = 00045, ID5 = 00400,
& ID6 = 00045, ID7 = 00045, ID8 = 00025, ID9 = 00010)
```

Due to the long length of the statement, it is continued over multiple lines using a FORTRAN continuation character – '&' in the sixth column on all except the first line. Each line in this file can be no more than 72 characters in length.

The minimum acceptable values of the parameters ID1 through ID9 are described below in terms of the input variables. The input variables are explained in detail in the next section.

```
ID1  ≥  IMAX * JMAX * NPSG
ID2  ≥  2*(IMAX + JMAX * NPSG)
ID3  ≥  IMAX
ID4  ≥  JMAX
ID5  ≥  JMAX * NPSG
ID6  ≥  MAX(NUAIR, NLAIR, NPAF)
ID7  ≥  NPAF
ID8  ≥  NPW
ID9  ≥  NTPC+1
```

### 3.2 Input Data File: fpcas2d.f

This file contains the standard (unit 5) input that the FPCAS2D code requires. All input is read in free format using 'READ (5,*)' FORTRAN statements. The only exceptions are the first two inputs (job identifier and title) which are read in as character variables. Typically, each READ statement is used to read the values of many input variables. In such cases, the input values are separated by one or more blank spaces. If the input values do not fit on a single line, they are included on additional line(s). No continuation character is required, but individual values cannot be split across lines. In the input file, the values of each

set of input variables is preceded by a line containing the names of the variables. The code does not read these names of variables and these are included in the input data file only to help the user in identifying the variables whose values are present on the subsequent line(s). Since the contents of these lines are ignored by the code, the user can use these lines to annotate the input file to a limited extent.

The input variables are described below in the order in which they are required in the input data file. In addition, sample values are also given. The following section contains some sample input data files and the corresponding output.

variable: CJOB
type: character variable of length 7
description: job identifier
example: TEST001

variable: TITLE
type: character variable of length 80
description: job title
example: SAMPLE RUN OF FPCAS2D.

variable: PHASE
type: real variable
description: interblade phase angle in degrees
example: 0.0

variable: TH1
type: real variable
description: angle of flow at inlet in degrees
example: 4.3

variable: THS
type: real variable
description: cascade stagger angle in degrees
example: 0.0

variable: TH2
type: real variable
description: angle at which wake leaves the airfoil trailing edge in degrees
example: -4.3

variable: TH3
type: real variable
description: angle of flow at exit in degrees
example: -4.3

variable: XMINF
type: real variable
description: Mach number of flow at inlet
example: 0.7

variable: XMOUT
type: real variable
description: Mach number of flow at exit; this value is not used if IMOUT=0, in which case the code calculates the appropriate value of XMOUT
example: 0.7

variable: SBYC
type: real variable
description: cascade gap-to-chord ratio
example: 1.0

variable: A
type: real variable
description: location of pitching (elastic) axis, in units of semi-chord, measured from mid-chord towards trailing edge
example: 0.0

variable: XKC
type: real variable
description: reduced frequency of oscillation (IFLTR=0,1,2,3,4), non-dimensionalized with airfoil chord and inlet (free-stream) velocity; note that the non-dimensional time step is calculated as $2\pi$ / (XKC*XMINF*NTPC)
example: 1.0

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 in time domain flutter calculations

example: 1

variable: ALFAA
type: real variable
description: amplitude of oscillation in frequency domain flutter calculations using harmonic oscillation method (IFLTR=0,1,2) or influence coefficient method (IFLTR=3,4), amplitude of pulse in pulse response method or combined pulse response and influence coefficient method (IFLTR=5), proportional to initial velocity in time domain flutter calculations (IFLTR=-1,-2); the value of ALFAA is non-dimensionalized with airfoil chord for plunging motion (IMODE=0) and it is in degrees for pitching motion (IMODE=1) and for combined plunging-pitching motion in time domain flutter calculations (IMODE=2)
example: 0.1

variable: XCONV
type: real variable
description: convergence criterion for Newton-iterations
example: 1.0E-06

variable: NPMAX
type: integer variable
description: maximum number of blade passages to be included in the calculations
example: 1

variable: IMAX
type: integer variable
description: number of grid points in the axial direction
example: 61

variable: JMAX
type: integer variable
description: number of grid points in the circumferential direction in each blade passage
example: 21

variable: NPAF
type: integer variable
description: number of grid points on the each (upper and lower) airfoil

surface
example: 31

variable: NPW
type: integer variable
description: number of grid points on the on the wake (between the airfoil trailing edge and the exit boundary)
example: 14

variable: NTSS
type: integer variable
description: number of time steps for which the airfoils remain steady
example: 1000

variable: NTPC
type: integer variable
description: number of time steps per cycle of oscillation of the airfoils (IFLTR=0,1,2,3,4),
number of time steps in the duration of the pulse (IFLTR=5);
note that the non-dimensional time step is calculated as $2\pi$ / (XKC*XMINF*NTPC)
example: 360

variable: NCYE
type: integer variable
description: number of cycles of oscillation of the airfoils (IFLTR=0,1,2,3,4), not used for IFLTR=-1,-2,5
example: 0

variable: NTMX
type: integer variable
description: total number of time steps in the calculation (IFLTR=-1,-2,5); for IFLTR=0,1,2,3,4, this value is not used, instead the code calculates NTMX as NTSS+NTPC*NCYE
example: 0

variable: NTPRNT
type: integer variable
description: the number of time steps after which convergence information is written to standard output (unit 6) and lift and moment coefficients are written to data file(s)
example: 20

variable: IPLOT
type: integer variable
description: the number of PLOT3D data sets to be included in each file
example: 0

variable: NTPBEG
type: integer variable
description: the first time step at which PLOT3D data is written to file
example: 0

variable: NTPINC
type: integer variable
description: the number of time steps after integer multiples of which PLOT3D data is written to file, starting with NTPBEG; that is, PLOT3D data is written at time steps NTPBEG, NTPBEG+NTPINC, NTPBEG+2*NTPINC, NTPBEG+3*NTPINC, and so on until NTPEND is reached.
example: 0

variable: NTPEND
type: integer variable
description: the time step after which PLOT3D data is not written to file
example: 0

variable: IYBIA
type: integer variable
description: flag for biasing scheme,
IYBIA=0 for no biasing,
IYBIA=1 for simple biasing,
IYBIA=2 for flux biasing
example: 0

variable: ISUPER
type: integer variable
description: flag for supersonic axial flow,
ISUPER=0 for subsonic axial flow,
ISUPER=1 for supersonic axial flow
example: 0

variable: INITI
type: integer variable
description: flag for initial guess to begin Newton-iteration at each time step,

INITI=0 to use value from previous time step as initial guess,
INITI=1 to use linearized method to calculate initial guess,
INITI=2 to use linear extrapolation to calculate initial guess

example: 2

variable: ITMAX
type: integer variable
description: maximum number of Newton-iterations at each time step; fewer iterations may be performed if the residual falls below the convergence criterion before ITMAX iterations
example: 10

variable: ISMTH
type: integer variable
description: number of times the smoothing algorithm is applied on the original algebraic sheared grid
example: 0

variable: IMOUT
type: integer variable
description: flag for exit Mach number calculation,
if IMOUT=0, the code calculates the exit Mach number,
if IMOUT=1, the user-supplied value of XMOUT is used
example: 1

variable: IRUN
type: integer variable
description: flag for restart,
IRUN=0 for a new run;
IRUN=1 for a restart run, the code reads a binary restart file from unit 4
example: 0

variable: IFLTR
type: integer variable
description: flag for type of flutter calculation,
IFLTR=0 for an unsteady aerodynamic calculation using the harmonic oscillation method,
IFLTR=1 for a single degree-of-freedom frequency domain flutter calculation using the harmonic oscillation method,
IFLTR=2 for a two degree-of-freedom frequency domain flutter calculation using the harmonic oscillation method,
IFLTR=3 for a single degree-of-freedom frequency domain flutter

calculation using the influence coefficient method,
IFLTR=4 for a two degree-of-freedom frequency domain flutter calculation using the harmonic oscillation method,
IFLTR=5 for an unsteady aerodynamic calculation using the combined pulse response and influence coefficient method,
IFLTR=-1 for a single degree-of-freedom time domain flutter calculation,
IFLTR=-2 for a two degree-of-freedom time domain flutter calculation

example: 0

variable: ( MV(N), N = 1, NPMAX )
type: integer variable
description: flag for blade motion,
for the influence coefficient method and the combined pulse response and influence coefficient methods (IFLTR=3,4,5), for each blade MV(N)=0 indicates that the blade does not move, and MV(N)=1 indicates that the blade moves,
for time domain flutter calculations (IFLTR=-1,-2), MV(N) indicates whether or not the blade is given an initial velocity
example: 0

variable: GHS
type: real variable
description: natural frequency in bending (plunging); not used if IFLTR=0
example: 1.0

variable: GAS
type: real variable
description: natural frequency in torsion (pitching); not used if IFLTR=0
example: 1.0

variable: ZHS
type: real variable
description: damping ratio in bending (plunging); not used if IFLTR=0
example: 0.0

variable: ZAS
type: real variable
description: damping ratio in torsion (pitching); not used if IFLTR=0
example: 0.0

variable: XMU
type: real variable
description: mass ratio of typical section; not used if IFLTR=0
example: 100.0

variable: XRA
type: real variable
description: radius of gyration of typical section in airfoil semi-chord units; not used if IFLTR=0
example: 0.5

variable: XA
type: real variable
description: static imbalance of typical section, separation of center of gravity from the elastic axis in semi-chord units; not used if IFLTR=0
example: 0.0

variable: VSTAR
type: real variable
description: reduced velocity (IFLTR=-1,-2), non-dimensionalized with airfoil semi-chord and natural frequency in torsion (pitching)
example: 1.0

variable: IGRIDX
type: integer variable
description: flag for grid clustering in the i direction near the airfoil leading and trailing edges,
IGRIDX=0 for no clustering (uniform grid spacing),
IGRIDX=1 for parabolic clustering,
IGRIDX=2 for exponential clustering,
IGRIDX=3 for clustering using Roberts' transformation (Ref. 5),
IGRIDX=4 for clustering using Roberts' transformation, and uniform grid spacing on the airfoil surface,
IGRIDX=5 for clustering using fixed-ratio spacing (the ratio of adjacent spacings is constant), and uniform grid spacing on the airfoil surface,
IGRIDX=6 for tangent-function clustering
example: 0

variable: BETAX
type: real variable
description: parameter to control amount of clustering in the i direction, a higher value is used for added clustering, not used if IGRIDX=0

example: 0.0

variable: IGRIDY
type: integer variable
description: flag for grid clustering in the j direction near the airfoil upper and lower surfaces,
IGRIDY=0 for no clustering (uniform grid spacing),
IGRIDY=3 for clustering using Roberts' transformation,
IGRIDY=5 for clustering using fixed-ratio spacing (the ratio of adjacent spacings is constant),
IGRIDY=6 for tangent clustering
example: 0

variable: BETAY
type: real variable
description: parameter to control amount of clustering in the j direction, a higher value is used for added clustering, not used if IGRIDY=0
example: 0.0

variable: IAIRFL
type: integer variable
description: flag for airfoil type,
IAIRFL=0 for user-specified airfoil coordinates,
IAIRFL=1 for flat plate airfoil of zero thickness,
IAIRFL=2 for thin circular arc airfoil of zero thickness,
IAIRFL=3 for double circular arc airfoil,
IAIRFL=4 for single or flat bottom circular arc airfoil
example: 4

variable: TBYC
type: real variable
description: thickness-to-chord ratio (used only if IAIRFL=3 or 4)
example: 0.05

variable: HBYC
type: real variable
description: height-to-chord ratio (used only if IAIRFL=2)
example: 0.0

variable: NUAIR
type: integer variable
description: number of points at which airfoil upper surface coordinates are

specified, required only if IAIRFL=0
example: 0.0

variable: ( XU(I), I = 1, NUAIR )
type: real variable
description: airfoil upper surface x-coordinates, required only if IAIRFL=0
example: 0.0, 0.1, 0.2, 0.3, ... , 1.0

variable: ( YU(I), I = 1, NUAIR )
type: real variable
description: airfoil upper surface y-coordinates, required only if IAIRFL=0
example: 0.0, 0.0025, 0.005, 0.0075, ... , 0.0

variable: NLAIR
type: integer variable
description: number of points at which airfoil lower surface coordinates are specified, required only if IAIRFL=0
example: 0.0

variable: ( XL(I), I = 1, NLAIR )
type: real variable
description: airfoil lower surface x-coordinates, required only if IAIRFL=0
example: 0.0, 0.1, 0.2, 0.3, ... , 1.0

variable: ( YL(I), I = 1, NLAIR )
type: real variable
description: airfoil lower surface y-coordinates, required only if IAIRFL=0
example: 0.0, -0.0025, -0.005, -0.0075, ... , 0.0

## 4. TEST CASES

In this section some test cases are presented. For each case, a brief description of the test case is given. The contents of the input file, parameter definition file, and output file are listed. Also, a list of additional files created by the code is given. These cases are provided so that the user can verify the correct installation and operation of the code.

## 4.1 Test Case 1: Unsteady Aerodynamics of a Flat-Plate Cascade Using the Harmonic Oscillation Method

### Description:

In this test case (Ref. 4), the unsteady aerodynamic coefficients for a flat-plate cascade at zero incidence are calculated using the harmonic oscillation method. The cascade stagger angle is 45 deg. and the gap-to-chord ratio is 1.0. The Mach number at the inlet and exit is 0.5. The unsteady aerodynamic coefficients are calculated for pitching about the leading edge at a reduced frequency of 0.222 and an interblade phase angle of 0 deg. A pitching amplitude of 0.1 deg. is used in the calculations. The grid used has 41 points in the streamwise direction and 21 points in the circumferential direction. One blade passage is used in the calculations. 21 points are located on each (upper and lower) surface of the airfoil, and 19 points are located on the wake. Calculations are performed for 10 time steps with no blade motion, followed 3 cycles of blade oscillation with 1350 time steps per cycle. No flutter calculations are performed, therefore the structural parameters specified in the input data file are not used. The stability of the cascade can be determined from the unsteady aerodynamic coefficients.

### para.f:

```
      PARAMETER
     & (ID1 = 00900, ID2 = 00130, ID3 = 00065, ID4 = 00025, ID5 = 00025,
     &  ID6 = 00025, ID7 = 00025, ID8 = 00020, ID9 = 02000)
```

### fpcas2d.input:

```
CJOB
TEST001
TITLE
TEST CASE 001 FOR FPCAS2D
PHASE
0.0
TH1         THS         TH2         TH3
45.0        45.0        45.0        45.0
XMINF       XMOUT
0.5         0.5
SBYC
1.0
A
-1.0
XKC
0.222
IMODE
1
ALFAA       XCONV
0.1         1.0E-06
NPMAX       IMAX        JMAX        NPAF        NPW
1           41          21          21          9
NTSS        NTPC        NCYE        NTMX        NTPRNT
```

```
10          1350        3           0           100
IPLOT       NTPBEG      NTPINC      NTPEND
0           0           0           0
IYBIA       ISUPER      INITI       ITMAX       ISMTH       IMOUT
0           0           2           5           0           0
IRUN        IFLTR
0           0
MV    1   2   3   4   5   6   7   8   9  10
      0   0   0   0   0   0   0   0   0   0
GHS         GAS         ZHS         ZAS
1.0         1.0         0.0         0.0
XMU         XRA         XA
1.0         1.0         0.0
VSTAR
1.0
IGRIDX      BETAX       IGRIDY      BETAY
0           0.0         0           0.0
IAIRFL      TBYC        HBYC
1           0.0         0.0
```

## fpcas2d.output:

```
TEST CASE 001 FOR FPCAS2D

 1 PASSAGE(S) USED WITH A MULTIPLIER OF 0


  *******  GEOMETRY  *******

  AIRFOIL COORDINATES, UPPER ( XU AND YU ) :

    0.0000    0.0500    0.1000    0.1500    0.2000    0.2500    0.3000
    0.3500    0.4000    0.4500    0.5000    0.5500    0.6000    0.6500
    0.7000    0.7500    0.8000    0.8500    0.9000    0.9500    1.0000

    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000

  AIRFOIL COORDINATES, LOWER ( XL AND YL ) :

    0.0000    0.0500    0.1000    0.1500    0.2000    0.2500    0.3000
    0.3500    0.4000    0.4500    0.5000    0.5500    0.6000    0.6500
    0.7000    0.7500    0.8000    0.8500    0.9000    0.9500    1.0000

    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000

  OUTER BOUNDARY ( XX AND YY ) :

   -0.5000   -0.4500   -0.4000   -0.3500   -0.3000   -0.2500   -0.2000
```

```
  -0.1500   -0.1000   -0.0500    0.0000    0.0500    0.1000    0.1500
   0.2000    0.2500    0.3000    0.3500    0.4000    0.4500    0.5000
   0.5500    0.6000    0.6500    0.7000    0.7500    0.8000    0.8500
   0.9000    0.9500    1.0000    1.0500    1.1000    1.1500    1.2000
   1.2500    1.3000    1.3500    1.4000    1.4500    1.5000

   0.0000    0.0500    0.1000    0.1500    0.2000    0.2500    0.3000
   0.3500    0.4000    0.4500    0.5000    0.5500    0.6000    0.6500
   0.7000    0.7500    0.8000    0.8500    0.9000    0.9500    1.0000

SBYC =  1.000

CALCULATED EXIT MACH NUMBER=  0.50000


 *******    GRID    *******

NPSG= 1 IMAX= 41 JMAX= 21
NFW=  9 NPAF= 21 NPW=  9
IMODE= 1

 ******* FREESTREAM *******

MACH NUMBER=  0.5000
INTER-BLADE PHASE ANGLE=    0.0000
REDUCED FRE=  0.2220
ALFAA=    0.1000
TH1=   45.0000 THS=   45.0000 TH2=   45.0000 TH3=   45.0000

 *******  NUMERICAL *******

NTSS=  10 NTPC=1350 NCYE=   3
XP=  0.0000 YP=  0.0000
DT=  0.0419 XCONV=  0.10E-05
IRUN= 0 ISUPER= 0 IYBIA= 0 INITI= 2 ITMAX=  5


 CONVERGENCE HISTORY :

NT=    10     NITER=   1     MAX(DPHI)=   0.22E-13     IJ=   820
 **** DELTA CP NEAR I = ILE ****
  0.00000   0.00000   0.00000   0.00000   0.00000
 **** DELTA CP NEAR I = ITE ****
  0.00000   0.00000   0.00000   0.00000   0.00000
 **** PRESSURE ON UPPER SURFACE ****
  0.00000   0.00000   0.00000   0.00000   0.00000   0.00000   0.00000
  0.00000   0.00000   0.00000   0.00000   0.00000   0.00000   0.00000
  0.00000   0.00000   0.00000   0.00000   0.00000   0.00000   0.00000
 **** PRESSURE ON LOWER SURFACE ****
  0.00000   0.00000   0.00000   0.00000   0.00000   0.00000   0.00000
  0.00000   0.00000   0.00000   0.00000   0.00000   0.00000   0.00000
  0.00000   0.00000   0.00000   0.00000   0.00000   0.00000   0.00000
```

```
XU(II), CP(I), XL(II), CP(N)
0.00000000E+00  0.16240977E-12  0.00000000E+00  0.56843419E-12
0.50000000E-01  0.00000000E+00  0.50000000E-01  0.56843419E-12
0.10000000E+00  0.16240977E-12  0.10000000E+00  0.44662686E-12
0.15000000E+00  0.00000000E+00  0.15000000E+00  0.44662686E-12
0.20000000E+00  0.16240977E-12  0.20000000E+00  0.85265128E-12
0.25000000E+00  0.00000000E+00  0.25000000E+00  0.56843419E-12
0.30000000E+00  0.00000000E+00  0.30000000E+00  0.11368684E-11
0.35000000E+00  0.00000000E+00  0.35000000E+00  0.10150611E-11
0.40000000E+00  0.44662686E-12  0.40000000E+00  0.73084396E-12
0.45000000E+00  0.28421709E-12  0.45000000E+00  0.56843419E-12
0.50000000E+00  0.16240977E-12  0.50000000E+00  0.73084396E-12
0.55000000E+00  0.00000000E+00  0.55000000E+00  0.73084396E-12
0.60000000E+00  0.00000000E+00  0.60000000E+00  0.73084396E-12
0.65000000E+00  0.00000000E+00  0.65000000E+00  0.12992781E-11
0.70000000E+00  0.00000000E+00  0.70000000E+00  0.10150611E-11
0.75000000E+00  0.44662686E-12  0.75000000E+00  0.10150611E-11
0.80000000E+00  0.10150611E-11  0.80000000E+00  0.14210855E-11
0.85000000E+00  0.11368684E-11  0.85000000E+00  0.17053026E-11
0.90000000E+00  0.10150611E-11  0.90000000E+00  0.18677123E-11
0.95000000E+00  0.10150611E-11  0.95000000E+00  0.25579538E-11
0.10000000E+01  0.14210855E-11  0.10000000E+01  0.18677123E-11

**** MACH NUMBER ON UPPER SURFACE ****
 0.50000   0.50000   0.50000   0.50000   0.50000   0.50000   0.50000
 0.50000   0.50000   0.50000   0.50000   0.50000   0.50000   0.50000
 0.50000   0.50000   0.50000   0.50000   0.50000   0.50000   0.50000
**** MACH NUMBER ON LOWER SURFACE ****
 0.50000   0.50000   0.50000   0.50000   0.50000   0.50000   0.50000
 0.50000   0.50000   0.50000   0.50000   0.50000   0.50000   0.50000
 0.50000   0.50000   0.50000   0.50000   0.50000   0.50000   0.50000

XU(II), XMACH(I), XL(II), XMACH(N)
0.00000000E+00  0.50000000E+00  0.00000000E+00  0.50000000E+00
0.50000000E-01  0.50000000E+00  0.50000000E-01  0.50000000E+00
0.10000000E+00  0.50000000E+00  0.10000000E+00  0.50000000E+00
0.15000000E+00  0.50000000E+00  0.15000000E+00  0.50000000E+00
0.20000000E+00  0.50000000E+00  0.20000000E+00  0.50000000E+00
0.25000000E+00  0.50000000E+00  0.25000000E+00  0.50000000E+00
0.30000000E+00  0.50000000E+00  0.30000000E+00  0.50000000E+00
0.35000000E+00  0.50000000E+00  0.35000000E+00  0.50000000E+00
0.40000000E+00  0.50000000E+00  0.40000000E+00  0.50000000E+00
0.45000000E+00  0.50000000E+00  0.45000000E+00  0.50000000E+00
0.50000000E+00  0.50000000E+00  0.50000000E+00  0.50000000E+00
0.55000000E+00  0.50000000E+00  0.55000000E+00  0.50000000E+00
0.60000000E+00  0.50000000E+00  0.60000000E+00  0.50000000E+00
0.65000000E+00  0.50000000E+00  0.65000000E+00  0.50000000E+00
0.70000000E+00  0.50000000E+00  0.70000000E+00  0.50000000E+00
0.75000000E+00  0.50000000E+00  0.75000000E+00  0.50000000E+00
0.80000000E+00  0.50000000E+00  0.80000000E+00  0.50000000E+00
0.85000000E+00  0.50000000E+00  0.85000000E+00  0.50000000E+00
0.90000000E+00  0.50000000E+00  0.90000000E+00  0.50000000E+00
0.95000000E+00  0.50000000E+00  0.95000000E+00  0.50000000E+00
0.10000000E+01  0.50000000E+00  0.10000000E+01  0.50000000E+00
```

```
NT=    100     NITER=   1     MAX(DPHI)=   0.76E-07     IJ=    697
NT=    200     NITER=   1     MAX(DPHI)=   0.63E-07     IJ=    697
NT=    300     NITER=   1     MAX(DPHI)=   0.44E-07     IJ=    820
NT=    400     NITER=   1     MAX(DPHI)=   0.26E-07     IJ=     19
NT=    500     NITER=   1     MAX(DPHI)=   0.44E-07     IJ=     18
NT=    600     NITER=   1     MAX(DPHI)=   0.53E-07     IJ=     17
NT=    700     NITER=   1     MAX(DPHI)=   0.56E-07     IJ=    656
NT=    800     NITER=   1     MAX(DPHI)=   0.62E-07     IJ=    820
NT=    900     NITER=   1     MAX(DPHI)=   0.55E-07     IJ=    779
NT=   1000     NITER=   1     MAX(DPHI)=   0.37E-07     IJ=    820
NT=   1100     NITER=   1     MAX(DPHI)=   0.31E-07     IJ=     19
NT=   1200     NITER=   1     MAX(DPHI)=   0.47E-07     IJ=     18
NT=   1300     NITER=   1     MAX(DPHI)=   0.54E-07     IJ=     15
NT=   1400     NITER=   1     MAX(DPHI)=   0.58E-07     IJ=    738
NT=   1500     NITER=   1     MAX(DPHI)=   0.60E-07     IJ=    820
NT=   1600     NITER=   1     MAX(DPHI)=   0.51E-07     IJ=    820
NT=   1700     NITER=   1     MAX(DPHI)=   0.31E-07     IJ=    820
NT=   1800     NITER=   1     MAX(DPHI)=   0.36E-07     IJ=     19
NT=   1900     NITER=   1     MAX(DPHI)=   0.50E-07     IJ=     18
NT=   2000     NITER=   1     MAX(DPHI)=   0.54E-07     IJ=     14
NT=   2100     NITER=   1     MAX(DPHI)=   0.59E-07     IJ=    820
NT=   2200     NITER=   1     MAX(DPHI)=   0.60E-07     IJ=    820
NT=   2300     NITER=   1     MAX(DPHI)=   0.47E-07     IJ=    820
NT=   2400     NITER=   1     MAX(DPHI)=   0.25E-07     IJ=    820
NT=   2500     NITER=   1     MAX(DPHI)=   0.40E-07     IJ=     18
NT=   2600     NITER=   1     MAX(DPHI)=   0.52E-07     IJ=     17
NT=   2700     NITER=   1     MAX(DPHI)=   0.53E-07     IJ=    493
NT=   2800     NITER=   1     MAX(DPHI)=   0.61E-07     IJ=    820
NT=   2900     NITER=   1     MAX(DPHI)=   0.57E-07     IJ=    820
NT=   3000     NITER=   1     MAX(DPHI)=   0.42E-07     IJ=    820
NT=   3100     NITER=   1     MAX(DPHI)=   0.26E-07     IJ=     19
NT=   3200     NITER=   1     MAX(DPHI)=   0.44E-07     IJ=     18
NT=   3300     NITER=   1     MAX(DPHI)=   0.53E-07     IJ=     17
NT=   3400     NITER=   1     MAX(DPHI)=   0.54E-07     IJ=    851
NT=   3500     NITER=   1     MAX(DPHI)=   0.61E-07     IJ=    820
NT=   3600     NITER=   1     MAX(DPHI)=   0.55E-07     IJ=    820
NT=   3700     NITER=   1     MAX(DPHI)=   0.37E-07     IJ=    820
NT=   3800     NITER=   1     MAX(DPHI)=   0.31E-07     IJ=     19
NT=   3900     NITER=   1     MAX(DPHI)=   0.47E-07     IJ=     18
NT=   4000     NITER=   1     MAX(DPHI)=   0.54E-07     IJ=     15
 **** MACH NUMBER AT INLET SECTION ****
  0.50003   0.50003   0.50003   0.50003   0.50003   0.50003   0.50003
  0.50003   0.50003   0.50003   0.50003   0.50004   0.50004   0.50004
  0.50004   0.50004   0.50004   0.50004   0.50004   0.50003   0.50003
 **** MACH NUMBER AT EXIT SECTION ****
  0.49995   0.50000   0.49999   0.49999   0.49999   0.49999   0.50000
  0.50000   0.50000   0.50001   0.50001   0.50002   0.50003   0.50004
  0.50005   0.50006   0.50007   0.50009   0.50011   0.50014   0.50020
 **** FLOW ANGLE AT INLET SECTION ****
 44.99676  44.99668  44.99666  44.99665  44.99661  44.99656  44.99651
 44.99647  44.99644  44.99642  44.99642  44.99643  44.99645  44.99649
 44.99652  44.99655  44.99658  44.99660  44.99662  44.99691  44.99676
 **** FLOW ANGLE AT EXIT SECTION ****
```

```
 45.01302  44.99976  44.99708  44.99634  44.99554  44.99497  44.99457
 44.99432  44.99423  44.99430  44.99456  44.99499  44.99561  44.99642
 44.99741  44.99859  45.00001  45.00182  45.00450  45.00917  45.01268
 **** MACH NUMBER AT INLET AND EXIT ****
  0.50003   0.50004
 **** FLOW ANGLE AT INLET AND EXIT ****
 44.99658  44.99904

 TOTAL NEWTON-ITERATIONS= 4067
 TOTAL TIME STEPS= 4060
AVERAGE ITERATIONS PER TIME STEP=   1.0

 ***  UPPER SURFACE  ***
 X/C      AM0       AM1       TH1       RE1       IM1       %H2    %H3
0.000    0.0016    4.2211     3.55    4.2130    0.2614      0      0
0.050    0.0001    3.6609     5.84    3.6420    0.3723      0      0
0.100   -0.0013    2.9575     8.62    2.9241    0.4434      0      0
0.150   -0.0019    2.5324    11.17    2.4844    0.4906      0      0
0.200   -0.0021    2.2271    13.58    2.1648    0.5231      0      0
0.250   -0.0023    1.9819    15.98    1.9053    0.5455      0      0
0.300   -0.0024    1.7696    18.44    1.6787    0.5599      0      0
0.350   -0.0024    1.5770    21.08    1.4715    0.5671      0      0
0.400   -0.0023    1.3972    23.98    1.2767    0.5678      0      0
0.450   -0.0022    1.2273    27.26    1.0909    0.5622      0      0
0.500   -0.0021    1.0662    31.07    0.9132    0.5503      0      0
0.550   -0.0018    0.9145    35.59    0.7437    0.5322      0      0
0.600   -0.0016    0.7737    41.03    0.5836    0.5079      0      0
0.650   -0.0013    0.6455    47.68    0.4345    0.4773      0      0
0.700   -0.0010    0.5317    55.89    0.2982    0.4402      0      0
0.750   -0.0007    0.4338    66.00    0.1764    0.3963      0      0
0.800   -0.0005    0.3529    77.91    0.0739    0.3451      0      0
0.850   -0.0003    0.2854    89.20    0.0040    0.2853      0      0
0.900   -0.0002    0.2180   102.36   -0.0467    0.2130      0      0
0.950    0.0010    0.4855   166.61   -0.4723    0.1124      0      0
1.000    0.0007    0.3677  -173.99   -0.3656   -0.0385      0      0

 MAX. % 2ND AND 3RD HARMONIC (UPPER) = 0

 ***  LOWER SURFACE  ***
 X/C      AM0       AM1       TH1       RE1       IM1       %H2    %H3
0.000    0.0080    4.5161   176.24   -4.5064    0.2965      0      0
0.050    0.0036    3.1195   178.01   -3.1176    0.1084      0      0
0.100    0.0014    1.8504  -179.41   -1.8503   -0.0190      0      0
0.150    0.0008    1.3182  -175.72   -1.3146   -0.0984      0      0
0.200    0.0008    1.0758  -171.39   -1.0637   -0.1610      0      0
0.250    0.0008    0.9309  -166.64   -0.9058   -0.2151      0      0
0.300    0.0008    0.8366  -161.74   -0.7945   -0.2621      0      0
0.350    0.0008    0.7754  -157.02   -0.7139   -0.3027      0      0
0.400    0.0009    0.7364  -152.73   -0.6545   -0.3375      0      0
0.450    0.0009    0.7116  -148.99   -0.6099   -0.3666      0      0
0.500    0.0009    0.6956  -145.88   -0.5759   -0.3902      0      0
0.550    0.0010    0.6847  -143.38   -0.5495   -0.4084      0      0
0.600    0.0010    0.6762  -141.49   -0.5292   -0.4210      0      0
0.650    0.0010    0.6685  -140.20   -0.5136   -0.4279      0      0
```

```
0.700     0.0010     0.6604   -139.50    -0.5022    -0.4289      0      0
0.750     0.0011     0.6516   -139.48    -0.4953    -0.4233      0      0
0.800     0.0011     0.6422   -140.32    -0.4943    -0.4101      0      0
0.850     0.0012     0.6353   -142.45    -0.5036    -0.3872      0      0
0.900     0.0013     0.6448   -147.06    -0.5411    -0.3506      0      0
0.950     0.0015     0.7595   -157.41    -0.7013    -0.2918      0      0
1.000     0.0005     0.3931   -151.02    -0.3439    -0.1905      0      0

 MAX. % 2ND AND 3RD HARMONIC (LOWER) = 0

 ***  LOWER - UPPER  ***
 X/C       AM0        AM1        TH1        RE1        IM1       %H2    %H3
0.000     0.0063     8.7195    179.77    -8.7194     0.0351      0      0
0.050     0.0035     6.7647   -177.76    -6.7595    -0.2640      0      0
0.100     0.0027     4.7968   -174.47    -4.7744    -0.4625      0      0
0.150     0.0027     3.8444   -171.19    -3.7990    -0.5890      0      0
0.200     0.0029     3.3002   -168.04    -3.2285    -0.6841      0      0
0.250     0.0031     2.9121   -164.86    -2.8111    -0.7606      0      0
0.300     0.0032     2.6062   -161.62    -2.4732    -0.8220      0      0
0.350     0.0032     2.3521   -158.30    -2.1854    -0.8699      0      0
0.400     0.0032     2.1328   -154.88    -1.9312    -0.9053      0      0
0.450     0.0031     1.9379   -151.36    -1.7009    -0.9288      0      0
0.500     0.0030     1.7612   -147.72    -1.4890    -0.9405      0      0
0.550     0.0028     1.5991   -143.97    -1.2932    -0.9406      0      0
0.600     0.0026     1.4495   -140.15    -1.1128    -0.9289      0      0
0.650     0.0023     1.3109   -136.33    -0.9481    -0.9052      0      0
0.700     0.0021     1.1815   -132.64    -0.8004    -0.8691      0      0
0.750     0.0018     1.0597   -129.34    -0.6717    -0.8196      0      0
0.800     0.0016     0.9450   -126.96    -0.5682    -0.7552      0      0
0.850     0.0015     0.8426   -127.05    -0.5076    -0.6725      0      0
0.900     0.0015     0.7498   -131.26    -0.4945    -0.5636      0      0
0.950     0.0005     0.4646   -119.53    -0.2290    -0.4042      0      0
1.000    -0.0002     0.1535    -81.86     0.0217    -0.1520      0      0

 MAX. % 2ND AND 3RD HARMONIC (DIFF.) = 0


 LIFT AND MOMENT COEFFICIENTS :

        AM(CL)  TH(CL)   RE(CL)   IM(CL)    AM(CM)  TH(CM)   RE(CM)   IM(CM)
1ST:    2.222    18.6    2.106    0.707     0.665    33.3    0.556    0.365
2ND:    0.003   101.5   -0.001    0.003     0.001   109.7    0.000    0.001
3RD:    0.000  -171.0    0.000    0.000     0.000  -165.4    0.000    0.000


 >>>>>>>>  AERODYNAMIC COEFFICIENTS  <<<<<<<<

MACH NUMBER=  0.5000
REDUCED FREQUENCY=  0.2220
INTER-BLADE PHASE ANGLE=     0.0000
STAGGER ANGLE=    45.0000

 CFL  =   (  -0.3352 ,   -0.1126 )    LHL  =   (  -54.4163 ,   -18.2702 )
 CMA  =   (  -0.0885 ,   -0.0581 )    LLL  =   (  -28.7281 ,   -18.8730 )
```

**additional output files:**

| | |
|---|---|
| `fort.7` | binary flow file for use with restart option |
| `fort.9` | unsteady pressure difference coefficient plot data file |
| `fort.12` | unsteady lift and moment coefficient history file |

## 4.2 Test Case 2: Unsteady Aerodynamics of a Flat-Plate Cascade Using the Influence Coefficient Method

**Description:**

In this test case (Ref. 4), the unsteady aerodynamic coefficients for a flat-plate cascade at zero incidence are calculated using the influence coefficient method. The cascade stagger angle is 45 deg. and the gap-to-chord ratio is 1.0. The Mach number at the inlet and exit is 0.5. The unsteady aerodynamic coefficients are calculated for pitching about the leading edge at a reduced frequency of 0.222 for interblade phase angle values of 0, 40, 80, ... , 320 deg. A pitching amplitude of 0.1 deg. is used in the calculations. The grid used has 41 points in the streamwise direction and 21 points in the circumferential direction. 9 blade passages are used in the calculation. In each blade passage, 21 points are located on each (upper and lower) surface of the airfoil, and 19 points are located on the wake. Calculations are performed for 10 time steps with no blade motion, followed 3 cycles of blade oscillation with 360 time steps per cycle. Only one blade is oscillated, all other blades remain stationary. No flutter calculations are performed, therefore the structural parameters specified in the input data file are not used. The stability of the cascade can be determined from the unsteady aerodynamic coefficients.

Note that for this test case, additional post-processing of the results from FPCAS2D is required. The influence coefficients calculated by the code (written to standard output) need to be combined using the influence coefficient method. This is done using the post-processing code influnce.f. The influnce coefficients are read in from unit 4 and the unsteady aerodynamic coefficients are written to standard output. The input and output from influnce.f are also included in this section.

**para.f:**

```
      PARAMETER
     & (ID1 = 08000, ID2 = 00500, ID3 = 00065, ID4 = 00025, ID5 = 00220,
     &  ID6 = 00025, ID7 = 00025, ID8 = 00020, ID9 = 02000)
```

**fpcas2d.input:**

```
CJOB
TEST002
TITLE
```

```
TEST CASE 002 FOR FPCAS2D
PHASE
0.0
TH1         THS         TH2         TH3
45.0        45.0        45.0        45.0
XMINF       XMOUT
0.5         0.5
SBYC
1.0
A
-1.0
XKC
0.222
IMODE
1
ALFAA       XCONV
0.1         1.0E-06
NPMAX       IMAX        JMAX        NPAF        NPW
9           41          21          21          9
NTSS        NTPC        NCYE        NTMX        NTPRNT
10          1350        3           0           100
IPLOT       NTPBEG      NTPINC      NTPEND
0           0           0           0
IYBIA       ISUPER      INITI       ITMAX       ISMTH       IMOUT
0           0           2           5           0           0
IRUN        IFLTR
0           3
MV    1   2   3   4   5   6   7   8   9
      1   0   0   0   0   0   0   0   0
GHS         GAS         ZHS         ZAS
1.0         1.0         0.0         0.0
XMU         XRA         XA
1.0         1.0         0.0
VSTAR
1.0
IGRIDX      BETAX       IGRIDY      BETAY
0           0.0         0           0.0
IAIRFL      TBYC        HBYC
1           0.0         0.0
```

## fpcas2d.output:

```
TEST CASE 002 FOR FPCAS2D

 9 PASSAGE(S) USED WITH A MULTIPLIER OF 0

  BLADE(S) BEING OSCILLATED:
  NUMBER 1


  *******  GEOMETRY  *******

  AIRFOIL COORDINATES, UPPER ( XU AND YU ) :
```

```
   0.0000    0.0500    0.1000    0.1500    0.2000    0.2500    0.3000
   0.3500    0.4000    0.4500    0.5000    0.5500    0.6000    0.6500
   0.7000    0.7500    0.8000    0.8500    0.9000    0.9500    1.0000

   0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
   0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
   0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000

 AIRFOIL COORDINATES, LOWER ( XL AND YL ) :

   0.0000    0.0500    0.1000    0.1500    0.2000    0.2500    0.3000
   0.3500    0.4000    0.4500    0.5000    0.5500    0.6000    0.6500
   0.7000    0.7500    0.8000    0.8500    0.9000    0.9500    1.0000

   0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
   0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
   0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000

 OUTER BOUNDARY ( XX AND YY ) :

  -0.5000   -0.4500   -0.4000   -0.3500   -0.3000   -0.2500   -0.2000
  -0.1500   -0.1000   -0.0500    0.0000    0.0500    0.1000    0.1500
   0.2000    0.2500    0.3000    0.3500    0.4000    0.4500    0.5000
   0.5500    0.6000    0.6500    0.7000    0.7500    0.8000    0.8500
   0.9000    0.9500    1.0000    1.0500    1.1000    1.1500    1.2000
   1.2500    1.3000    1.3500    1.4000    1.4500    1.5000

   0.0000    0.0500    0.1000    0.1500    0.2000    0.2500    0.3000
   0.3500    0.4000    0.4500    0.5000    0.5500    0.6000    0.6500
   0.7000    0.7500    0.8000    0.8500    0.9000    0.9500    1.0000

SBYC =  1.000

CALCULATED EXIT MACH NUMBER=  0.50000


 *******    GRID    *******

NPSG= 9 IMAX= 41 JMAX= 21
NFW=  9 NPAF= 21 NPW=  9
IMODE= 1

 ******* FREESTREAM *******

MACH NUMBER=  0.5000
INTER-BLADE PHASE ANGLE=    0.0000
REDUCED FRE=  0.2220
ALFAA=    0.1000
TH1=   45.0000 THS=   45.0000 TH2=   45.0000 TH3=   45.0000

 *******  NUMERICAL *******
```

```
NTSS=  10 NTPC=1350 NCYE=   3
XP=  0.0000 YP=  0.0000
DT=  0.0419 XCONV=  0.10E-05
IRUN= 0 ISUPER= 0 IYBIA= 0 INITI= 2 ITMAX=  5


 CONVERGENCE HISTORY :

NT=    10     NITER=   1     MAX(DPHI)=   0.78E-13     IJ=   6519
 **** DELTA CP NEAR I = ILE ****
  0.00000   0.00000   0.00000   0.00000   0.00000
 **** DELTA CP NEAR I = ITE ****
  0.00000   0.00000   0.00000   0.00000   0.00000
 **** PRESSURE ON UPPER SURFACE ****
  0.00000   0.00000   0.00000   0.00000   0.00000   0.00000   0.00000
  0.00000   0.00000   0.00000   0.00000   0.00000   0.00000   0.00000
  0.00000   0.00000   0.00000   0.00000   0.00000   0.00000   0.00000
 **** PRESSURE ON LOWER SURFACE ****
  0.00000   0.00000   0.00000   0.00000   0.00000   0.00000   0.00000
  0.00000   0.00000   0.00000   0.00000   0.00000   0.00000   0.00000
  0.00000   0.00000   0.00000   0.00000   0.00000   0.00000   0.00000

 XU(II), CP(I), XL(II), CP(N)
 0.00000000E+00 -0.16240977E-12  0.00000000E+00  0.15834952E-11
 0.50000000E-01 -0.28421709E-12  0.50000000E-01  0.21519294E-11
 0.10000000E+00  0.16240977E-12  0.10000000E+00  0.10150611E-11
 0.15000000E+00  0.44662686E-12  0.15000000E+00  0.69836200E-11
 0.20000000E+00  0.44662686E-12  0.20000000E+00  0.48316906E-11
 0.25000000E+00  0.44662686E-12  0.25000000E+00  0.32887978E-11
 0.30000000E+00  0.16240977E-12  0.30000000E+00  0.71054274E-11
 0.35000000E+00  0.44662686E-12  0.35000000E+00  0.27203636E-11
 0.40000000E+00  0.56843419E-12  0.40000000E+00  0.21519294E-11
 0.45000000E+00  0.73084396E-12  0.45000000E+00  0.27203636E-11
 0.50000000E+00  0.73084396E-12  0.50000000E+00  0.35730149E-11
 0.55000000E+00  0.16240977E-12  0.55000000E+00  0.89731397E-11
 0.60000000E+00  0.00000000E+00  0.60000000E+00  0.48316906E-11
 0.65000000E+00  0.00000000E+00  0.65000000E+00  0.48316906E-11
 0.70000000E+00  0.00000000E+00  0.70000000E+00  0.59685590E-11
 0.75000000E+00  0.85265128E-12  0.75000000E+00  0.59685590E-11
 0.80000000E+00  0.10150611E-11  0.80000000E+00  0.59685590E-11
 0.85000000E+00  0.11368684E-11  0.85000000E+00  0.59685590E-11
 0.90000000E+00  0.11368684E-11  0.90000000E+00  0.59685590E-11
 0.95000000E+00  0.24361465E-11  0.95000000E+00  0.59685590E-11
 0.10000000E+01  0.35730149E-11  0.10000000E+01  0.59685590E-11

 **** MACH NUMBER ON UPPER SURFACE ****
  0.50000   0.50000   0.50000   0.50000   0.50000   0.50000   0.50000
  0.50000   0.50000   0.50000   0.50000   0.50000   0.50000   0.50000
  0.50000   0.50000   0.50000   0.50000   0.50000   0.50000   0.50000
 **** MACH NUMBER ON LOWER SURFACE ****
  0.50000   0.50000   0.50000   0.50000   0.50000   0.50000   0.50000
  0.50000   0.50000   0.50000   0.50000   0.50000   0.50000   0.50000
  0.50000   0.50000   0.50000   0.50000   0.50000   0.50000   0.50000
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 XU(II), XMACH(I), XL(II), XMACH(N)
 0.00000000E+00  0.50000000E+00  0.00000000E+00  0.50000000E+00
 0.50000000E-01  0.50000000E+00  0.50000000E-01  0.50000000E+00
 0.10000000E+00  0.50000000E+00  0.10000000E+00  0.50000000E+00
 0.15000000E+00  0.50000000E+00  0.15000000E+00  0.50000000E+00
 0.20000000E+00  0.50000000E+00  0.20000000E+00  0.50000000E+00
 0.25000000E+00  0.50000000E+00  0.25000000E+00  0.50000000E+00
 0.30000000E+00  0.50000000E+00  0.30000000E+00  0.50000000E+00
 0.35000000E+00  0.50000000E+00  0.35000000E+00  0.50000000E+00
 0.40000000E+00  0.50000000E+00  0.40000000E+00  0.50000000E+00
 0.45000000E+00  0.50000000E+00  0.45000000E+00  0.50000000E+00
 0.50000000E+00  0.50000000E+00  0.50000000E+00  0.50000000E+00
 0.55000000E+00  0.50000000E+00  0.55000000E+00  0.50000000E+00
 0.60000000E+00  0.50000000E+00  0.60000000E+00  0.50000000E+00
 0.65000000E+00  0.50000000E+00  0.65000000E+00  0.50000000E+00
 0.70000000E+00  0.50000000E+00  0.70000000E+00  0.50000000E+00
 0.75000000E+00  0.50000000E+00  0.75000000E+00  0.50000000E+00
 0.80000000E+00  0.50000000E+00  0.80000000E+00  0.50000000E+00
 0.85000000E+00  0.50000000E+00  0.85000000E+00  0.50000000E+00
 0.90000000E+00  0.50000000E+00  0.90000000E+00  0.50000000E+00
 0.95000000E+00  0.50000000E+00  0.95000000E+00  0.50000000E+00
 0.10000000E+01  0.50000000E+00  0.10000000E+01  0.50000000E+00

NT=   100     NITER=   1     MAX(DPHI)=   0.26E-07     IJ=    843
NT=   200     NITER=   1     MAX(DPHI)=   0.29E-07     IJ=   7708
NT=   300     NITER=   1     MAX(DPHI)=   0.37E-07     IJ=   7708
NT=   400     NITER=   1     MAX(DPHI)=   0.38E-07     IJ=   7708
NT=   500     NITER=   1     MAX(DPHI)=   0.31E-07     IJ=   7708
NT=   600     NITER=   1     MAX(DPHI)=   0.25E-07     IJ=    820
NT=   700     NITER=   1     MAX(DPHI)=   0.13E-07     IJ=    820
NT=   800     NITER=   1     MAX(DPHI)=   0.19E-07     IJ=   7708
NT=   900     NITER=   1     MAX(DPHI)=   0.33E-07     IJ=   7708
NT=  1000     NITER=   1     MAX(DPHI)=   0.39E-07     IJ=   7708
NT=  1100     NITER=   1     MAX(DPHI)=   0.38E-07     IJ=   7708
NT=  1200     NITER=   1     MAX(DPHI)=   0.30E-07     IJ=    820
NT=  1300     NITER=   1     MAX(DPHI)=   0.22E-07     IJ=    820
NT=  1400     NITER=   1     MAX(DPHI)=   0.11E-07     IJ=   2501
NT=  1500     NITER=   1     MAX(DPHI)=   0.23E-07     IJ=   7708
NT=  1600     NITER=   1     MAX(DPHI)=   0.35E-07     IJ=   7708
NT=  1700     NITER=   1     MAX(DPHI)=   0.40E-07     IJ=   7708
NT=  1800     NITER=   1     MAX(DPHI)=   0.36E-07     IJ=   7708
NT=  1900     NITER=   1     MAX(DPHI)=   0.28E-07     IJ=    820
NT=  2000     NITER=   1     MAX(DPHI)=   0.19E-07     IJ=    820
NT=  2100     NITER=   1     MAX(DPHI)=   0.10E-07     IJ=   7737
NT=  2200     NITER=   1     MAX(DPHI)=   0.26E-07     IJ=   7708
NT=  2300     NITER=   1     MAX(DPHI)=   0.37E-07     IJ=   7708
NT=  2400     NITER=   1     MAX(DPHI)=   0.40E-07     IJ=   7708
NT=  2500     NITER=   1     MAX(DPHI)=   0.34E-07     IJ=   7708
NT=  2600     NITER=   1     MAX(DPHI)=   0.26E-07     IJ=    820
NT=  2700     NITER=   1     MAX(DPHI)=   0.16E-07     IJ=    820
NT=  2800     NITER=   1     MAX(DPHI)=   0.15E-07     IJ=   7667
NT=  2900     NITER=   1     MAX(DPHI)=   0.30E-07     IJ=   7708
NT=  3000     NITER=   1     MAX(DPHI)=   0.38E-07     IJ=   7708
NT=  3100     NITER=   1     MAX(DPHI)=   0.39E-07     IJ=   7708
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NT=  3200     NITER=   1     MAX(DPHI)=   0.31E-07     IJ=   7708
NT=  3300     NITER=   1     MAX(DPHI)=   0.24E-07     IJ=    820
NT=  3400     NITER=   1     MAX(DPHI)=   0.13E-07     IJ=    820
NT=  3500     NITER=   1     MAX(DPHI)=   0.19E-07     IJ=   7708
NT=  3600     NITER=   1     MAX(DPHI)=   0.33E-07     IJ=   7708
NT=  3700     NITER=   1     MAX(DPHI)=   0.39E-07     IJ=   7708
NT=  3800     NITER=   1     MAX(DPHI)=   0.38E-07     IJ=   7708
NT=  3900     NITER=   1     MAX(DPHI)=   0.30E-07     IJ=    820
NT=  4000     NITER=   1     MAX(DPHI)=   0.22E-07     IJ=    820
 **** MACH NUMBER AT INLET SECTION ****
  0.49974   0.49972   0.49970   0.49968   0.49966   0.49964   0.49962
  0.49961   0.49960   0.49960   0.49961   0.49962   0.49963   0.49965
  0.49967   0.49969   0.49971   0.49972   0.49974   0.49976   0.49978
  0.49978   0.49979   0.49981   0.49983   0.49984   0.49986   0.49987
  0.49988   0.49990   0.49991   0.49992   0.49993   0.49994   0.49995
  0.49996   0.49997   0.49998   0.49999   0.49999   0.50000   0.50001
  0.50001   0.50001   0.50002   0.50002   0.50003   0.50003   0.50004
  0.50004   0.50004   0.50005   0.50005   0.50005   0.50006   0.50006
  0.50006   0.50007   0.50007   0.50007   0.50007   0.50008   0.50008
  0.50008   0.50009   0.50009   0.50010   0.50010   0.50011   0.50011
  0.50012   0.50012   0.50012   0.50012   0.50012   0.50012   0.50012
  0.50012   0.50012   0.50012   0.50012   0.50012   0.50012   0.50012
  0.50012   0.50013   0.50013   0.50013   0.50014   0.50014   0.50015
  0.50015   0.50015   0.50015   0.50015   0.50015   0.50015   0.50015
  0.50014   0.50014   0.50014   0.50014   0.50013   0.50013   0.50013
  0.50013   0.50014   0.50014   0.50014   0.50015   0.50015   0.50015
  0.50015   0.50015   0.50015   0.50015   0.50015   0.50014   0.50014
  0.50014   0.50013   0.50013   0.50013   0.50012   0.50012   0.50012
  0.50012   0.50012   0.50012   0.50012   0.50012   0.50013   0.50013
  0.50013   0.50013   0.50013   0.50012   0.50012   0.50011   0.50011
  0.50010   0.50010   0.50009   0.50009   0.50008   0.50008   0.50008
  0.50008   0.50007   0.50007   0.50007   0.50007   0.50006   0.50006
  0.50006   0.50005   0.50005   0.50004   0.50004   0.50003   0.50003
  0.50002   0.50001   0.50000   0.50000   0.49999   0.49998   0.49997
  0.49997   0.49996   0.49995   0.49994   0.49993   0.49991   0.49990
  0.49989   0.49988   0.49987   0.49986   0.49985   0.49985   0.49984
  0.49983   0.49982   0.49981   0.49979   0.49978   0.49976   0.49974
 **** MACH NUMBER AT EXIT SECTION ****
  0.49984   0.49995   0.49992   0.49991   0.49990   0.49990   0.49989
  0.49989   0.49988   0.49988   0.49988   0.49987   0.49987   0.49987
  0.49987   0.49986   0.49986   0.49985   0.49984   0.49982   0.49978
  0.49997   0.49993   0.49994   0.49995   0.49995   0.49995   0.49995
  0.49995   0.49996   0.49996   0.49996   0.49996   0.49996   0.49996
  0.49996   0.49996   0.49995   0.49995   0.49995   0.49995   0.49993
  0.49999   0.49998   0.49998   0.49998   0.49998   0.49998   0.49999
  0.49999   0.49999   0.49999   0.49999   0.49999   0.49999   0.49999
  0.49999   0.49999   0.49998   0.49998   0.49998   0.49998   0.49997
  0.50001   0.50000   0.50000   0.50000   0.50000   0.50000   0.50000
  0.50000   0.50000   0.50000   0.50000   0.50000   0.50000   0.50000
  0.50000   0.50000   0.50000   0.50000   0.50000   0.50000   0.50000
  0.50002   0.50001   0.50001   0.50001   0.50001   0.50001   0.50001
  0.50001   0.50001   0.50001   0.50001   0.50001   0.50001   0.50001
  0.50001   0.50001   0.50001   0.50001   0.50001   0.50001   0.50001
  0.50002   0.50002   0.50002   0.50002   0.50002   0.50002   0.50002
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 0.50002   0.50002   0.50002   0.50002   0.50002   0.50002   0.50002
 0.50002   0.50002   0.50002   0.50002   0.50002   0.50002   0.50002
 0.50002   0.50002   0.50002   0.50002   0.50002   0.50002   0.50002
 0.50002   0.50002   0.50002   0.50002   0.50002   0.50002   0.50002
 0.50002   0.50002   0.50002   0.50002   0.50002   0.50002   0.50002
 0.50003   0.50003   0.50003   0.50003   0.50003   0.50003   0.50003
 0.50003   0.50003   0.50003   0.50003   0.50003   0.50003   0.50003
 0.50003   0.50003   0.50003   0.50002   0.50002   0.50002   0.50000
 0.50006   0.50005   0.50006   0.50006   0.50006   0.50007   0.50007
 0.50008   0.50008   0.50009   0.50010   0.50011   0.50012   0.50014
 0.50015   0.50017   0.50019   0.50022   0.50025   0.50032   0.50047
**** FLOW ANGLE AT INLET SECTION ****
44.99637  44.99531  44.99412  44.99279  44.99135  44.98988  44.98843
44.98706  44.98584  44.98478  44.98389  44.98317  44.98259  44.98214
44.98180  44.98155  44.98138  44.98129  44.98126  44.98131  44.98136
44.98136  44.98157  44.98177  44.98205  44.98239  44.98280  44.98327
44.98379  44.98435  44.98494  44.98554  44.98615  44.98675  44.98733
44.98790  44.98844  44.98896  44.98946  44.98994  44.99044  44.99083
44.99083  44.99134  44.99174  44.99217  44.99259  44.99301  44.99342
44.99383  44.99424  44.99464  44.99503  44.99540  44.99577  44.99613
44.99648  44.99681  44.99715  44.99747  44.99781  44.99817  44.99846
44.99846  44.99889  44.99923  44.99962  45.00001  45.00039  45.00076
45.00110  45.00141  45.00168  45.00192  45.00214  45.00232  45.00250
45.00266  45.00281  45.00297  45.00314  45.00332  45.00353  45.00370
45.00370  45.00401  45.00425  45.00454  45.00483  45.00513  45.00540
45.00564  45.00583  45.00598  45.00608  45.00615  45.00620  45.00622
45.00624  45.00626  45.00629  45.00633  45.00638  45.00648  45.00655
45.00655  45.00673  45.00688  45.00707  45.00727  45.00747  45.00765
45.00779  45.00788  45.00793  45.00794  45.00792  45.00786  45.00780
45.00773  45.00766  45.00760  45.00755  45.00753  45.00753  45.00753
45.00753  45.00760  45.00766  45.00776  45.00787  45.00798  45.00806
45.00812  45.00814  45.00812  45.00807  45.00799  45.00788  45.00777
45.00764  45.00752  45.00741  45.00730  45.00720  45.00712  45.00704
45.00704  45.00699  45.00695  45.00692  45.00689  45.00687  45.00683
45.00678  45.00671  45.00661  45.00650  45.00637  45.00622  45.00606
45.00590  45.00572  45.00553  45.00533  45.00511  45.00487  45.00462
45.00462  45.00434  45.00403  45.00370  45.00336  45.00300  45.00265
45.00231  45.00199  45.00169  45.00140  45.00111  45.00082  45.00050
45.00014  44.99973  44.99926  44.99870  44.99804  44.99727  44.99637
**** FLOW ANGLE AT EXIT SECTION ****
45.04557  45.01338  45.00662  45.00502  45.00333  45.00210  45.00110
45.00026  44.99952  44.99885  44.99821  44.99758  44.99694  44.99627
44.99555  44.99475  44.99379  44.99256  44.99075  44.98738  44.98492
44.98501  44.99442  44.99652  44.99706  44.99758  44.99795  44.99823
44.99844  44.99858  44.99867  44.99872  44.99872  44.99868  44.99860
44.99848  44.99831  44.99808  44.99775  44.99725  44.99627  44.99556
44.99563  44.99839  44.99904  44.99920  44.99935  44.99944  44.99951
44.99956  44.99958  44.99959  44.99958  44.99955  44.99951  44.99945
44.99936  44.99925  44.99911  44.99891  44.99861  44.99803  44.99761
44.99767  44.99928  44.99966  44.99975  44.99982  44.99987  44.99991
44.99993  44.99994  44.99995  44.99994  44.99993  44.99991  44.99989
44.99984  44.99979  44.99971  44.99961  44.99945  44.99914  44.99892
44.99896  44.99980  45.00000  45.00004  45.00007  45.00009  45.00010
45.00011  45.00011  45.00011  45.00011  45.00011  45.00010  45.00009
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 45.00008  45.00005  45.00002  44.99997  44.99989  44.99975  44.99965
 44.99968  45.00004  45.00012  45.00013  45.00013  45.00013  45.00013
 45.00012  45.00011  45.00011  45.00010  45.00009  45.00008  45.00006
 45.00005  45.00002  44.99999  44.99995  44.99988  44.99976  44.99967
 44.99968  45.00001  45.00008  45.00008  45.00009  45.00009  45.00008
 45.00007  45.00005  45.00003  45.00001  44.99998  44.99995  44.99991
 44.99986  44.99980  44.99972  44.99962  44.99945  44.99915  44.99893
 44.99893  44.99972  44.99985  44.99984  44.99980  44.99974  44.99963
 44.99949  44.99931  44.99908  44.99880  44.99848  44.99809  44.99766
 44.99717  44.99662  44.99601  44.99530  44.99439  44.99300  44.99190
 44.99189  44.99472  44.99519  44.99523  44.99536  44.99556  44.99588
 44.99635  44.99701  44.99791  44.99907  45.00054  45.00234  45.00448
 45.00701  45.00998  45.01356  45.01814  45.02478  45.03666  45.04548
 **** MACH NUMBER AT INLET AND EXIT ****
  0.50000   0.50000
 **** FLOW ANGLE AT INLET AND EXIT ****
 44.99961  44.99989

 TOTAL NEWTON-ITERATIONS= 4067
 TOTAL TIME STEPS= 4060
AVERAGE ITERATIONS PER TIME STEP=   1.0
 >>>>>>>>  INFLUENCE COEFFICIENTS  <<<<<<<<

MACH NUMBER=  0.5000
REDUCED FREQUENCY=  0.2220
STAGGER ANGLE=   45.0000


 LIFT AND MOMENT COEFFICIENTS FOR BLADE K= 1

        AM(CL) TH(CL)  RE(CL)  IM(CL)   AM(CM) TH(CM)  RE(CM)  IM(CM)
1ST:    5.608    3.8   5.596   0.368    1.728   11.2   1.695   0.336
2ND:    0.001  117.1   0.000   0.001    0.000 -162.7   0.000   0.000
3RD:    0.000    3.5   0.000   0.000    0.000   -3.0   0.000   0.000


4
 CFL  =   (  -0.8906 ,  -0.0586 )    LHL  =   ( -144.5736 ,   -9.5069 )
 CMA  =   (  -0.2697 ,  -0.0534 )    LLL  =   (  -87.5649 ,  -17.3385 )


 LIFT AND MOMENT COEFFICIENTS FOR BLADE K= 2

        AM(CL) TH(CL)  RE(CL)  IM(CL)   AM(CM) TH(CM)  RE(CM)  IM(CM)
1ST:    1.566 -176.4  -1.563  -0.099    0.387 -175.4  -0.386  -0.031
2ND:    0.001   39.1   0.001   0.000    0.000   55.6   0.000   0.000
3RD:    0.000  170.8   0.000   0.000    0.000 -172.0   0.000   0.000


3
 CFL  =   (   0.2487 ,   0.0158 )    LHL  =   (   40.3708 ,    2.5685 )
 CMA  =   (   0.0614 ,   0.0049 )    LLL  =   (   19.9256 ,    1.5989 )
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 LIFT AND MOMENT COEFFICIENTS FOR BLADE K= 3

        AM(CL) TH(CL)  RE(CL)  IM(CL)   AM(CM) TH(CM)  RE(CM)  IM(CM)
1ST:    0.459 -175.5  -0.457  -0.036    0.114 -172.3  -0.113  -0.015
2ND:    0.000  -14.9   0.000   0.000    0.000   -5.6   0.000   0.000
3RD:    0.000   82.9   0.000   0.000    0.000  100.5   0.000   0.000


2
 CFL  =   (   0.0728 ,   0.0057 )    LHL  =   (   11.8178 ,    0.9320 )
 CMA  =   (   0.0179 ,   0.0024 )    LLL  =   (    5.8216 ,    0.7860 )

 LIFT AND MOMENT COEFFICIENTS FOR BLADE K= 4

        AM(CL) TH(CL)  RE(CL)  IM(CL)   AM(CM) TH(CM)  RE(CM)  IM(CM)
1ST:    0.338  157.7  -0.312   0.128    0.082  159.0  -0.077   0.030
2ND:    0.000  -57.7   0.000   0.000    0.000  -52.6   0.000   0.000
3RD:    0.000   39.4   0.000   0.000    0.000   52.3   0.000   0.000


1
 CFL  =   (   0.0497 ,  -0.0204 )    LHL  =   (    8.0698 ,   -3.3138 )
 CMA  =   (   0.0122 ,  -0.0047 )    LLL  =   (    3.9758 ,   -1.5268 )

 LIFT AND MOMENT COEFFICIENTS FOR BLADE K= 5

        AM(CL) TH(CL)  RE(CL)  IM(CL)   AM(CM) TH(CM)  RE(CM)  IM(CM)
1ST:    0.284  136.0  -0.205   0.198    0.070  137.9  -0.052   0.047
2ND:    0.000  -81.5   0.000   0.000    0.000  -72.1   0.000   0.000
3RD:    0.000   17.7   0.000   0.000    0.000   38.9   0.000   0.000


0
 CFL  =   (   0.0326 ,  -0.0314 )    LHL  =   (    5.2885 ,   -5.1026 )
 CMA  =   (   0.0083 ,  -0.0075 )    LLL  =   (    2.7023 ,   -2.4391 )

 LIFT AND MOMENT COEFFICIENTS FOR BLADE K= 6

        AM(CL) TH(CL)  RE(CL)  IM(CL)   AM(CM) TH(CM)  RE(CM)  IM(CM)
1ST:    0.247  122.0  -0.131   0.210    0.062  126.2  -0.036   0.050
2ND:    0.000 -127.4   0.000   0.000    0.000 -174.7   0.000   0.000
3RD:    0.000 -148.2   0.000   0.000    0.000 -148.5   0.000   0.000


-1
 CFL  =   (   0.0209 ,  -0.0334 )    LHL  =   (    3.3888 ,   -5.4179 )
 CMA  =   (   0.0058 ,  -0.0079 )    LLL  =   (    1.8839 ,   -2.5728 )

 LIFT AND MOMENT COEFFICIENTS FOR BLADE K= 7
```

```
        AM(CL)  TH(CL)   RE(CL)   IM(CL)    AM(CM)  TH(CM)   RE(CM)   IM(CM)
1ST:    0.201   124.6   -0.114    0.166     0.051   134.7   -0.036    0.036
2ND:    0.000   125.4    0.000    0.000     0.000   130.5    0.000    0.000
3RD:    0.000  -133.7    0.000    0.000     0.000  -118.0    0.000    0.000


-2
 CFL  =   (   0.0182 ,  -0.0263 )    LHL  =   (    2.9553 ,   -4.2764 )
 CMA  =   (   0.0057 ,  -0.0058 )    LLL  =   (    1.8621 ,   -1.8831 )


 LIFT AND MOMENT COEFFICIENTS FOR BLADE K= 8

        AM(CL)  TH(CL)   RE(CL)   IM(CL)    AM(CM)  TH(CM)   RE(CM)   IM(CM)
1ST:    0.169   168.3   -0.166    0.034     0.064  -179.2   -0.064   -0.001
2ND:    0.000   143.6    0.000    0.000     0.000   153.4    0.000    0.000
3RD:    0.000   -91.3    0.000    0.000     0.000   -73.1    0.000    0.000


-3
 CFL  =   (   0.0264 ,  -0.0055 )    LHL  =   (    4.2804 ,   -0.8886 )
 CMA  =   (   0.0102 ,   0.0001 )    LLL  =   (    3.3002 ,    0.0451 )


 LIFT AND MOMENT COEFFICIENTS FOR BLADE K= 9

        AM(CL)  TH(CL)   RE(CL)   IM(CL)    AM(CM)  TH(CM)   RE(CM)   IM(CM)
1ST:    0.601  -154.3   -0.541   -0.261     0.385  -167.0   -0.375   -0.086
2ND:    0.001  -138.3   -0.001   -0.001     0.001  -122.4    0.000    0.000
3RD:    0.000   -39.1    0.000    0.000     0.000   -27.5    0.000    0.000


-4
 CFL  =   (   0.0862 ,   0.0415 )    LHL  =   (   13.9868 ,    6.7354 )
 CMA  =   (   0.0597 ,   0.0137 )    LLL  =   (   19.3662 ,    4.4573 )
```

## additional output files:

`fort.7` binary flow file for use with restart option

`fort.21-29` unsteady lift and moment coefficient history file for blades 1-9

## influnce input and output:

```
  ENTER THE NUMBER OF BLADES IN THE CASCADE
9

  ENTER THE INDEX OF THE BLADE THAT WAS MOVED
1

  ENTER IMODE
1
 PHASE    RE(LHL)    IM(LHL)    RE(LLL)    IM(LLL)
```

```
  0.0   -54.4154   -18.2703   -28.7272   -18.8730
 40.0  -113.7484   -18.1522   -63.8636   -11.0934
 80.0  -153.6444   -35.1069   -91.6754   -18.2589
120.0  -178.0273   -34.4773  -111.2282   -20.6957
160.0  -189.3991   -22.9856  -120.8990   -21.1533
200.0  -185.2546    -9.5109  -118.3450   -21.9630
240.0  -168.2028     1.4563  -105.2256   -22.6765
280.0  -144.6100    10.7146   -85.7633   -20.1455
320.0  -113.8604    40.7702   -62.3568    -1.1872
360.0   -54.4154   -18.2703   -28.7272   -18.8730
```

## 4.3 Test Case 3: Frequency Domain Flutter of a Cascade Using the Combined Pulse Response and Influence Coefficient Method

**Description:**

In this test case (Ref. 4), frequency domain flutter calculations are done for a cascade using the combined pulse response and influence coefficient method. Two separate runs are required for the plunging and pitching motions. The cascade stagger angle is 10.65 deg. and the gap-to-chord ratio is 1.85. The Mach number at the inlet is 0.5. Five blade passages are included in the calculation to obtain results for interblade phase angle values of 0, 72, 144, 216, and 288 deg. The amplitude of the pulse is 0.002 for plunging and 0.1 deg. for pitching. The grid used has 61 points in the streamwise direction and 57 points in the circumferential direction. In each blade passage, 31 points are located on each (upper and lower) surface of the airfoil, and 14 points are located on the wake. Calculations are performed for 600 time steps with no blade motion, followed by 900 time steps of blade pulse motion. After the pulse, calculations are continued with the blade in the original stationary position. The total number of time steps in the calculation is 2400. Only one blade is moved, all other blades remain stationary.

The structural parameters specified in the input data file are not used. Instead, a post-processing code fltr2d.f is used to calculate the unsteady aerodynamic coefficients using the combined pulse response and influence coefficient method. The code also uses the unsteady aerodynamic coefficients to calculate eigenvalues that are used to determine flutter stability. Note that since the input files for the two runs (for plunging and pitching) are very similar, the input for the pitching part is not listed. Instead, only those lines that are different from the plunging part are listed. Also, since the output files are similar, the output from the pitching part is not included. The history of the lift and moment coefficients on each blade, along with the blade motion history are used as input to fltr2d.f. The history of blade motion is read in from units 8 and 9 for plunging and pitching. The history of lift and moment coefficients are read in from units

11 through 15 for plunging, and 31 through 35 for pitching. In addition, the structural parameters are read in from standard input. The structural parameters used are as follows. The mass ratio is 115.0, the radius if gyration is 1.076, the offset between elastic axis and center of mass is 0.964, the ratio of uncoupled natural frequencies in bending and torsion is 0.567, and the damping ratios are 0.0. The input and output for fltr2d.f are also included in this section.

### para.f:

```
      PARAMETER
     & (ID1 = 18000, ID2 = 00800, ID3 = 00065, ID4 = 00065, ID5 = 00300,
     &  ID6 = 00105, ID7 = 00035, ID8 = 00020, ID9 = 00010)
```

### fpcas2d.input (part 1, plunging):

```
CJOB
TEST003
TITLE
TEST CASE 003 FOR FPCAS2D, PART 1, PLUNGING
PHASE
0.0
TH1         THS         TH2         TH3
12.50       10.65       10.65       9.06
XMINF       XMOUT
0.5         0.5
SBYC
1.85
A
-1.0
XKC
0.2
IMODE
0
ALFAA       XCONV
0.002       1.0E-06
NPMAX       IMAX        JMAX        NPAF        NPW
5           61          57          31          14
NTSS        NTPC        NCYE        NTMX        NTPRNT
600         900         0           2400        20
IPLOT       NTPBEG      NTPINC      NTPEND
0           0           0           0
IYBIA       ISUPER      INITI       ITMAX       ISMTH       IMOUT
2           0           2           10          0           0
IRUN        IFLTR
0           5
MV    1   2   3   4   5
      0   0   1   0   0
GHS         GAS         ZHS         ZAS
1.0         1.0         0.0         0.0
XMU         XRA         XA
1.0         1.0         0.0
VSTAR
1.0
```

```
IGRIDX     BETAX      IGRIDY     BETAY
0          0.0        0          0.0
IAIRFL     TBYC       HBYC
0          0.0        0.0
 NUAIR
           101
 ( XU(I), I = 1, NUAIR )
  0.00000E+00
  0.96841E-02
  0.19625E-01
  0.29593E-01
  0.39573E-01
```

... 91 lines deleted for brevity

```
  0.96022E+00
  0.97019E+00
  0.98015E+00
  0.99011E+00
  0.10000E+01
 ( YU(I), I = 1, NUAIR )
  0.00000E+00
  0.42167E-02
  0.63777E-02
  0.81254E-02
  0.96410E-02
```

... 91 lines deleted for brevity

```
  0.69296E-02
  0.55102E-02
  0.39877E-02
  0.23183E-02
  0.00000E+00
 NLAIR
           101
 ( XL(I), I = 1, NLAIR )
  0.00000E+00
  0.10316E-01
  0.20375E-01
  0.30407E-01
  0.40427E-01
```

... 91 lines deleted for brevity

```
  0.95978E+00
  0.96981E+00
  0.97985E+00
  0.98989E+00
  0.10000E+01
 ( YL(I), I = 1, NLAIR )
  0.00000E+00
```

```
-0.15429E-02
-0.16967E-02
-0.16920E-02
-0.16223E-02
```

... 91 lines deleted for brevity

```
 0.10891E-02
 0.92327E-03
 0.69329E-03
 0.35554E-03
 0.00000E+00
```

## fpcas2d.output (part 1, plunging):

```
TEST CASE 003 FOR FPCAS2D, PART 1, PLUNGING

 5 PASSAGE(S) USED WITH A MULTIPLIER OF 0

  BLADE(S) BEING PULSED:
  NUMBER 3


  *******  GEOMETRY  *******

  AIRFOIL COORDINATES, UPPER ( XU AND YU ) :

    0.0000    0.0097    0.0196    0.0296    0.0396    0.0496    0.0596
    0.0695    0.0795    0.0895    0.0995    0.1096    0.1195    0.1296
    0.1396    0.1496    0.1596    0.1696    0.1796    0.1896    0.1996
    0.2096    0.2196    0.2296    0.2397    0.2497    0.2597    0.2697
    0.2797    0.2897    0.2997    0.3097    0.3198    0.3298    0.3398
    0.3498    0.3598    0.3698    0.3798    0.3898    0.3999    0.4099
    0.4199    0.4299    0.4399    0.4499    0.4599    0.4700    0.4800
    0.4900    0.5000    0.5100    0.5200    0.5300    0.5401    0.5501
    0.5601    0.5701    0.5801    0.5901    0.6001    0.6102    0.6202
    0.6302    0.6402    0.6502    0.6602    0.6702    0.6802    0.6903
    0.7003    0.7103    0.7203    0.7303    0.7403    0.7503    0.7603
    0.7703    0.7803    0.7903    0.8004    0.8103    0.8204    0.8304
    0.8404    0.8504    0.8604    0.8703    0.8803    0.8903    0.9003
    0.9103    0.9203    0.9303    0.9403    0.9503    0.9602    0.9702
    0.9801    0.9901    1.0000

    0.0000    0.0042    0.0064    0.0081    0.0096    0.0110    0.0122
    0.0134    0.0144    0.0154    0.0164    0.0173    0.0181    0.0189
    0.0197    0.0204    0.0211    0.0218    0.0224    0.0230    0.0236
    0.0242    0.0247    0.0252    0.0257    0.0261    0.0266    0.0270
    0.0274    0.0278    0.0281    0.0285    0.0288    0.0291    0.0294
    0.0296    0.0299    0.0301    0.0303    0.0305    0.0307    0.0309
    0.0310    0.0311    0.0312    0.0313    0.0314    0.0315    0.0315
    0.0315    0.0315    0.0315    0.0315    0.0315    0.0314    0.0313
    0.0312    0.0311    0.0310    0.0308    0.0307    0.0305    0.0302
```

```
  0.0300    0.0298    0.0295    0.0292    0.0289    0.0285    0.0281
  0.0278    0.0273    0.0269    0.0264    0.0259    0.0254    0.0249
  0.0243    0.0237    0.0231    0.0224    0.0218    0.0210    0.0203
  0.0195    0.0187    0.0178    0.0169    0.0160    0.0151    0.0140
  0.0130    0.0119    0.0107    0.0095    0.0083    0.0069    0.0055
  0.0040    0.0023    0.0000

AIRFOIL COORDINATES, LOWER ( XL AND YL ) :

  0.0000    0.0103    0.0204    0.0304    0.0404    0.0504    0.0604
  0.0705    0.0805    0.0905    0.1004    0.1105    0.1204    0.1304
  0.1404    0.1504    0.1604    0.1704    0.1804    0.1904    0.2004
  0.2104    0.2204    0.2304    0.2403    0.2503    0.2603    0.2703
  0.2803    0.2903    0.3003    0.3103    0.3202    0.3302    0.3402
  0.3502    0.3602    0.3702    0.3802    0.3902    0.4001    0.4101
  0.4201    0.4301    0.4401    0.4501    0.4601    0.4700    0.4800
  0.4900    0.5000    0.5100    0.5200    0.5300    0.5399    0.5499
  0.5599    0.5699    0.5799    0.5899    0.5999    0.6099    0.6198
  0.6298    0.6398    0.6498    0.6598    0.6698    0.6798    0.6897
  0.6997    0.7097    0.7197    0.7297    0.7397    0.7497    0.7597
  0.7697    0.7797    0.7897    0.7996    0.8097    0.8196    0.8296
  0.8396    0.8496    0.8596    0.8697    0.8797    0.8897    0.8997
  0.9097    0.9197    0.9297    0.9397    0.9498    0.9598    0.9698
  0.9798    0.9899    1.0000

  0.0000   -0.0015   -0.0017   -0.0017   -0.0016   -0.0015   -0.0014
 -0.0013   -0.0011   -0.0010   -0.0009   -0.0007   -0.0006   -0.0005
 -0.0004   -0.0002   -0.0001    0.0000    0.0001    0.0002    0.0003
  0.0004    0.0005    0.0006    0.0006    0.0007    0.0008    0.0009
  0.0009    0.0010    0.0010    0.0011    0.0011    0.0012    0.0012
  0.0013    0.0013    0.0013    0.0014    0.0014    0.0014    0.0015
  0.0015    0.0015    0.0015    0.0015    0.0015    0.0015    0.0015
  0.0015    0.0015    0.0015    0.0015    0.0015    0.0015    0.0015
  0.0015    0.0015    0.0015    0.0015    0.0015    0.0015    0.0015
  0.0015    0.0014    0.0014    0.0014    0.0014    0.0014    0.0014
  0.0014    0.0014    0.0014    0.0014    0.0014    0.0014    0.0014
  0.0014    0.0014    0.0014    0.0015    0.0015    0.0015    0.0015
  0.0015    0.0015    0.0015    0.0015    0.0015    0.0015    0.0015
  0.0015    0.0014    0.0014    0.0013    0.0012    0.0011    0.0009
  0.0007    0.0004    0.0000

OUTER BOUNDARY ( XX AND YY ) :

 -0.5000   -0.4667   -0.4333   -0.4000   -0.3667   -0.3333   -0.3000
 -0.2667   -0.2333   -0.2000   -0.1667   -0.1333   -0.1000   -0.0667
 -0.0333    0.0000    0.0333    0.0667    0.1000    0.1333    0.1667
  0.2000    0.2333    0.2667    0.3000    0.3333    0.3667    0.4000
  0.4333    0.4667    0.5000    0.5333    0.5667    0.6000    0.6333
  0.6667    0.7000    0.7333    0.7667    0.8000    0.8333    0.8667
  0.9000    0.9333    0.9667    1.0000    1.0333    1.0667    1.1000
  1.1333    1.1667    1.2000    1.2333    1.2667    1.3000    1.3333
  1.3667    1.4000    1.4333    1.4667    1.5000

  0.0000    0.0330    0.0661    0.0991    0.1321    0.1652    0.1982
```

```
   0.2312    0.2643    0.2973    0.3304    0.3634    0.3964    0.4295
   0.4625    0.4955    0.5286    0.5616    0.5946    0.6277    0.6607
   0.6938    0.7268    0.7598    0.7929    0.8259    0.8589    0.8920
   0.9250    0.9580    0.9911    1.0241    1.0571    1.0902    1.1232
   1.1563    1.1893    1.2223    1.2554    1.2884    1.3214    1.3545
   1.3875    1.4205    1.4536    1.4866    1.5196    1.5527    1.5857
   1.6187    1.6518    1.6848    1.7179    1.7509    1.7839    1.8170
   1.8500

SBYC =  1.850

CALCULATED EXIT MACH NUMBER=  0.49211


 *******     GRID     *******

NPSG= 5 IMAX= 61 JMAX= 57
NFW= 14 NPAF= 31 NPW= 14
IMODE= 0

 ******* FREESTREAM *******

MACH NUMBER=  0.5000
INTER-BLADE PHASE ANGLE=     0.0000
REDUCED FRE=  0.2000
ALFAA=     0.0020
TH1=    12.5000 THS=    10.6500 TH2=    10.6500 TH3=     9.0600

 *******  NUMERICAL *******

NTSS= 600 NTPC= 900 NCYE=    0
XP=  0.0000 YP=  0.0000
DT=  0.0698 XCONV=  0.10E-05
IRUN= 0 ISUPER= 0 IYBIA= 2 INITI= 2 ITMAX= 10


 CONVERGENCE HISTORY :

<<< CAUTION >>>  NT=      1   MAX(DPHI)=    0.31E-04     IJ=  10539
<<< CAUTION >>>  NT=      2   MAX(DPHI)=    0.44E-05     IJ=  14076
<<< CAUTION >>>  NT=      3   MAX(DPHI)=    0.55E-05     IJ=    108
<<< CAUTION >>>  NT=      4   MAX(DPHI)=    0.58E-05     IJ=  14016
<<< CAUTION >>>  NT=      5   MAX(DPHI)=    0.47E-05     IJ=  10539
<<< CAUTION >>>  NT=      6   MAX(DPHI)=    0.38E-05     IJ=  14016
<<< CAUTION >>>  NT=      7   MAX(DPHI)=    0.29E-05     IJ=  14016
<<< CAUTION >>>  NT=      8   MAX(DPHI)=    0.23E-05     IJ=  14016
<<< CAUTION >>>  NT=      9   MAX(DPHI)=    0.17E-05     IJ=  14016
<<< CAUTION >>>  NT=     10   MAX(DPHI)=    0.13E-05     IJ=  10539
<<< CAUTION >>>  NT=     12   MAX(DPHI)=    0.11E-05     IJ=  17324
<<< CAUTION >>>  NT=     13   MAX(DPHI)=    0.11E-05     IJ=   6893
NT=     20     NITER=    6   MAX(DPHI)=    0.10E-05     IJ=    122
NT=     40     NITER=    8   MAX(DPHI)=    0.97E-06     IJ=  13971
NT=     60     NITER=    6   MAX(DPHI)=    0.86E-06     IJ=  13971
```

```
NT=    80     NITER=   5     MAX(DPHI)=   0.56E-06     IJ=     76
NT=   100     NITER=   4     MAX(DPHI)=   0.82E-06     IJ=   6832
NT=   120     NITER=   4     MAX(DPHI)=   0.55E-06     IJ=   6832
NT=   140     NITER=   4     MAX(DPHI)=   0.32E-06     IJ=   6832
NT=   160     NITER=   3     MAX(DPHI)=   0.71E-06     IJ=   6893
NT=   180     NITER=   3     MAX(DPHI)=   0.39E-06     IJ=  10370
NT=   200     NITER=   2     MAX(DPHI)=   0.96E-06     IJ=  10553
NT=   220     NITER=   1     MAX(DPHI)=   0.58E-06     IJ=  13934
NT=   240     NITER=   1     MAX(DPHI)=   0.38E-06     IJ=  10459
NT=   260     NITER=   1     MAX(DPHI)=   0.26E-06     IJ=  13937
NT=   280     NITER=   1     MAX(DPHI)=   0.17E-06     IJ=  13938
NT=   300     NITER=   1     MAX(DPHI)=   0.10E-06     IJ=  13939
NT=   320     NITER=   1     MAX(DPHI)=   0.63E-07     IJ=  13941
NT=   340     NITER=   1     MAX(DPHI)=   0.36E-07     IJ=  10465
NT=   360     NITER=   1     MAX(DPHI)=   0.20E-07     IJ=  10466
NT=   380     NITER=   1     MAX(DPHI)=   0.11E-07     IJ=  10467
NT=   400     NITER=   1     MAX(DPHI)=   0.56E-08     IJ=  10468
NT=   420     NITER=   1     MAX(DPHI)=   0.29E-08     IJ=  17202
NT=   440     NITER=   1     MAX(DPHI)=   0.21E-08     IJ=  16958
NT=   460     NITER=   1     MAX(DPHI)=   0.16E-08     IJ=   9821
NT=   480     NITER=   1     MAX(DPHI)=   0.12E-08     IJ=  16775
NT=   500     NITER=   1     MAX(DPHI)=   0.11E-08     IJ=   1037
NT=   520     NITER=   1     MAX(DPHI)=   0.84E-09     IJ=   2928
NT=   540     NITER=   1     MAX(DPHI)=   0.81E-09     IJ=   1098
NT=   560     NITER=   1     MAX(DPHI)=   0.60E-09     IJ=  14762
NT=   580     NITER=   1     MAX(DPHI)=   0.58E-09     IJ=   1037
NT=   600     NITER=   1     MAX(DPHI)=   0.45E-09     IJ=   4270
 **** DELTA CP NEAR I = ILE ****
  0.00000  -0.00611   0.00002  -0.08574  -0.21840
 **** DELTA CP NEAR I = ITE ****
 -0.17281  -0.06511   0.00268   0.00000   0.00000
 **** PRESSURE ON UPPER SURFACE ****
 -0.14012   0.01804   0.17734   0.18030   0.18586   0.18982   0.19280
  0.19509   0.19693   0.19845   0.19970   0.20070   0.20145   0.20201
  0.20246   0.20282   0.20306   0.20300   0.20229   0.20067   0.19794
  0.19382   0.18794   0.17986   0.16899   0.15440   0.13452   0.10626
  0.06080  -0.04776  -0.13210
 **** PRESSURE ON LOWER SURFACE ****
 -0.14009  -0.06770  -0.04106  -0.04894  -0.05424  -0.05649  -0.05741
 -0.05767  -0.05757  -0.05728  -0.05688  -0.05646  -0.05604  -0.05566
 -0.05529  -0.05488  -0.05444  -0.05412  -0.05414  -0.05468  -0.05589
 -0.05792  -0.06094  -0.06515  -0.07076  -0.07805  -0.08736  -0.09896
 -0.11202  -0.11287  -0.12942

 XU(II), CP(I), XL(II), CP(N)
 0.00000000E+00 -0.14011838E+00  0.28897199E-18 -0.14009472E+00
 0.35021916E-01  0.18039968E-01  0.33017019E-01 -0.67697457E-01
 0.69175406E-01  0.17733749E+00  0.66417588E-01 -0.41057732E-01
 0.10314360E+00  0.18029766E+00  0.99834980E-01 -0.48937989E-01
 0.13700014E+00  0.18585997E+00  0.13324968E+00 -0.54243284E-01
 0.17077659E+00  0.18981930E+00  0.16665668E+00 -0.56491593E-01
 0.20448914E+00  0.19280421E+00  0.20005465E+00 -0.57412987E-01
 0.23814727E+00  0.19509303E+00  0.23344353E+00 -0.57673723E-01
 0.27175786E+00  0.19692958E+00  0.26682370E+00 -0.57574967E-01
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0.30532501E+00  0.19845095E+00  0.30019574E+00 -0.57277218E-01
0.33885188E+00  0.19970399E+00  0.33356026E+00 -0.56882089E-01
0.37234032E+00  0.20070323E+00  0.36691793E+00 -0.56457439E-01
0.40579179E+00  0.20145220E+00  0.40026933E+00 -0.56042938E-01
0.43920719E+00  0.20201322E+00  0.43361500E+00 -0.55659203E-01
0.47258733E+00  0.20246051E+00  0.46695544E+00 -0.55291672E-01
0.50593195E+00  0.20281575E+00  0.50029104E+00 -0.54881676E-01
0.53924081E+00  0.20305880E+00  0.53362239E+00 -0.54437136E-01
0.57251238E+00  0.20300055E+00  0.56695095E+00 -0.54118880E-01
0.60574441E+00  0.20228827E+00  0.60027831E+00 -0.54142248E-01
0.63893477E+00  0.20066608E+00  0.63360584E+00 -0.54684577E-01
0.67208133E+00  0.19793755E+00  0.66693465E+00 -0.55893880E-01
0.70518136E+00  0.19382295E+00  0.70026558E+00 -0.57923259E-01
0.73823197E+00  0.18794417E+00  0.73359917E+00 -0.60944770E-01
0.77122955E+00  0.17985572E+00  0.76693545E+00 -0.65148468E-01
0.80417066E+00  0.16899069E+00  0.80027383E+00 -0.70758522E-01
0.83705003E+00  0.15439723E+00  0.83361277E+00 -0.78052579E-01
0.86986165E+00  0.13452246E+00  0.86694921E+00 -0.87358409E-01
0.90259696E+00  0.10625931E+00  0.90027745E+00 -0.98960358E-01
0.93524195E+00  0.60796287E-01  0.93358641E+00 -0.11201709E+00
0.96776959E+00 -0.47759528E-01  0.96685039E+00 -0.11286673E+00
0.10000000E+01 -0.13209788E+00  0.10000000E+01 -0.12941803E+00

**** MACH NUMBER ON UPPER SURFACE ****
 0.46239   0.50473   0.54545   0.54619   0.54758   0.54857   0.54932
 0.54989   0.55035   0.55073   0.55104   0.55129   0.55148   0.55161
 0.55173   0.55181   0.55188   0.55186   0.55168   0.55128   0.55060
 0.54957   0.54810   0.54608   0.54336   0.53969   0.53467   0.52749
 0.51583   0.48738   0.46459
**** MACH NUMBER ON LOWER SURFACE ****
 0.46239   0.48205   0.48917   0.48707   0.48565   0.48505   0.48481
 0.48474   0.48476   0.48484   0.48495   0.48506   0.48517   0.48528
 0.48537   0.48548   0.48560   0.48569   0.48568   0.48554   0.48521
 0.48467   0.48386   0.48274   0.48123   0.47927   0.47676   0.47362
 0.47008   0.46985   0.46532

XU(II), XMACH(I), XL(II), XMACH(N)
0.00000000E+00  0.46238506E+00  0.28897199E-18  0.46239157E+00
0.35021916E-01  0.50473465E+00  0.33017019E-01  0.48205335E+00
0.69175406E-01  0.54544878E+00  0.66417588E-01  0.48916639E+00
0.10314360E+00  0.54619030E+00  0.99834980E-01  0.48706872E+00
0.13700014E+00  0.54758231E+00  0.13324968E+00  0.48565347E+00
0.17077659E+00  0.54857210E+00  0.16665668E+00  0.48505297E+00
0.20448914E+00  0.54931772E+00  0.20005465E+00  0.48480675E+00
0.23814727E+00  0.54988912E+00  0.23344353E+00  0.48473706E+00
0.27175786E+00  0.55034741E+00  0.26682370E+00  0.48476346E+00
0.30532501E+00  0.55072690E+00  0.30019574E+00  0.48484304E+00
0.33885188E+00  0.55103937E+00  0.33356026E+00  0.48494863E+00
0.37234032E+00  0.55128849E+00  0.36691793E+00  0.48506210E+00
0.40579179E+00  0.55147518E+00  0.40026933E+00  0.48517284E+00
0.43920719E+00  0.55161499E+00  0.43361500E+00  0.48527535E+00
0.47258733E+00  0.55172646E+00  0.46695544E+00  0.48537352E+00
0.50593195E+00  0.55181497E+00  0.50029104E+00  0.48548301E+00
0.53924081E+00  0.55187553E+00  0.53362239E+00  0.48560172E+00
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0.57251238E+00  0.55186102E+00  0.56695095E+00  0.48568669E+00
0.60574441E+00  0.55168353E+00  0.60027831E+00  0.48568045E+00
0.63893477E+00  0.55127922E+00  0.63360584E+00  0.48553565E+00
0.67208133E+00  0.55059885E+00  0.66693465E+00  0.48521266E+00
0.70518136E+00  0.54957208E+00  0.70026558E+00  0.48467036E+00
0.73823197E+00  0.54810344E+00  0.73359917E+00  0.48386227E+00
0.77122955E+00  0.54607962E+00  0.76693545E+00  0.48273665E+00
0.80417066E+00  0.54335523E+00  0.80027383E+00  0.48123201E+00
0.83705003E+00  0.53968518E+00  0.83361277E+00  0.47927146E+00
0.86986165E+00  0.53466656E+00  0.86694921E+00  0.47676311E+00
0.90259696E+00  0.52748772E+00  0.90027745E+00  0.47362455E+00
0.93524195E+00  0.51583043E+00  0.93358641E+00  0.47007710E+00
0.96776959E+00  0.48738276E+00  0.96685039E+00  0.46984568E+00
0.10000000E+01  0.46458859E+00  0.10000000E+01  0.46532339E+00

**** MACH NUMBER AT INLET SECTION ****
 0.49999   0.50018   0.50036   0.50054   0.50072   0.50089   0.50105
 0.50119   0.50131   0.50141   0.50148   0.50152   0.50154   0.50154
 0.50151   0.50146   0.50139   0.50130   0.50119   0.50108   0.50095
 0.50081   0.50067   0.50053   0.50038   0.50023   0.50008   0.49994
 0.49980   0.49967   0.49954   0.49941   0.49930   0.49919   0.49909
 0.49900   0.49893   0.49886   0.49880   0.49875   0.49872   0.49869
 0.49868   0.49868   0.49870   0.49873   0.49877   0.49883   0.49890
 0.49899   0.49909   0.49921   0.49934   0.49949   0.49965   0.49982
 0.49999   0.49999   0.50018   0.50036   0.50054   0.50072   0.50089
 0.50105   0.50119   0.50131   0.50141   0.50148   0.50152   0.50154
 0.50154   0.50151   0.50146   0.50139   0.50130   0.50119   0.50108
 0.50095   0.50081   0.50067   0.50053   0.50038   0.50023   0.50008
 0.49994   0.49980   0.49967   0.49954   0.49941   0.49930   0.49919
 0.49909   0.49900   0.49893   0.49886   0.49880   0.49875   0.49872
 0.49869   0.49868   0.49868   0.49870   0.49873   0.49877   0.49883
 0.49890   0.49899   0.49909   0.49921   0.49934   0.49949   0.49965
 0.49982   0.49999   0.49999   0.50018   0.50036   0.50054   0.50072
 0.50089   0.50105   0.50119   0.50131   0.50141   0.50148   0.50152
 0.50154   0.50154   0.50151   0.50146   0.50139   0.50130   0.50119
 0.50108   0.50095   0.50081   0.50067   0.50053   0.50038   0.50023
 0.50008   0.49994   0.49980   0.49967   0.49954   0.49941   0.49930
 0.49919   0.49909   0.49900   0.49893   0.49886   0.49880   0.49875
 0.49872   0.49869   0.49868   0.49868   0.49870   0.49873   0.49877
 0.49883   0.49890   0.49899   0.49909   0.49921   0.49934   0.49949
 0.49965   0.49982   0.49999   0.49999   0.50018   0.50036   0.50054
 0.50072   0.50089   0.50105   0.50119   0.50131   0.50141   0.50148
 0.50152   0.50154   0.50154   0.50151   0.50146   0.50139   0.50130
 0.50119   0.50108   0.50095   0.50081   0.50067   0.50053   0.50038
 0.50023   0.50008   0.49994   0.49980   0.49967   0.49954   0.49941
 0.49930   0.49919   0.49909   0.49900   0.49893   0.49886   0.49880
 0.49875   0.49872   0.49869   0.49868   0.49868   0.49870   0.49873
 0.49877   0.49883   0.49890   0.49899   0.49909   0.49921   0.49934
 0.49949   0.49965   0.49982   0.49999   0.49999   0.50018   0.50036
 0.50054   0.50072   0.50089   0.50105   0.50119   0.50131   0.50141
 0.50148   0.50152   0.50154   0.50154   0.50151   0.50146   0.50139
 0.50130   0.50119   0.50108   0.50095   0.50081   0.50067   0.50053
 0.50038   0.50023   0.50008   0.49994   0.49980   0.49967   0.49954
 0.49941   0.49930   0.49919   0.49909   0.49900   0.49893   0.49886
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 0.49880   0.49875   0.49872   0.49869   0.49868   0.49868   0.49870
 0.49873   0.49877   0.49883   0.49890   0.49899   0.49909   0.49921
 0.49934   0.49949   0.49965   0.49982   0.49999
**** MACH NUMBER AT EXIT SECTION ****
 0.49157   0.49157   0.49157   0.49157   0.49158   0.49159   0.49161
 0.49163   0.49165   0.49168   0.49170   0.49173   0.49176   0.49179
 0.49182   0.49185   0.49188   0.49191   0.49193   0.49196   0.49198
 0.49200   0.49203   0.49205   0.49206   0.49208   0.49209   0.49210
 0.49211   0.49211   0.49212   0.49212   0.49212   0.49211   0.49210
 0.49209   0.49208   0.49207   0.49205   0.49203   0.49200   0.49198
 0.49195   0.49192   0.49189   0.49186   0.49182   0.49179   0.49176
 0.49172   0.49169   0.49166   0.49164   0.49162   0.49160   0.49158
 0.49157   0.49157   0.49157   0.49157   0.49157   0.49158   0.49159
 0.49161   0.49163   0.49165   0.49168   0.49170   0.49173   0.49176
 0.49179   0.49182   0.49185   0.49188   0.49191   0.49193   0.49196
 0.49198   0.49200   0.49203   0.49205   0.49206   0.49208   0.49209
 0.49210   0.49211   0.49211   0.49212   0.49212   0.49212   0.49211
 0.49210   0.49209   0.49208   0.49207   0.49205   0.49203   0.49200
 0.49198   0.49195   0.49192   0.49189   0.49186   0.49182   0.49179
 0.49176   0.49172   0.49169   0.49166   0.49164   0.49162   0.49160
 0.49158   0.49157   0.49157   0.49157   0.49157   0.49157   0.49158
 0.49159   0.49161   0.49163   0.49165   0.49168   0.49170   0.49173
 0.49176   0.49179   0.49182   0.49185   0.49188   0.49191   0.49193
 0.49196   0.49198   0.49200   0.49203   0.49205   0.49206   0.49208
 0.49209   0.49210   0.49211   0.49211   0.49212   0.49212   0.49212
 0.49211   0.49210   0.49209   0.49208   0.49207   0.49205   0.49203
 0.49200   0.49198   0.49195   0.49192   0.49189   0.49186   0.49182
 0.49179   0.49176   0.49172   0.49169   0.49166   0.49164   0.49162
 0.49160   0.49158   0.49157   0.49157   0.49157   0.49157   0.49157
 0.49158   0.49159   0.49161   0.49163   0.49165   0.49168   0.49170
 0.49173   0.49176   0.49179   0.49182   0.49185   0.49188   0.49191
 0.49193   0.49196   0.49198   0.49200   0.49203   0.49205   0.49206
 0.49208   0.49209   0.49210   0.49211   0.49211   0.49212   0.49212
 0.49212   0.49211   0.49210   0.49209   0.49208   0.49207   0.49205
 0.49203   0.49200   0.49198   0.49195   0.49192   0.49189   0.49186
 0.49182   0.49179   0.49176   0.49172   0.49169   0.49166   0.49164
 0.49162   0.49160   0.49158   0.49157   0.49157   0.49157   0.49157
 0.49157   0.49158   0.49159   0.49161   0.49163   0.49165   0.49168
 0.49170   0.49173   0.49176   0.49179   0.49182   0.49185   0.49188
 0.49191   0.49193   0.49196   0.49198   0.49200   0.49203   0.49205
 0.49206   0.49208   0.49209   0.49210   0.49211   0.49211   0.49212
 0.49212   0.49212   0.49211   0.49210   0.49209   0.49208   0.49207
 0.49205   0.49203   0.49200   0.49198   0.49195   0.49192   0.49189
 0.49186   0.49182   0.49179   0.49176   0.49172   0.49169   0.49166
 0.49164   0.49162   0.49160   0.49158   0.49157
**** FLOW ANGLE AT INLET SECTION ****
12.50169  12.54532  12.58951  12.63326  12.67561  12.71559  12.75229
12.78485  12.81257  12.83489  12.85145  12.86204  12.86667  12.86548
12.85877  12.84691  12.83037  12.80968  12.78537  12.75801  12.72813
12.69627  12.66292  12.62854  12.59358  12.55842  12.52344  12.48896
12.45527  12.42264  12.39133  12.36153  12.33346  12.30729  12.28319
12.26131  12.24180  12.22478  12.21038  12.19874  12.18997  12.18418
12.18150  12.18203  12.18588  12.19315  12.20393  12.21830  12.23630
12.25797  12.28328  12.31215  12.34445  12.37996  12.41833  12.45917
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12.50169  12.50169  12.54532  12.58951  12.63326  12.67561  12.71559
12.75229  12.78485  12.81257  12.83489  12.85145  12.86204  12.86667
12.86548  12.85877  12.84691  12.83037  12.80968  12.78537  12.75801
12.72813  12.69627  12.66292  12.62854  12.59358  12.55842  12.52344
12.48896  12.45527  12.42264  12.39133  12.36153  12.33346  12.30729
12.28319  12.26131  12.24180  12.22478  12.21038  12.19874  12.18997
12.18418  12.18150  12.18203  12.18588  12.19315  12.20393  12.21830
12.23630  12.25797  12.28328  12.31215  12.34445  12.37996  12.41833
12.45917  12.50169  12.50169  12.54532  12.58951  12.63326  12.67561
12.71559  12.75229  12.78485  12.81257  12.83489  12.85145  12.86204
12.86667  12.86548  12.85877  12.84691  12.83037  12.80968  12.78537
12.75801  12.72813  12.69627  12.66292  12.62854  12.59358  12.55842
12.52344  12.48896  12.45527  12.42264  12.39133  12.36153  12.33346
12.30729  12.28319  12.26131  12.24180  12.22478  12.21038  12.19874
12.18997  12.18418  12.18150  12.18203  12.18588  12.19315  12.20393
12.21830  12.23630  12.25797  12.28328  12.31215  12.34445  12.37996
12.41833  12.45917  12.50169  12.50169  12.54532  12.58951  12.63326
12.67561  12.71559  12.75229  12.78485  12.81257  12.83489  12.85145
12.86204  12.86667  12.86548  12.85877  12.84691  12.83037  12.80968
12.78537  12.75801  12.72813  12.69627  12.66292  12.62854  12.59358
12.55842  12.52344  12.48896  12.45527  12.42264  12.39133  12.36153
12.33346  12.30729  12.28319  12.26131  12.24180  12.22478  12.21038
12.19874  12.18997  12.18418  12.18150  12.18203  12.18588  12.19315
12.20393  12.21830  12.23630  12.25797  12.28328  12.31215  12.34445
12.37996  12.41833  12.45917  12.50169  12.50169  12.54532  12.58951
12.63326  12.67561  12.71559  12.75229  12.78485  12.81257  12.83489
12.85145  12.86204  12.86667  12.86548  12.85877  12.84691  12.83037
12.80968  12.78537  12.75801  12.72813  12.69627  12.66292  12.62854
12.59358  12.55842  12.52344  12.48896  12.45527  12.42264  12.39133
12.36153  12.33346  12.30729  12.28319  12.26131  12.24180  12.22478
12.21038  12.19874  12.18997  12.18418  12.18150  12.18203  12.18588
12.19315  12.20393  12.21830  12.23630  12.25797  12.28328  12.31215
12.34445  12.37996  12.41833  12.45917  12.50169
**** FLOW ANGLE AT EXIT SECTION ****
 8.75980   8.75702   8.75673   8.76142   8.77083   8.78459   8.80227
 8.82336   8.84735   8.87371   8.90192   8.93147   8.96191   8.99281
 9.02375   9.05441   9.08445   9.11360   9.14160   9.16825   9.19335
 9.21674   9.23827   9.25781   9.27526   9.29052   9.30350   9.31412
 9.32232   9.32802   9.33118   9.33174   9.32966   9.32490   9.31742
 9.30720   9.29422   9.27851   9.26007   9.23895   9.21524   9.18905
 9.16056   9.12998   9.09760   9.06379   9.02898   8.99369   8.95851
 8.92411   8.89118   8.86045   8.83264   8.80841   8.78834   8.77289
 8.75979   8.75980   8.75702   8.75673   8.76142   8.77083   8.78459
 8.80227   8.82336   8.84735   8.87371   8.90192   8.93147   8.96191
 8.99281   9.02375   9.05441   9.08445   9.11360   9.14160   9.16825
 9.19335   9.21674   9.23827   9.25781   9.27526   9.29052   9.30350
 9.31412   9.32232   9.32802   9.33118   9.33174   9.32966   9.32490
 9.31742   9.30720   9.29422   9.27851   9.26007   9.23895   9.21524
 9.18905   9.16056   9.12998   9.09760   9.06379   9.02898   8.99369
 8.95851   8.92411   8.89118   8.86045   8.83264   8.80841   8.78834
 8.77289   8.75979   8.75980   8.75702   8.75673   8.76142   8.77083
 8.78459   8.80227   8.82336   8.84735   8.87371   8.90192   8.93147
 8.96191   8.99281   9.02375   9.05441   9.08445   9.11360   9.14160
 9.16825   9.19335   9.21674   9.23827   9.25781   9.27526   9.29052
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 9.30350   9.31412   9.32232   9.32802   9.33118   9.33174   9.32966
 9.32490   9.31742   9.30720   9.29422   9.27851   9.26007   9.23895
 9.21524   9.18905   9.16056   9.12998   9.09760   9.06379   9.02898
 8.99369   8.95851   8.92411   8.89118   8.86045   8.83264   8.80841
 8.78834   8.77289   8.75979   8.75980   8.75702   8.75673   8.76142
 8.77083   8.78459   8.80227   8.82336   8.84735   8.87371   8.90192
 8.93147   8.96191   8.99281   9.02375   9.05441   9.08445   9.11360
 9.14160   9.16825   9.19335   9.21674   9.23827   9.25781   9.27526
 9.29052   9.30350   9.31412   9.32232   9.32802   9.33118   9.33174
 9.32966   9.32490   9.31742   9.30720   9.29422   9.27851   9.26007
 9.23895   9.21524   9.18905   9.16056   9.12998   9.09760   9.06379
 9.02898   8.99369   8.95851   8.92411   8.89118   8.86045   8.83264
 8.80841   8.78834   8.77289   8.75979   8.75980   8.75702   8.75673
 8.76142   8.77083   8.78459   8.80227   8.82336   8.84735   8.87371
 8.90192   8.93147   8.96191   8.99281   9.02375   9.05441   9.08445
 9.11360   9.14160   9.16825   9.19335   9.21674   9.23827   9.25781
 9.27526   9.29052   9.30350   9.31412   9.32232   9.32802   9.33118
 9.33174   9.32966   9.32490   9.31742   9.30720   9.29422   9.27851
 9.26007   9.23895   9.21524   9.18905   9.16056   9.12998   9.09760
 9.06379   9.02898   8.99369   8.95851   8.92411   8.89118   8.86045
 8.83264   8.80841   8.78834   8.77289   8.75979
**** MACH NUMBER AT INLET AND EXIT ****
 0.50000   0.49186
**** FLOW ANGLE AT INLET AND EXIT ****
 12.49973   9.06211
NT=   620     NITER=   1     MAX(DPHI)=   0.28E-07     IJ=   6892
NT=   640     NITER=   1     MAX(DPHI)=   0.16E-07     IJ=  10369
NT=   660     NITER=   1     MAX(DPHI)=   0.63E-08     IJ=   7076
NT=   680     NITER=   1     MAX(DPHI)=   0.46E-08     IJ=  10248
NT=   700     NITER=   1     MAX(DPHI)=   0.28E-08     IJ=  11530
NT=   720     NITER=   1     MAX(DPHI)=   0.31E-08     IJ=   6932
NT=   740     NITER=   1     MAX(DPHI)=   0.37E-08     IJ=   6937
NT=   760     NITER=   1     MAX(DPHI)=   0.47E-08     IJ=   6936
NT=   780     NITER=   1     MAX(DPHI)=   0.52E-08     IJ=   6938
NT=   800     NITER=   1     MAX(DPHI)=   0.58E-08     IJ=   6938
NT=   820     NITER=   1     MAX(DPHI)=   0.62E-08     IJ=   6939
NT=   840     NITER=   1     MAX(DPHI)=   0.65E-08     IJ=   6939
NT=   860     NITER=   1     MAX(DPHI)=   0.67E-08     IJ=   6939
NT=   880     NITER=   1     MAX(DPHI)=   0.69E-08     IJ=   6939
NT=   900     NITER=   1     MAX(DPHI)=   0.72E-08     IJ=   7000
NT=   920     NITER=   1     MAX(DPHI)=   0.74E-08     IJ=   7000
NT=   940     NITER=   1     MAX(DPHI)=   0.75E-08     IJ=   7000
NT=   960     NITER=   1     MAX(DPHI)=   0.76E-08     IJ=   7000
NT=   980     NITER=   1     MAX(DPHI)=   0.75E-08     IJ=   7000
```

... 65 lines deleted for brevity

```
NT=  2300     NITER=   1     MAX(DPHI)=   0.39E-12     IJ=  11895
NT=  2320     NITER=   1     MAX(DPHI)=   0.33E-12     IJ=  11285
NT=  2340     NITER=   1     MAX(DPHI)=   0.31E-12     IJ=  12749
NT=  2360     NITER=   1     MAX(DPHI)=   0.25E-12     IJ=  14945
NT=  2380     NITER=   1     MAX(DPHI)=   0.29E-12     IJ=  13664
NT=  2400     NITER=   1     MAX(DPHI)=   0.21E-12     IJ=  14701
```

```
  TOTAL NEWTON-ITERATIONS= 3217
  TOTAL TIME STEPS= 2400
 AVERAGE ITERATIONS PER TIME STEP=   1.3
```

### additional output files (part 1, plunging):

`fort.7` binary flow file for use with restart option
`fort.15` blade motion history file
`fort.21-25` unsteady lift and moment coefficient history file for blades 1-5

### fpcas2d.input (part 2, pitching):

Only the input lines that are different from the plunging part are listed.

```
TITLE
TEST CASE 003 FOR FPCAS2D, PART 2, PITCHING
IMODE
1
ALFAA      XCONV
0.1        1.0E-06
```

### fpcas2d.output (part 2, pitching):

Not shown due to similarity to plunging part.

### additional output files (part 2, pitching):

Same as for the plunging part.

### fltr2d input and output:

```
  ENTER THE NUMBER OF BLADES IN THE CASCADE
5

  ENTER THE INDEX OF THE BLADE THAT WAS MOVED
3

  ENTER M, KC, NTSS, NTPC USED IN FP RUN
0.5 0.2 600 900

  ENTER IMODE
2

  ENTER GHS, GAS, ZHS, ZAS, XMU, XRA, XA
0.567 1.0 0.0 0.0 115.0 1.076 0.964

  READING MOTION FILE(S)

  READING FORCE FILE(S)

  ENTER THE REDUCED FREQUENCY, NEGATIVE VALUE TO STOP
0.1956
 KC = 0.1956  PHASE       NU          MU          VSTAR
               0.0     0.54485    -0.03509        5.57
```

```
                0.0      1.43872      0.03454      14.71  <=== UNSTABLE
               72.0      0.70441     -0.06500       7.20
               72.0      0.89107     -0.05095       9.11
              144.0      0.64970     -0.19142       6.64
              144.0      0.87015      0.15463       8.90  <=== UNSTABLE
              216.0      0.65286     -0.19634       6.68
              216.0      0.86466      0.14444       8.84  <=== UNSTABLE
              288.0      0.75910     -0.00045       7.76
              288.0      0.79522     -0.15082       8.13

  ENTER THE REDUCED FREQUENCY, NEGATIVE VALUE TO STOP
0.1955
 KC = 0.1955  PHASE       NU           MU          VSTAR
                0.0      0.54491     -0.03513       5.57
                0.0      1.43812      0.03461      14.71  <=== UNSTABLE
               72.0      0.70524     -0.06546       7.21
               72.0      0.88961     -0.05037       9.10
              144.0      0.64957     -0.19182       6.65
              144.0      0.86970      0.15514       8.90  <=== UNSTABLE
              216.0      0.65271     -0.19675       6.68
              216.0      0.86423      0.14497       8.84  <=== UNSTABLE
              288.0      0.75969      0.00070       7.77  <=== UNSTABLE
              288.0      0.79402     -0.15182       8.12

  ENTER THE REDUCED FREQUENCY, NEGATIVE VALUE TO STOP
-10.0
```

## 4.4 Test Case 4: Time Domain Flutter of a Cascade

**Description:**

In this test case (Ref. 3), time domain flutter calculations are done for a cascade. The cascade stagger angle is 10.65 deg. and the gap-to-chord ratio is 1.85. The Mach number at the inlet is 0.7. Five blade passages are included in the calculation. The grid used has 61 points in the streamwise direction and 57 points in the circumferential direction. In each blade passage, 31 points are located on each (upper and lower) surface of the airfoil, and 14 points are located on the wake. Calculations are performed for 1000 time steps with no blade motion and then the first blade is given an initial velocity perturbation. The total number of time steps in the calculation is 20000.

The structural parameters used are as follows. The mass ratio is 115.0, the radius if gyration is 1.076, the offset between elastic axis and center of mass is 0.964, the ratio of uncoupled natural frequencies in bending and torsion is 0.567, and the damping ratios are 0.0. The reduced velocity is 5.6.

**para.f:**

```
      PARAMETER
```

```
     & (ID1 = 18000, ID2 = 00800, ID3 = 00065, ID4 = 00065, ID5 = 00300,
     &  ID6 = 00105, ID7 = 00035, ID8 = 00020, ID9 = 00010)
```

## fpcas2d.input:

```
CJOB
TEST004
TITLE
TEST CASE 004 FOR FPCAS2D
PHASE
0.0
TH1       THS       TH2       TH3
12.8      10.65     10.65     8.85
XMINF     XMOUT
0.7       0.7
SBYC
1.85
A
-1.0
XKC
1.0
IMODE
2
ALFAA     XCONV
0.1       1.0E-06
NPMAX     IMAX      JMAX      NPAF      NPW
5         49        31        25        11
NTSS      NTPC      NCYE      NTMX      NTPRNT
1000      120       0         20000     50
IPLOT     NTPBEG    NTPINC    NTPEND
0         0         0         0
IYBIA     ISUPER    INITI     ITMAX     ISMTH     IMOUT
2         0         2         20        0         0
IRUN      IFLTR
0         -2
MV   1   2   3   4   5
     1   0   0   0   0
GHS       GAS       ZHS       ZAS
0.567     1.0       0.0       0.0
XMU       XRA       XA
115.0     1.0759    0.9644
VSTAR
5.6
IGRIDX    BETAX     IGRIDY    BETAY
0         1.0       3         1.5
IAIRFL    TBYC      HBYC
0         0.0       0.0
 NUAIR
          101
 ( XU(I), I = 1, NUAIR )
  0.00000E+00
  0.96841E-02
  0.19625E-01
  0.29593E-01
```

```
 0.39573E-01
```

... 91 lines deleted for brevity

```
 0.96022E+00
 0.97019E+00
 0.98015E+00
 0.99011E+00
 0.10000E+01
( YU(I), I = 1, NUAIR )
 0.00000E+00
 0.42167E-02
 0.63777E-02
 0.81254E-02
 0.96410E-02
```

... 91 lines deleted for brevity

```
 0.69296E-02
 0.55102E-02
 0.39877E-02
 0.23183E-02
 0.00000E+00
NLAIR
         101
( XL(I), I = 1, NLAIR )
 0.00000E+00
 0.10316E-01
 0.20375E-01
 0.30407E-01
 0.40427E-01
```

... 91 lines deleted for brevity

```
 0.95978E+00
 0.96981E+00
 0.97985E+00
 0.98989E+00
 0.10000E+01
( YL(I), I = 1, NLAIR )
 0.00000E+00
-0.15429E-02
-0.16967E-02
-0.16920E-02
-0.16223E-02
```

... 91 lines deleted for brevity

```
 0.10891E-02
 0.92327E-03
 0.69329E-03
```

```
 0.35554E-03
 0.00000E+00
```

## fpcas2d.output:

```
TEST CASE 004 FOR FPCAS2D

 5 PASSAGE(S) USED WITH A MULTIPLIER OF 0


  ******* GEOMETRY *******

  AIRFOIL COORDINATES, UPPER ( XU AND YU ) :

    0.0000    0.0097    0.0196    0.0296    0.0396    0.0496    0.0596
    0.0695    0.0795    0.0895    0.0995    0.1096    0.1195    0.1296
    0.1396    0.1496    0.1596    0.1696    0.1796    0.1896    0.1996
    0.2096    0.2196    0.2296    0.2397    0.2497    0.2597    0.2697
    0.2797    0.2897    0.2997    0.3097    0.3198    0.3298    0.3398
    0.3498    0.3598    0.3698    0.3798    0.3898    0.3999    0.4099
    0.4199    0.4299    0.4399    0.4499    0.4599    0.4700    0.4800
    0.4900    0.5000    0.5100    0.5200    0.5300    0.5401    0.5501
    0.5601    0.5701    0.5801    0.5901    0.6001    0.6102    0.6202
    0.6302    0.6402    0.6502    0.6602    0.6702    0.6802    0.6903
    0.7003    0.7103    0.7203    0.7303    0.7403    0.7503    0.7603
    0.7703    0.7803    0.7903    0.8004    0.8103    0.8204    0.8304
    0.8404    0.8504    0.8604    0.8703    0.8803    0.8903    0.9003
    0.9103    0.9203    0.9303    0.9403    0.9503    0.9602    0.9702
    0.9801    0.9901    1.0000

    0.0000    0.0042    0.0064    0.0081    0.0096    0.0110    0.0122
    0.0134    0.0144    0.0154    0.0164    0.0173    0.0181    0.0189
    0.0197    0.0204    0.0211    0.0218    0.0224    0.0230    0.0236
    0.0242    0.0247    0.0252    0.0257    0.0261    0.0266    0.0270
    0.0274    0.0278    0.0281    0.0285    0.0288    0.0291    0.0294
    0.0296    0.0299    0.0301    0.0303    0.0305    0.0307    0.0309
    0.0310    0.0311    0.0312    0.0313    0.0314    0.0315    0.0315
    0.0315    0.0315    0.0315    0.0315    0.0315    0.0314    0.0313
    0.0312    0.0311    0.0310    0.0308    0.0307    0.0305    0.0302
    0.0300    0.0298    0.0295    0.0292    0.0289    0.0285    0.0281
    0.0278    0.0273    0.0269    0.0264    0.0259    0.0254    0.0249
    0.0243    0.0237    0.0231    0.0224    0.0218    0.0210    0.0203
    0.0195    0.0187    0.0178    0.0169    0.0160    0.0151    0.0140
    0.0130    0.0119    0.0107    0.0095    0.0083    0.0069    0.0055
    0.0040    0.0023    0.0000

  AIRFOIL COORDINATES, LOWER ( XL AND YL ) :

    0.0000    0.0103    0.0204    0.0304    0.0404    0.0504    0.0604
    0.0705    0.0805    0.0905    0.1004    0.1105    0.1204    0.1304
    0.1404    0.1504    0.1604    0.1704    0.1804    0.1904    0.2004
    0.2104    0.2204    0.2304    0.2403    0.2503    0.2603    0.2703
```

```
  0.2803    0.2903    0.3003    0.3103    0.3202    0.3302    0.3402
  0.3502    0.3602    0.3702    0.3802    0.3902    0.4001    0.4101
  0.4201    0.4301    0.4401    0.4501    0.4601    0.4700    0.4800
  0.4900    0.5000    0.5100    0.5200    0.5300    0.5399    0.5499
  0.5599    0.5699    0.5799    0.5899    0.5999    0.6099    0.6198
  0.6298    0.6398    0.6498    0.6598    0.6698    0.6798    0.6897
  0.6997    0.7097    0.7197    0.7297    0.7397    0.7497    0.7597
  0.7697    0.7797    0.7897    0.7996    0.8097    0.8196    0.8296
  0.8396    0.8496    0.8596    0.8697    0.8797    0.8897    0.8997
  0.9097    0.9197    0.9297    0.9397    0.9498    0.9598    0.9698
  0.9798    0.9899    1.0000

  0.0000   -0.0015   -0.0017   -0.0017   -0.0016   -0.0015   -0.0014
 -0.0013   -0.0011   -0.0010   -0.0009   -0.0007   -0.0006   -0.0005
 -0.0004   -0.0002   -0.0001    0.0000    0.0001    0.0002    0.0003
  0.0004    0.0005    0.0006    0.0006    0.0007    0.0008    0.0009
  0.0009    0.0010    0.0010    0.0011    0.0011    0.0012    0.0012
  0.0013    0.0013    0.0013    0.0014    0.0014    0.0014    0.0015
  0.0015    0.0015    0.0015    0.0015    0.0015    0.0015    0.0015
  0.0015    0.0015    0.0015    0.0015    0.0015    0.0015    0.0015
  0.0015    0.0015    0.0015    0.0015    0.0015    0.0015    0.0015
  0.0015    0.0014    0.0014    0.0014    0.0014    0.0014    0.0014
  0.0014    0.0014    0.0014    0.0014    0.0014    0.0014    0.0014
  0.0014    0.0014    0.0014    0.0015    0.0015    0.0015    0.0015
  0.0015    0.0015    0.0015    0.0015    0.0015    0.0015    0.0015
  0.0015    0.0014    0.0014    0.0013    0.0012    0.0011    0.0009
  0.0007    0.0004    0.0000

OUTER BOUNDARY ( XX AND YY ) :

 -0.5000   -0.4583   -0.4167   -0.3750   -0.3333   -0.2917   -0.2500
 -0.2083   -0.1667   -0.1250   -0.0833   -0.0417    0.0000    0.0417
  0.0833    0.1250    0.1667    0.2083    0.2500    0.2917    0.3333
  0.3750    0.4167    0.4583    0.5000    0.5417    0.5833    0.6250
  0.6667    0.7083    0.7500    0.7917    0.8333    0.8750    0.9167
  0.9583    1.0000    1.0417    1.0833    1.1250    1.1667    1.2083
  1.2500    1.2917    1.3333    1.3750    1.4167    1.4583    1.5000

  0.0000    0.0428    0.0887    0.1376    0.1896    0.2447    0.3027
  0.3636    0.4271    0.4932    0.5615    0.6317    0.7036    0.7767
  0.8506    0.9250    0.9994    1.0733    1.1464    1.2183    1.2885
  1.3568    1.4229    1.4864    1.5473    1.6053    1.6604    1.7124
  1.7613    1.8072    1.8500

SBYC =  1.850

CALCULATED EXIT MACH NUMBER=  0.68094


 *******     GRID     *******

NPSG= 5 IMAX= 49 JMAX= 31
NFW= 11 NPAF= 25 NPW= 11
```

```
IMODE= 2

 ******* FREESTREAM *******

MACH NUMBER=  0.7000
INTER-BLADE PHASE ANGLE=     0.0000
REDUCED FRE=  1.0000
ALFAA=     0.1000
TH1=   12.8000 THS=   10.6500 TH2=   10.6500 TH3=     8.8500

 *******  NUMERICAL *******

NTSS=1000 NTPC= 120 NCYE=    0
XP=  0.0000 YP=  0.0000
DT=  0.0748 XCONV=  0.10E-05
IRUN= 0 ISUPER= 0 IYBIA= 2 INITI= 2 ITMAX= 20


 CONVERGENCE HISTORY :

<<< CAUTION >>>  NT=      1   MAX(DPHI)=   0.35E-05     IJ=   4644
NT=    50      NITER=   7     MAX(DPHI)=   0.88E-06     IJ=   6127
NT=   100      NITER=   4     MAX(DPHI)=   0.97E-06     IJ=   7505
NT=   150      NITER=   4     MAX(DPHI)=   0.49E-06     IJ=   6131
NT=   200      NITER=   3     MAX(DPHI)=   0.54E-06     IJ=   6027
NT=   250      NITER=   2     MAX(DPHI)=   0.88E-06     IJ=   6174
NT=   300      NITER=   1     MAX(DPHI)=   0.44E-06     IJ=   6101
NT=   350      NITER=   1     MAX(DPHI)=   0.16E-06     IJ=   6103
NT=   400      NITER=   1     MAX(DPHI)=   0.48E-07     IJ=   6105
NT=   450      NITER=   1     MAX(DPHI)=   0.13E-07     IJ=     31
NT=   500      NITER=   1     MAX(DPHI)=   0.47E-08     IJ=   4576
NT=   550      NITER=   1     MAX(DPHI)=   0.21E-08     IJ=   3060
NT=   600      NITER=   1     MAX(DPHI)=   0.86E-09     IJ=   3062
NT=   650      NITER=   1     MAX(DPHI)=   0.32E-09     IJ=   4583
NT=   700      NITER=   1     MAX(DPHI)=   0.10E-09     IJ=   4585
NT=   750      NITER=   1     MAX(DPHI)=   0.30E-10     IJ=   4587
NT=   800      NITER=   1     MAX(DPHI)=   0.84E-11     IJ=   4576
NT=   850      NITER=   1     MAX(DPHI)=   0.39E-11     IJ=   6097
NT=   900      NITER=   1     MAX(DPHI)=   0.17E-11     IJ=   4580
NT=   950      NITER=   1     MAX(DPHI)=   0.65E-12     IJ=   4582
NT=  1000      NITER=   1     MAX(DPHI)=   0.23E-12     IJ=   4633
 **** DELTA CP NEAR I = ILE ****
  0.00000  -0.00929  -0.01452  -0.12432  -0.26951
 **** DELTA CP NEAR I = ITE ****
 -0.20547  -0.07808   0.00485   0.00000   0.00000
 **** PRESSURE ON UPPER SURFACE ****
 -0.13932   0.05180   0.22172   0.22408   0.22846   0.23163   0.23382
  0.23536   0.23643   0.23705   0.23725   0.23716   0.23695   0.23648
  0.23520   0.23239   0.22739   0.21949   0.20780   0.19111   0.16747
  0.13318   0.07792  -0.05353  -0.15562
 **** PRESSURE ON LOWER SURFACE ****
 -0.15384  -0.07252  -0.04780  -0.05759  -0.06262  -0.06427  -0.06468
 -0.06458  -0.06429  -0.06400  -0.06379  -0.06367  -0.06357  -0.06351
 -0.06384  -0.06498  -0.06731  -0.07116  -0.07690  -0.08497  -0.09588
```

```
-0.11017  -0.12755  -0.13162  -0.15076

XU(II), CP(I), XL(II), CP(N)
0.00000000E+00 -0.13932396E+00  0.28897199E-18 -0.15384290E+00
0.43584934E-01  0.51800671E-01  0.41363288E-01 -0.72521503E-01
0.86176427E-01  0.22171660E+00  0.83125989E-01 -0.47797284E-01
0.12854442E+00  0.22408018E+00  0.12489662E+00 -0.57592542E-01
0.17077659E+00  0.22845929E+00  0.16665668E+00 -0.62615965E-01
0.21290844E+00  0.23163251E+00  0.20840271E+00 -0.64273881E-01
0.25495818E+00  0.23382268E+00  0.25013467E+00 -0.64682441E-01
0.29693712E+00  0.23536360E+00  0.29185345E+00 -0.64577169E-01
0.33885188E+00  0.23642920E+00  0.33356026E+00 -0.64290546E-01
0.38070666E+00  0.23704577E+00  0.37525635E+00 -0.63999415E-01
0.42250403E+00  0.23725106E+00  0.41694285E+00 -0.63791420E-01
0.46424554E+00  0.23716446E+00  0.45862080E+00 -0.63674865E-01
0.50593195E+00  0.23694753E+00  0.50029104E+00 -0.63567072E-01
0.54756225E+00  0.23647865E+00  0.54195473E+00 -0.63509579E-01
0.58913336E+00  0.23519682E+00  0.58361470E+00 -0.63837104E-01
0.63064120E+00  0.23238532E+00  0.62527388E+00 -0.64980224E-01
0.67208133E+00  0.22738628E+00  0.66693465E+00 -0.67306475E-01
0.71344875E+00  0.21948673E+00  0.70859872E+00 -0.71155517E-01
0.75473752E+00  0.20779990E+00  0.75026699E+00 -0.76899460E-01
0.79594093E+00  0.19111038E+00  0.79193911E+00 -0.84968709E-01
0.83705003E+00  0.16747011E+00  0.83361277E+00 -0.95875878E-01
0.87805321E+00  0.13317516E+00  0.87528234E+00 -0.11017496E+00
0.91893203E+00  0.77919986E-01  0.91693540E+00 -0.12754595E+00
0.95965114E+00 -0.53531514E-01  0.95854138E+00 -0.13161633E+00
0.10000000E+01 -0.15561794E+00  0.10000000E+01 -0.15076496E+00

**** MACH NUMBER ON UPPER SURFACE ****
 0.64644   0.72029   0.78494   0.78583   0.78749   0.78870   0.78953
 0.79011   0.79052   0.79075   0.79083   0.79080   0.79071   0.79054
 0.79005   0.78898   0.78709   0.78409   0.77965   0.77332   0.76434
 0.75131   0.73027   0.67982   0.64004
**** MACH NUMBER ON LOWER SURFACE ****
 0.64074   0.67247   0.68204   0.67825   0.67631   0.67567   0.67551
 0.67555   0.67566   0.67577   0.67585   0.67590   0.67594   0.67596
 0.67584   0.67539   0.67449   0.67300   0.67077   0.66764   0.66340
 0.65783   0.65105   0.64946   0.64195

XU(II), XMACH(I), XL(II), XMACH(N)
0.00000000E+00  0.64643893E+00  0.28897199E-18  0.64074052E+00
0.43584934E-01  0.72029459E+00  0.41363288E-01  0.67247193E+00
0.86176427E-01  0.78493516E+00  0.83125989E-01  0.68203918E+00
0.12854442E+00  0.78583200E+00  0.12489662E+00  0.67825275E+00
0.17077659E+00  0.78749360E+00  0.16665668E+00  0.67630894E+00
0.21290844E+00  0.78869762E+00  0.20840271E+00  0.67566710E+00
0.25495818E+00  0.78952863E+00  0.25013467E+00  0.67550891E+00
0.29693712E+00  0.79011331E+00  0.29185345E+00  0.67554968E+00
0.33885188E+00  0.79051763E+00  0.33356026E+00  0.67566065E+00
0.38070666E+00  0.79075157E+00  0.37525635E+00  0.67577337E+00
0.42250403E+00  0.79082946E+00  0.41694285E+00  0.67585390E+00
0.46424554E+00  0.79079660E+00  0.45862080E+00  0.67589902E+00
0.50593195E+00  0.79071429E+00  0.50029104E+00  0.67594075E+00
```

```
0.54756225E+00  0.79053639E+00  0.54195473E+00  0.67596301E+00
0.58913336E+00  0.79005002E+00  0.58361470E+00  0.67583621E+00
0.63064120E+00  0.78898326E+00  0.62527388E+00  0.67539361E+00
0.67208133E+00  0.78708646E+00  0.66693465E+00  0.67449270E+00
0.71344875E+00  0.78408904E+00  0.70859872E+00  0.67300139E+00
0.75473752E+00  0.77965423E+00  0.75026699E+00  0.67077433E+00
0.79594093E+00  0.77331991E+00  0.79193911E+00  0.66764248E+00
0.83705003E+00  0.76434391E+00  0.83361277E+00  0.66340300E+00
0.87805321E+00  0.75131088E+00  0.87528234E+00  0.65783389E+00
0.91893203E+00  0.73026793E+00  0.91693540E+00  0.65105029E+00
0.95965114E+00  0.67982318E+00  0.95854138E+00  0.64945776E+00
0.10000000E+01  0.64004276E+00  0.10000000E+01  0.64194987E+00

**** MACH NUMBER AT INLET SECTION ****
 0.69852   0.69917   0.69878   0.69907   0.69956   0.70010   0.70065
 0.70114   0.70152   0.70176   0.70182   0.70169   0.70140   0.70096
 0.70041   0.69980   0.69915   0.69852   0.69792   0.69738   0.69693
 0.69656   0.69630   0.69613   0.69606   0.69608   0.69617   0.69636
 0.69635   0.69725   0.69913   0.69913   0.69929   0.69880   0.69908
 0.69956   0.70011   0.70065   0.70114   0.70152   0.70176   0.70182
 0.70169   0.70140   0.70096   0.70041   0.69980   0.69915   0.69852
 0.69792   0.69738   0.69693   0.69656   0.69630   0.69613   0.69606
 0.69608   0.69617   0.69636   0.69635   0.69725   0.69913   0.69913
 0.69929   0.69880   0.69908   0.69956   0.70011   0.70065   0.70114
 0.70152   0.70176   0.70182   0.70169   0.70140   0.70096   0.70041
 0.69980   0.69915   0.69852   0.69792   0.69738   0.69693   0.69656
 0.69630   0.69613   0.69606   0.69608   0.69617   0.69636   0.69635
 0.69725   0.69913   0.69913   0.69929   0.69880   0.69908   0.69956
 0.70011   0.70065   0.70114   0.70152   0.70176   0.70182   0.70169
 0.70140   0.70096   0.70041   0.69980   0.69915   0.69852   0.69792
 0.69738   0.69693   0.69656   0.69630   0.69613   0.69606   0.69608
 0.69617   0.69636   0.69635   0.69725   0.69913   0.69913   0.69929
 0.69880   0.69908   0.69956   0.70011   0.70065   0.70114   0.70152
 0.70176   0.70182   0.70169   0.70140   0.70096   0.70041   0.69980
 0.69915   0.69852   0.69792   0.69738   0.69693   0.69656   0.69630
 0.69613   0.69606   0.69608   0.69617   0.69636   0.69632   0.69738
 0.69852
**** MACH NUMBER AT EXIT SECTION ****
 0.67985   0.67984   0.67984   0.67985   0.67987   0.67990   0.67993
 0.67998   0.68003   0.68009   0.68014   0.68020   0.68025   0.68030
 0.68033   0.68036   0.68037   0.68037   0.68036   0.68033   0.68029
 0.68024   0.68018   0.68012   0.68006   0.68001   0.67996   0.67992
 0.67988   0.67986   0.67985   0.67985   0.67984   0.67984   0.67985
 0.67987   0.67990   0.67993   0.67998   0.68003   0.68009   0.68014
 0.68020   0.68025   0.68030   0.68033   0.68036   0.68037   0.68037
 0.68036   0.68033   0.68029   0.68024   0.68018   0.68012   0.68006
 0.68001   0.67996   0.67992   0.67988   0.67986   0.67985   0.67985
 0.67984   0.67984   0.67985   0.67987   0.67990   0.67993   0.67998
 0.68003   0.68009   0.68014   0.68020   0.68025   0.68030   0.68033
 0.68036   0.68037   0.68037   0.68036   0.68033   0.68029   0.68024
 0.68018   0.68012   0.68006   0.68001   0.67996   0.67992   0.67988
 0.67986   0.67985   0.67985   0.67984   0.67984   0.67985   0.67987
 0.67990   0.67993   0.67998   0.68003   0.68009   0.68014   0.68020
 0.68025   0.68030   0.68033   0.68036   0.68037   0.68037   0.68036
```

```
 0.68033   0.68029   0.68024   0.68018   0.68012   0.68006   0.68001
 0.67996   0.67992   0.67988   0.67986   0.67985   0.67985   0.67984
 0.67984   0.67985   0.67987   0.67990   0.67993   0.67998   0.68003
 0.68009   0.68014   0.68020   0.68025   0.68030   0.68033   0.68036
 0.68037   0.68037   0.68036   0.68033   0.68029   0.68024   0.68018
 0.68012   0.68006   0.68001   0.67996   0.67992   0.67988   0.67986
 0.67985
**** FLOW ANGLE AT INLET SECTION ****
12.85835  12.84316  12.80657  12.83396  12.87885  12.92917  12.97897
13.02330  13.05772  13.07868  13.08396  13.07296  13.04659  13.00706
12.95741  12.90112  12.84171  12.78249  12.72633  12.67560  12.63214
12.59721  12.57159  12.55552  12.54878  12.55081  12.55948  12.57731
12.57704  12.66322  12.83930  12.83930  12.85419  12.80908  12.83475
12.87920  12.92937  12.97909  13.02339  13.05778  13.07873  13.08400
13.07299  13.04661  13.00708  12.95742  12.90113  12.84172  12.78250
12.72634  12.67561  12.63215  12.59722  12.57159  12.55553  12.54879
12.55082  12.55949  12.57732  12.57705  12.66322  12.83931  12.83931
12.85420  12.80909  12.83476  12.87921  12.92938  12.97910  13.02340
13.05779  13.07874  13.08401  13.07299  13.04662  13.00708  12.95743
12.90114  12.84173  12.78251  12.72635  12.67562  12.63216  12.59723
12.57160  12.55554  12.54880  12.55083  12.55950  12.57734  12.57706
12.66324  12.83933  12.83933  12.85421  12.80911  12.83477  12.87922
12.92939  12.97912  13.02341  13.05781  13.07875  13.08402  13.07301
13.04664  13.00710  12.95745  12.90115  12.84175  12.78252  12.72636
12.67564  12.63217  12.59725  12.57162  12.55556  12.54881  12.55085
12.55952  12.57735  12.57707  12.66325  12.83934  12.83934  12.85423
12.80913  12.83479  12.87924  12.92941  12.97914  13.02343  13.05783
13.07877  13.08404  13.07303  13.04665  13.00712  12.95746  12.90117
12.84177  12.78254  12.72638  12.67566  12.63219  12.59727  12.57164
12.55558  12.54883  12.55088  12.55941  12.57786  12.57415  12.67553
12.85835
**** FLOW ANGLE AT EXIT SECTION ****
 8.66942   8.67128   8.67416   8.68229   8.69842   8.72264   8.75452
 8.79304   8.83663   8.88336   8.93099   8.97723   9.01983   9.05670
 9.08603   9.10632   9.11648   9.11581   9.10413   9.08179   9.04974
 9.00959   8.96352   8.91423   8.86467   8.81768   8.77570   8.74043
 8.71266   8.69079   8.66942   8.66942   8.67128   8.67416   8.68229
 8.69842   8.72264   8.75452   8.79304   8.83663   8.88336   8.93099
 8.97723   9.01983   9.05670   9.08603   9.10632   9.11648   9.11581
 9.10413   9.08179   9.04974   9.00959   8.96352   8.91423   8.86467
 8.81768   8.77570   8.74043   8.71266   8.69079   8.66942   8.66942
 8.67128   8.67416   8.68229   8.69842   8.72264   8.75452   8.79304
 8.83664   8.88336   8.93099   8.97723   9.01983   9.05670   9.08603
 9.10632   9.11648   9.11581   9.10413   9.08179   9.04975   9.00959
 8.96352   8.91424   8.86467   8.81769   8.77570   8.74043   8.71266
 8.69079   8.66942   8.66942   8.67128   8.67416   8.68229   8.69842
 8.72265   8.75452   8.79304   8.83664   8.88336   8.93099   8.97724
 9.01983   9.05670   9.08603   9.10633   9.11648   9.11581   9.10413
 9.08179   9.04975   9.00959   8.96352   8.91424   8.86467   8.81769
 8.77570   8.74043   8.71266   8.69079   8.66942   8.66942   8.67128
 8.67416   8.68229   8.69843   8.72265   8.75453   8.79304   8.83664
 8.88336   8.93100   8.97724   9.01983   9.05670   9.08603   9.10633
 9.11648   9.11581   9.10413   9.08179   9.04975   9.00959   8.96352
 8.91424   8.86467   8.81769   8.77570   8.74043   8.71266   8.69079
```

```
  8.66942
 **** MACH NUMBER AT INLET AND EXIT ****
  0.69881   0.68008
 **** FLOW ANGLE AT INLET AND EXIT ****
 12.80838   8.87708
INITIAL CONDITIONS: K, H, A, HD, AD, HDD, ADD
 1    0.00000E+00    0.00000E+00    0.00000E+00    0.43633E-03    0.00000E+00
0.00000E+00
 2    0.00000E+00    0.00000E+00    0.00000E+00    0.00000E+00    0.00000E+00
0.00000E+00
 3    0.00000E+00    0.00000E+00    0.00000E+00    0.00000E+00    0.00000E+00
0.00000E+00
 4    0.00000E+00    0.00000E+00    0.00000E+00    0.00000E+00    0.00000E+00
0.00000E+00
 5    0.00000E+00    0.00000E+00    0.00000E+00    0.00000E+00    0.00000E+00
0.00000E+00
 NT=  1050     NITER=   3     MAX(DPHI)=   0.27E-06     IJ=   7546
 NT=  1100     NITER=   1     MAX(DPHI)=   0.34E-06     IJ=   1470
 NT=  1150     NITER=   1     MAX(DPHI)=   0.28E-06     IJ=   1470
 NT=  1200     NITER=   1     MAX(DPHI)=   0.53E-06     IJ=   7546
 NT=  1250     NITER=   1     MAX(DPHI)=   0.38E-06     IJ=     29
 NT=  1300     NITER=   1     MAX(DPHI)=   0.24E-06     IJ=   1470
 NT=  1350     NITER=   1     MAX(DPHI)=   0.13E-06     IJ=   6027
 NT=  1400     NITER=   1     MAX(DPHI)=   0.43E-06     IJ=   7546
 NT=  1450     NITER=   1     MAX(DPHI)=   0.21E-06     IJ=   1470
 NT=  1500     NITER=   1     MAX(DPHI)=   0.13E-06     IJ=   1505
 NT=  1550     NITER=   1     MAX(DPHI)=   0.17E-06     IJ=   6027
 NT=  1600     NITER=   1     MAX(DPHI)=   0.30E-06     IJ=   7545
 NT=  1650     NITER=   1     MAX(DPHI)=   0.19E-06     IJ=   1470
 NT=  1700     NITER=   1     MAX(DPHI)=   0.11E-06     IJ=     34
```

... 360 lines deleted for brevity

```
 NT= 19750     NITER=   1     MAX(DPHI)=   0.71E-06     IJ=   6112
 NT= 19800     NITER=   1     MAX(DPHI)=   0.73E-06     IJ=   3075
 NT= 19850     NITER=   1     MAX(DPHI)=   0.74E-06     IJ=     37
 NT= 19900     NITER=   1     MAX(DPHI)=   0.72E-06     IJ=   4593
 NT= 19950     NITER=   1     MAX(DPHI)=   0.73E-06     IJ=   1555
 NT= 20000     NITER=   1     MAX(DPHI)=   0.75E-06     IJ=   6112

  TOTAL NEWTON-ITERATIONS= 21134
  TOTAL TIME STEPS= 20000
 AVERAGE ITERATIONS PER TIME STEP=   1.1
```

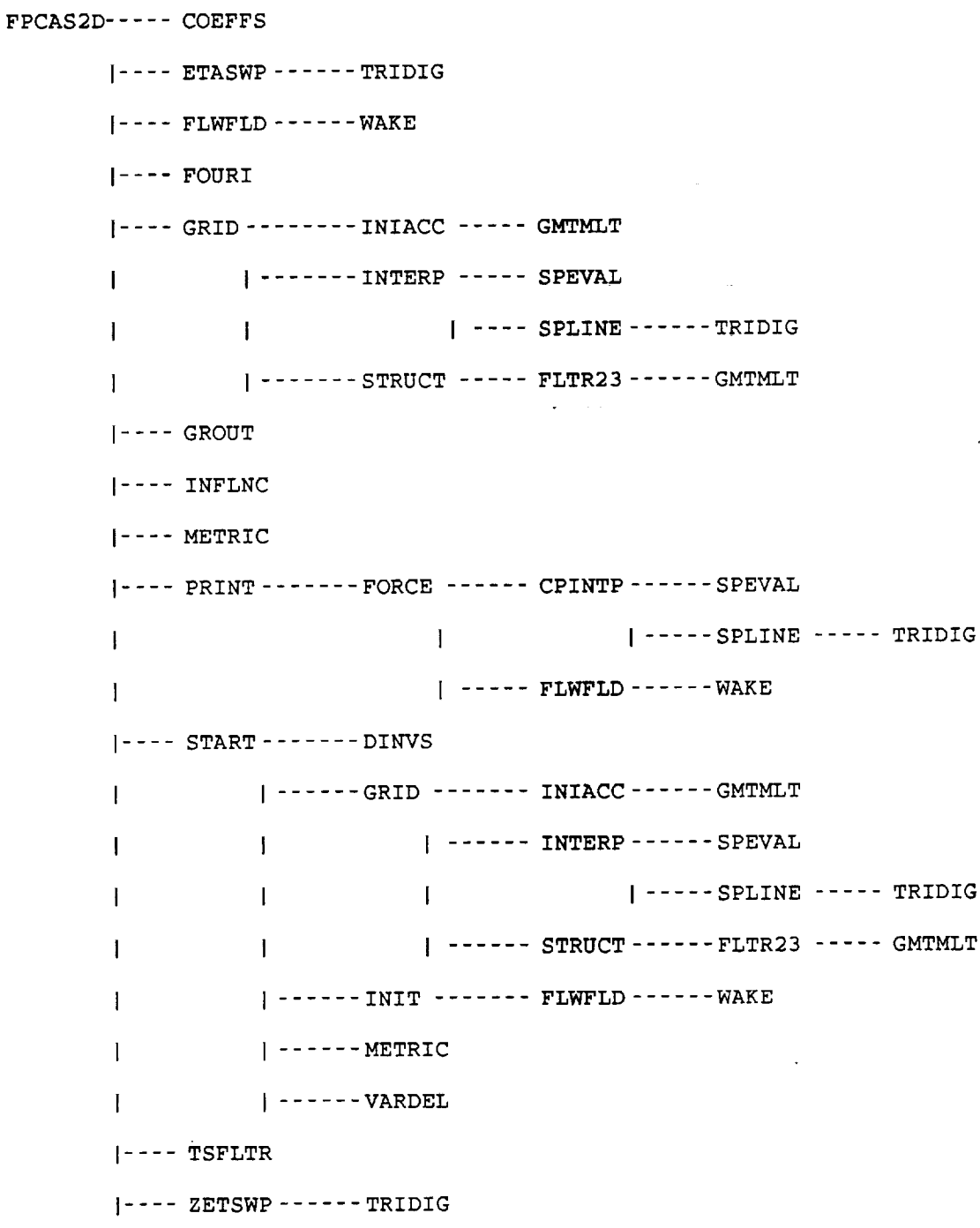
## additional output files :

`fort.7` binary flow file for use with restart option

`fort.21-25` unsteady motion, lift and moment coefficient history file for blades 1-5

## 5. PROGRAM CALLING TREE

The following is the static calling tree for the FPCAS2D code:



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

The FPCAS2D computer code has been developed for aeroelastic stability analysis of bladed disks such as those in fans, compressors, turbines, propellers, or propfans. The aerodynamic analysis used in this code is based on the unsteady two-dimensional full potential equation which is solved for a cascade of blades. The structural analysis is based on a two degree-of-freedom rigid typical section model for each blade. Detailed explanations of the aerodynamic analysis, the numerical algorithms, and the aeroelastic analysis are not given in this report. This guide can be used to assist in the preparation of the input data required by the FPCAS2D code. A complete description of the input data is provided in this report. In addition, four test cases, including inputs and outputs, are provided.

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