NASA - IN - 39 - 43612

NASA Contractor Report 198471

PROP3D: A Program for 3D Euler Unsteady Aerodynamic and Aeroelastic (Flutter and Forced Response) Analysis of Propellers

Version 1.0

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April 1996

Prepared for
Lewis Research Center
Under Grant NAG3–1230

National Aeronautics and
Space Administration

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SUMMARY

This guide describes the input data required, for steady or unsteady aerodynamic and aeroelastic analysis of propellers and the output files generated, in using PROP3D. The aerodynamic forces are obtained by solving three dimensional unsteady, compressible Euler equations. A normal mode structural analysis is used to obtain the aeroelastic equations, which are solved using either time domain or frequency domain solution method. Sample input and output files are included in this guide for steady aerodynamic analysis of single and counter-rotation propellers, and aeroelastic analysis of single-rotation propeller.

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1. INTRODUCTION

This is a user's guide for the PROP3D (Propeller Three Dimensional Analysis) computer code, which has been developed for steady or unsteady aerodynamic analysis and flutter and forced response analysis of propellers. This guide will help the user in the preparation of the input data file required by the PROP3D code. Detailed explanations of the aerodynamic analysis, the numerical algorithms, and the aeroelastic analysis are not given in this guide. Instead, the reader is directed to specific references that deal with each of these items. The PROP3D 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 any individuals who have contributed to the development of the code, assume any liability resulting from the use of this code beyond research needs.

2. ANALYSIS

The aerodynamic analysis used in this code is based on the unsteady three-dimensional Euler equations. These equations are solved for a cascade of blades. The coordinate system used is shown in Fig. 1. Detailed descriptions of the aerodynamic analysis can be found in Refs. 1 and 2. These references contain a full description of the 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. A finite difference ADI scheme is used to solve the Euler equations. A hybrid implicit-explicit scheme is used to reduce computational time. The aeroelastic analysis is described in Refs. 3 and 4. The aeroelastic equations are formulated in normal mode form and are solved for flutter in both time and frequency domains. The aeroelastic equations, for time domain analysis, are integrated in time using Newmark's method. The nature of the response indicates the stability. For frequency domain aeroelastic analysis, the blades are oscillated in a prescribed pulse motion. The time history of the forces (generalized forces), due to the pulse motion, is Fourier analyzed to obtain unsteady aerodynamic coefficients. These unsteady aerodynamic coefficients are then used in an eigen analysis. The eignevalues determine the stability.

3. DESCRIPTION OF INPUT DATA

The PROP3D code is written in FORTRAN. It was developed and is operational on the Cray YMP computer at NASA Lewis Research Center under the UNICOS operating system. The source code is designated as *prop3d.f*, and the input data for the code is provided in the input file *prop3d.inp*. The axis system and a typical grid used by the analysis is shown in Fig. 1.

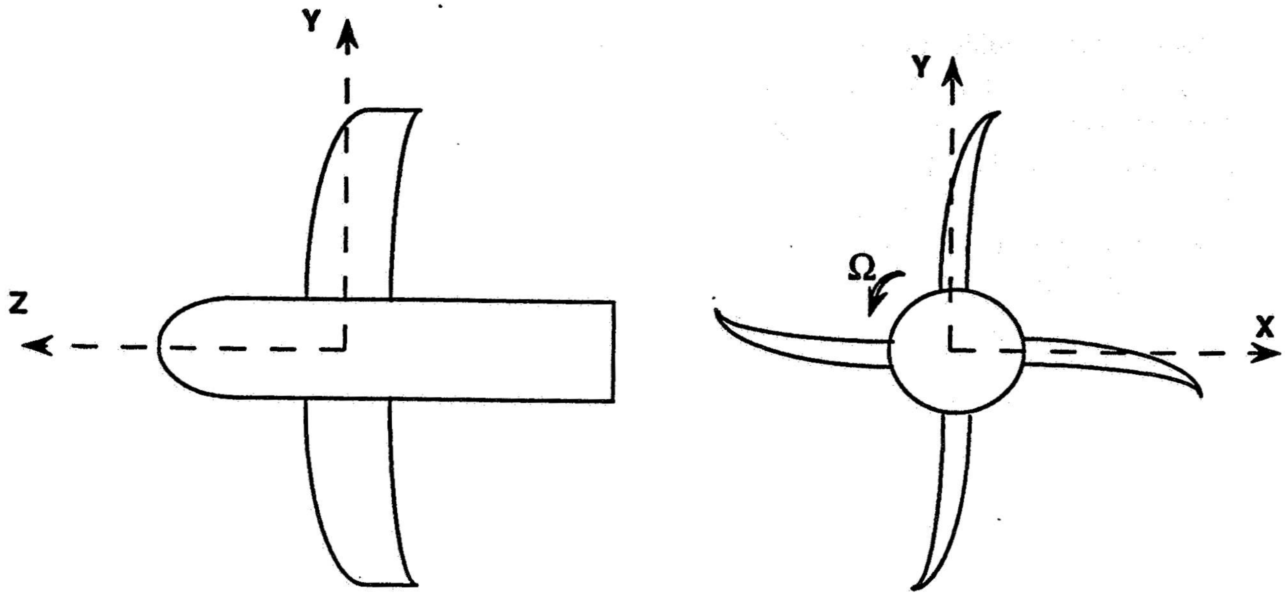

Fig 1a Axes system used by PROP3D

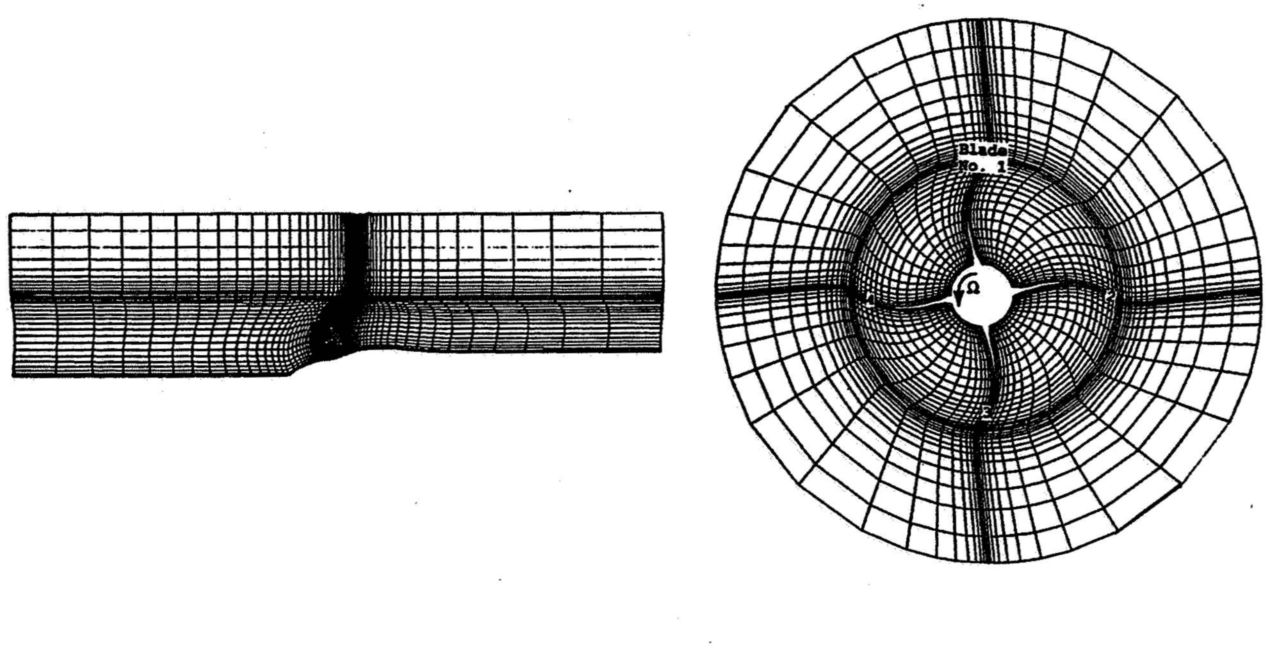

Fig 1b Typical grid used by PROP3D

3.1 Dimension Statements

The source code contains a parameter card that defines the largest possible size of the grid and number of blocks (passages) for calculation. For a given grid size and required blocks for computation taht are larger than defined by the parameter statement, the parameter statement should be changed **globally** in the source code and the source code should be then compiled. An example card is as follows:

```
parameter(imx=100,jmx=33,kmx=22,nblk=4,kmd=3,nblk3=nblk*3+1)
```

where

imx = maximum number of grid points in the axial (chordwise) direction

jmx = maximum number of grid points in the radial direction

kmx = maximum number of grid points + 1 in the circumferential direction

nblk = maximum number blade passages for computation

kmd = maximum number of structural modes in the analysis

3.2 Input Data File: prop3d.inp

This file contains the standard (UNIT 5) input that the PROP3D code requires. In the input file, the values of each set of input variables is preceded by an informational line containing the names of the variables. This name of the variables listed on the informational line are not used by the program. Following this line the values of the variables are listed. The real values are read in 8F10.4 format and integer values are read in 8I10 format. There are also a few logical variables that require either 'true' or 'false' as inputs.

The input variables are described below in the order in which they are required in the input data file (sample input file is shown on page 14). The informational card is listed first, followed by the description of the variables appearing on this informational card. In addition, sample values also are given.

The first card is a title and can be up to 80 characters long. The title card is a dummy card and is not used in the program.

example: SR3CX2 PROPFAN AEROELASTIC ANALYSIS

```
ADV    GMU    ALFA    PSI    WW    DT    REYREF
```

variable:	`ADV`
type:	real-variable
description:	advance ratio
example:	`3.55`

variable:	`GMU`
type:	real variable
description:	reserved for future use
example:	`0.0`

variable:	`ALFA`
type:	real variable
description:	angle of attack of center body with respect to free stream
example:	`0.0`

variable:	`PSI`
type:	real variable
description:	reserved for future use
example:	`0.0`

variable:	`WW`
type:	real variable
description:	artificial dissipation factor
example:	`7.0`

variable:	`DT`
type:	real variable
description:	time step, suggested values 0.0001 <DT<0.005
example:	`0.003`

variable:	`REYFRE`
type:	real variable
description:	Reynolds number * 10*E-06, must specify as +ve or -ve -ve Euler equations, +ve Navier-Stokes equations (not available)
example:	`-1.0`

```
IMAX    JMAX    KMAX    JTIP    ITEL    ILE    INOSE
```

variable:	`IMAX`
type:	integer variable
description:	total number of grid points in axial direction (≤ imx)
example:	`100`

variable:	`JMAX`
type:	integer variable
description:	total number of grid points in radial direction, hub to tip and beyond (≤ jmx)
example:	`33`

variable:	`KMAX`
type:	integer variable

description: total number of grid points in azimuthal direction + 1 (≤ kmx)
example: 22

variable: JTIP
type: integer variable
description: number of grids up to the tip of the blade along radial direction
example: 20

variable: ITEL
type: integer variable
description: number of grid points between downstream boundary and trailing
example: 30

variable: ILE
type: integer variable
description: number of grid points between upstream boundary and leading
example: 36

variable: INOSE
type: integer variable
description: number of grid points between the nose of the hub and upstream boundary
example: 16

FSTP FMINF BETA34 DIA DX DZ VIBFRE

variable: FSTP
type: real variable
description: total number of time steps
example: 1800.0

variable: FMINF
type: real variable
description: free stream Mach number
example: 0.50

variable: BETA34
type: real variable
description: blade setting angle at 75% radius from plane of rotation in degrees, used only if grid is internally generated.
example: 61.2

variable: DIA
type: real variable
description: diameter of the propeller
example: 1.0

variable: DX
type: real variable
description: the distance of the first grid point off the blade in the axial direction, as a percentage of local chord. Used only if grid is internally generated.
example: 0.01

variable: DZ
type: real variable
description: the distance of the first point off the blade in the direction normal to the blade, as a percentage of local chord. Used only if grid is internally generated.
example: 0.02

variable: VIBFRE
type: real variable
description: vibration frequency in Hz or pulse width in nondimensional time used in frequency domain flutter analysis
example: 0.6

```
ICCW      ITURB      LTHIN      IGR      ISWF
```

variable: ICCW
type: integer variable
description: indicator for direction of rotation of the propeller, see Fig. 1
example: =0 rotates clockwise (-ve Z rotation)
=1 rotates counter-clockwise (+ve Z rotation)

variable: ITURB
type: integer variable
description: viscous runs (not currently used)
example: =1 turbulent boundary layer
=2 laminar boundary layer

variable: LTHIN
type: integer variable
description: viscous control (not currently used)
example: =0 full Navier-Stokes analysis
=1 thin layer Navier-Stokes analysis

variable: IGR
type: integer variable
description: control for reading in the computational grid, see subroutine WINGEO for detail
example: = 0 algebraic aerodynamic grid generated within the program
= 1 externally generated aerodynamic grid is read in from UNIT 2, input file

variable: ISWF
type: integer variable
description: control for output of computational grid
example: =0 no print out
=1 print grid (aerodynamic mesh) to UNIT 7 output file

```
RESTART , QUASISTEADY , INFLOW , AEROELASTIC, COUNTER ROTATION, RESABD
```

variable: RESTART
type: logical variable
description: restart option
example: FALSE: start new case
TRUE: restarts, will read grid and flowfield information from UNIT 11 input file

variable: QUASISTEADY
type: logical variable
description: quasisteady or unsteady
example: FALSE: unsteady case
TRUE: quasi-steady case

variable: INFLOW
type: logical variable
description: not currently used: must be set to FALSE
example: FALSE

variable: AEROELASTIC
type: logical variable
description: aerodynamic or aeroelastic analysis
example: TRUE: aeroelastic analysis
FALSE: aerodynamic analysis

variable: COUNTER ROTATION
type: logical variable
description: single or counter rotation analysis
example: FALSE: single rotation analysis
TRUE: counter rotation analysis

variable: RESABD
type: logical variable
description: restart for deflection calculations
example: FALSE: Restart values are used
TRUE: will read previous solution but generates grid

```
IFLTR    NUMCYC    NSTDY    JMODE    NBLOKS
```

variable: IFLTR
type: integer variable
description: flutter analysis control, ignored if aeroelastic is FALSE
example: < 0 time domain flutter analysis
> 0 frequency domain flutter analysis

variable: NUMCYC
type: integer variable
description: number of cycles of harmonic oscillations, ignored for other cases
example: 3

variable: NSTDY
type: integer variable
description: type of oscillation used for frequency domain flutter analysis, ignored for other cases
example: = 1 harmonic oscillations
= 2 pulse oscillation, VIBFRE is treated as pulse width

variable: JMODE
type: integer variable

description: mode number in which the blade is to be oscillated for frequency domain flutter analysis, ignored for other cases
example: `2`

variable: `NBLOKS`
type: integer variable
description: number of blade passages used in the analysis, number of blades should be an integer multiple of `NBLOKS`
example: `= 1`

```
XLOC        DIAA     BETAA     ITELA      ILEA
```

variable: `XLOC`
type: real variable
description: axial distance of the pitch change axis of aft propeller from the pitch change axis of front propeller
example: `23.776`

variable: `DIAA`
type: real variable
description: diameter of the aft propeller
example: `140.0`

variable: `BETAA`
type: real variable
description: setting angle of the aft propeller
example: `54.4`

variable: `ITELA`
type: integer variable
description: number of grid points from trailing edge of aft propeller to downstream boundary.
example: `38`

variable: `ILEA`
type: integer variable
description: number of grid points upstream of leading edge of aft propeller
example: `8`

NOTE : The above data line is required only for counter-rotation analysis. It must be removed for any single-rotation analysis.

```
FNRS
```

variable:	`FNRS`
type:	real variable
description:	number of axial data points to define center body or hub, converted to integer inside the program
example:	`63.010`

```
XR        RR
```

variable:	`XR`
type:	real variable
description:	value of the axial station defining hub geometry

example:	`0.1`
	`0.2`
	`...`
	`...`
	`1.5`

variable:	`RR`
type:	real variable
description:	value of hub radius at axial station XR

example:	`0.05`
	`0.08`
	`...`
	`...`
	`0.225`

NOTE: a total of FNRS values should follow

```
INASTRAN
```

variable:	`INASTRAN`
type:	integer variable
description:	static aeroelastic analysis, ignored if `aeroelastic` is `false`
example:	`= 1` static aeroelastic analysis `= 0` no static aeroelastic analysis

```
FNC    FROTAT     FB    FTPRP    FTWST    FCOB    FGR
```

variable:	`FNC`
type:	real variable
description:	number of stations at which blade is defined, converted to integer within the program
example:	`13.0`

variable: FROTAT
type: real variable
description: for future use, must use a value of 1.01
example: 1.01

variable: FB
type: real variable
description: number of blades of the propeller, converted to integer within the program
example: 4.0

variable: FTPRP
type: real variable
description: for future use, must use a value of 1.01
example: 1.01

variable: FTWST
type: real variable
description: for future use, must use a value of 1.01
example: 1.01

variable: FCOB
type: real variable
description: number of root chord lengths the upstream and downstream boundaries are located at from the pitch change axis
example: 8.0

variable: FGR
type: real variable
description: control for future use, must use a value of 1.01
example: 1.01

DATA TYPE

variable: DATA TYPE
type: real variable
description: determines the input format for airfoil crossection
example:
=1 format is 3f10.6 XUPPER, ZUPPER, ZLOWER
=2 format is 6f10.6 XUPPER, ZUPPER, ZLOWER, XUPPER, ZUPPER, ZLOWER
=3 format is 10x, 6f10.6 XUPPER, ZUPPER, ZLOWER, XUPPER, ZUPPER, ZLOWER
=6 format is 10x, 4f10.6 XUPPER, ZUPPER, XLOWER, ZLOWER

YW(J) AL ALED FAD CHD FSEC THICK

variable: YW(J)
type: real variable
description: span station or radius location
example: 0.191708

variable: AL
type: real variable

description:	angle with respect to blade setting angle in degrees
example:	`0.0`

variable:	`ALED`
type:	real variable
description:	leading edge alignment
example:	`0.01`

variable:	`FAD`
type:	real variable
description:	face alignment
example:	`-0.01`

variable:	`CHD`
type:	real variable
description:	chord
example:	`0.2`

variable:	`FSEC`
type:	real variable
description:	blade geometry parameter
example:	`=1` section airfoil cross-sections are identical along the blade span `=2` section airfoil cross-sections are different along the blade span

variable:	`THICK`
type:	real variable
description:	control for future use, must use a value of 1.01
example:	`1.01`

```
        ZSYM        FNU        FNL
```

variable:	`ZSYM`
type:	real variable
description:	symmetry parameter
example:	`=0` non-symmetric airfoil cross-section `=1` symmetric airfoil cross-section

variable:	`FNU`
type:	real variable
description:	number of points on the upper surface of airfoil, converted to integer within the program
example:	`25.0`

variable:	`FNL`
type:	real variable
description:	number of points on the lower surface of airfoil, converted to integer within the program
example:	`25.0`

```
      X        ZUPPER     ZLOWER
```

variable: XUPPER
type: real variable
description: chordwise distance from leading edge, normalized with local chord
example: `0.0 .. 1.0`

variable: ZUPPER
type: real variable
description: upper surface coordinates corresponding to XUPPER values, normalized with local chord
example: `0.0 .. 0.02`

variable: XLOWER
type: real variable
description: chordwise distance from leading edge, normalized with local chord
example: `0.0 .. 1.0`

variable: ZLOWER
type: real variable
description: lower surface coordinates corresponding to XLOWER values, normalized with local chord
example: `0.0 .. -0.02`

NOTE 1: See input variable DATA TYPE. If ZSYM = 1, input contains only the upper surface definition. Must have FNU sets of data for upper surface and FNL for lower surface.

NOTE 2: Input data set from the line of variables YW(J) should be repeated FNC times.

```
      a0       p0
```

variable: a0
type: real variable
description: sonic velocity of the fluid (inch/sec)
example: `13040.`

variable: p0
type: real variable
description: static pressure (psi)
example: `14.7`

4. DESCRIPTION OF INPUT & OUTPUT FILES

The code uses the following files:

(1) UNIT 2: input file; unformatted file containing externally generated grid. Not required if grid is generated internally.

(2) UNIT 3: input file; formatted file containing blade structural grid. Required only for aeroelastic analysis. See subroutine STRUC0 for detail.

(3) UNIT 4: input file; formatted file containing blade generalized mass, natural frequencies and normal mode shapes. Required only for aeroelastic analysis. See subroutine STRUC0 for detail.

(4) UNIT 5 : input file; formatted input file named as prop3d.inp. Contains information on geometry, grid generation parameters, operating condition and solution control parameters. The file format and input variables have been defined in the previous section.

(5) UNIT 6: output file; formatted file renamed as prop3d.out. Contains information on grid generation, operating condition of the solution, convergence history and chordwise pressure coefficients.

(6) UNITs 7 & 9: output files; unformatted grid files for PLOT3D created at the end of the calculations. UNIT 7 contains grid for front row and UNIT 9 for aft row.

(7) UNITs 8 & 10: output files; unformatted aerodynamic solution files for PLOT3D created at the end of the calculations. UNIT 8 contains flow information for front row and UNIT 10 contains for aft row.

(8) UNIT(s) 10+n, $1 \leq n \leq$ NBLOKS: input file(s); unformatted file(s) for restart run. For restart, previous run output files UNIT 30+n are renamed as UNIT 10+n for present run.

(9) UNIT(s) 30+n, $1 \leq n \leq$ NBLOKS: output file(s); unformatted file(s) written at the end of each run. Used for restarting a run.

(10) UNIT 57: output file; formatted file containing variation of normal modes for all blades and all modes used in the analysis. In time domain aeroelastic analysis it contains the time history of the blade response; in frequency domain it is used as input motion file in Fourier analysis. It has four or more colums which are iteration count, blade number, time, blade displacements in the normal modes. This file is not generated for aerodynamic analysis.

(11) UNITs 95, 96 & 97: output files; formatted file containing generalized force variation with time for all the blades. Each unit contains forces for one mode of analysis. These forces in conjunction with the motion file UNIT 57 are used in frequency domain flutter analysis.

These files have five columns which are, iteration count, blade number, total generalized force, steady generalized force and unsteady generalized force. Unsteady generalized force (fifth column) is used to determine the aeroleastic stability. This file is not generated for aerodynamic analysis.

(12) UNIT 98: output file; formatted file containing the information of force coefficients. It has four columns which are iteration count, power coefficient, thrust coefficient and efficiency.

5. ADDITIONAL NOTES

The aerodynamic and aeroelastic analysis assumes the following normalizations: all lengths are normalized by the diameter of the rotor, speeds with the free stream speed of sound and density with free stream density. The input geometry may be prescribed either in non-dimensional quantities normalized by the diameter or in dimensional quantities. If geometry is defined in non-dimensional quantities, th ediameter should be defined as 1. Additional inputs are required for geometry definitions in the case of a counter rotating geometry. For counter rotation geometry, the front rotor diameter is used for normalization

6. TEST CASES

Some sample test cases are provided in this section. A brief description of the test case along with input and output file listing is provided. In order to save space several lines from the listings have been deleted. The listings are provided to ensure that the solution obtained by the user compares favorably with the listings provided here.

The output listing is organized as follows:

The beginning of the output file contains the information regarding the type of solution being obtained, e.g. steady aerodynamic solution, aeroelastic solution, single-rotation propfan, counter-rotation propfan, etc., followed by the flight conditions.

Geometry input data is then echoed for fresh runs, it is suppressed for restart runs. The maximum and minimum Jacobians follow the geometry input echo. This provides information about the grid. If the maximum and minimum Jacobians have opposite signs, a grid line crossover is indicated and a new grid will have to be generated. This calculation is made only in the first time step.

The residuals are listed next. Maximum absolute change in the density along with the location of this change is printed. At this location, changes in momentum and energy are also listed. These quantities are printed for the first ten iterations and then every 25th iteration beginning from the 26th iteration. Also every 50th iteration, the average value of the residuals are printed. The solution is stopped any time any one of the maximum residuals become larger than one. The listing of the residuals continue until the maximum number of time steps provided in the input has been reached.

The pressure coefficient for each spanwise station of each blade is printed at the last time step. For the counter-rotation cases, front row pressure coefficients are followed by the listing for aft row. Along with the listing, a line plot of the pressure coefficient variation with the grid streamwise index is also provided for a quick reference

The power coefficient, thrust coefficient and efficiency are listed next. For the single-rotation calculation the Cartesian velocity components and the swirl angle at a specified axial location are listed at the end along with information about the CPU time and memory used per time step.

The following test cases are provided in this manual:

6.1 Steady aerodynamic analysis of a single-rotation propeller.
6.2 Steady aerodynamic analysis of a counter-rotation propeller.
6.3 Time domain aeroelastic analysis of a single-rotation propeller with four blades.
6.4 Frequency domain aeroelastic analysis of a single-rotation propeller with four blades.

6.1 Steady aerodynamic analysis of a single-rotation propeller

Description:

In this case a single rotation propfan (SR3C-X2) with four blades is analyzed. The inflow is axial and uniform, with a free stream Mach number of 0.62. The advance ratio is 3.55 and setting angle at blade 75% radius is 61.2°. The input parameters are provided in the listing of the input. For a steady solution, the input parameter `QUASISTEADY` should be set to `TRUE`. Once the `AEROELASTIC` variable is set to `FALSE` all other input related to aeroelastic calculation is ignored. For a restart solution, the UNIT 31 file generated in the previous analysis should be linked to UNIT 11 file of the current analysis and the input variable `RESTART` should be set to `TRUE`.

UNIT 5 (prop3d.inp; input file)

```
SR3 METRIC IN BC WWY=1.0 -  WWI=20*WW IEX=0 ISWCH=1
     ADV        GMU       ALFA        PSI         WW         DT     REYREF
   3.5500       0.0        0.0        0.0        7.0      .0030       -1.0
     IMAX       JMAX       KMAX       JTIP       ITEL        ILE      INOSE
      100         33         22         20         30         36         16
     FSTP      FMINF     BETA34        DIA         DX         DZ     VIBFRE
   1500.0      0.620      61.20        1.0       0.01      0.030        1.8
     ICCW      ITURB      LTHIN        IGR       ISWF
        1          0          0          0          0
RESTART , QUASISTEADY , INFLOW , AEROELASTIC, COUNTER ROTATION, RESABD
```

```
FALSE TRUEFALSEFALSEFALSEFALSE
     IFLTR    NUMCYC     NSTDY     JMODE    NBLOKS
        -1         0         2         1         1
     FNRS
   60.01
    XR         RR
 -0.295920  0.010000
 -0.287760  0.014857
 -0.279590  0.022857
 -0.271430  0.029796
```

••••••

*** Several lines of hub geometry definition deleted ***

••••••

```
  0.661220  0.154650
  0.700000  0.154650
  0.800000  0.154650
  1.099999  0.154650
  INASTRAN
         0
       FNC    FROTAT        FB     FTPRP     FTWST      FCOB       FGR
      13.0      1.01       4.0      1.01      1.01        8.      1.01
 DATA TYPE
      2.05
     YW(J)        AL      ALED       FAD       CHD      FSEC     THICK
   0.00000  33.01000  -0.02075   0.00000   0.16695  1.000000      1.00
      ZSYM       FNU       FNL
  0.000000 25.000000 25.000000
      X       ZUPPER    ZLOWER
  0.000000  0.000000  0.000000  0.043924  0.027370 -0.027239
  0.085493  0.038369 -0.039117  0.126746  0.048135 -0.050491
  0.167928  0.056366 -0.060960  0.209243  0.063894 -0.071346
  0.250325  0.070800 -0.081508  0.291401  0.077129 -0.091354
  0.332469  0.082918 -0.100846  0.373520  0.088131 -0.109802
  0.414583  0.092607 -0.117979  0.455679  0.096111 -0.124962
  0.496797  0.098159 -0.130168  0.537985  0.098408 -0.133133
  0.579236  0.096783 -0.133664  0.620573  0.093367 -0.131732
  0.662011  0.088250 -0.127295  0.703559  0.081441 -0.120175
  0.745148  0.073052 -0.110456  0.786971  0.063141 -0.098069
  0.829177  0.052067 -0.083190  0.871426  0.040052 -0.065918
  0.913613  0.027690 -0.046729  0.956337  0.014398 -0.024961
  1.000000  0.000000  0.000000
     YW(J)        AL      ALED       FAD       CHD      FSEC     THICK
```

••••••

*** Several sets of blade geometry definition deleted ***

••••••

```
     YW(J)        AL      ALED       FAD       CHD      FSEC     THICK
   0.50004  -7.85471   0.10204   0.00164   0.07007  1.000000      1.00
      ZSYM       FNU       FNL
  0.000000 25.000000 25.000000
      X       ZUPPER    ZLOWER
  0.000000  0.000000  0.000000  0.045021  0.006198 -0.001988
  0.088813  0.009473 -0.001168  0.131787  0.012711 -0.000386
  0.175385  0.015168  0.000824  0.217988  0.017158  0.001177
  0.260786  0.019148  0.001959  0.303389  0.020749  0.002702
  0.345622  0.021492  0.002627  0.387620  0.022625  0.003370
  0.429638  0.023369  0.003685  0.471071  0.023255  0.003572
  0.513108  0.023570  0.003496  0.554346  0.023457  0.002955
  0.595993  0.022953  0.002841  0.636626  0.021983  0.002689
  0.677473  0.021012  0.002147  0.718321  0.019652  0.001996
```

```
 0.758973  0.017863  0.001844  0.799664  0.015256  0.000874
 0.839498  0.013429  0.000684  0.879974  0.010393  0.000532
 0.920041  0.007747 -0.000048  0.959719  0.003854 -0.000238
 1.000000  0.000000  0.000000
      a0        p0
   13040.      14.7
```

UNIT 6 (prop3d.out; output file)

```
1     SR3 METRIC IN BC WWY=1.0 -  WWI=20*WW IEX=0 ISWCH=1
 *******************************************************
 *                                                     *
 *              STEADY EULER ANALYSIS                  *
 *                                                     *
 *******************************************************
 ++++++++++++++++++++++++++++
 +  atmospheric conditions
 ----------------------------------------
 +  pressure=14.288
 +  speed of sound (in/sec)=13341.26
 +  density=1.123843353053E-7
 ++++++++++++++++++++++++++++
 *    operating conditions:
 ----------------------------------------
 *  rotor speed(rpm)=139801.3723944
 *  rotor speed(rad/sec)=14639.96548253
 *  Mach no.= 0.62
 *  advance ratio (J).= 3.55
 *  tip radius (inches)=0.5
 ----------------------------------------

 NOT A RESTART, NO INITIAL SOLUTION.
  FRONT BLADE ROW ROTATING IN COUNTER CLOCKWISE DIRN.
  CONTRAVARIANT VELOCITIES EXTRAPOLATED ON SOLID SURFACES
  RADIAL MOMENTUM  EQUILLIBRIUM APPLIED ON DOWNSTREAM BOUNDARY
  UPSTREAM BOUNDARY FIXED TO FREESTREAM
      IN DISSIPATION SUBROUTINE THE COEFFICIENTS ARE :
      IJDIS =     2
      IKDIS =     1
      IJ2   =     0
      IIDIS =     1
      IHPQ  =     1
      WWY COEFFICIENT IN DIS2 IS =1.
      ICHAR IN JBC =1
      IN WALLBC THE CONSTANTS ARE :
      IWHIT =     0
      INL   =     0
      IEX   =     2
      JEX   =     1
      INRES =0
      IHORD =0
      KHORD =0
      ISMTH =0
      KSMTH =0
      IVIBR =0
        WWF =50.


     IMAX=        100
     JMAX=         33
     KMAX=         22
     JTIP=         20
```

```
    ITEL=         71
    ILE =         36
    INOSE=         16
    NSTEP=      1500
     DX =          0.01000000
     DZ =          0.03000000
      DT=          0.00300000
      WW=          7.00000000
    ALFA=          0.00000000
   AMTIP=          0.54867252
    FMINF=          0.62000000
    ADVANCE RATIO =    3.55000000
    vibration freq. =    0.00000000
    VIBRATING IN    2  MODE


     GMU=          0.00000000


     PSI=          0.00000000
 **** NSTDY =0
 **** JMODE =2
 cosa=1. sina=0.
 No. OF RADIAL STATIONS ON BODY = 62
 ILE=65 NSURF=36
 XLOC =0.
  NBLADS=4
     IGR=1
    ITPR=1
    ITWS=1
     THT=89.9999998342
    IROT=1
     DIA1 = 1.
 BETA=61.2deg
 PMB2=-0.5026548220322    IN DEGRESS = -28.79999988726
INPUT WING GEOMETRY


PROFILE AT Y =     0.00000
     XLE           ZLE          CHORD     THICKNESS FACTOR     ALPHA
    -0.0174        0.0113        0.1669          1.0000         0.5761
INPUT WING GEOMETRY


PROFILE AT Y =     0.11961
     XLE           ZLE          CHORD     THICKNESS FACTOR     ALPHA
    -0.0736        0.0308        0.1762          1.0000         0.3836
......
```

*** Several output lines of input data echo deleted ***

```
......
INPUT WING GEOMETRY


 PROFILE AT Y =     0.50004
      XLE           ZLE          CHORD     THICKNESS FACTOR     ALPHA
      0.1009        0.0156        0.0701          1.0000        -0.1371
   DELTA BETA AT 75% SPAN IS =2.3477352984433E-2
  SPAN=0.50004 YWN =0.50004
  TOTAL NUMBER OF STEPS  1500
  FMINF=0.62 SMINF=0. ICBU=16 ICBD=100
  MAX JACOB=8.2683062780772E-3 MIN JACOB=3.2260211171297E-7 AT 32
  IJMAX=99 KJMAX=11 IJMIN=36 KJMIN=2
```

```
MAX JACOB=6.2555744999246E-3 MIN JACOB=2.7947610222754E-7 AT 31
IJMAX=99 KJMAX=11 IJMIN=36 KJMIN=2
MAX JACOB=4.2717852958704E-3 MIN JACOB=2.1382828121481E-7 AT 30
IJMAX=99 KJMAX=11 IJMIN=36 KJMIN=2
MAX JACOB=2.9815914704659E-3 MIN JACOB=1.6510371527081E-7 AT 29
IJMAX=99 KJMAX=11 IJMIN=36 KJMIN=2
```

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*** Several lines of Jacobian output deleted ***

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```
MAX JACOB=1.883714413152E-4 MIN JACOB=1.7937733961897E-7 AT 4
IJMAX=99 KJMAX=11 IJMIN=71 KJMIN=20
MAX JACOB=1.3526460248794E-4 MIN JACOB=1.4001297799132E-7 AT 3
IJMAX=99 KJMAX=11 IJMIN=71 KJMIN=20
MAX JACOB=9.3614072799749E-5 MIN JACOB=1.0437063440033E-7 AT 2
IJMAX=99 KJMAX=11 IJMIN=71 KJMIN=20

   DRMAX         DUMAX         DVMAX         DWMAX         DEMAX          IB      IROW    IR    JR    KR
   0.1367E-16   0.4705E-16   0.4782E-16   0.1127E-16   0.3006E-15        1     1    10     2    18
   0.3170E-01   0.6309E-02   0.6139E-02   0.1197E-01   0.8035E-01        1     1    48     2    20
   0.3172E-01   0.8775E-02   0.8324E-02   0.1539E-01   0.8143E-01        1     1    48     2    20
   0.3016E-01   0.1108E-01   0.1088E-01   0.1672E-01   0.7692E-01        1     1    49     2    20
   0.2922E-01   0.1283E-01   0.1290E-01   0.1792E-01   0.7620E-01        1     1    49     2    20
   0.2708E-01   0.1480E-01   0.1513E-01   0.1784E-01   0.7019E-01        1     1    49     2    20
   0.2523E-01   0.1589E-01   0.1613E-01   0.1806E-01   0.6713E-01        1     1    49     2    20
   0.2323E-01   0.1685E-01   0.1731E-01   0.1740E-01   0.6221E-01        1     1    37     2    20
   0.2279E-01   0.1847E-01   0.1739E-01   0.1717E-01   0.6244E-01        1     1    37     2    20
   0.2205E-01   0.1897E-01   0.1773E-01   0.1680E-01   0.5981E-01        1     1    36     2    20
   0.1746E-01   0.9755E-02   0.1052E-01   0.9266E-02   0.4711E-01        1     1    68     3     2
AVERAGE RESIDUES --  0.58889E-03  0.44693E-03  0.39636E-03  0.31048E-03  0.14207E-02      50
   0.9994E-02   0.6865E-02   0.6074E-02   0.5178E-02   0.2662E-01        1     1    63     6     5
   0.7117E-02   0.4358E-02   0.4601E-02   0.3613E-02   0.1871E-01        1     1    62     8     2
AVERAGE RESIDUES --  0.56324E-03  0.38709E-03  0.39564E-03  0.22725E-03  0.14979E-02     100
```

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*** Several output lines deleted ***

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```
AVERAGE RESIDUES --  0.10102E-04  0.88353E-04  0.80228E-04  0.54203E-05  0.25972E-04    1450
    0.5747E-04   0.7340E-03   0.8173E-03   0.2343E-04   0.1440E-03        1     1    39    20     3
    0.5983E-04   0.6822E-03   0.7671E-03   0.2580E-04   0.1566E-03        1     1    79    18     3
    0.5884E-04   0.6779E-03   0.7265E-03   0.2440E-04   0.1544E-03        1     1    79    18     3
 AVERAGE  RESIDUES  --    0.88288E-05    0.91179E-04    0.76495E-04    0.48206E-05    0.23359E-04
1500
     ISTP= 1500     IB =    1     IROW =     1     TIME =     4.5000


     J=      1      Y=     0.2431      CL=    0.0254      CD=    0.2967      CM=   -0.0034
```

```
0PLOT OF CP AT EQUAL INTERVALS IN THE MAPPED PLANE
0  X      X/CL   X/CU    CPL     CPU
 -0.0725 0.0000 0.0000 0.2078  0.2078                    *    I
 -0.0709 0.0092 0.0109 0.9013 -0.4321     *                    I        +
 -0.0692 0.0196 0.0230 0.7194 -0.6535          *               I              +
 -0.0672 0.0315 0.0365 0.6566 -0.8434           *              I                  +
 -0.0649 0.0450 0.0516 0.5807 -0.9567             *            I                     +
 -0.0624 0.0606 0.0682 0.5219 -0.9166              *           I                    +
 -0.0595 0.0781 0.0868 0.4997 -0.7339               *          I                +
 -0.0563 0.0980 0.1079 0.4731 -0.5455                *         I            +
 -0.0527 0.1203 0.1315 0.4464 -0.3944                 *        I        +
 -0.0487 0.1455 0.1581 0.4207 -0.2773                  *       I     +
```

```
-0.0441 0.1739 0.1881 0.3897 -0.1925                  *        I   +
-0.0389 0.2059 0.2218 0.3459 -0.1473                    *      I  +
-0.0331 0.2419 0.2597 0.2809 -0.1555                     *     I  +
-0.0260 0.2864 0.3065 0.1987 -0.1780                       *   I  +
-0.0188 0.3310 0.3533 0.1191 -0.1734                         * I  +
-0.0116 0.3756 0.3999 0.0555 -0.1515                          *I  +
-0.0045 0.4203 0.4464 0.0080 -0.1362                           *  +
 0.0027 0.4653 0.4924 -0.0147 -0.1212                          I* +
 0.0098 0.5113 0.5376 -0.0016 -0.0876                          * +
 0.0170 0.5577 0.5823 0.0140 -0.0613                           * +
 0.0241 0.6044 0.6267 -0.0007 -0.0694                          * +
 0.0313 0.6511 0.6709 -0.0235 -0.0862                          I* +
 0.0384 0.6978 0.7149 -0.0306 -0.0863                          I* +
 0.0455 0.7443 0.7591 -0.0183 -0.0658                          I*+
 0.0513 0.7819 0.7948 0.0004 -0.0367                           *+
 0.0564 0.8154 0.8263 0.0160 -0.0130                           *+
 0.0609 0.8452 0.8543 0.0290 0.0045                           *+
 0.0649 0.8716 0.8791 0.0435 0.0221                            *I
 0.0685 0.8950 0.9012 0.0591 0.0424                           *+I
 0.0717 0.9158 0.9208 0.0766 0.0671                           * I
 0.0745 0.9343 0.9382 0.0984 0.0963                          *  I
 0.0770 0.9508 0.9536 0.1235 0.1289                         *   I
 0.0792 0.9653 0.9674 0.1485 0.1636                        +*   I
 0.0812 0.9783 0.9795 0.1758 0.2016                       +*    I
 0.0829 0.9898 0.9904 0.1982 0.2368                      +*     I
 0.0845 1.0000 1.0000 0.2199 0.2676                     + *     I

  J=   2   Y=  0.2642   CL=  0.0282   CD=  0.3088   CM=  0.0006

0PLOT OF CP AT EQUAL INTERVALS IN THE MAPPED PLANE
0  X     X/CL   X/CU   CPL    CPU
 -0.0784 0.0000 0.0000 0.1883 0.1883                        *  I
 -0.0768 0.0091 0.0108 0.8702 -0.4111         *                I        +
```

••••••

*** Several lines deleted ***

••••••

```
 0.0799 0.9898 0.9903 0.1798 0.2202                       +*   I
 0.0814 1.0000 1.0000 0.2004 0.2482                       +*   I
```

••••••

*** Several sets of pressure coefficient output deleted ***

••••••

```
  J=  20   Y=  1.0000   CL=  0.0680   CD=  0.0929   CM=  0.0081

0PLOT OF CP AT EQUAL INTERVALS IN THE MAPPED PLANE
0  X     X/CL   X/CU   CPL    CPU
 0.0765 0.0000 0.0000 -0.0919 -0.0919                          I *
 0.0771 0.0086 0.0104 0.0071 -0.1902                           *     +
```

••••••

*** Several lines deleted ***

```
......
 0.1357  0.9891  0.9899 -0.0568 -0.0921                              I *+
 0.1363  1.0000  1.0000 -0.0568 -0.0899                              I *+
  FOR THE SINGLE ROTATION PROPFAN :
    ADVANCE RATIO =         3.55000000
    POWER COEFFICIENT =     1.16427290
    THRUST COEFFICIENT =   0.16134077
    EFFICIENCY =            0.49194628
  OMEGA =0. z0=-6.8835563759422E-2 za(1)=1.965719937436
```

J	R	UZ	UTHT	UR	SWIRL
1	3.745646	695.370472	88.942215	247.670698	7.288910
2	4.023340	710.062044	86.946403	210.927013	6.981060
3	4.393593	721.541604	85.335453	182.194839	6.744939
4	4.856410	732.698949	82.386715	152.681082	6.415550
5	5.411791	741.232966	77.345295	125.386323	5.957073
6	6.059737	746.751892	71.200541	101.273376	5.446515
7	6.800245	749.543707	64.015404	80.239107	4.881548
8	7.633303	750.105832	56.793996	62.603223	4.329868
9	8.466386	748.584435	50.190912	49.090205	3.835813
10	9.206862	746.329704	43.699846	39.360538	3.351014
11	9.854806	744.135713	37.723908	32.589780	2.902121
12	10.410134	741.958514	32.539601	27.682213	2.511175
13	10.872973	739.423273	27.917859	23.870617	2.162247
14	11.335816	736.346817	23.281027	20.400642	1.810913
15	11.798605	732.805581	18.257391	17.167977	1.427193
16	12.168886	729.279763	13.849154	14.568209	1.087926
17	12.446610	725.974579	9.911635	12.584108	0.782203
18	12.631739	723.089153	6.847764	11.165339	0.542584
19	12.816868	719.374141	3.071305	10.166736	0.244618
20	13.002000	719.350213	-1.551131	10.135987	-0.123546
21	13.132020	718.725592	-1.935807	10.235105	-0.154319
22	13.392060	718.179230	-1.982420	10.301059	-0.158156
23	13.652100	717.645822	-1.905495	10.263184	-0.152132
24	13.912140	717.031800	-1.769436	10.229087	-0.141390
25	14.302200	716.247243	-1.571123	10.081094	-0.125681
26	14.822280	715.271333	-1.338680	9.824402	-0.107233
27	15.342360	714.128972	-1.070988	9.477032	-0.085927
28	16.122480	712.803415	-0.730715	8.594471	-0.058736
29	17.292660	711.439303	-0.335931	7.450806	-0.027054
30	18.852900	710.256928	0.025269	7.605093	0.002038
31	20.803200	709.321231	0.194493	9.457326	0.015710
32	23.403600	708.374494	0.107728	9.153142	0.008713
33	26.004000	707.163141	0.085857	-0.154188	0.006956

```
      TIME/ITERATION =1.660518196928
  MAXMEM= 3590144.
  MAXMEM= 3.423828125 MEGAWORDS
```

UNIT 98 (Output file; contains performance characteristics)

```
itn      cpwr                cth                      eff
2,   0.2089131049155,   -6.3080217427871E-2,   -1.071903899756
3,   0.4113417547967,   -2.6435901999093E-2,   -0.2281495885171
4,   0.6040402890523,   8.572613561171E-3,   5.0382033605583E-2
5,   0.7858853041612,   4.159139766715E-2,   0.1878766035407
6,   0.9554422193855,   7.2491623442388E-2,   0.2693467569248
7,   1.110984097197,   0.1008092265343,   0.3221223013901
8,   1.252814101613,   0.1267401765265,   0.359133590602
9,   1.378710907948,   0.1497362710891,   0.3855512851187
10,   1.49055908798,   0.1702781621551,   0.405544121347
```

......

*** 1480 lines of output deleted ***

......

```
 1491,  1.164470727066,  0.1613760868728,  0.4919703819796
 1492,  1.164376981478,  0.1613510957017,  0.4919337970885
 1493,  1.164442169547,  0.1613728757137,  0.4919726576085
 1494,  1.164349071091,  0.1613480460623,  0.4919362910509
 1495,  1.164414879101,  0.1613699786852,  0.4919753557037
 1496,  1.164322425184,  0.1613453095895,  0.4919392057161
 1497,  1.164388849205,  0.1613673935376,  0.4919784721825
 1498,  1.164297036828,  0.1613428839329,  0.4919425368654
 1499,  1.164364072562,  0.1613651178314,  0.4919820027087
 1500,  1.164272898347,  0.1613407665605,  0.4919462800368
```

6.2 Steady aerodynamic analysis of a counter-rotation propeller

Description:

In this case a counter-rotation propfan (F21-A21) with 12 blades in each row is analyzed. The inflow is axial and uniform, with a free stream Mach number of 0.5. The advance ratio based on the front row is 2.80 and setting angle at blade 75% radius for the front row is 58.3° and for the aft row is 54.4°. The input file required for this run is very similar to the single-rotation analysis. The only additional information required are used for grid generation and are shown in **bold** in the sample input file shown below. Further, the input parameter COUNTER should be set to **TRUE** as well. For a restart solution, the UNIT 31 and UNIT 32 files generated in the previous analysis should be linked to UNIT 11 and UNIT 12 files of the current analysis and the input variable RESTART should be set to TRUE.

UNIT 5 (prop3d.inp; input file)

```
GE7, FROM GE.F7.ORIG AND GE.A7.ORIG IN TOHUNG
      ADV       GMU       ALFA       PSI        WW        DT    REYREF
   2.8000       0.0        0.0       0.0       6.0     .0030      -1.0
     IMAX      JMAX       KMAX      JTIP      ITEL       ILE     INOSE
       80        33         16        20         8        38         8
     FSTP     FMINF     BETA34       DIA        DX        DZ    VIBFRE
   3000.0     0.710      58.30     140.0      0.01     0.030       1.8
     ICCW     ITURB      LTHIN       IGR      ISWF
        1         0          0         0         0
RESTART , QUASISTEADY , INFLOW , AEROELASTIC, COUNTER ROTATION, RESABD
FALSE TRUEFALSEFALSE TRUEFALSE
    IFLTR    NUMCYC      NSTDY     JMODE    NBLOKS
       -1         0          2         1         1
     XLOC      DIAA      BETAA     ITELA      ILEA
   23.776     140.0       54.4        38         8
    FNRS
  107.01
        Z         R
-144.09889   1.40000
-144.07901   1.40000
-144.03889   1.40000
```

......

*** Several lines of hub geometry definition deleted ***

```
......
  90.94482  17.87398
  94.77979  17.48097
  98.61377  17.23097
 102.44873  17.14297
 INASTRAN
        0
      FNC    FROTAT        FB     FTPRP     FTWST      FCOB       FGR
     12.0      1.01       8.0      1.01      1.01        8.      1.01
   IDTYPE
     3.05
    YW(J)        AL      ALED       FAD       CHD      FSEC     THICK
 33.30499  12.16362  -9.86136  -0.08906  17.82556    1.0000      1.00
     ZSYM       FNU       FNL
       0.     54.01     54.01
                  X       ZUP    ZLOWER         X       ZUP    ZLOWER
             0.0000  0.000000  0.000000    0.0003  0.000993 -0.000925
             0.0013  0.002048 -0.001786    0.0030  0.003161 -0.002581
             0.0053  0.004328 -0.003309    0.0083  0.005550 -0.003975
             0.0120  0.006836 -0.004594    0.0164  0.008209 -0.005199
             0.0258  0.010994 -0.006341    0.0515  0.017367 -0.008789
             0.0771  0.022711 -0.010888    0.1026  0.027424 -0.012959
             0.1279  0.031630 -0.015053    0.1532  0.035446 -0.017197
             0.1785  0.038815 -0.019341    0.2036  0.041839 -0.021396
             0.2338  0.045056 -0.023723    0.2639  0.047824 -0.025764
             0.2941  0.050176 -0.027342    0.3243  0.052155 -0.028280
             0.3545  0.053567 -0.028506    0.3847  0.054591 -0.028056
             0.4150  0.055265 -0.027045    0.4454  0.055555 -0.025591
             0.4757  0.055453 -0.023811    0.5059  0.055004 -0.021801
             0.5362  0.054115 -0.019590    0.5664  0.052830 -0.017317
             0.5965  0.051198 -0.015056    0.6265  0.049216 -0.012832
             0.6565  0.046829 -0.010676    0.6864  0.044258 -0.008802
             0.7162  0.041327 -0.007094    0.7459  0.038205 -0.005686
             0.7755  0.034843 -0.004529    0.8050  0.031174 -0.003571
             0.8345  0.027346 -0.002947    0.8638  0.023359 -0.002583
             0.8931  0.019255 -0.002578    0.9223  0.015015 -0.002764
             0.9515  0.010680 -0.003170    0.9758  0.007033 -0.003715
             0.9962  0.003911 -0.004246    0.9967  0.003800 -0.004227
             0.9972  0.003627 -0.004144    0.9977  0.003395 -0.003998
             0.9981  0.003106 -0.003791    0.9985  0.002767 -0.003527
             0.9989  0.002382 -0.003210    0.9992  0.001957 -0.002844
             0.9995  0.001499 -0.002436    0.9997  0.001015 -0.001992
             0.9999  0.000513 -0.001519    1.0000  0.000000  0.000000
    YW(J)        AL      ALED       FAD       CHD      FSEC     THICK
 37.33099  10.15210 -10.83628  -0.12331  18.02148    1.0000      1.00
......
```

*** Several sets of blade geometry definition deleted ***

```
......
    YW(J)        AL      ALED       FAD       CHD      FSEC     THICK
 68.16100 -11.48779   9.25917  -0.78241   4.23209    1.0000      1.00
     ZSYM       FNU       FNL
       0.     54.01     54.01
                  X       ZUP    ZLOWER         X       ZUP    ZLOWER
             0.0000  0.000000  0.000000    0.0006  0.001196 -0.001280
             0.0024  0.002287 -0.002625    0.0053  0.003227 -0.003993
             0.0095  0.003957 -0.005322    0.0148  0.004424 -0.006557

......
```

***** Several lines deleted *****

```
......
              0.9988  0.003746 -0.003724    0.9992  0.003071 -0.003055
              0.9995  0.002347 -0.002337    0.9998  0.001586 -0.001580
              0.9999  0.000799 -0.000797    1.0000  0.000000  0.000000
       a0        p0
    13040.      14.7
```

UNIT 6 (prop3d.out; output file)

```
1      GE7, FROM GE.F7.ORIG AND GE.A7.ORIG IN TOHUNG
 ******************************************************
 *                                                    *
 *              STEADY EULER ANALYSIS                 *
 *                 COUNTER ROTATION                   *
 *                                                    *
 ******************************************************
 ++++++++++++++++++++++++++++
 +  atmospheric conditions
 ----------------------------------------
 +  pressure=14.288
 +  speed of sound (in/sec)=13341.26
 +  density=1.123843353053E-7
 ++++++++++++++++++++++++++++
 *    operating conditions:
 ----------------------------------------
 *  rotor speed(rpm)=1449.841010204
 *  rotor speed(rad/sec)=151.826995551
 *  Mach no.= 0.71
 *  advance ratio (J).= 2.8
 *  tip radius (inches)=70.
 *rear blade row tip radius =70.
 ----------------------------------------

 NOT A RESTART, NO INITIAL SOLUTION.
  FRONT BLADE ROW ROTATING IN COUNTER CLOCKWISE DIRN.
  CONTRAVARIANT VELOCITIES EXTRAPOLATED ON SOLID SURFACES
  RADIAL MOMENTUM  EQUILLIBRIUM APPLIED ON DOWNSTREAM BOUNDARY
  UPSTREAM BOUNDARY FIXED TO FREESTREAM
      IN DISSIPATION SUBROUTINE THE COEFFICIENTS ARE :
      IJDIS =    2
      IKDIS =    1
      IJ2   =    0
      IIDIS =    1
      IHPQ  =    1
      WWY COEFFICIENT IN DIS2 IS =1.
      ICHAR IN JBC =1
      IN WALLBC THE CONSTANTS ARE :
      IWHIT =    0
      INL  =    0
      IEX   =    2
      JEX   =    1
      INRES =0
      IHORD =0
      KHORD =0
      ISMTH =0
      KSMTH =0
      IVIBR =0
        WWF =50.


     IMAX=         80
     JMAX=         33
```

```
    KMAX=         16
    JTIP=         20
    ITEL=         73
    ILE =         38
    INOSE=         8
    NSTEP=      3000
      DX =          0.01000000
      DZ =          0.03000000
        DT=         0.00300000
        WW=         6.00000000
      ALFA=         0.00000000
     AMTIP=         0.79661814
      FMINF=        `0.71000000
    ADVANCE RATIO =    2.80000000
    vibration freq. =    0.00000000
    VIBRATING IN     1  MODE


      GMU=          0.00000000


      PSI=          0.00000000
 **** NSTDY =0
 **** JMODE =1
 cosa=1. sina=0.
 No. OF RADIAL STATIONS ON BODY = 109
 ILE=43 NSURF=36
 XLOC =23.776
  NBLADS=8
     IGR=1
    ITPR=1
    ITWS=1
     THT=44.9999999171
    IROT=1
     DIA1 = 140.
 BETA=58.3deg
 PMB2=-0.5532693703755     IN DEGRESS = -31.6999998926
INPUT WING GEOMETRY


PROFILE AT Y =     0.23789
     XLE            ZLE             CHORD      THICKNESS FACTOR       ALPHA
   -0.0690          0.0142          0.1273            1.0000          0.2123
INPUT WING GEOMETRY


PROFILE AT Y =     0.26665
     XLE            ZLE             CHORD      THICKNESS FACTOR       ALPHA
   -0.0763          0.0128          0.1287            1.0000          0.1772
INPUT WING GEOMETRY
```

••••••

*** Several output lines of input data echo deleted ***

••••••

```
PROFILE AT Y =     0.48232
     XLE            ZLE             CHORD      THICKNESS FACTOR       ALPHA
     0.0341         0.0086          0.0700            1.0000         -0.1976
INPUT WING GEOMETRY


PROFILE AT Y =     0.49651
```

```
     XLE            ZLE            CHORD     THICKNESS FACTOR      ALPHA
     0.0580         0.0146          0.0427          1.0000        -0.2458
INPUT WING GEOMETRY


PROFILE AT Y =    0.50119
     XLE            ZLE            CHORD     THICKNESS FACTOR      ALPHA
     0.0685         0.0173          0.0305          1.0000        -0.2836
  DELTA BETA AT 75% SPAN IS =-1.533974178141
 SPAN=0.5011927857143 YWN =0.5011927857143
 ILE=73 NSURF=36
 XLOC =0.1698285714286
  NBLADS=8
     IGR=1
    ITPR=1
    ITWS=1
     THT=44.9999999171
    IROT=1
     DIA1 = 140.
 BETA=54.4deg
 PMB2=-0.6213372112509    IN DEGRESS = -35.59999989978
INPUT WING GEOMETRY


PROFILE AT Y =    0.22785
     XLE            ZLE            CHORD     THICKNESS FACTOR      ALPHA
    -0.0728         0.0101          0.1280          1.0000         0.1548
INPUT WING GEOMETRY


PROFILE AT Y =    0.25614
     XLE            ZLE            CHORD     THICKNESS FACTOR      ALPHA
    -0.0806         0.0086          0.1285          1.0000         0.1266
INPUT WING GEOMETRY


PROFILE AT Y =    0.28441
     XLE            ZLE            CHORD     THICKNESS FACTOR      ALPHA
    -0.0815         0.0043          0.1279          1.0000         0.0801
INPUT WING GEOMETRY
```

......

*** Several output lines of input data echo deleted ***

......

```
PROFILE AT Y =    0.46824
     XLE            ZLE            CHORD     THICKNESS FACTOR      ALPHA
     0.0329        -0.0025          0.0695          1.0000        -0.1432
INPUT WING GEOMETRY


PROFILE AT Y =    0.48182
     XLE            ZLE            CHORD     THICKNESS FACTOR      ALPHA
     0.0554         0.0018          0.0432          1.0000        -0.1686
INPUT WING GEOMETRY


PROFILE AT Y =    0.48686
     XLE            ZLE            CHORD     THICKNESS FACTOR      ALPHA
     0.0659         0.0077          0.0302          1.0000        -0.2005
```

```
DELTA BETA AT 75% SPAN IS =-2.020938987938
SPAN=0.4868642857143 YWN =0.4868642857143
TOTAL NUMBER OF STEPS  3000
FMINF=0.71 SMINF=0. ICBU=8 ICBD=80
MAX JACOB=3.6035190426693E-3 MIN JACOB=7.4587500314585E-8 AT 32
IJMAX=8 KJMAX=8 IJMIN=38 KJMIN=2
MAX JACOB=2.7315955957938E-3 MIN JACOB=6.4250585273909E-8 AT 31
IJMAX=8 KJMAX=8 IJMIN=38 KJMIN=2
MAX JACOB=1.8672618817368E-3 MIN JACOB=4.8924246080006E-8 AT 30
IJMAX=8 KJMAX=8 IJMIN=38 KJMIN=2
MAX JACOB=1.3051223917082E-3 MIN JACOB=3.7618113606858E-8 AT 29
IJMAX=8 KJMAX=8 IJMIN=38 KJMIN=2
MAX JACOB=8.5426844358705E-4 MIN JACOB=2.6621199228781E-8 AT 28
IJMAX=8 KJMAX=8 IJMIN=38 KJMIN=2
MAX JACOB=5.3518249612119E-4 MIN JACOB=1.7631829709623E-8 AT 27
IJMAX=8 KJMAX=8 IJMIN=38 KJMIN=2
MAX JACOB=4.0995984246672E-4 MIN JACOB=1.404233348018E-8 AT 26
IJMAX=8 KJMAX=8 IJMIN=38 KJMIN=2
```

......

*** Several lines of Jacobian output deleted ***

......

```
MAX JACOB=8.6528930178537E-5 MIN JACOB=9.4156779805543E-8 AT 5
IJMAX=9 KJMAX=8 IJMIN=39 KJMIN=2
MAX JACOB=6.5392636939157E-5 MIN JACOB=7.9562358267909E-8 AT 4
IJMAX=9 KJMAX=8 IJMIN=39 KJMIN=2
MAX JACOB=4.782748895815E-5 MIN JACOB=6.4484754422494E-8 AT 3
IJMAX=9 KJMAX=8 IJMIN=39 KJMIN=2
MAX JACOB=3.3736584940549E-5 MIN JACOB=4.9683970853408E-8 AT 2
IJMAX=9 KJMAX=8 IJMIN=39 KJMIN=2

  DRMAX        DUMAX        DVMAX        DWMAX        DEMAX        IB     IROW    IR    JR    KR
  0.3312E-16   0.6494E-16   0.4857E-16   0.2103E-16   0.2644E-15          1      1     7     2    13
FMINF=0.71 SMINF=0. ICBU=1 ICBD=77
MAX JACOB=-7.5762580198099E-8 MIN JACOB=-4.2625434982367E-3 AT 32
IJMAX=43 KJMAX=2 IJMIN=79 KJMIN=8
MAX JACOB=-6.5146139393417E-8 MIN JACOB=-3.218528393426E-3 AT 31
IJMAX=43 KJMAX=2 IJMIN=79 KJMIN=8
MAX JACOB=-4.9648292422822E-8 MIN JACOB=-2.1973368210249E-3 AT 30
IJMAX=43 KJMAX=2 IJMIN=79 KJMIN=8
MAX JACOB=-3.8236961314381E-8 MIN JACOB=-1.5345195172806E-3 AT 29
IJMAX=43 KJMAX=2 IJMIN=79 KJMIN=8
MAX JACOB=-2.7207472681275E-8 MIN JACOB=-1.0077949431377E-3 AT 28
IJMAX=43 KJMAX=2 IJMIN=79 KJMIN=8
MAX JACOB=-1.8231354419393E-8 MIN JACOB=-6.3729046766418E-4 AT 27
IJMAX=43 KJMAX=2 IJMIN=79 KJMIN=8
MAX JACOB=-1.4621506161849E-8 MIN JACOB=-4.904507967531E-4 AT 26
IJMAX=43 KJMAX=2 IJMIN=79 KJMIN=8
```

......

*** Several lines of Jacobian output deleted ***

......

```
MAX JACOB=-8.1525635026464E-8 MIN JACOB=-9.3615102534493E-5 AT 5
IJMAX=8 KJMAX=2 IJMIN=79 KJMIN=8
MAX JACOB=-6.8855907608706E-8 MIN JACOB=-6.5523129030512E-5 AT 4
IJMAX=8 KJMAX=2 IJMIN=79 KJMIN=8
MAX JACOB=-5.6128523957994E-8 MIN JACOB=-4.4735690898399E-5 AT 3
IJMAX=9 KJMAX=2 IJMIN=79 KJMIN=8
MAX JACOB=-4.3367787480278E-8 MIN JACOB=-2.9532551423106E-5 AT 2
```

```
IJMAX=9 KJMAX=2 IJMIN=79 KJMIN=8
  0.6090E-17  0.1432E-16  0.1891E-16  0.2215E-16  0.2630E-15         1   2   43   20   14
  0.3862E-01  0.1208E-01  0.8009E-02  0.1337E-01  0.9631E-01         1   1   72    2    2
  0.2708E-01  0.4283E-02  0.6379E-02  0.2136E-01  0.6777E-01         1   2    9    3    2
  0.3583E-01  0.8877E-02  0.8539E-02  0.1448E-01  0.9020E-01         1   1   70    2    2
  0.2545E-01  0.6369E-02  0.7649E-02  0.2543E-01  0.6442E-01         1   2    9    3    2
  0.3284E-01  0.1136E-01  0.1207E-01  0.1499E-01  0.8014E-01         1   1   70    2    2
  0.2234E-01  0.8919E-02  0.7924E-02  0.2548E-01  0.5716E-01         1   2    9    3    2
  0.3054E-01  0.1364E-01  0.1442E-01  0.1509E-01  0.7546E-01         1   1   68    2    2
  0.2144E-01  0.1117E-01  0.9119E-02  0.2535E-01  0.5572E-01         1   2    9    3    2
  0.2707E-01  0.1564E-01  0.1670E-01  0.1464E-01  0.6484E-01         1   1   68    2    2
  0.1819E-01  0.1217E-01  0.1051E-01  0.2340E-01  0.4823E-01         1   2    9    3    2
  0.2399E-01  0.1677E-01  0.1826E-01  0.1440E-01  0.5819E-01         1   1   68    2    2
  0.1673E-01  0.1301E-01  0.1051E-01  0.2259E-01  0.4591E-01         1   2    8    3    2
  0.2136E-01  0.1862E-01  0.2001E-01  0.1347E-01  0.5278E-01         1   1    9    2    9
  0.1453E-01  0.1267E-01  0.1140E-01  0.2099E-01  0.4118E-01         1   2    8    3    2
  0.1938E-01  0.1866E-01  0.2057E-01  0.1319E-01  0.4933E-01         1   1    9    2   14
  0.1401E-01  0.1247E-01  0.1075E-01  0.1987E-01  0.4103E-01         1   2    7    3    2
  0.1847E-01  0.1915E-01  0.2140E-01  0.1239E-01  0.4664E-01         1   1    9    2   14
  0.1227E-01  0.1152E-01  0.1111E-01  0.1870E-01  0.3667E-01         1   2    7    4    2
  0.1809E-01  0.1046E-01  0.1220E-01  0.1217E-01  0.3773E-01         1   1   69    2    2
  0.8360E-02  0.5459E-02  0.6377E-02  0.7174E-02  0.1986E-01         1   2   68    4    2
AVERAGE RESIDUES --  0.60831E-03  0.48239E-03  0.43115E-03  0.37539E-03  0.14597E-02      50
AVERAGE RESIDUES --  0.42246E-03  0.35977E-03  0.34795E-03  0.32509E-03  0.10276E-02      50
  0.1174E-01  0.5049E-02  0.6663E-02  0.6170E-02  0.2597E-01         1   1   64    2    5
  0.5520E-02  0.5910E-02  0.3568E-02  0.5762E-02  0.1282E-01         1   2   34    2    5
  0.8775E-02  0.3536E-02  0.3349E-02  0.4129E-02  0.1478E-01         1   1   62    2    3
  0.5010E-02  0.4864E-02  0.2393E-02  0.3570E-02  0.1014E-01         1   2   33    2    3
AVERAGE RESIDUES --  0.50505E-03  0.39242E-03  0.33583E-03  0.31305E-03  0.12329E-02     100
AVERAGE RESIDUES --  0.47970E-03  0.44231E-03  0.37495E-03  0.29910E-03  0.11703E-02     100
```

......

*** Several output lines deleted ***

......

```
  0.5794E-02  0.2161E-02  0.1905E-02  0.3631E-02  0.1262E-01         1   1   79    2    6
  0.4732E-02  0.2177E-02  0.2605E-02  0.1288E-02  0.3505E-02         1   2    2    2    5
  0.4901E-02  0.2030E-02  0.1604E-02  0.3655E-02  0.8407E-02         1   1   79    2    5
  0.1962E-02  0.1967E-02  0.1926E-02  0.1198E-02  0.2607E-02         1   2    2    2   13
AVERAGE RESIDUES --  0.19958E-03  0.26916E-03  0.27090E-03  0.90783E-04  0.52514E-03    2900
AVERAGE RESIDUES --  0.17040E-03  0.23977E-03  0.29091E-03  0.12074E-03  0.38676E-03    2900
  0.4199E-02  0.2876E-02  0.2373E-02  0.4694E-02  0.9126E-02         1   1   79    2   12
  0.2239E-02  0.1830E-02  0.2093E-02  0.1071E-02  0.2847E-02         1   2    3    2    6
  0.6568E-02  0.3037E-02  0.1840E-02  0.4153E-02  0.1283E-01         1   1   79    2    5
  0.4653E-02  0.1871E-02  0.2443E-02  0.1082E-02  0.3188E-02         1   2    2    2    4
AVERAGE RESIDUES --  0.23252E-03  0.26116E-03  0.24841E-03  0.10415E-03  0.55977E-03    2950
AVERAGE RESIDUES --  0.17333E-03  0.29257E-03  0.28149E-03  0.14276E-03  0.39672E-03    2950
  0.5540E-02  0.1717E-02  0.1624E-02  0.3692E-02  0.9556E-02         1   1   79    2    4
  0.1913E-02  0.2286E-02  0.1912E-02  0.1421E-02  0.2925E-02         1   2    2    2    7
  0.3928E-02  0.3381E-02  0.2638E-02  0.4022E-02  0.9272E-02         1   1   79    2    7
  0.2205E-02  0.2019E-02  0.2120E-02  0.1034E-02  0.2844E-02         1   2    2    2    5
  0.7025E-02  0.1962E-02  0.2706E-02  0.5206E-02  0.1320E-01         1   1   79    2    4
AVERAGE RESIDUES --  0.25433E-03  0.27023E-03  0.27739E-03  0.99632E-04  0.56743E-03    3000
   ISTP= 3000     IB =    1    IROW =    1    TIME =     9.0000


   J=     1     Y=    0.4259     CL=   0.2363     CD=   0.5449     CM=    0.0432


OPLOT OF CP AT EQUAL INTERVALS IN THE MAPPED PLANE
0   X      X/CL   X/CU     CPL     CPU
 -0.0628 0.0000 0.0000 0.1346 0.1346                        * I
 -0.0616 0.0078 0.0115 0.6534 -0.4305                 *         I        +
```

```
-0.0602 0.0177 0.0233  0.5424 -0.6312                *               I                 +
-0.0587 0.0291 0.0366  0.5174 -0.7336                *               I                    +
-0.0571 0.0420 0.0513  0.4791 -0.7916                  *             I                      +
-0.0551 0.0567 0.0679  0.4302 -0.8470                   *            I                       +
-0.0530 0.0734 0.0865  0.3811 -0.9050                     *          I                         +
-0.0505 0.0923 0.1075  0.3304 -0.9638                      *         I                           +
-0.0478 0.1137 0.1310  0.2780 -1.0106                        *       I                            +
-0.0447 0.1378 0.1576  0.2189 -1.0505                         *      I                             +
-0.0412 0.1652 0.1875  0.1496 -1.0955                           *    I                               +
-0.0372 0.1963 0.2211  0.0749 -1.1459                              * I                                +
-0.0328 0.2314 0.2588  0.0041 -1.2038                                *                                  +
-0.0273 0.2751 0.3052 -0.0583 -1.2715                                I *                                  +
-0.0218 0.3192 0.3509 -0.1009 -1.3372                                I  *                                   +
-0.0163 0.3637 0.3961 -0.1001 -1.3380                                I  *                                   +
-0.0108 0.4085 0.4407 -0.0590 -1.0743                                I *                             +
-0.0054 0.4538 0.4850 -0.0176 -0.5423                                *               +
 0.0001 0.4995 0.5292  0.0059 -0.0427                                *+
 0.0057 0.5456 0.5732  0.0239  0.1796                           +    *I
 0.0112 0.5920 0.6173  0.0411  0.1592                           +    *I
 0.0168 0.6389 0.6615  0.0598  0.0341                              *+I
 0.0224 0.6860 0.7060  0.0781 -0.0899                              * I  +
 0.0280 0.7334 0.7506  0.0849 -0.1606                             *  I    +
 0.0326 0.7721 0.7870  0.0761 -0.1709                              * I    +
 0.0367 0.8066 0.8195  0.0582 -0.1343                              * I   +
 0.0403 0.8373 0.8485  0.0390 -0.0789                               *I +
 0.0436 0.8647 0.8744  0.0212 -0.0328                               *I+
 0.0465 0.8890 0.8974  0.0037 -0.0090                                *
 0.0491 0.9108 0.9180 -0.0128 -0.0039                                *
 0.0514 0.9301 0.9363 -0.0289 -0.0090                                +*
 0.0534 0.9472 0.9526 -0.0449 -0.0115                                +*
 0.0552 0.9625 0.9671 -0.0695 -0.0127                                + *
 0.0569 0.9761 0.9801 -0.0933  0.0132                                +   *
 0.0583 0.9882 0.9917 -0.1053  0.0451                               +I   *
 0.0595 1.0000 1.0000  0.0242  0.1604                           +    *I


     J=      2      Y=     0.4432      CL=    0.2330      CD=    0.5405      CM=    0.0390


OPLOT OF CP AT EQUAL INTERVALS IN THE MAPPED PLANE
0    X       X/CL     X/CU      CPL      CPU
 -0.0644   0.0000   0.0000   0.1176   0.1176                              *    I
 -0.0632   0.0078   0.0115   0.6218  -0.3931                 *                 I              +
 -0.0619   0.0178   0.0233   0.5180  -0.5828                    *              I                     +
 -0.0604   0.0291   0.0364   0.4968  -0.6757                     *             I                       +
......
```

*** Several lines deleted ***

```
......
   0.0551   0.9761   0.9801  -0.0766   0.0194                                 +I *
   0.0565   0.9881   0.9916  -0.0886   0.0484                                 +I  *
   0.0578   1.0000   1.0000   0.0334   0.1573                             +    *I


     J=      3      Y=     0.4663      CL=    0.2267      CD=    0.5429      CM=    0.0325


......
```

*** Several sets of pressure coefficient output deleted ***

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```
     J=     20      Y=     1.0000      CL=    0.1359      CD=    0.1389      CM=    0.2227

OPLOT OF CP AT EQUAL INTERVALS IN THE MAPPED PLANE
0    X       X/CL    X/CU      CPL      CPU
 0.0440 0.0000 0.0000 -0.1309 -0.1309                                         I  *
 0.0442 0.0048 0.0131 -0.0135 -0.2600                                         *       +
 0.0445 0.0140 0.0241 -0.0194 -0.2744                                         *        +
```

••••••

*** Several lines deleted ***

••••••

```
 0.0714 0.9726 0.9836 -0.2200 -0.3330                                         I     *   +
 0.0717 0.9846 0.9948 -0.2223 -0.3336                                         I     *   +
 0.0720 1.0000 1.0000 -0.2152 -0.3241                                         I     *  +
   FOR FIRST BLADE ROW ONLY :
     ADVANCE RATIO =            2.80000000
     POWER COEFFICIENT =        2.65678708
     THRUST COEFFICIENT =     0.73925643
     EFFICIENCY =               0.77910572
    0.3838E-02  0.2099E-02  0.1770E-02  0.1041E-02  0.3077E-02         1    2    2    2   13
  AVERAGE RESIDUES --  0.15714E-03  0.22671E-03  0.28714E-03  0.12600E-03  0.34570E-03    3000
     ISTP= 3000      IB =    1     IROW =    2     TIME =     9.0000

     J=      1      Y=     0.4161      CL=    0.2609      CD=    0.4944      CM=    0.1123

OPLOT OF CP AT EQUAL INTERVALS IN THE MAPPED PLANE
0    X       X/CL    X/CU      CPL      CPU
 -0.0604 0.0000 0.0000 0.5809 0.5809                   *                  I
 -0.0592 0.0069 0.0122 1.0514 -0.0031       *                               +
 -0.0580 0.0163 0.0244 0.9293 -0.2158           *                           I     +
 -0.0566 0.0272 0.0380 0.9170 -0.2736           *                           I       +
 -0.0550 0.0396 0.0530 0.8800 -0.3263            *                          I         +
 -0.0532 0.0538 0.0699 0.8351 -0.3866              *                        I          +
 -0.0511 0.0699 0.0889 0.7878 -0.4425               *                       I            +
 -0.0488 0.0883 0.1102 0.7232 -0.5042                 *                     I              +
 -0.0462 0.1091 0.1343 0.6503 -0.5755                   *                   I                +
 -0.0433 0.1328 0.1614 0.5763 -0.6490                     *                 I                  +
 -0.0400 0.1596 0.1920 0.4942 -0.7199                       *               I                    +
 -0.0362 0.1901 0.2263 0.4060 -0.7829                           *           I                      +
 -0.0320 0.2248 0.2649 0.2990 -0.8367                             *         I                        +
 -0.0267 0.2682 0.3121 0.1567 -0.8879                                 *     I                          +
 -0.0215 0.3120 0.3586 0.0037 -0.9431                                      *                            +
 -0.0162 0.3565 0.4041 -0.1101 -0.9958                                      I  *                          +
 -0.0110 0.4014 0.4488 -0.1693 -1.0380                                      I    *                         +
 -0.0058 0.4468 0.4930 -0.1728 -1.0356                                      I    *                         +
 -0.0007 0.4926 0.5367 -0.1150 -0.8882                                      I  *                        +
  0.0046 0.5390 0.5801 -0.0165 -0.5192                                     *               +
  0.0098 0.5857 0.6235 0.0889 -0.0477                                    *  I+
  0.0150 0.6330 0.6668 0.1761 0.2801                               +   *     I
  0.0203 0.6807 0.7104 0.2320 0.3962                            +     *      I
  0.0257 0.7287 0.7543 0.2537 0.3637                             +   *       I
  0.0300 0.7679 0.7901 0.2474 0.2748                                *       I
```

```
0.0339 0.8029 0.8221 0.2302 0.1989                     *+    I
0.0374 0.8341 0.8507 0.2187 0.1661                     * +   I
0.0405 0.8620 0.8763 0.2084 0.1757                      *+   I
0.0432 0.8867 0.8991 0.1904 0.2041                      *   I
0.0457 0.9088 0.9195 0.1645 0.2339                     + *   I
0.0479 0.9284 0.9376 0.1312 0.2578                    +  *   I
0.0498 0.9459 0.9538 0.0938 0.2848                   +    *  I
0.0516 0.9614 0.9682 0.0553 0.3070                   +     * I
0.0531 0.9752 0.9811 0.0166 0.3533                  +       *I
0.0545 0.9875 0.9926 0.0023 0.3895                 +         *
0.0556 1.0000 1.0000 0.1693 0.5169               +      *    I

    J=      2      Y=     0.4336      CL=    0.2607      CD=    0.4943      CM=    0.1167

OPLOT OF CP AT EQUAL INTERVALS IN THE MAPPED PLANE
0   X       X/CL    X/CU     CPL      CPU
-0.0620 0.0000 0.0000 0.5430 0.5430              *         I
-0.0609 0.0069 0.0122 1.0142 0.0169       *                +I
-0.0596 0.0163 0.0242 0.8984 -0.1869        *              I   +
-0.0582 0.0272 0.0377 0.8884 -0.2411        *              I    +
......
```

*** Several lines deleted ***

```
......
 0.0511 0.9753 0.9810 0.0314 0.3463                  +     *I
 0.0524 0.9875 0.9925 0.0149 0.3778                 +       *
 0.0536 1.0000 1.0000 0.1705 0.4974               +     *   I

    J=      3      Y=     0.4571      CL=    0.2628      CD=    0.5083      CM=    0.1150

......
```

*** Several sets of pressure coefficient output deleted ***

```
......

    J=     20      Y=     1.0000      CL=    0.1385      CD=    0.1520      CM=   -0.4425

OPLOT OF CP AT EQUAL INTERVALS IN THE MAPPED PLANE
0   X       X/CL     X/CU     CPL      CPU
  0.0473  0.0000  0.0000 -0.1179 -0.1179                                I  *
  0.0476  0.0048  0.0129  0.0177 -0.2648                               *I      +
  0.0478  0.0140  0.0240  0.0122 -0.2852                               *I       +
  0.0481  0.0246  0.0361  0.0119 -0.2848                               *I       +
......
```

*** Several lines deleted ***

```
......
  0.0728  0.9593  0.9703 -0.1308 -0.2356                                I  *   +
  0.0731  0.9725  0.9835 -0.1334 -0.2317                                I   * +
  0.0734  0.9845  0.9949 -0.1358 -0.2298                                I   * +
  0.0737  1.0000  1.0000 -0.1278 -0.2277                                I  *  +
   FOR THE COUNTER ROTATION PROPFAN :
```

```
   ADVANCE RATIO =          2.80000000
   POWER COEFFICIENT =      5.00728966
   THRUST COEFFICIENT =    1.51081683
   EFFICIENCY =             0.84482573
wrote grid on ibx=31
wrote q on ibr=31 irow=1
wrote grid on ibx=32
wrote q on ibr=32 irow=2
     TIME/ITERATION =2.996620009612
MAXMEM= 3303424.
MAXMEM= 3.150390625 MEGAWORDS
```

6.3 Time domain aeroelastic analysis of a single-rotation propeller

Description:

A test case for an aeroelastic stability analysis using time domain method is provided here. The propfan analyzed (SR3C-X2) has four blades and the first three normal modes are included in the analysis. A steady solution is first generated using the sample case provided in 6.1 for the desired flow conditions. The aeroelastic analysis is then carried out by restarting the analysis form the steady solution. In order to carry out the aeroelastic analysis, additional input files, structural grid (UNIT 3) and structural mode shapes (UNIT 4), are needed. The input file for this analysis is very similar to the steady analysis with changes in the lines shown below in the input file **prop3d.inp**. The input variables `RESTART` and `AEROELASTIC` are set to `TRUE`, `IFLTR` to a negative integer and `NBLOKS` to 4. The variables that need to be changed are indicated in **bold** print. All other input parameters remain the same as used in the steady aerodynamic analysis.

For starting the aeroelastic solution, the file generated on `UNIT 31` in the steady analysis is linked to `UNIT 11` for the current analysis. For an aeroelastic restart, i.e. restarting the solution from a previous aeroelastic solution, the only change required is to link the files generated on `UNIT(s) 30+n` by the previous aeroelastic analysis to `UNIT(s) 10+n` for the current analysis. Since, the time domain analysis method is used, any number of normal modes can be included in the analysis.

In addition to `UNIT 98`, additional output files are generated in this analysis. The file linked to `UNIT 57` contains the time history of the normal mode displacements for all the modes and all the blades included in the analysis. The variation of normal modes provides the aeroelastic stability of the propeller. An increasing oscillation amplitude indicates instability. The interblade phase angle can be assessed from the time history of the normal modes. The other files generated do not contain any useful information and can be ignored.

UNIT 5 (prop3d.inp; input file)

```
SR3 METRIC IN BC WWY=1.0 -  WWI=20*WW IEX=0 ISWCH=1
```

.....

*** same as steady aerodynamic input, see section 6.1 ***

.....

```
RESTART , QUASISTEADY , INFLOW , AEROELASTIC, COUNTER ROTATION, RESABD
 TRUE TRUEFALSE TRUEFALSEFALSE
     IFLTR      NUMCYC      NSTDY      JMODE      NBLOKS
        -1           0          2          1           4
     FNRS
```

.....

*** same as steady aerodynamic input, see section 6.1 ***

.....

UNIT 6 (prop3d.out; output file)

```
1     SR3 METRIC IN BC WWY=1.0 -  WWI=20*WW IEX=0 ISWCH=1
 ********************************************************
 *        aeroelastic stability analysis               *
 *      using normal mode structural model             *
 *        with Euler aerodynamic model in              *
 *                 TIME DOMAIN                         *
 ********************************************************

 --------------------------------------------------------
        Interblade Phase Angle =90. Degrees
 --------------------------------------------------------

 ++++++++++++++++++++++++++++
 +  atmospheric conditions
 ----------------------------------------
 +  pressure=14.288
 +  speed of sound (in/sec)=13341.26
 +  density=1.123843353053E-7
 ++++++++++++++++++++++++++++
 *    operating conditions:
 ----------------------------------------
 *  rotor speed(rpm)=139801.3723944
 *  rotor speed(rad/sec)=14639.96548253
 *  Mach no.= 0.62
 *  advance ratio (J).= 3.55
 *  tip radius (inches)=0.5
 ----------------------------------------

 RESTART RUN FROM A PREVIOUS SOLUTION
  FRONT BLADE ROW ROTATING IN COUNTER CLOCKWISE DIRN.
  CONTRAVARIANT VELOCITIES EXTRAPOLATED ON SOLID SURFACES
  RADIAL MOMENTUM  EQUILLIBRIUM APPLIED ON DOWNSTREAM BOUNDARY
  UPSTREAM BOUNDARY FIXED TO FREESTREAM
      IN DISSIPATION SUBROUTINE THE COEFFICIENTS ARE :
      IJDIS =     2
      IKDIS =     1
      IJ2   =     0
      IIDIS =     1
      IHPQ  =     1
      WWY COEFFICIENT IN DIS2 IS =1.
      ICHAR IN JBC =1
      IN WALLBC THE CONSTANTS ARE :
```

```
IWHIT =    0
INL  =    0
IEX   =    2
JEX   =    1
INRES =0
IHORD =0
KHORD =0
ISMTH =0
KSMTH =0
IVIBR =1
  WWF =50.


IMAX=       100
JMAX=        33
KMAX=        22
JTIP=        20
ITEL=        71
ILE =        36
INOSE=        16
NSTEP=      1400
 DX =          0.01000000
 DZ =          0.03000000
  DT=          0.00300000
  WW=          7.00000000
ALFA=          0.00000000
AMTIP=          0.54867252
FMINF=          0.62000000
ADVANCE RATIO =    3.55000000
vibration freq. =    1.80000000
VIBRATING IN    1  MODE


  GMU=          0.00000000
**** NSTDY =2
**** JMODE =1
cosa=1. sina=0.
TOTAL NUMBER OF STEPS  1400
reyref=-1000000. reynum=0.
writting ixl=62 irl=82 ib=1 it=1
writting ixl=63 irl=83 ib=1 it=1
writting ixl=64 irl=84 ib=1 it=1
FMINF=0.62 SMINF=0. ICBU=16 ICBD=100
MAX JACOB=8.2683062780992E-3 MIN JACOB=3.2260211171261E-7 AT 32
IJMAX=99 KJMAX=11 IJMIN=36 KJMIN=2
MAX JACOB=6.2555744999379E-3 MIN JACOB=2.7947610222889E-7 AT 31
IJMAX=99 KJMAX=11 IJMIN=36 KJMIN=2
MAX JACOB=4.2717852958751E-3 MIN JACOB=2.1382828121379E-7 AT 30
IJMAX=99 KJMAX=11 IJMIN=36 KJMIN=2
MAX JACOB=2.9815914704682E-3 MIN JACOB=1.6510371527111E-7 AT 29
IJMAX=99 KJMAX=11 IJMIN=36 KJMIN=2
MAX JACOB=1.9496322411226E-3 MIN JACOB=1.1723420600107E-7 AT 28
IJMAX=99 KJMAX=11 IJMIN=36 KJMIN=2
MAX JACOB=1.2228074442684E-3 MIN JACOB=7.7832137798948E-8 AT 27
IJMAX=99 KJMAX=11 IJMIN=36 KJMIN=2
MAX JACOB=9.3626103824691E-4 MIN JACOB=6.2091388022634E-8 AT 26
IJMAX=99 KJMAX=11 IJMIN=36 KJMIN=2
```

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*** Several lines of Jacobian output deleted ***

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```
MAX JACOB=3.4084365403986E-4 MIN JACOB=2.6885929096627E-7 AT 6
IJMAX=99 KJMAX=11 IJMIN=71 KJMIN=20
```

```
MAX JACOB=2.5593023462248E-4 MIN JACOB=2.2207905285811E-7 AT 5
 IJMAX=99 KJMAX=11 IJMIN=71 KJMIN=20
MAX JACOB=1.8837144131556E-4 MIN JACOB=1.7937733961933E-7 AT 4
 IJMAX=99 KJMAX=11 IJMIN=71 KJMIN=20
MAX JACOB=1.3526460248837E-4 MIN JACOB=1.4001297799166E-7 AT 3
 IJMAX=99 KJMAX=11 IJMIN=71 KJMIN=20
MAX JACOB=9.3614072799827E-5 MIN JACOB=1.043706344004E-7 AT 2
 IJMAX=99 KJMAX=11 IJMIN=71 KJMIN=20

   DRMAX        DUMAX        DVMAX        DWMAX        DEMAX        IB     IROW    IR    JR    KR
   0.5535E-04  0.7544E-03  0.7509E-03  0.8726E-05  0.1423E-03        1     1     79    18     3
 FMINF=0.62 SMINF=0. ICBU=16 ICBD=100
   0.5535E-04  0.7509E-03  0.7544E-03  0.8616E-05  0.1423E-03        2     1     79    18     3
 FMINF=0.62 SMINF=0. ICBU=16 ICBD=100
   0.5535E-04  0.7544E-03  0.7509E-03  0.8690E-05  0.1423E-03        3     1     79    18     3
 FMINF=0.62 SMINF=0. ICBU=16 ICBD=100
   0.5535E-04  0.7509E-03  0.7544E-03  0.8494E-05  0.1423E-03        4     1     79    18     3
 READING NASTRAN DATA: GRID COORDINATES
DIAMET = 24.5
BETGRD = 61.19985038786DBET =-1.4965495847719E-4
MODAL DISPLACEMENTS: MODE 1
GMASS =2.408413E-5 FREQ(hz) =221.082
FINISHED READING NASTRAN DATA
MODAL DISPLACEMENTS: MODE 2
GMASS =2.444044E-5 FREQ(hz) =402.1287
FINISHED READING NASTRAN DATA
MODAL DISPLACEMENTS: MODE 3
GMASS =1.445758E-5 FREQ(hz) =698.2002
FINISHED READING NASTRAN DATA
*  tip radius for structural model (inches)=12.25
Newmark constants
     0.50000E+00    0.25000E+00
     0.44444E+06    0.66667E+03
     0.13333E+04    0.10000E+01
     0.10000E+01    0.00000E+00
     0.15000E-02    0.15000E-02
*  airmas                =4.049208303452E-2
        analysis using 3    modes:

                  structural model
 mode     freq(hz)     gen. mass
----------------------------------------
  1        221.08        0.2408E-04
  1          2.55        0.5948E-03
  2        402.13        0.2444E-04
  2          4.64        0.6036E-03
  3        698.20        0.1446E-04
  3          8.06        0.3570E-03
-----------------------------------------
 mass, damping and stiffness matrices
----------------------------------------
     0.59479E-03    0.00000E+00
     0.00000E+00
     0.00000E+00    0.00000E+00
     0.00000E+00
     0.38705E-02    0.00000E+00
     0.00000E+00
     0.00000E+00    0.60359E-03
     0.00000E+00
     0.00000E+00    0.00000E+00
     0.00000E+00
     0.00000E+00    0.12995E-01
     0.00000E+00
     0.00000E+00    0.00000E+00
```

```
    0.35705E-03
    0.00000E+00    0.00000E+00
    0.00000E+00
    0.00000E+00    0.00000E+00
    0.23173E-01
    0.16813E+04    0.00000E+00
    0.00000E+00
    0.37828E-02    0.00000E+00
    0.00000E+00
    0.00000E+00    0.16568E+04
    0.00000E+00
    0.00000E+00    0.37275E-02
    0.00000E+00
    0.00000E+00    0.00000E+00
    0.28008E+04
    0.00000E+00    0.00000E+00
    0.63008E-02
    finished job in routine strdat
NUMBER OF TIME STEPS FOR ONE REVOLUTION =  1908
   0.5740E-04  0.7268E-03  0.7331E-03  0.2347E-04  0.1492E-03       1    1   79   18    3
   0.5452E-04  0.7330E-03  0.7268E-03  0.6946E-05  0.1402E-03       2    1   79   18    3
   0.5453E-04  0.7268E-03  0.7330E-03  0.6796E-05  0.1402E-03       3    1   79   18    3
   0.5423E-04  0.7330E-03  0.7268E-03  0.1408E-04  0.1398E-03       4    1   79   18    3
   0.1983E-03  0.7564E-03  0.7537E-03  0.7419E-04  0.5031E-03       1    1   68   18    2
   0.5536E-04  0.7539E-03  0.7564E-03  0.8471E-05  0.1423E-03       2    1   79   18    3
   0.5535E-04  0.7564E-03  0.7538E-03  0.8663E-05  0.1423E-03       3    1   79   18    3
   0.1463E-03  0.7538E-03  0.7564E-03  0.7350E-04  0.3701E-03       4    1   67   19   20
   0.1228E-03  0.7287E-03  0.7357E-03  0.7820E-04  0.2957E-03       1    1   65   19    2
   0.5452E-04  0.7359E-03  0.7287E-03  0.7073E-05  0.1402E-03       2    1   79   18    3
   0.5453E-04  0.7287E-03  0.7359E-03  0.6820E-05  0.1402E-03       3    1   79   18    3
   0.1921E-03  0.7359E-03  0.7287E-03  0.8615E-04  0.4925E-03       4    1   67   18   20
   0.1867E-03  0.7585E-03  0.7565E-03  0.7717E-04  0.4683E-03       1    1   67   18    2
   0.5536E-04  0.7568E-03  0.7584E-03  0.8361E-05  0.1423E-03       2    1   79   18    3
   0.5535E-04  0.7584E-03  0.7567E-03  0.8642E-05  0.1423E-03       3    1   79   18    3
   0.1299E-03  0.7567E-03  0.7584E-03  0.8815E-04  0.3320E-03       4    1   67   16   20
   0.1119E-03  0.7306E-03  0.7386E-03  0.7279E-04  0.2624E-03       1    1   64   19    2
   0.5452E-04  0.7388E-03  0.7305E-03  0.7155E-05  0.1402E-03       2    1   79   18    3
   0.5452E-04  0.7305E-03  0.7388E-03  0.6850E-05  0.1402E-03       3    1   79   18    3
   0.1792E-03  0.7388E-03  0.7305E-03  0.9229E-04  0.4594E-03       4    1   65   18   20
   0.1714E-03  0.7605E-03  0.7593E-03  0.7007E-04  0.4237E-03       1    1   65   17    2
   0.5536E-04  0.7596E-03  0.7604E-03  0.8300E-05  0.1423E-03       2    1   79   18    3
   0.5535E-04  0.7604E-03  0.7596E-03  0.8624E-05  0.1423E-03       3    1   79   18    3
   0.1180E-03  0.7596E-03  0.7604E-03  0.9099E-04  0.3011E-03       4    1   66   16   20
   0.1010E-03  0.7324E-03  0.7414E-03  0.6250E-04  0.2415E-03       1    1   65   16    2
   0.5452E-04  0.7416E-03  0.7323E-03  0.7192E-05  0.1402E-03       2    1   79   18    3
   0.5453E-04  0.7323E-03  0.7416E-03  0.6873E-05  0.1402E-03       3    1   79   18    3
   0.1613E-03  0.7416E-03  0.7323E-03  0.9356E-04  0.4138E-03       4    1   64   18   20
   0.1583E-03  0.7624E-03  0.7622E-03  0.6016E-04  0.3868E-03       1    1   64   17    2
   0.5537E-04  0.7625E-03  0.7624E-03  0.8278E-05  0.1424E-03       2    1   79   18    3
   0.5535E-04  0.7624E-03  0.7624E-03  0.8609E-05  0.1423E-03       3    1   79   18    3
   0.1039E-03  0.7624E-03  0.7624E-03  0.9347E-04  0.2646E-03       4    1   65   16   20
   0.9249E-04  0.7342E-03  0.7443E-03  0.6289E-04  0.2178E-03       1    1   64   16    2
   0.5451E-04  0.7445E-03  0.7341E-03  0.7198E-05  0.1401E-03       2    1   79   18    3
   0.5453E-04  0.7341E-03  0.7444E-03  0.6870E-05  0.1402E-03       3    1   79   18    3
   0.1446E-03  0.7445E-03  0.7341E-03  0.9305E-04  0.3691E-03       4    1   64   17   20
   0.9912E-04  0.7474E-03  0.7660E-03  0.6515E-04  0.2675E-03       1    1   69   17    2
   0.5474E-04  0.7659E-03  0.7473E-03  0.6956E-05  0.1406E-03       2    1   79   18    3
   0.5458E-04  0.7473E-03  0.7659E-03  0.6876E-05  0.1403E-03       3    1   79   18    3
   0.7958E-04  0.7659E-03  0.7473E-03  0.6690E-04  0.2077E-03       4    1   64   17   18
  AVERAGE RESIDUES --  0.57212E-05  0.71264E-04  0.92716E-04  0.13397E-05  0.14482E-04     50
  AVERAGE RESIDUES --  0.51743E-05  0.92792E-04  0.71036E-04  0.41131E-06  0.13185E-04     50
  AVERAGE RESIDUES --  0.51737E-05  0.71034E-04  0.92798E-04  0.41398E-06  0.13185E-04     50
  AVERAGE RESIDUES --  0.55674E-05  0.92671E-04  0.69927E-04  0.93538E-06  0.14231E-04     50
```

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*** Several lines of residual history deleted ***

••••••

```
 AVERAGE RESIDUES --  0.51780E-05  0.89452E-04  0.77345E-04  0.26116E-06  0.13256E-04    1350
 AVERAGE RESIDUES --  0.51569E-05  0.77382E-04  0.89471E-04  0.23089E-06  0.13200E-04    1350
 AVERAGE RESIDUES --  0.51556E-05  0.89463E-04  0.77371E-04  0.23235E-06  0.13197E-04    1350
 AVERAGE RESIDUES --  0.51590E-05  0.77331E-04  0.89445E-04  0.24599E-06  0.13208E-04    1350
   0.5549E-04  0.7151E-03  0.7606E-03  0.7684E-05  0.1424E-03        1    1   79   18    3
   0.5494E-04  0.7608E-03  0.7150E-03  0.7982E-05  0.1415E-03        2    1   79   18    3
   0.5480E-04  0.7150E-03  0.7607E-03  0.8210E-05  0.1412E-03        3    1   79   18    3
   0.5474E-04  0.7607E-03  0.7150E-03  0.7031E-05  0.1410E-03        4    1   79   18    3
   0.5432E-04  0.6761E-03  0.7058E-03  0.8333E-05  0.1399E-03        1    1   79   18    3
   0.5490E-04  0.7060E-03  0.6764E-03  0.7629E-05  0.1411E-03        2    1   79   18    3
   0.5523E-04  0.6763E-03  0.7059E-03  0.7372E-05  0.1418E-03        3    1   79   18    3
   0.5535E-04  0.7059E-03  0.6762E-03  0.8520E-05  0.1420E-03        4    1   79   18    3
   0.5453E-04  0.6945E-03  0.6907E-03  0.8546E-05  0.1404E-03        1    1   79   18    3
 AVERAGE RESIDUES --  0.51634E-05  0.91524E-04  0.74182E-04  0.26331E-06  0.13220E-04    1400
   0.5476E-04  0.6908E-03  0.6946E-03  0.7732E-05  0.1408E-03        2    1   79   18    3
 AVERAGE RESIDUES --  0.51626E-05  0.74231E-04  0.91553E-04  0.23332E-06  0.13214E-04    1400
   0.5516E-04  0.6945E-03  0.6907E-03  0.7454E-05  0.1417E-03        3    1   79   18    3
 AVERAGE RESIDUES --  0.51554E-05  0.91555E-04  0.74226E-04  0.23076E-06  0.13198E-04    1400
   0.5533E-04  0.6907E-03  0.6945E-03  0.8148E-05  0.1419E-03        4    1   79   18    3
 AVERAGE RESIDUES --  0.51437E-05  0.74219E-04  0.91540E-04  0.23789E-06  0.13168E-04    1400
    ISTP= 1400      IB =     1     IROW =     1      TIME =     13.2000


    J=     1      Y=     0.2431      CL=    0.0265      CD=    0.2971      CM=   -0.0045


0PLOT OF CP AT EQUAL INTERVALS IN THE MAPPED PLANE
0   X      X/CL    X/CU     CPL     CPU
 -0.0725  0.0000  0.0000  0.1907  0.1907                                 *     I
 -0.0709  0.0092  0.0109  0.9031 -0.4319          *                            I           +
```

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*** Several lines deleted ***

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```
  0.0812  0.9783  0.9795  0.1830  0.2087                                +*     I
  0.0829  0.9898  0.9904  0.2053  0.2440                               +*      I
  0.0845  1.0000  1.0000  0.2272  0.2749                              +*       I


    J=     2      Y=     0.2642      CL=    0.0290      CD=    0.3093      CM=   -0.0002


0PLOT OF CP AT EQUAL INTERVALS IN THE MAPPED PLANE
0   X      X/CL    X/CU     CPL     CPU
 -0.0784  0.0000  0.0000  0.1892  0.1892                                 *     I
 -0.0768  0.0091  0.0108  0.8719 -0.4109           *                           I          +
```

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*** Several lines deleted ***

••••••

```
  0.0781  0.9784  0.9793  0.1660  0.1946                                +*     I
  0.0799  0.9898  0.9903  0.1868  0.2271                               + *     I
  0.0814  1.0000  1.0000  0.2075  0.2552                               +*      I
```

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*** Several sets of pressure coefficient output deleted ***

......

```
     J=    20      Y=     1.0000      CL=    0.0684      CD=    0.0934      CM=    0.0080


0PLOT OF CP AT EQUAL INTERVALS IN THE MAPPED PLANE
0   X       X/CL    X/CU     CPL     CPU
  0.0765  0.0000  0.0000 -0.0899 -0.0899                                                  I  *
  0.0771  0.0086  0.0104  0.0094 -0.1884                                                  *     +
  0.0777  0.0184  0.0221  0.0084 -0.1904                                                  *     +
```

......

*** Several lines deleted ***

......

```
  0.1350  0.9769  0.9785 -0.0535 -0.0936                                                  I *+
  0.1357  0.9891  0.9899 -0.0545 -0.0900                                                  I *+
  0.1363  1.0000  1.0000 -0.0545 -0.0878                                                  I *+
     ISTP= 1400     IB =    2     IROW =    1     TIME =   13.2000


     J=     1      Y=.    0.2431      CL=    0.0265      CD=    0.2972      CM=   -0.0045


0PLOT OF CP AT EQUAL INTERVALS IN THE MAPPED PLANE
0   X       X/CL    X/CU     CPL     CPU
 -0.0725  0.0000  0.0000  0.1905  0.1905                                            *     I
 -0.0709  0.0092  0.0109  0.9031 -0.4321                         *                        I            +
 -0.0692   0.0196   0.0230   0.7212  -0.6540                            *                                      I
+
```

......

*** Several lines deleted ***

......

```
  0.0812  0.9783  0.9795  0.1830  0.2087                                            +*    I
  0.0829  0.9898  0.9904  0.2054  0.2440                                           +*     I
  0.0845  1.0000  1.0000  0.2273  0.2748                                          +*      I
```

......

*** Several sets of pressure coefficient output deleted ***

......

```
     J=    20      Y=     1.0000      CL=    0.0685      CD=    0.0935      CM=    0.0081


0PLOT OF CP AT EQUAL INTERVALS IN THE MAPPED PLANE
0   X       X/CL    X/CU     CPL     CPU
  0.0765  0.0000  0.0000 -0.0900 -0.0900                                                  I  *
  0.0771  0.0086  0.0104  0.0094 -0.1888                                                  *     +
  0.0777  0.0184  0.0221  0.0084 -0.1907                                                  *     +
  0.0784  0.0297  0.0350  0.0064 -0.1873                                                  *     +
```

......

*** Several lines deleted ***

......

```
  0.1342  0.9632  0.9658 -0.0539 -0.0977                                                  I *+
```

```
  0.1350  0.9769  0.9785 -0.0538 -0.0939                                      I *+
  0.1357  0.9891  0.9899 -0.0548 -0.0903                                      I *+
  0.1363  1.0000  1.0000 -0.0548 -0.0881                                      I *+
     ISTP= 1400     IB =    3     IROW =    1     TIME =   13.2000


     J=     1     Y=    0.2431     CL=   0.0265     CD=   0.2971     CM=  -0.0045


0PLOT OF CP AT EQUAL INTERVALS IN THE MAPPED PLANE
0   X      X/CL   X/CU     CPL     CPU
 -0.0725  0.0000  0.0000  0.1906  0.1906                              *     I
 -0.0709  0.0092  0.0109  0.9031 -0.4319         *                          I            +
```

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*** Several lines deleted ***

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```
  0.0792  0.9653  0.9674  0.1555  0.1705                               *    I
  0.0812  0.9783  0.9795  0.1830  0.2087                              +*    I
  0.0829  0.9898  0.9904  0.2054  0.2440                             +*     I
  0.0845  1.0000  1.0000  0.2272  0.2748                            +*      I
```

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*** Several sets of pressure coefficient output deleted ***

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```
     J=    20     Y=    1.0000     CL=   0.0685     CD=   0.0935     CM=   0.0081


0PLOT OF CP AT EQUAL INTERVALS IN THE MAPPED PLANE
0   X      X/CL   X/CU     CPL     CPU
  0.0765  0.0000  0.0000 -0.0900 -0.0900                                       I  *
  0.0771  0.0086  0.0104  0.0094 -0.1887                                       *     +
  0.0777  0.0184  0.0221  0.0084 -0.1906                                       *     +
  0.0784  0.0297  0.0350  0.0065 -0.1872                                       *     +
```

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*** Several lines deleted ***

••••••

```
  0.1342  0.9632  0.9658 -0.0538 -0.0976                                      I *+
  0.1350  0.9769  0.9785 -0.0538 -0.0939                                      I *+
  0.1357  0.9891  0.9899 -0.0548 -0.0903                                      I *+
  0.1363  1.0000  1.0000 -0.0547 -0.0881                                      I *+
     ISTP= 1400     IB =    4     IROW =    1     TIME =   13.2000


     J=     1     Y=    0.2431     CL=   0.0265     CD=   0.2971     CM=  -0.0045


0PLOT OF CP AT EQUAL INTERVALS IN THE MAPPED PLANE
0   X      X/CL   X/CU     CPL     CPU
 -0.0725  0.0000  0.0000  0.1906  0.1906                              *     I
 -0.0709  0.0092  0.0109  0.9031 -0.4320         *                          I            +
```

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*** Several lines deleted ***

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```
  0.0829  0.9898  0.9904  0.2053  0.2440                                   +*     I
  0.0845  1.0000  1.0000  0.2272  0.2748                                  +*      I
```

......

*** Several sets of pressure coefficient output deleted ***

......

```
     J=     20      Y=     1.0000      CL=    0.0685      CD=    0.0935      CM=    0.0081


0PLOT OF CP AT EQUAL INTERVALS IN THE MAPPED PLANE
0   X       X/CL    X/CU      CPL     CPU
  0.0765  0.0000  0.0000 -0.0900 -0.0900                                         I  *
  0.0771  0.0086  0.0104  0.0094 -0.1887                                         *     +
  0.0777  0.0184  0.0221  0.0084 -0.1906                                         *     +
  0.0784  0.0297  0.0350  0.0065 -0.1872                                         *     +
```

......

*** Several lines deleted ***

......

```
  0.1342  0.9632  0.9658 -0.0538 -0.0976                                         I *+
  0.1350  0.9769  0.9785 -0.0538 -0.0939                                         I *+
  0.1357  0.9891  0.9899 -0.0548 -0.0903                                         I *+
  0.1363  1.0000  1.0000 -0.0547 -0.0881                                         I *+
   FOR THE SINGLE ROTATION PROPFAN :
     ADVANCE RATIO =          3.55000000
     POWER COEFFICIENT =      1.17079124
     THRUST COEFFICIENT =    0.16302397
     EFFICIENCY =             0.49431108
  wrote grid on ibx=31
  wrote q on ibr=31 irow=1
  wrote grid on ibx=32
  wrote q on ibr=32 irow=1
  wrote grid on ibx=33
  wrote q on ibr=33 irow=1
  wrote grid on ibx=34
  wrote q on ibr=34 irow=1
       TIME/ITERATION =7.086200827187
  MAXMEM= 3835904.
  MAXMEM= 3.658203125 MEGAWORDS
```

UNIT 98 (output file; contains performance characteristics)

```
ITERATION     CP          CT          EFF
 1,  1.170986629076,  0.1630965652094,  0.4944486914852
 2,  1.170909068424,  0.1630749946307,  0.4944160452344
 3,  1.170911579097,  0.1630838065863,  0.4944417014204
 4,  1.170757504322,  0.1630464766731,  0.4943935785612
 5,  1.170756462135,  0.163054401491,  0.4944180485133
 6,  1.170599987637,  0.1630164209018,  0.4943689563586
 7,  1.170597934118,  0.163023983745,  0.4943927589716
 8,  1.170441330947,  0.1629858241081,  0.4943431680728
 9,  1.170440202223,  0.1629934289566,  0.4943667106592
 10,  1.170285143089,  0.1629554414594,  0.4943169795812
 11,  1.170286310099,  0.1629633783389,  0.4943405627417
 12,  1.17013392629,  0.1629258045948,  0.4942909468026
 13,  1.170138265935,  0.1629342635095,  0.4943147765507
 14,  1.169989229033,  0.1628972518219,  0.4942654424654
 15,  1.16999720891,  0.1629063396769,  0.4942896456925
```

```
 16,  1.169851820344,  0.1628699630407,  0.4942406882134
 17,  1.169863584777,  0.1628797209071,  0.4942653286626
 18,  1.169721862285,  0.1628439944058,  0.4942167867251
 19,  1.169737312822,  0.1628544136674,  0.4942418799348
 20,  1.169599068849,  0.1628193102166,  0.4941937512294
 21,  1.169617936526,  0.1628303470482,  0.4942192779104
 22,  1.169482846906,  0.1627958111651,  0.4941715316004
 23,  1.169504755513,  0.1628073992056,  0.4941974493524
 24,  1.169372418422,  0.1627733588288,  0.4941500370104
 25,  1.169396938816,  0.1627854200804,  0.4941762904482
```

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*** 1350 output lines deleted ***

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```
 1376,  1.170807008699,  0.1630267375306,  0.4943128234915
 1377,  1.170883506896,  0.1630494163869,  0.4943492881782
 1378,  1.170805157252,  0.163026401029,  0.4943125848636
 1379,  1.170881700364,  0.1630490889295,  0.4943490580816
 1380,  1.17080339541,  0.1630260825103,  0.4943123629301
 1381,  1.170879984893,  0.1630487796858,  0.4943488447599
 1382,  1.170801726125,  0.1630257824482,  0.4943121578807
 1383,  1.170878363318,  0.1630484891049,  0.494348648379
 1384,  1.170800152111,  0.1630255012674,  0.4943119698574
 1385,  1.170876838232,  0.1630482175874,  0.4943484690579
 1386,  1.170798675842,  0.1630252393437,  0.4943117989556
 1387,  1.170875411989,  0.1630479654849,  0.4943483068691
 1388,  1.170797299549,  0.1630249970041,  0.4943116452248
 1389,  1.170874086701,  0.1630477331003,  0.4943481618396
 1390,  1.170796025222,  0.1630247745272,  0.4943115086692
 1391,  1.170872864237,  0.1630475206881,  0.4943480339516
 1392,  1.170794854611,  0.163024572143,  0.4943113892485
 1393,  1.170871746227,  0.1630473284548,  0.4943479231436
 1394,  1.170793789222,  0.163024390034,  0.4943112868796
 1395,  1.170870734057,  0.1630471565591,  0.4943478293111
 1396,  1.170792830321,  0.163024228335,  0.4943112014364
 1397,  1.170869828875,  0.1630470051126,  0.4943477523081
 1398,  1.170791978936,  0.1630240871338,  0.494311132752
 1399,  1.170869031592,  0.1630468741804,  0.4943476919478
 1400,  1.170791235857,  0.1630239664722,  0.4943110806194
```

UNIT 57 (output file; contains blade motion)

```
   1   1   0.30000E-02   0.00000E+00   0.00000E+00   0.00000E+00
   1   1   0.30000E-02   0.30000E-04   0.29999E-04   0.29996E-04
   1   2   0.30000E-02   0.00000E+00   0.00000E+00   0.00000E+00
   1   2   0.30000E-02   0.00000E+00   0.00000E+00   0.00000E+00
   1   3   0.30000E-02   0.00000E+00   0.00000E+00   0.00000E+00
   1   3   0.30000E-02   0.00000E+00   0.00000E+00   0.00000E+00
   1   4   0.30000E-02   0.00000E+00   0.00000E+00   0.00000E+00
   1   4   0.30000E-02   0.00000E+00   0.00000E+00   0.00000E+00
   2   1   0.60000E-02   0.59998E-04   0.59995E-04   0.59983E-04
   2   2   0.60000E-02  -0.27745E-09   0.28632E-09   0.15961E-09
   2   3   0.60000E-02  -0.27780E-09   0.28667E-09   0.16017E-09
   2   4   0.60000E-02  -0.27662E-09   0.28750E-09   0.16063E-09
   3   1   0.90000E-02   0.89989E-04   0.89977E-04   0.89932E-04
   3   2   0.90000E-02  -0.10954E-08   0.11343E-08   0.64215E-09
   3   3   0.90000E-02  -0.11006E-08   0.11336E-08   0.64249E-09
   3   4   0.90000E-02  -0.10937E-08   0.11388E-08   0.64588E-09
   4   1   0.12000E-01   0.11996E-03   0.11993E-03   0.11982E-03
   4   2   0.12000E-01  -0.24218E-08   0.25246E-08   0.14572E-08
   4   3   0.12000E-01  -0.24476E-08   0.25145E-08   0.14504E-08
   4   4   0.12000E-01  -0.24259E-08   0.25313E-08   0.14619E-08
   5   1   0.15000E-01   0.14991E-03   0.14984E-03   0.14961E-03
```

5	2	0.15000E-01	-0.42188E-08	0.44420E-08	0.26183E-08
5	3	0.15000E-01	-0.42979E-08	0.44029E-08	0.25870E-08
5	4	0.15000E-01	-0.42482E-08	0.44417E-08	0.26137E-08
6	1	0.18000E-01	0.17981E-03	0.17969E-03	0.17928E-03
6	2	0.18000E-01	-0.64437E-08	0.68755E-08	0.41423E-08
6	3	0.18000E-01	-0.66309E-08	0.67720E-08	0.40547E-08
6	4	0.18000E-01	-0.65361E-08	0.68460E-08	0.41050E-08
7	1	0.21000E-01	0.20965E-03	0.20946E-03	0.20880E-03
7	2	0.21000E-01	-0.90493E-08	0.98168E-08	0.60487E-08
7	3	0.21000E-01	-0.94262E-08	0.95948E-08	0.58554E-08
7	4	0.21000E-01	-0.92653E-08	0.97192E-08	0.59382E-08
8	1	0.24000E-01	0.23943E-03	0.23913E-03	0.23814E-03
8	2	0.24000E-01	-0.11985E-07	0.13260E-07	0.83589E-08
8	3	0.24000E-01	-0.12663E-07	0.12844E-07	0.79901E-08
8	4	0.24000E-01	-0.12412E-07	0.13036E-07	0.81146E-08
9	1	0.27000E-01	0.26912E-03	0.26870E-03	0.26728E-03
9	2	0.27000E-01	-0.15199E-07	0.17202E-07	0.11096E-07
9	3	0.27000E-01	-0.16322E-07	0.16492E-07	0.10459E-07
9	4	0.27000E-01	-0.15954E-07	0.16769E-07	0.10634E-07
10	1	0.30000E-01	0.29872E-03	0.29814E-03	0.29619E-03
10	2	0.30000E-01	-0.18635E-07	0.21640E-07	0.14284E-07
10	3	0.30000E-01	-0.20382E-07	0.20510E-07	0.13263E-07
10	4	0.30000E-01	-0.19869E-07	0.20893E-07	0.13496E-07

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*** 5520 lines deleted ***

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1391	2	0.41730E+01	-0.21969E-03	-0.21856E-04	0.25405E-05
1391	3	0.41730E+01	-0.12945E-03	-0.12849E-04	-0.57664E-05
1391	4	0.41730E+01	-0.16884E-03	-0.74540E-05	-0.35661E-05
1392	1	0.41760E+01	0.22346E-03	0.83515E-04	0.45879E-04
1392	2	0.41760E+01	-0.21793E-03	-0.21662E-04	0.27075E-05
1392	3	0.41760E+01	-0.12946E-03	-0.12800E-04	-0.57669E-05
1392	4	0.41760E+01	-0.16941E-03	-0.76388E-05	-0.35654E-05
1393	1	0.41790E+01	0.21922E-03	0.84342E-04	0.45869E-04
1393	2	0.41790E+01	-0.21616E-03	-0.21468E-04	0.28696E-05
1393	3	0.41790E+01	-0.12946E-03	-0.12748E-04	-0.57658E-05
1393	4	0.41790E+01	-0.16996E-03	-0.78225E-05	-0.35646E-05
1394	1	0.41820E+01	0.21496E-03	0.85152E-04	0.45840E-04
1394	2	0.41820E+01	-0.21437E-03	-0.21276E-04	0.30270E-05
1394	3	0.41820E+01	-0.12945E-03	-0.12695E-04	-0.57634E-05
1394	4	0.41820E+01	-0.17050E-03	-0.80051E-05	-0.35637E-05
1395	1	0.41850E+01	0.21066E-03	0.85945E-04	0.45791E-04
1395	2	0.41850E+01	-0.21257E-03	-0.21085E-04	0.31796E-05
1395	3	0.41850E+01	-0.12944E-03	-0.12640E-04	-0.57595E-05
1395	4	0.41850E+01	-0.17104E-03	-0.81865E-05	-0.35627E-05
1396	1	0.41880E+01	0.20634E-03	0.86722E-04	0.45722E-04
1396	2	0.41880E+01	-0.21077E-03	-0.20896E-04	0.33274E-05
1396	3	0.41880E+01	-0.12942E-03	-0.12584E-04	-0.57541E-05
1396	4	0.41880E+01	-0.17155E-03	-0.83666E-05	-0.35616E-05
1397	1	0.41910E+01	0.20198E-03	0.87482E-04	0.45633E-04
1397	2	0.41910E+01	-0.20894E-03	-0.20707E-04	0.34703E-05
1397	3	0.41910E+01	-0.12938E-03	-0.12526E-04	-0.57474E-05
1397	4	0.41910E+01	-0.17206E-03	-0.85456E-05	-0.35604E-05
1398	1	0.41940E+01	0.19759E-03	0.88225E-04	0.45526E-04
1398	2	0.41940E+01	-0.20711E-03	-0.20520E-04	0.36083E-05
1398	3	0.41940E+01	-0.12934E-03	-0.12467E-04	-0.57392E-05
1398	4	0.41940E+01	-0.17255E-03	-0.87233E-05	-0.35592E-05
1399	1	0.41970E+01	0.19318E-03	0.88951E-04	0.45399E-04
1399	2	0.41970E+01	-0.20526E-03	-0.20335E-04	0.37414E-05
1399	3	0.41970E+01	-0.12930E-03	-0.12406E-04	-0.57295E-05
1399	4	0.41970E+01	-0.17303E-03	-0.88999E-05	-0.35579E-05
1400	1	0.42000E+01	0.18874E-03	0.89661E-04	0.45253E-04

1400	2	0.42000E+01	-0.20341E-03	-0.20150E-04	0.38696E-05
1400	3	0.42000E+01	-0.12924E-03	-0.12343E-04	-0.57185E-05
1400	4	0.42000E+01	-0.17350E-03	-0.90751E-05	-0.35566E-05

6.4 Frequency domain aeroelastic analysis of a single-rotation propeller

Description:

A test case for frequency domain aeroelastic analysis for all the possible interblade phase angles is provided here. The propfan analyzed (SR3C-X2) has four blades and first three normal modes are included in the analysis. It is identical to the case analyzed using time domain method, for which the sample case was presented in section 6.3. Again, as mentioned in section 6.3, a steady aerodynamic solution is first generated using the sample case provided in 6.1 for the desired flow conditions. The aeroelastic analysis is then carried out by restarting the solution from the steady aerodynamic solution. In order to carry out the aeroelastic analysis additional input files, structural grid (`UNIT 3`) and structural mode shapes (`UNIT 4`) will be needed. The input file for this analysis is very similar to the steady aerodynamic analysis with changes in the lines shown below in the input file **prop3d.inp**. The input variables `RESTART` and `AEROELASTIC` are set to `TRUE`, `IFLTR` is set to a positive integer, `NSTDY` to 2 and `NBLOKS` to `4`. The input variable `VIBFRE` is the non-dimensional time for the duration of the pulse and `JMODE` is the mode number in which the blade is oscillated. The variables that need to be changed are indicated in **bold** print. All other input parameters remain the same as used in the steady aerodynamic analysis.

For starting the aeroelastic solution, the file generated in the steady analysis run, `UNIT 31`, is linked to `UNIT 11` for the current analysis. For an aeroelastic restart, i.e. restarting the solution from a previous aeroelastic solution, the only change required is to link the files generated on `UNIT(s) 30+n` by the previous aeroelastic analysis to `UNIT(s) 10+n` of the current analysis. The analysis is repeated with the variable `JMODE` varying over the number of normal modes included in the analysis.

In addition to `UNIT 98`, other output files are generated in the analysis. The output file on `UNIT 57` contains the time history of the prescribed normal mode displacement for the reference blade. Since three modes are included in the analysis, the analysis is carried out for a total of three times, once each for vibration of the reference blade in each of the three modes, *i. e.* once each for `JMODE` = 1, 2, & 3. Files on `UNITs 95` through `97` contain the generalized forces for the three different modes due to oscillation in the given mode (`JMODE`). In all, nine files containing generalized forces, three files each corresponding to the three modes, are generated. These nine files along with the output file on `UNIT 57` are Fourier analyzed using a post processor to provide the variation of aerodynamic damping with frequency for each of the three modes for all possible interblade phase angles.

UNIT 5 (prop3d.inp; input file)

```
SR3 METRIC IN BC WWY=1.0 -  WWI=20*WW IEX=0 ISWCH=1
```

......

*** same as steady aerodynamic input, see section 6.1 ***

```
......
    FSTP      FMINF     BETA34       DIA         DX         DZ      VIBFRE
   2000.0      0.620     61.20        1.0        0.01      0.030       1.8
      ICCW      ITURB     LTHIN       IGR        ISWF
         1          0         0         0          0
RESTART , QUASISTEADY , INFLOW , AEROELASTIC, COUNTER ROTATION, RESABD
 TRUE TRUEFALSE TRUEFALSEFALSE
     IFLTR      NUMCYC      NSTDY      JMODE      NBLOKS
         1          0          2          1          4
     FNRS
......
```

*** same as steady aerodynamic input, see section 6.1 ***

......

UNIT 6 (prop3d.out; output file)

```
1     SR3 METRIC IN BC WWY=1.0 -  WWI=20*WW IEX=0 ISWCH=1
 *******************************************************
 *        aeroelastic stability analysis               *
 *      using normal mode structural model             *
 *        with Euler aerodynamic model in              *
 *              FREQUENCY DOMAIN                       .*
 *******************************************************
 ++++++++++++++++++++++++++++
 +  atmospheric conditions
 ----------------------------------------
 +  pressure=14.288
 +  speed of sound (in/sec)=13341.26
 +  density=1.123843353053E-7
 ++++++++++++++++++++++++++++
 *    operating conditions:
 ----------------------------------------
 *  rotor speed(rpm)=139801.3723944
 *  rotor speed(rad/sec)=14639.96548253
 *  Mach no.= 0.62
 *  advance ratio (J).= 3.55
 *  tip radius (inches)=0.5
 ----------------------------------------

 RESTART RUN FROM A PREVIOUS SOLUTION
  FRONT BLADE ROW ROTATING IN COUNTER CLOCKWISE DIRN.
  CONTRAVARIANT VELOCITIES EXTRAPOLATED ON SOLID SURFACES
  RADIAL MOMENTUM  EQUILLIBRIUM APPLIED ON DOWNSTREAM BOUNDARY
  UPSTREAM BOUNDARY FIXED TO FREESTREAM
      IN DISSIPATION SUBROUTINE THE COEFFICIENTS ARE :
      IJDIS =     2
      IKDIS =     1
      IJ2   =     0
      IIDIS =     1
      IHPQ  =     1
      WWY COEFFICIENT IN DIS2 IS =1.
      ICHAR IN JBC =1
      IN WALLBC THE CONSTANTS ARE :
      IWHIT =     0
      INL   =    0
      IEX   =     2
      JEX   =     1
```

```
      INRES =0
      IHORD =0
      KHORD =0
      ISMTH =0
      KSMTH =0
      IVIBR =1
        WWF =50.


     IMAX=        100
     JMAX=         33
     KMAX=         22
     JTIP=         20
     ITEL=         71
     ILE =         36
     INOSE=         16
     NSTEP=       2000
      DX =           0.01000000
      DZ =           0.03000000
       DT=           0.00300000
       WW=           7.00000000
     ALFA=           0.00000000
    AMTIP=           0.54867252
     FMINF=           0.62000000
     ADVANCE RATIO =    3.55000000
     vibration freq. =    1.80000000
     VIBRATING IN     1  MODE


      GMU=           0.00000000
  **** NSTDY =2
  **** JMODE =1
  cosa=1. sina=0.
  NUMBER OF TIME STEPS FOR ONE CYCLE = 1163
  TOTAL NUMBER OF STEPS FOR 0 CYCLES =2000
  TOTAL NUMBER OF STEPS  2000
  reyref=-1000000. reynum=0.
  writting ix1=62 ir1=82 ib=1 it=1
  writting ix1=63 ir1=83 ib=1 it=1
  writting ix1=64 ir1=84 ib=1 it=1
  FMINF=0.62 SMINF=0. ICBU=16 ICBD=100
  MAX JACOB=8.2683062780992E-3 MIN JACOB=3.2260211171261E-7 AT 32
  IJMAX=99 KJMAX=11 IJMIN=36 KJMIN=2
  MAX JACOB=6.2555744999379E-3 MIN JACOB=2.7947610222889E-7 AT 31
  IJMAX=99 KJMAX=11 IJMIN=36 KJMIN=2
  MAX JACOB=4.2717852958751E-3 MIN JACOB=2.1382828121379E-7 AT 30
  IJMAX=99 KJMAX=11 IJMIN=36 KJMIN=2
  MAX JACOB=2.9815914704682E-3 MIN JACOB=1.6510371527111E-7 AT 29
  IJMAX=99 KJMAX=11 IJMIN=36 KJMIN=2
  MAX JACOB=1.9496322411226E-3 MIN JACOB=1.1723420600107E-7 AT 28
  IJMAX=99 KJMAX=11 IJMIN=36 KJMIN=2
  MAX JACOB=1.2228074442684E-3 MIN JACOB=7.7832137798948E-8 AT 27
  IJMAX=99 KJMAX=11 IJMIN=36 KJMIN=2
  MAX JACOB=9.3626103824691E-4 MIN JACOB=6.2091388022634E-8 AT 26
  IJMAX=99 KJMAX=11 IJMIN=36 KJMIN=2
```

......

*** Several lines of Jacobian output deleted ***

......

```
MAX JACOB=3.4084365403986E-4 MIN JACOB=2.6885929096627E-7 AT 6
  IJMAX=99 KJMAX=11 IJMIN=71 KJMIN=20
  MAX JACOB=2.5593023462248E-4 MIN JACOB=2.2207905285811E-7 AT 5
  IJMAX=99 KJMAX=11 IJMIN=71 KJMIN=20
```

```
MAX JACOB=1.8837144131556E-4 MIN JACOB=1.7937733961933E-7 AT 4
IJMAX=99 KJMAX=11 IJMIN=71 KJMIN=20
MAX JACOB=1.3526460248837E-4 MIN JACOB=1.4001297799166E-7 AT 3
IJMAX=99 KJMAX=11 IJMIN=71 KJMIN=20
MAX JACOB=9.3614072799827E-5 MIN JACOB=1.043706344004E-7 AT 2
IJMAX=99 KJMAX=11 IJMIN=71 KJMIN=20

  DRMAX       DUMAX       DVMAX       DWMAX       DEMAX       IB   IROW   IR   JR   KR
  0.5535E-04  0.7544E-03  0.7509E-03  0.8726E-05  0.1423E-03       1    1   79   18    3
FMINF=0.62 SMINF=0. ICBU=16 ICBD=100
  0.5535E-04  0.7509E-03  0.7544E-03  0.8616E-05  0.1423E-03       2    1   79   18    3
FMINF=0.62 SMINF=0. ICBU=16 ICBD=100
  0.5535E-04  0.7544E-03  0.7509E-03  0.8690E-05  0.1423E-03       3    1   79   18    3
FMINF=0.62 SMINF=0. ICBU=16 ICBD=100
  0.5535E-04  0.7509E-03  0.7544E-03  0.8494E-05  0.1423E-03       4    1   79   18    3
READING NASTRAN DATA: GRID COORDINATES
DIAMET = 24.5
BETGRD = 61.19985038786DBET =-1.4965495847719E-4
MODAL DISPLACEMENTS: MODE 1
GMASS =2.408413E-5 FREQ(hz) =221.082
FINISHED READING NASTRAN DATA
MODAL DISPLACEMENTS: MODE 2
GMASS =2.444044E-5 FREQ(hz) =402.1287
FINISHED READING NASTRAN DATA
MODAL DISPLACEMENTS: MODE 3
GMASS =1.445758E-5 FREQ(hz) =698.2002
FINISHED READING NASTRAN DATA
*  tip radius for structural model (inches)=12.25
NUMBER OF TIME STEPS FOR ONE REVOLUTION =  1908
 IGFCAL =0
 IGFCAL =0
 IGFCAL =0
 IGFCAL =0
  0.5457E-04  0.7268E-03  0.7330E-03  0.6777E-05  0.1403E-03       1    1   79   18    3
  0.5452E-04  0.7330E-03  0.7268E-03  0.6946E-05  0.1402E-03       2    1   79   18    3
  0.5453E-04  0.7268E-03  0.7330E-03  0.6796E-05  0.1402E-03       3    1   79   18    3
  0.5452E-04  0.7330E-03  0.7268E-03  0.6884E-05  0.1402E-03       4    1   79   18    3
  0.5563E-04  0.7564E-03  0.7538E-03  0.8728E-05  0.1430E-03       1    1   79   18    3
  0.5536E-04  0.7539E-03  0.7564E-03  0.8471E-05  0.1423E-03       2    1   79   18    3
  0.5535E-04  0.7564E-03  0.7538E-03  0.8664E-05  0.1423E-03       3    1   79   18    3
  0.5538E-04  0.7538E-03  0.7564E-03  0.8472E-05  0.1424E-03       4    1   79   18    3
  0.5454E-04  0.7286E-03  0.7359E-03  0.6743E-05  0.1404E-03       1    1   79   18    3
  0.5452E-04  0.7359E-03  0.7287E-03  0.7073E-05  0.1402E-03       2    1   79   18    3
  0.5453E-04  0.7287E-03  0.7359E-03  0.6817E-05  0.1402E-03       3    1   79   18    3
  0.5449E-04  0.7359E-03  0.7287E-03  0.7637E-05  0.1401E-03       4    1   79   18    3
  0.5644E-04  0.7584E-03  0.7567E-03  0.8730E-05  0.1454E-03       1    1   69   18    2
  0.5536E-04  0.7568E-03  0.7584E-03  0.8361E-05  0.1423E-03       2    1   79   18    3
  0.5535E-04  0.7584E-03  0.7567E-03  0.8647E-05  0.1423E-03       3    1   79   18    3
  0.5542E-04  0.7567E-03  0.7584E-03  0.7454E-05  0.1425E-03       4    1   79   18    3
  0.5494E-04  0.7305E-03  0.7388E-03  0.7545E-05  0.1392E-03       1    1   38   20    2
  0.5451E-04  0.7388E-03  0.7305E-03  0.7155E-05  0.1402E-03       2    1   79   18    3
  0.5453E-04  0.7305E-03  0.7388E-03  0.6850E-05  0.1402E-03       3    1   79   18    3
  0.5447E-04  0.7388E-03  0.7305E-03  0.8802E-05  0.1401E-03       4    1   79   18    3
  0.6295E-04  0.7604E-03  0.7596E-03  0.1165E-04  0.1611E-03       1    1   68   18    2
  0.5536E-04  0.7596E-03  0.7604E-03  0.8300E-05  0.1424E-03       2    1   79   18    3
  0.5535E-04  0.7604E-03  0.7596E-03  0.8632E-05  0.1423E-03       3    1   79   18    3
  0.5546E-04  0.7596E-03  0.7604E-03  0.1207E-04  0.1425E-03       4    1   79   18    3
  0.5799E-04  0.7323E-03  0.7416E-03  0.1135E-04  0.1420E-03       1    1   38   20    2
  0.5452E-04  0.7416E-03  0.7323E-03  0.7193E-05  0.1402E-03       2    1   79   18    3
  0.5453E-04  0.7323E-03  0.7416E-03  0.6872E-05  0.1402E-03       3    1   79   18    3
  0.5445E-04  0.7416E-03  0.7323E-03  0.1402E-04  0.1401E-03       4    1   79   18    3
  0.6804E-04  0.7623E-03  0.7624E-03  0.1523E-04  0.1728E-03       1    1   67   18    2
  0.5536E-04  0.7625E-03  0.7624E-03  0.8278E-05  0.1423E-03       2    1   79   18    3
  0.5534E-04  0.7624E-03  0.7624E-03  0.8620E-05  0.1423E-03       3    1   79   18    3
```

```
  0.5548E-04  0.7624E-03  0.7624E-03  0.1728E-04  0.1426E-03         4    1   79   18    3
  0.6117E-04  0.7341E-03  0.7445E-03  0.1429E-04  0.1493E-03         1    1   38   20    2
  0.5452E-04  0.7445E-03  0.7341E-03  0.7199E-05  0.1402E-03         2    1   79   18    3
  0.5453E-04  0.7341E-03  0.7444E-03  0.6869E-05  0.1402E-03         3    1   79   18    3
  0.5942E-04  0.7445E-03  0.7341E-03  0.1912E-04  0.1518E-03         4    1   63   18   20
  0.8232E-04  0.7472E-03  0.7658E-03  0.3037E-04  0.1945E-03         1    1   36   19    2
  0.5460E-04  0.7659E-03  0.7473E-03  0.6958E-05  0.1403E-03         2    1   79   18    3
  0.5458E-04  0.7473E-03  0.7659E-03  0.6846E-05  0.1403E-03         3    1   79   18    3
  0.6380E-04  0.7659E-03  0.7473E-03  0.4182E-04  0.1639E-03         4    1   60   17   20
 AVERAGE RESIDUES --  0.58427E-05  0.71339E-04  0.93044E-04  0.12929E-05  0.14740E-04      50
 AVERAGE RESIDUES --  0.51739E-05  0.92795E-04  0.71034E-04  0.41110E-06  0.13182E-04      50
 AVERAGE RESIDUES --  0.51718E-05  0.71033E-04  0.92797E-04  0.41445E-06  0.13180E-04      50
 AVERAGE RESIDUES --  0.58683E-05  0.92595E-04  0.69543E-04  0.10930E-05  0.15079E-04      50
```

••••••

*** Several lines of residual history deleted ***

••••••

```
 AVERAGE RESIDUES --  0.51481E-05  0.71195E-04  0.92836E-04  0.22940E-06  0.13181E-04    1950
 AVERAGE RESIDUES --  0.51439E-05  0.92832E-04  0.71199E-04  0.23514E-06  0.13168E-04    1950
 AVERAGE RESIDUES --  0.51469E-05  0.71200E-04  0.92840E-04  0.23475E-06  0.13180E-04    1950
 AVERAGE RESIDUES --  0.51529E-05  0.92847E-04  0.71198E-04  0.23062E-06  0.13193E-04    1950
  0.5500E-04  0.7901E-03  0.8069E-03  0.7815E-05  0.1414E-03        1    1   79   18    3
  0.5500E-04  0.8068E-03  0.7901E-03  0.7874E-05  0.1414E-03        2    1   79   18    3
  0.5505E-04  0.7901E-03  0.8069E-03  0.7690E-05  0.1415E-03        3    1   79   18    3
  0.5504E-04  0.8069E-03  0.7901E-03  0.7750E-05  0.1415E-03        4    1   79   18    3
  0.5501E-04  0.7718E-03  0.8171E-03  0.7726E-05  0.1414E-03        1    1   79   18    3
  0.5499E-04  0.8172E-03  0.7718E-03  0.7659E-05  0.1414E-03        2    1   79   18    3
  0.5496E-04  0.7718E-03  0.8172E-03  0.7824E-05  0.1413E-03        3    1   79   18    3
  0.5497E-04  0.8172E-03  0.7718E-03  0.7766E-05  0.1414E-03        4    1   79   18    3
  0.5500E-04  0.7801E-03  0.8421E-03  0.7740E-05  0.1414E-03        1    1   79   18    3
 AVERAGE RESIDUES --  0.51493E-05  0.70898E-04  0.92505E-04  0.22929E-06  0.13183E-04    2000
  0.5499E-04  0.8421E-03  0.7801E-03  0.7653E-05  0.1414E-03        2    1   79   18    3
 AVERAGE RESIDUES --  0.51455E-05  0.92499E-04  0.70903E-04  0.23315E-06  0.13172E-04    2000
  0.5496E-04  0.7801E-03  0.8421E-03  0.7815E-05  0.1413E-03        3    1   79   18    3
 AVERAGE RESIDUES --  0.51464E-05  0.70904E-04  0.92505E-04  0.23447E-06  0.13177E-04    2000
  0.5497E-04  0.8422E-03  0.7801E-03  0.7753E-05  0.1414E-03        4    1   79   18    3
 AVERAGE RESIDUES --  0.51522E-05  0.92512E-04  0.70900E-04  0.23151E-06  0.13191E-04    2000
     ISTP= 2000      IB =     1      IROW =     1       TIME =    15.0000


     J=      1      Y=     0.2431      CL=    0.0265      CD=    0.2971      CM=  -0.0045


OPLOT OF CP AT EQUAL INTERVALS IN THE MAPPED PLANE
O    X       X/CL    X/GU     CPL     CPU
 -0.0725  0.0000  0.0000  0.1906  0.1906                         *      I
 -0.0709  0.0092  0.0109  0.9031 -0.4320      *                         I          +
 -0.0692  0.0196  0.0230  0.7212 -0.6539          *                     I               +
```

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*** Several lines deleted ***

••••••

```
  0.0792  0.9653  0.9674  0.1555  0.1705                          *     I
  0.0812  0.9783  0.9795  0.1829  0.2086                         +*     I
  0.0829  0.9898  0.9904  0.2053  0.2440                        +*      I
  0.0845  1.0000  1.0000  0.2272  0.2748                        +*      I


     J=      2      Y=     0.2642      CL=    0.0290      CD=    0.3093      CM=  -0.0002


OPLOT OF CP AT EQUAL INTERVALS IN THE MAPPED PLANE
```

```
0    X        X/CL    X/CU     CPL      CPU
 -0.0784  0.0000  0.0000  0.1891  0.1891                                   *     I
 -0.0768  0.0091  0.0108  0.8718 -0.4110                  *                     I          +
 -0.0750  0.0195  0.0229  0.6994 -0.6170                      *                 I               +
 -0.0730   0.0313   0.0365   0.6341  -0.8016                           *                    I
```

••••••

*** Several lines deleted ***

••••••

```
  0.0761  0.9655  0.9670  0.1409  0.1593                                   +*    I
  0.0781  0.9784  0.9793  0.1659  0.1945                                  +*     I
  0.0799  0.9898  0.9903  0.1868  0.2271                                 + *     I
  0.0814  1.0000  1.0000  0.2074  0.2552                                 +*      I
```

••••••

*** Several sets of pressure coefficient output deleted ***

••••••

```
     J=    20      Y=     1.0000      CL=    0.0685      CD=    0.0935      CM=    0.0080


0PLOT OF CP AT EQUAL INTERVALS IN THE MAPPED PLANE
0    X        X/CL    X/CU     CPL      CPU
  0.0765  0.0000  0.0000 -0.0899 -0.0899                                          I  *
  0.0771  0.0086  0.0104  0.0094 -0.1886                                          *     +
  0.0777  0.0184  0.0221  0.0084 -0.1905                                          *     +
  0.0784  0.0297  0.0350  0.0064 -0.1871                                          *     +
  0.0792  0.0428  0.0491  0.0045 -0.1854                                          *     +
```

••••••

*** Several lines deleted ***

••••••

```
  0.1333  0.9478  0.9514 -0.0534 -0.1024                                          I * +
  0.1342  0.9632  0.9658 -0.0538 -0.0976                                          I *+
  0.1350  0.9769  0.9785 -0.0537 -0.0938                                          I *+
  0.1357  0.9891  0.9899 -0.0547 -0.0902                                          I *+
  0.1363  1.0000  1.0000 -0.0547 -0.0880                                          I *+
     ISTP= 2000     IB =     2      IROW =     1      TIME =    15.0000


     J=     1      Y=     0.2431      CL=    0.0265      CD=    0.2971      CM=  -0.0045


0PLOT OF CP AT EQUAL INTERVALS IN THE MAPPED PLANE
0    X        X/CL    X/CU     CPL      CPU
 -0.0725  0.0000  0.0000  0.1906  0.1906                                   *     I
 -0.0709  0.0092  0.0109  0.9031 -0.4321                  *                     I          +
 -0.0692  0.0196  0.0230  0.7212 -0.6539                      *                 I               +
 -0.0672   0.0315   0.0365   0.6586  -0.8444                          *                     I
```

••••••

*** Several lines deleted ***

••••••

```
  0.0770  0.9508  0.9536  0.1304  0.1357                                     *   I
```

```
 0.0792  0.9653  0.9674  0.1555  0.1705                                              *    I
 0.0812  0.9783  0.9795  0.1829  0.2086                                             +*    I
 0.0829  0.9898  0.9904  0.2053  0.2440                                            +*     I
 0.0845  1.0000  1.0000  0.2272  0.2748                                           +*      I


    J=     2     Y=     0.2642     CL=    0.0290     CD=    0.3093     CM=   -0.0002


0PLOT OF CP AT EQUAL INTERVALS IN THE MAPPED PLANE
0    X       X/CL    X/CU      CPL      CPU
 -0.0784  0.0000  0.0000  0.1891  0.1891                                            *     I
 -0.0768  0.0091  0.0108  0.8719 -0.4110                 *                                I           +
 -0.0750  0.0195  0.0229  0.6994 -0.6171                      *                           I                 +
 -0.0730   0.0313   0.0365   0.6341  -0.8016                              *                           I
```

••••••

*** Several lines deleted ***

••••••

```
 0.0738  0.9510  0.9532  0.1185  0.1269                                               +*  I
 0.0761  0.9655  0.9670  0.1409  0.1593                                              +*   I
 0.0781  0.9784  0.9793  0.1659  0.1945                                             +*    I
 0.0799  0.9898  0.9903  0.1868  0.2271                                            + *    I
 0.0814  1.0000  1.0000  0.2075  0.2552                                            +*     I
```

••••••

*** Several sets of pressure coefficient output deleted ***

••••••

```
    J=    20     Y=     1.0000     CL=    0.0685     CD=    0.0935     CM=    0.0080


0PLOT OF CP AT EQUAL INTERVALS IN THE MAPPED PLANE
0    X       X/CL    X/CU      CPL      CPU
  0.0765  0.0000  0.0000 -0.0899 -0.0899                                                    I  *
  0.0771  0.0086  0.0104  0.0094 -0.1886                                                    *     +
  0.0777  0.0184  0.0221  0.0084 -0.1905                                                    *     +
  0.0784  0.0297  0.0350  0.0064 -0.1871                                                    *     +
  0.0792  0.0428  0.0491  0.0045 -0.1854                                                    *     +
```

••••••

*** Several lines deleted ***

••••••

```
  0.1333  0.9478  0.9514 -0.0534 -0.1024                                                    I * +
  0.1342  0.9632  0.9658 -0.0538 -0.0976                                                    I *+
  0.1350  0.9769  0.9785 -0.0537 -0.0938                                                    I *+
  0.1357  0.9891  0.9899 -0.0547 -0.0902                                                    I *+
  0.1363  1.0000  1.0000 -0.0547 -0.0880                                                    I *+
     ISTP= 2000      IB =     3     IROW =     1      TIME =    15.0000


    J=     1     Y=     0.2431     CL=    0.0265     CD=    0.2971     CM=   -0.0045


0PLOT OF CP AT EQUAL INTERVALS IN THE MAPPED PLANE
0    X       X/CL    X/CU      CPL      CPU
 -0.0725  0.0000  0.0000  0.1906  0.1906                                            *     I
```

```
 -0.0709  0.0092  0.0109  0.9031 -0.4320              *                  I          +
 -0.0692  0.0196  0.0230  0.7212 -0.6539                   *             I                +
 -0.0672   0.0315   0.0365   0.6586  -0.8443                     *               I
```

......

*** Several lines deleted ***

......

```
  0.0770  0.9508  0.9536  0.1304  0.1357                                *   I
  0.0792  0.9653  0.9674  0.1555  0.1705                               *    I
  0.0812  0.9783  0.9795  0.1829  0.2086                              +*    I
  0.0829  0.9898  0.9904  0.2053  0.2440                             +*     I
  0.0845  1.0000  1.0000  0.2272  0.2748                            +*      I


     J=      2      Y=    0.2642      CL=    0.0290      CD=    0.3093      CM=  -0.0002


OPLOT OF CP AT EQUAL INTERVALS IN THE MAPPED PLANE
0    X       X/CL    X/CU      CPL     CPU
 -0.0784  0.0000  0.0000  0.1891  0.1891                              *     I
 -0.0768  0.0091  0.0108  0.8719 -0.4110             *                      I          +
 -0.0750  0.0195  0.0229  0.6994 -0.6170                 *                  I                +
 -0.0730   0.0313   0.0365   0.6341  -0.8016                     *                I
```

......

*** Several lines deleted ***

......

```
  0.0738  0.9510  0.9532  0.1185  0.1269                                +*  I
  0.0761  0.9655  0.9670  0.1409  0.1593                               +*   I
  0.0781  0.9784  0.9793  0.1659  0.1945                              +*    I
  0.0799  0.9898  0.9903  0.1868  0.2271                             + *    I
  0.0814  1.0000  1.0000  0.2074  0.2552                             +*     I
```

......

*** Several sets of pressure coefficient output deleted ***

......

```
     J=     20      Y=    1.0000      CL=    0.0685      CD=    0.0935      CM=    0.0080


OPLOT OF CP AT EQUAL INTERVALS IN THE MAPPED PLANE
0    X       X/CL    X/CU      CPL     CPU
  0.0765  0.0000  0.0000 -0.0899 -0.0899                                    I  *
  0.0771  0.0086  0.0104  0.0094 -0.1886                                    *     +
  0.0777  0.0184  0.0221  0.0084 -0.1905                                    *     +
  0.0784  0.0297  0.0350  0.0064 -0.1871                                    *     +
  0.0792  0.0428  0.0491  0.0045 -0.1854                                    *     +
```

......

*** Several lines deleted ***

......

```
  0.1333  0.9478  0.9514 -0.0534 -0.1024                                    I * +
  0.1342  0.9632  0.9658 -0.0538 -0.0976                                    I *+
  0.1350  0.9769  0.9785 -0.0537 -0.0938                                    I *+
```

```
  0.1357  0.9891  0.9899 -0.0547 -0.0902                                            I *+
  0.1363  1.0000  1.0000 -0.0547 -0.0880                                            I *+
     ISTP= 2000     IB =    4     IROW =    1     TIME =    15.0000


     J=      1      Y=     0.2431      CL=    0.0265      CD=    0.2971      CM=   -0.0045


0PLOT OF CP AT EQUAL INTERVALS IN THE MAPPED PLANE
0   X       X/CL    X/CU      CPL      CPU
 -0.0725  0.0000  0.0000  0.1906  0.1906                                     *     I
 -0.0709  0.0092  0.0109  0.9031 -0.4320                   *                       I           +
 -0.0692  0.0196  0.0230  0.7212 -0.6538                         *                 I                  +
 -0.0672   0.0315   0.0365   0.6586 -0.8443                               *                       I
```

......

*** Several lines deleted ***

......

```
  0.0770  0.9508  0.9536  0.1304  0.1357                                       *   I
  0.0792  0.9653  0.9674  0.1555  0.1705                                      *    I
  0.0812  0.9783  0.9795  0.1829  0.2086                                     +*    I
  0.0829  0.9898  0.9904  0.2053  0.2440                                    +*     I
  0.0845  1.0000  1.0000  0.2272  0.2748                                   +*      I


     J=      2      Y=     0.2642      CL=    0.0290      CD=    0.3093      CM=   -0.0002


0PLOT OF CP AT EQUAL INTERVALS IN THE MAPPED PLANE
0   X       X/CL    X/CU      CPL      CPU
 -0.0784  0.0000  0.0000  0.1892  0.1892                                     *     I
 -0.0768  0.0091  0.0108  0.8719 -0.4110                    *                      I          +
 -0.0750  0.0195  0.0229  0.6994 -0.6170                         *                 I                 +
 -0.0730   0.0313   0.0365   0.6341  -0.8015                               *                  I
```

......

*** Several lines deleted ***

......

```
  0.0738  0.9510  0.9532  0.1185  0.1269                                       +*  I
  0.0761  0.9655  0.9670  0.1409  0.1593                                      +*   I
  0.0781  0.9784  0.9793  0.1659  0.1945                                     +*    I
  0.0799  0.9898  0.9903  0.1868  0.2271                                    + *    I
  0.0814  1.0000  1.0000  0.2074  0.2552                                    +*     I
```

......

*** Several sets of pressure coefficient output deleted ***

......

```
     J=     20      Y=     1.0000      CL=    0.0685      CD=    0.0935      CM=    0.0080


0PLOT OF CP AT EQUAL INTERVALS IN THE MAPPED PLANE
0   X       X/CL    X/CU      CPL      CPU
  0.0765  0.0000  0.0000 -0.0899 -0.0899                                            I  *
  0.0771  0.0086  0.0104  0.0094 -0.1886                                            *     +
```

```
  0.0777  0.0184  0.0221  0.0084 -0.1905                                         *     +
  0.0784  0.0297  0.0350  0.0064 -0.1871                                         *     +
  0.0792  0.0428  0.0491  0.0045 -0.1854                                         *     +
```

......

*** Several lines deleted ***

......

```
  0.1323  0.9305  0.9352 -0.0537 -0.1077                                         I * +
  0.1333  0.9478  0.9514 -0.0534 -0.1024                                         I * +
  0.1342  0.9632  0.9658 -0.0538 -0.0976                                         I *+
  0.1350  0.9769  0.9785 -0.0537 -0.0938                                         I *+
  0.1357  0.9891  0.9899 -0.0547 -0.0902                                         I *+
  0.1363  1.0000  1.0000 -0.0547 -0.0880                                         I *+
   FOR THE SINGLE ROTATION PROPFAN :
     ADVANCE RATIO =           3.55000000
     POWER COEFFICIENT =       1.17066473
     THRUST COEFFICIENT =     0.16299756
     EFFICIENCY =              0.49428442
  wrote grid on ibx=31
  wrote q on ibr=31 irow=1
  wrote grid on ibx=32
  wrote q on ibr=32 irow=1
  wrote grid on ibx=33
  wrote q on ibr=33 irow=1
  wrote grid on ibx=34
  wrote q on ibr=34 irow=1
       TIME/ITERATION =7.011070388964
  MAXMEM= 3825664.
  MAXMEM= 3.6484375 MEGAWORDS
```

UNIT 98 (output file; contains performance characteristics)

```
ITERATION     CP          CT         EFF
 1,  1.170986629076,  0.1630965652094,  0.4944486914852
 2,  1.170911149646,  0.1630740808829,  0.494412396115
 3,  1.170986381725,  0.16309638513,  0.4944482499947
 4,  1.170899654249,  0.163071449467,  0.4944092719706
 5,  1.170960144484,  0.1630905277572,  0.4944415711036
 6,  1.170859402613,  0.1630625276631,  0.4943992181404
 7,  1.170906478007,  0.1630786802382,  0.4944283132081
 8,  1.170793228536,  0.1630479544736,  0.4943829741011
 9,  1.170828630365,  0.1630615717823,  0.4944093138949
 10,  1.170704710744,  0.1630285309136,  0.4943614554825
```

.....

*** 1980 lines of output deleted ***

.....

```
 1991,  1.170741211662,  0.1630201932627,  0.4943207604873
 1992,  1.170663895035,  0.1629973712266,  0.4942842008783
 1993,  1.170741421359,  0.163020240872,  0.4943208163114
 1994,  1.170664104348,  0.1629974186928,  0.4942842564406
 1995,  1.170741630211,  0.1630202881779,  0.494320871572
 1996,  1.170664312803,  0.1629974658527,  0.4942843114365
 1997,  1.170741838193,  0.1630203351751,  0.494320926264
 1998,  1.170664520373,  0.1629975127009,  0.4942843658609
 1999,  1.170742045278,  0.1630203818582,  0.4943209803825
 2000,  1.170664727033,  0.1629975592324,  0.4942844197087
```

UNIT 57 (output file; contains blade motion)

```
    0    1    0.00000E-00    0.00000E-00    0.00000E-00    0.00000E-00
    1    1    0.30000E-02    0.15076E-05    0.15076E-05    0.15076E-05
```

```
   2    1    0.60000E-02    0.60205E-05    0.60205E-05    0.60205E-05
   3    1    0.90000E-02    0.13523E-04    0.13523E-04    0.13523E-04
   4    1    0.12000E-01    0.24001E-04    0.24001E-04    0.24001E-04
   5    1    0.15000E-01    0.37438E-04    0.37438E-04    0.37438E-04
   6    1    0.18000E-01    0.53819E-04    0.53819E-04    0.53819E-04
   7    1    0.21000E-01    0.73129E-04    0.73129E-04    0.73129E-04
   8    1    0.24000E-01    0.95353E-04    0.95353E-04    0.95353E-04
   9    1    0.27000E-01    0.12047E-03    0.12047E-03    0.12047E-03
  10    1    0.30000E-01    0.14848E-03    0.14848E-03    0.14848E-03
```

.....

*** 1980 lines of output deleted ***

.....

```
1991    1    0.59730E+01    0.00000E+00    0.00000E+00    0.00000E+00
1992    1    0.59760E+01    0.00000E+00    0.00000E+00    0.00000E+00
1993    1    0.59790E+01    0.00000E+00    0.00000E+00    0.00000E+00
1994    1    0.59820E+01    0.00000E+00    0.00000E+00    0.00000E+00
1995    1    0.59850E+01    0.00000E+00    0.00000E+00    0.00000E+00
1996    1    0.59880E+01    0.00000E+00    0.00000E+00    0.00000E+00
1997    1    0.59910E+01    0.00000E+00    0.00000E+00    0.00000E+00
1998    1    0.59940E+01    0.00000E+00    0.00000E+00    0.00000E+00
1999    1    0.59970E+01    0.00000E+00    0.00000E+00    0.00000E+00
2000    1    0.60000E+01    0.00000E+00    0.00000E+00    0.00000E+00
```

UNIT 95 (output file; contains generalized force for first mode)

```
-1,  1,  0.,  9.3272423363529E-4,  0.
 2*1,  2*9.3272423363529E-4,  0.
 -1,  2,  8.6338023144652E-5,  9.3272430265099E-4,  0.
 1,  2,  2*9.3272430265099E-4,  0.
 -1,  3,  8.6337979065049E-5,  9.3272424925355E-4,  0.
 1,  3,  2*9.3272424925355E-4,  0.
 -1,  4,  8.633802202664E-5,  9.3272424705699E-4,  0.
 1,  4,  2*9.3272424705699E-4,  0.
 2,  1,  9.3265048147302E-4,  9.3272423363529E-4,  -7.3752162269708E-8
 2*2,  9.3265103880372E-4,  9.3272430265099E-4,  -7.3263847266691E-8
 2,  3,  9.3265081195937E-4,  9.3272424925355E-4,  -7.3437294176304E-8
 2,  4,  9.3265094490809E-4,  9.3272424705699E-4,  -7.330214889939E-8
 3,  1,  9.3270125842582E-4,  9.3272423363529E-4,  -2.2975209471032E-8
 3,  2,  9.3272737599901E-4,  9.3272430265099E-4,  3.0733480205214E-9
 2*3,  9.3272703386586E-4,  9.3272424925355E-4,  2.7846123150377E-9
 3,  4,  9.3272722488909E-4,  9.3272424705699E-4,  2.9778320989604E-9
 4,  1,  9.3255404967164E-4,  9.3272423363529E-4,  -1.7018396364366E-7
 4,  2,  9.3265410455182E-4,  9.3272430265099E-4,  -7.0198099170332E-8
 4,  3,  9.3265355494977E-4,  9.3272424925355E-4,  -7.0694303778984E-8
 2*4,  9.3265393036439E-4,  9.3272424705699E-4,  -7.0316692604017E-8
 5,  1,  9.3250863250921E-4,  9.3272423363529E-4,  -2.1560112607732E-7
 5,  2,  9.3273046105311E-4,  9.3272430265099E-4,  6.1584021215921E-9
 5,  3,  9.327297410168E-4,  9.3272424925355E-4,  5.4917632559548E-9
 5,  4,  9.3273022836454E-4,  9.3272424705699E-4,  5.981307549946E-9
 6,  1,  9.3226979732964E-4,  9.3272423363529E-4,  -4.5443630564482E-7
 6,  2,  9.3265719677248E-4,  9.3272430265099E-4,  -6.7105878510249E-8
 6,  3,  9.3265623398532E-4,  9.3272424925355E-4,  -6.8015268226557E-8
 6,  4,  9.3265694045326E-4,  9.3272424705699E-4,  -6.7306603734885E-8
 7,  1,  9.3213717394783E-4,  9.3272423363529E-4,  -5.8705968745271E-7
 7,  2,  9.3273358277443E-4,  9.3272430265099E-4,  9.2801234440054E-9
 7,  3,  9.3273239653226E-4,  9.3272424925355E-4,  8.1472787162584E-9
 7,  4,  9.3273325613247E-4,  9.3272424705699E-4,  9.0090754752137E-9
 8,  1,  9.318169101444E-4,  9.3272423363529E-4,  -9.0732349088823E-7
 8,  2,  9.3266033625564E-4,  9.3272430265099E-4,  -6.3966395347226E-8
 8,  3,  9.3265887175434E-4,  9.3272424925355E-4,  -6.5377499209457E-8
 8,  4,  9.3265997105273E-4,  9.3272424705699E-4,  -6.4276004258651E-8
 9,  1,  9.3160896958035E-4,  9.3272423363529E-4,  -1.1152640549336E-6
```

```
9,  2,  9.3273675678045E-4,  9.3272430265099E-4,  1.2454129460354E-8
9,  3,  9.3273502129516E-4,  9.3272424925355E-4,  1.0772041612872E-8
9,  4,  9.3273630125296E-4,  9.3272424705699E-4,  1.2054195967781E-8
10,  1,  9.312197975159E-4,  9.3272423363529E-4,  -1.5044361193831E-6
10,  2,  9.3266353336087E-4,  9.3272430265099E-4,  -6.0769290113893E-8
10,  3,  9.3266148755481E-4,  9.3272424925355E-4,  -6.2761698733926E-8
10,  4,  9.3266301275924E-4,  9.3272424705699E-4,  -6.1234297753926E-8
```

.....

***** 7920 lines of output deleted *****

.....

```
1991,  1,  9.324545031481E-4,  9.3272423363529E-4,  -2.6973048718529E-7
1991,  2,  9.3247905448372E-4,  9.3272430265099E-4,  -2.4524816727087E-7
1991,  3,  9.3246481742304E-4,  9.3272424925355E-4,  -2.594318305113E-7
1991,  4,  9.3243604230263E-4,  9.3272424705699E-4,  -2.8820475436037E-7
1992,  1,  9.3237931686655E-4,  9.3272423363529E-4,  -3.4491676874013E-7
1992,  2,  9.3240406535008E-4,  9.3272430265099E-4,  -3.2023730090619E-7
1992,  3,  9.3238999877929E-4,  9.3272424925355E-4,  -3.3425047425706E-7
1992,  4,  9.3236110239934E-4,  9.3272424705699E-4,  -3.6314465765366E-7
1993,  1,  9.3245443765829E-4,  9.3272423363529E-4,  -2.6979597699331E-7
1993,  2,  9.3247910671435E-4,  9.3272430265099E-4,  -2.4519593663438E-7
1993,  3,  9.3246530181552E-4,  9.3272424925355E-4,  -2.5894743802338E-7
1993,  4,  9.3243630420842E-4,  9.3272424705699E-4,  -2.8794284856817E-7
1994,  1,  9.3237925265286E-4,  9.3272423363529E-4,  -3.4498098242311E-7
1994,  2,  9.3240411314445E-4,  9.3272430265099E-4,  -3.201895065405E-7
1994,  3,  9.323904811111E-4,  9.3272424925355E-4,  -3.3376814244368E-7
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1995,  3,  9.3246577983846E-4,  9.3272424925355E-4,  -2.5846941508617E-7
1995,  4,  9.3243657406528E-4,  9.3272424705699E-4,  -2.8767299171603E-7
1996,  1,  9.3237919057869E-4,  9.3272423363529E-4,  -3.4504305659877E-7
1996,  2,  9.3240415300909E-4,  9.3272430265099E-4,  -3.201496418942E-7
1996,  3,  9.3239095700458E-4,  9.3272424925355E-4,  -3.3329224896281E-7
1996,  4,  9.3236164069756E-4,  9.3272424705699E-4,  -3.6260635942822E-7
1997,  1,  9.3245431298195E-4,  9.3272423363529E-4,  -2.6992065333548E-7
1997,  2,  9.3247918736442E-4,  9.3272430265099E-4,  -2.451152865679E-7
1997,  3,  9.324662513811E-4,  9.3272424925355E-4,  -2.579978724479E-7
1997,  4,  9.324368517418E-4,  9.3272424705699E-4,  -2.8739531519537E-7
1998,  1,  9.3237913075167E-4,  9.3272423363529E-4,  -3.4510288361364E-7
1998,  2,  9.3240418502578E-4,  9.3272430265099E-4,  -3.2011762520628E-7
1998,  3,  9.3239142635007E-4,  9.3272424925355E-4,  -3.3282290348019E-7
1998,  4,  9.3236192153162E-4,  9.3272424705699E-4,  -3.6232552536736E-7
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2000,  2,  9.3240420927814E-4,  9.3272430265099E-4,  -3.2009337284228E-7
2000,  3,  9.3239188903996E-4,  9.3272424925355E-4,  -3.3236021358338E-7
2000,  4,  9.3236220997513E-4,  9.3272424705699E-4,  -3.6203708186217E-7
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UNIT 96 (output file; contains generalized force for second mode)

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 2*1,  2*-5.6799231706952E-4,  0.
 -1,  2,  8.6338023144652E-5,  -5.6799237621539E-4,  0.
 1,  2,  2*-5.6799237621539E-4,  0.
 -1,  3,  8.6337979065049E-5,  -5.6799233862589E-4,  0.
 1,  3,  2*-5.6799233862589E-4,  0.
 -1,  4,  8.633802202664E-5,  -5.6799233433599E-4,  0.
 1,  4,  2*-5.6799233433599E-4,  0.
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2*2, -5.6791555110161E-4, -5.6799237621539E-4, 7.6825113777546E-8
2, 3, -5.679154315581E-4, -5.6799233862589E-4, 7.6907067783627E-8
2, 4, -5.6791548343309E-4, -5.6799233433599E-4, 7.6850902901854E-8
3, 1, -5.6800385660182E-4, -5.6799231706952E-4, -1.153953230193E-8
3, 2, -5.6799598970774E-4, -5.6799237621539E-4, -3.613492352561E-9
2*3, -5.679958357869E-4, -5.6799233862589E-4, -3.4971610156365E-9
3, 4, -5.6799588319481E-4, -5.6799233433599E-4, -3.548858821395E-9
4, 1, -5.6795172028959E-4, -5.6799231706952E-4, 4.0596779927321E-8
4, 2, -5.6791914979635E-4, -5.6799237621539E-4, 7.3226419039507E-8
4, 3, -5.6791893616861E-4, -5.6799233862589E-4, 7.3402457275579E-8
2*4, -5.6791903497756E-4, -5.6799233433599E-4, 7.3299358433615E-8
5, 1, -5.6807369285242E-4, -5.6799231706952E-4, -8.1375782896853E-8
5, 2, -5.6799954227487E-4, -5.6799237621539E-4, -7.1660594784528E-9
5, 3, -5.679993517004E-4, -5.6799233862589E-4, -7.0130745134789E-9
5, 4, -5.6799944299742E-4, -5.6799233433599E-4, -7.1086614268634E-9
6, 1, -5.6805333269459E-4, -5.6799231706952E-4, -6.1015625073269E-8
6, 2, -5.679226480329E-4, -5.6799237621539E-4, 6.9728182491846E-8
6, 3, -5.6792246531052E-4, -5.6799233862589E-4, 6.9873315366314E-8
6, 4, -5.6792260808051E-4, -5.6799233433599E-4, 6.9726255481212E-8
7, 1, -5.6820562763981E-4, -5.6799231706952E-4, -2.1331057029408E-7
7, 2, -5.6800296008295E-4, -5.6799237621539E-4, -1.0583867556674E-8
7, 3, -5.680028946E-4, -5.6799233862589E-4, -1.055632011665E-8
7, 4, -5.6800302964289E-4, -5.6799233433599E-4, -1.0695306893599E-8
8, 1, -5.6821344595977E-4, -5.6799231706952E-4, -2.2112889024734E-7
8, 2, -5.6792598233345E-4, -5.6799237621539E-4, 6.6393881933968E-8
8, 3, -5.6792602240764E-4, -5.6799233862589E-4, 6.6316218245988E-8
8, 4, -5.679262125326E-4, -5.6799233433599E-4, 6.6121803393715E-8
9, 1, -5.683916717551E-4, -5.6799231706952E-4, -3.9935468558461E-7
9, 2, -5.6800619001059E-4, -5.6799237621539E-4, -1.3813795197992E-8
9, 3, -5.6800646467965E-4, -5.6799233862589E-4, -1.4126053760749E-8
9, 4, -5.6800664750794E-4, -5.6799233433599E-4, -1.4313171942809E-8
10, 1, -5.6842289948416E-4, -5.6799231706952E-4, -4.3058241464E-7
10, 2, -5.6792910884277E-4, -5.6799237621539E-4, 6.3267372622106E-8
10, 3, -5.6792960321168E-4, -5.6799233862589E-4, 6.2735414207288E-8
10, 4, -5.6792984789117E-4, -5.6799233433599E-4, 6.2486444823984E-8
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*** 7920 lines of output deleted ***

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1991, 3, -5.67989432957E-4, -5.6799233862589E-4, 2.9056688860551E-9
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1992, 1, -5.6790880727581E-4, -5.6799231706952E-4, 8.3509793708664E-8
1992, 2, -5.6793813052909E-4, -5.6799237621539E-4, 5.4245686293558E-8
1992, 3, -5.6791100443326E-4, -5.6799233862589E-4, 8.1334192623961E-8
1992, 4, -5.6789371963627E-4, -5.6799233433599E-4, 9.8614699718669E-8
1993, 1, -5.6798748963772E-4, -5.6799231706952E-4, 4.8274317980546E-9
1993, 2, -5.6801683834637E-4, -5.6799237621539E-4, -2.4462130980563E-8
1993, 3, -5.6798987728889E-4, -5.6799233862589E-4, 2.4613369987991E-9
1993, 4, -5.679723841776E-4, -5.6799233433599E-4, 1.9950158393345E-8
1994, 1, -5.6790876020815E-4, -5.6799231706952E-4, 8.3556861370931E-8
1994, 2, -5.6793823099947E-4, -5.6799237621539E-4, 5.4145215918483E-8
1994, 3, -5.6791144869808E-4, -5.6799233862589E-4, 8.0889927811523E-8
1994, 4, -5.678937151706E-4, -5.6799233433599E-4, 9.8619165389557E-8
1995, 1, -5.6798744249313E-4, -5.6799231706952E-4, 4.8745763849001E-9
1995, 2, -5.6801693524665E-4, -5.6799237621539E-4, -2.455903125656E-8
1995, 3, -5.6799032073396E-4, -5.6799233862589E-4, 2.0178919264702E-9
1995, 4, -5.6797238507821E-4, -5.6799233433599E-4, 1.9949257783897E-8
1996, 1, -5.6790871380986E-4, -5.6799231706952E-4, 8.360325966239E-8
1996, 2, -5.6793832399892E-4, -5.6799237621539E-4, 5.4052216470063E-8
1996, 3, -5.6791189195862E-4, -5.6799233862589E-4, 8.0446667265199E-8
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1997,  2,  -5.6801702469595E-4,  -5.6799237621539E-4,  -2.4648480562162E-8
1997,  3,  -5.6799076307422E-4,  -5.6799233862589E-4,  1.575551668298E-9
1997,  4,  -5.6797239554776E-4,  -5.6799233433599E-4,  1.9938788228119E-8
1998,  1,  -5.6790866817359E-4,  -5.6799231706952E-4,  8.364889593146E-8
1998,  2,  -5.67938409564E-4,  -5.6799237621539E-4,  5.3966651387266E-8
1998,  3,  -5.6791233399969E-4,  -5.6799233862589E-4,  8.0004626194785E-8
1998,  4,  -5.6789373496329E-4,  -5.6799233433599E-4,  9.8599372704705E-8
1999,  1,  -5.6798735041707E-4,  -5.6799231706952E-4,  4.9666524469527E-9
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1999,  4,  -5.6797241553879E-4,  -5.6799233433599E-4,  1.9918797198454E-8
2000,  1,  -5.6790862339324E-4,  -5.6799231706952E-4,  8.3693676284496E-8
2000,  2,  -5.6793848773478E-4,  -5.6799237621539E-4,  5.3888480608388E-8
2000,  3,  -5.6791277461201E-4,  -5.6799233862589E-4,  7.9564013873851E-8
2000,  4,  -5.6789375912703E-4,  -5.6799233433599E-4,  9.8575208964252E-8
```

UNIT 97 (output file; contains generalized force for third mode)

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-1,  1,  0.,  8.6338023144652E-5,  0.
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 1,  2,  2*8.6337979065049E-5,  0.
 -1,  3,  8.6337979065049E-5,  8.633802202664E-5,  0.
 1,  3,  2*8.633802202664E-5,  0.
 -1,  4,  8.633802202664E-5,  8.6338030705128E-5,  0.
 1,  4,  2*8.6338030705128E-5,  0.
 2,  1,  8.6363680812671E-5,  8.6338023144652E-5,  2.5657668018854E-8
 2*2,  8.6363233953982E-5,  8.6337979065049E-5,  2.5254888932295E-8
 2,  3,  8.6363442240491E-5,  8.633802202664E-5,  2.542021385098E-8
 2,  4,  8.6363313457792E-5,  8.6338030705128E-5,  2.5282752664016E-8
 3,  1,  8.6335706011552E-5,  8.6338023144652E-5,  -2.3171331008445E-9
 3,  2,  8.6338049778342E-5,  8.6337979065049E-5,  7.0713292426444E-11
 2*3,  8.6338326548335E-5,  8.633802202664E-5,  3.0452169518663E-10
 3,  4,  8.6338173985603E-5,  8.6338030705128E-5,  1.4328047515805E-10
 4,  1,  8.6352742306455E-5,  8.6338023144652E-5,  1.4719161802162E-8
 4,  2,  8.6363299232811E-5,  8.6337979065049E-5,  2.5320167761512E-8
 4,  3,  8.6363734891814E-5,  8.633802202664E-5,  2.571286517386E-8
 2*4,  8.6363421262376E-5,  8.6338030705128E-5,  2.5390557248286E-8
 5,  1,  8.6313005108648E-5,  8.6338023144652E-5,  -2.5018036004833E-8
 5,  2,  8.6338126479529E-5,  8.6337979065049E-5,  1.474144799285E-10
 5,  3,  8.6338600905616E-5,  8.633802202664E-5,  5.7887897600417E-10
 5,  4,  8.6338237375307E-5,  8.6338030705128E-5,  2.0667017923415E-10
 6,  1,  8.6319299996068E-5,  8.6338023144652E-5,  -1.8723148584483E-8
 6,  2,  8.6363400085761E-5,  8.6337979065049E-5,  2.5421020712069E-8
 6,  3,  8.6363984883223E-5,  8.633802202664E-5,  2.5962856583378E-8
 6,  4,  8.6363439389368E-5,  8.6338030705128E-5,  2.5408684240381E-8
 7,  1,  8.6269179229618E-5,  8.6338023144652E-5,  -6.8843915034845E-8
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 7,  3,  8.633882319763E-5,  8.633802202664E-5,  8.0117099022711E-10
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 8,  2,  8.6363584731458E-5,  8.6337979065049E-5,  2.5605666409238E-8
 8,  3,  8.6364176480838E-5,  8.633802202664E-5,  2.6154454198322E-8
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*** 7920 lines of output deleted ***

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 1997,  3,  8.6357612892845E-5,  8.633802202664E-5,  1.9590866205763E-8
 1997,  4,  8.635139196697E-5,  8.6338030705128E-5,  1.3361261842152E-8
 1998,  1,  8.6382426545377E-5,  8.6338023144652E-5,  4.4403400724976E-8
 1998,  2,  8.6390082621153E-5,  8.6337979065049E-5,  5.2103556103314E-8
 1998,  3,  8.6382917566031E-5,  8.633802202664E-5,  4.48955393916E-8
 1998,  4,  8.6376681553437E-5,  8.6338030705128E-5,  3.8650848309223E-8
 1999,  1,  8.6357025000086E-5,  8.6338023144652E-5,  1.9001855433316E-8
 1999,  2,  8.6364826504447E-5,  8.6337979065049E-5,  2.6847439397494E-8
 1999,  3,  8.6357660774427E-5,  8.633802202664E-5,  1.9638747787275E-8
 1999,  4,  8.6351367138942E-5,  8.6338030705128E-5,  1.3336433814064E-8
 2000,  1,  8.6382395402842E-5,  8.6338023144652E-5,  4.4372258189377E-8
 2000,  2,  8.6390097493236E-5,  8.6337979065049E-5,  5.211842818648E-8
 2000,  3,  8.6382964937909E-5,  8.633802202664E-5,  4.4942911269722E-8
 2000,  4,  8.6376659378731E-5,  8.6338030705128E-5,  3.8628673603575E-8
```

7. RUN STREAM ON CRAY YMP

```
#   QSUB-r tm6243
#   QSUB-lM 6.0Mw
#   QSUB-eo
#
cd /wrk/smsriv/sr3/tm6243
/bin/rm *
cat > prop3d.f << EOF
C      PROGRAM MAIN(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,
.....
***  FORTRAN program goes here  ***
.....
```

```
END
EOF
cat > prop3d.inp << EOF
SR3 METRIC IN BC WWY=1.0 -   WWI=20*WW IEX=0 ISWCH=1
.....
***  Input file goes here  ***
.....
a0        p0
13040.      14.7
EOF
cft77 -V -exs -a static prop3d.f
segldr -V -o prop3d prop3d.o
ln ../std621/fort.31 ./fort.11
#n ../tm6242/fort.31 ./fort.11
#n ../tm6242/fort.32 ./fort.12
#n ../tm6242/fort.33 ./fort.13
#n ../tm6242/fort.34 ./fort.14
#n grid.den fort.2
ln $HOME/sr3grd.nas fort.3
ln $HOME/sr3mod.nas fort.4
rm *.1
time prop3d < sr3.inp > prop3d.out
#v fort.7 grid.dat
#v fort.9 flow.dat
rm fort.1* fort.2* fort.6* fort.8*  fort.7*
rm fort.90 fort.91 fort.92 fort.93 *.1 prop3d.
```

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (*Leave blank*)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	April 1996	Final Contractor Report

4. TITLE AND SUBTITLE
PROP3D: A Program for 3D Euler Unsteady Aerodynamic and Aeroelastic (Flutter and Forced Response) Analysis of Propellers
Version 1.0

5. FUNDING NUMBERS
WU–538–06–13
G–NAG3–1230

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8. PERFORMING ORGANIZATION REPORT NUMBER
E–10191

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
National Aeronautics and Space Administration
Lewis Research Center
Cleveland, Ohio 44135–3191

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
NASA CR–198471

11. SUPPLEMENTARY NOTES
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12a. DISTRIBUTION/AVAILABILITY STATEMENT
Unclassified - Unlimited
Subject Category 39

This publication is available from the NASA Center for AeroSpace Information, (301) 621–0390.

12b. DISTRIBUTION CODE

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

This guide describes the input data required, for steady or unsteady aerodynamic and aeroelastic analysis of propellers and the output files generated, in using PROP3D. The aerodynamic forces are obtained by solving three dimensional unsteady, compressible Euler equations. A normal mode structural analysis is used to obtain the aeroelastic equations, which are solved using either time domain or frequency domain solution method. Sample input and output files are included in this guide for steady aerodynamic analysis of single and counter-rotation propellers, and aeroelastic analysis of single-rotation propeller.

14. SUBJECT TERMS
Flutter; Propfans; Inviscid aerodynamics; Time domain flutter analysis; Frequency domain flutter analysis; Counter rotation

15. NUMBER OF PAGES
63

16. PRICE CODE
A04

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	