

# **APAME – Aircraft Panel Method**

## **Tutorial**

APAME version 3.0

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## Preface

The goal of this document is to show the user how to use APAME software on a series of examples. We shall start with basic example in order to explain input and output files, and finish with more complex geometries.

APAME was initially available in engineering packages Matlab, Scilab and Octave, however, I have decided to make APAME standalone executable and chosen FORTRAN for that number crunching operation. This standalone executable is easily called from other tools such as Matlab and Scilab, or manually from the command line, or it could be even integrated with other engineering software.

Keywords: potential flow, panel method, aircraft configuration, FORTRAN, Matlab, Scilab

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## 1. BASIC EXAMPLE

In this case we will create input file containing simple geometry.

Geometry will represent a simple lifting surface containing nine quadrilateral, two triangular and three wake panels. This totals in 16 nodes and 14 panels (Figure 1.).

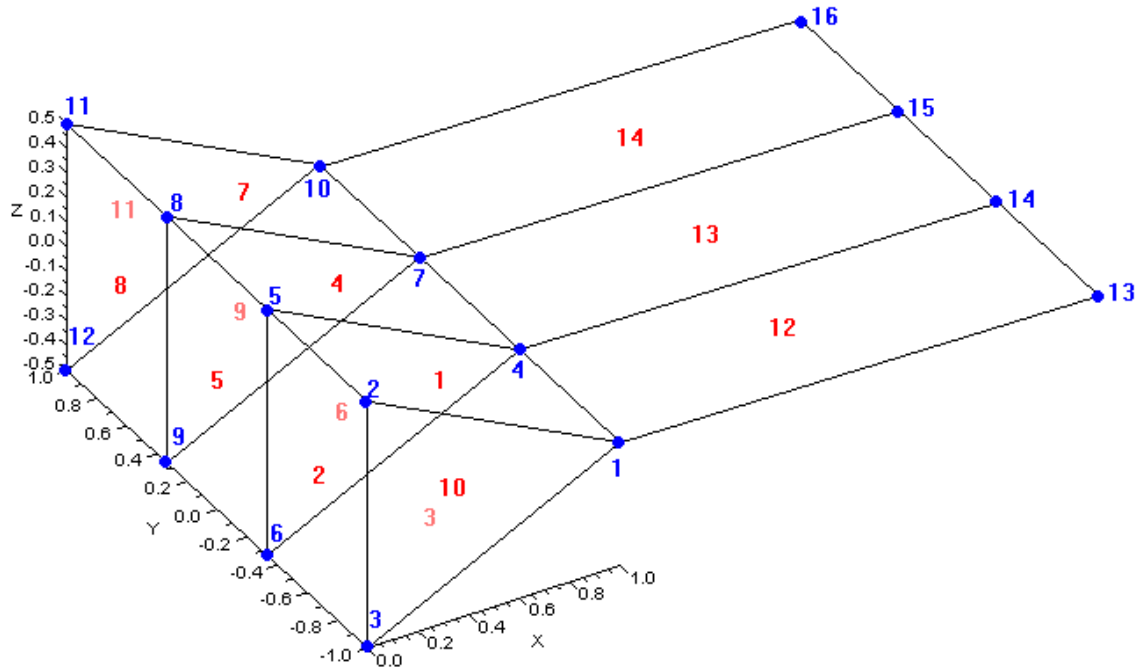


Figure 1. Simple geometry

Input file looks like this:

```
APAME input file
VERSION 3.0

# FLOW PARAMETERS

# airspeed [m/s]
AIRSPEED 27.778
# air density [kg/m^3]
DENSITY 1.225
# atmospheric pressure [Pa]
PRESSURE 101325
# prandtl-glauert correction:
# 0-no correction
# *-Mach number
MACH 0
# number of cases
# angles of attack [degrees]
# sideslip angles [degrees]
CASE_NUM 1
0
0
```

```
# REFERENCE VALUES

# wing span [m]
WINGSPAN 2
# mean aerodynamic chord [m]
MAC 1
# wing surface [m^2]
SURFACE 2
# reference point [m]
ORIGIN *
0 0 0

# SOLVER PARAMETERS

# singularity method:
# 0-constant source/doublet
# 1-constant doublet
METHOD 0
# error
ERROR 0.0000001
# collocation point depth
COLLDIST 0.0000001
# "far field" coefficient
FARFIELD 5
# collocation point calculation:
# 0-approximate
# 1-accurate
COLLCALC 0
# interpolation method/order for velocity calculations:
# 0-nodal
# 1-first
# 2-second
VELORDER 2

# RESULT REQUESTS
# 0-no
# 1-yes
# RESULTS <1> or <0> (yes or no will the result file be written)
# 1 coefficients
# 2 forces
# 3 geometry
# 4 velocity
# 5 pressure
# 6 center points
# 7 doublet values
# 8 source values
# 9 velocity components
# 10 mesh characteristics
# 11 static pressure
# 12 dynamic pressure
# 13 manometer pressure
RESULTS 1
1 1 1 1 1 1 1 1 1 1 1 1 1
# 1 2 3 4 5 6 7 8 9 10 11 12 13

# GEOMETRY

# x y z [m]
NODES 16
1. -1. 0.
0. -1. 0.5
0. -1. -0.5
1. -0.3333 0.
0. -0.3333 0.5
```

```

0. -0.3333 -0.5
1. 0.3333 0.
0. 0.3333 0.5
0. 0.3333 -0.5
1. 1. 0.
0. 1. 0.5
0. 1. -0.5
10. -1. 0.
10. -0.3333 0.
10. 0.3333 0.
10. 1. -0.

# type node_id1 node_id2 node_id3 [node_id4] elem_id1 [elem_id2 [elem_id3
[elem_id4]]]
PANELS 14
1 1 4 5 2 4 2 10 0
1 2 5 6 3 1 5 3 10
1 3 6 4 1 2 6 10 0
1 4 7 8 5 7 5 1 0
1 5 8 9 6 4 8 6 2
1 6 9 7 4 5 9 3 0
1 7 10 11 8 8 4 11 0
1 8 11 12 9 7 9 5 11
1 9 12 10 7 8 6 11 0
2 1 2 3 1 2 3
2 10 12 11 9 8 7
10 4 1 13 14 1 3
10 7 4 14 15 4 6
10 10 7 15 16 7 9
# end of input file

```

#### Input file explanation:

- Input file starts with keyword APAME, this is important since if this keyword is omitted, APAME solver will report an error and terminate as it did not recognize it as an APAME input file.
- Second line states version and if the file version is different from the solver version, job will also terminate.
- Inside input file comment or blank lines can be inserted with comment lines starting with character “#” at first column of a line.
- Units system can be arbitrary, but user must be cautious; if Newton Meter Seconds are used then kilograms and pascals are used for mass and pressure, but if Newton Millimeter Seconds are used then tonnes and newtons per square millimeter must be used for mass and pressure.
- Next are values of flow parameters; AIRSPEED and DENSITY represent free stream velocity and air density.
- PRESSURE is used as reference for static pressure calculations.
- MACH keyword is used to include Prandtl-Glauert's compressibility correction into consideration. Use it if your aircraft speed is greater than 0.3 Mach.

- CASE\_NUM states number of cases for analysis followed with two lines. First line will contain angles of attack and second sideslip angles in degrees. Of course their number must match the number of cases. Also important to notice here is that stating more cases has small slowing down effect on solver (for 3840 panels, if we calculate 4 cases instead of only one, time for solving increases by only half).
- Next are reference values. They are needed for coefficients calculation. WINGSPAN and SURFACE are total wing span and wing surface area, while MAC is mean aerodynamic chord.
- ORIGIN is reference point for moment calculations. Next to keyword ORIGIN, dummy sign “\*” must be placed. Next line must contain three values representing x,y and z coordinates.
- Next are solver parameters. First one, METHOD, is most important and selects type of singularities used. 0 is for constant source/doublet combination, and 1 is for constant doublet only. Constant source/doublet combination gives much finer results at the expense of a slightly more time needed for calculation and also more memory.
- ERROR is minimal value or distance used by solver. It can represent machine precision and is used to distinguish small values from zeros. For single precision solver it can be safely left at 0.0000001.
- COLLDIST is distance at which collocation point is moved below panel.
- FARFIELD parameter states at which multiple of a longer panel diagonal will panel be replaced with point singularity. With this parameter, time for calculating influence coefficients is reduced multiple times without any accuracy penalties.
- COLLCALC keyword enables approximate or accurate collocation point calculation. Accurate calculation calculates panel's center of weight, whereas approximate averages corner point locations, therefore finding center of weight equivalent. This equivalent is closer to panel's center of weight if panel is closer to parallelogram.
- Next keyword VELORDER selects method for velocity calculation. Enter 0 for nodal method, in which first doublet strengths will be found in panel nodes and then using these values linear surface will be interpolated and its derivative (velocity) will be calculated. Enter 1 or 2 for linear or quadratic interpolation using neighboring panels. Methods 1 and 2 are much more precise, but require for each panel that its neighbors are defined. Second order is more accurate and needs slightly more time for results calculation. Still, this time

is far less than time for influence coefficients calculation and time for solving the system of equations.

- Next, we need to define which results do we want in our results file. Keyword RESULTS is continued by 1 or 0 whether we want results file or not. In next line we enter “1” for results that we want, they are:
  1. coefficients (Cx, Cy, Cz, Cl, Cm, Cn)
  2. forces (Fx, Fy, Fz, Fl, Fm, Fn)
  3. geometry (nodes and panels)
  4. velocity coefficient distribution (v)
  5. pressure coefficient distribution (cp)
  6. panel center points
  7. doublet values
  8. source values
  9. velocity coefficient components distribution (vx, vy, vz)
  10. mesh characteristics; panel surfaces, far-field values, panel normals, panel lengthwise and perpendicular vectors (S, FF, nx, ny, nz, lx, ly, lz, px, py, pz)
  11. static pressure distribution
  12. dynamic pressure distribution
  13. manometer pressure distributioneach integer must exist, whether 1 or 0.
- Finally, we get to define our geometry. First keyword NODES states total number of nodes. **After this line there should be no comment or empty lines.** Next lines consist of three values x, y and z node coordinates and number of lines must be the same as number of nodes.
- Next keyword is PANEL and states how many panels we have. After that we have lines defining each panel. First integer defines panel type:
  - ID 1 – quadrilateral panel - is defined by four nodes and four neighboring panels. Neighboring panels are panels that share same sides (pair of nodes) and is needed for velocity and pressure calculation (methods 1 and 2). Missing neighbors (for example for panels near the trailing edge) are filled with value 0 (see figure 1).
  - ID 2 – triangular panel – is defined by three nodes and three neighboring panels.



– ID 10 – wake panel – is quadrilateral panel defined with four nodes and with two (neighboring) panels which are located on the trailing edge (panels to which wake panel is applying Kutta condition).

Panel types 1 and 2 must be defined before type 10 in input file.

Important to notice is the surface normal; order of nodes defining panels should be counter clockwise. By the right-hand rule if fingers are bended to follow numbering, thumb will show normal vector that should point “outwards” geometry.

– Finally, input file must end with empty or comment line.

Calculation can be started in two ways. First one is done by starting solver executable alone. In this case we enter interactive mode and solver will ask us for input file. Input file is entered without .INP extension. Next, calculation log will be printed on screen and written in .LOG file.

Other way is non-interactive mode and is accomplished with executing solver executable with input file as its argument (again, input file is entered without .INP extension). In this case no log will be printed on screen, but .LOG file will be created.

If we created input file named simple.inp containing data from the above and position ourselves to the folder containing that file, we can start APAME solver. This can be done in various ways. On Windows, it is done by executing .exe file (for example, apame\_win32.exe), in which case path can be added to environment so that solver can be executed from any folder. On Linux, same procedure can be done with executing solver with following command, for example:

```
./apame_lnx64
```

In case apame\_lnx64 is not executable (which can happen after downloading file over the Internet), one can change it into executable with command:

```
chmod 755 apame_lnx64
```

Also, like on Windows, one can enter a path to the solver (export or setenv command), or simply copy executable to /usr/bin/:

```
sudo cp apame_lnx64 /usr/bin/
```

After we started our solver, program will ask us for input file, in which case we enter it without .INP extension. Following information should be printed on screen:

```
test@test-linux:/home/test/APAME/apame$ ./apame_lnx64
```

```
=====
=
=          APAME - Aircraft Panel Method          =
=
```

```

=====
3D potential flow solver
Version: 3.0
=====

```

Please enter input file without .INP extension: simple

Date: 01/01/2010 Time: 12:00

Reading APAME input file... Done!

Job name: simple

Total number of panels: 14  
 ...excluding dummy panels: 11

KEYWORD values:

```

Airspeed: .27778E+02
Density: .12250E+01
Atmospheric pressure: .10132E+06
Mach number: .00000E+00
Wing span: .20000E+01
Mean aerodynamic chord: .10000E+01
Wing surface: .20000E+01
Origin: .00000E+00 .00000E+00 .00000E+00
Singularity method: constant source/doublet
Error parameter: .10000E-06
Farfield parameter: .50000E+01
Collocation calculation: approximative
Velocity interp. order: quadratic

```

Angles of interest [deg]:

```

Angles of attack: 0.0
Sideslip angles: 0.0

```

Calculating grid information... Done!

Time for preprocessing.....: 0.030 s

Calculating influence coefficients... Done!

Time for calculating influence coefficients.....: -0.001 s

Calculating right-hand side... Done!

Time for calculating right-hand side.....: -0.001 s

Solving system of equations... Done!

Time for solving system of equations.....: -0.001 s

Postprocessing... Done!

Time for postprocessing.....: 0.015 s

Coefficients in body reference frame:

```

CX   CY   CZ   CL   CM   CN
8.9704 0.0000 -0.0000 0.0000 0.0000 -0.0000

```

Coefficients in aerodynamic reference frame:

```

CD   CK   CL
8.9704 0.0000 -0.0000

```

Writing results file... Done!

```
Time for writing results file.....: -0.001 s
Job complete!
```

We can also notice there are two new files created; one is simple.log and the other simple.res. .LOG file contains same information as printed on screen and .RES file contains all the results we requested in input file (in our case all possible results).

If everything worked well, following results should have been obtained (results may insignificantly differ based on a compiler or platform used):

```
APAME results file
Date: 01/01/2010 Time: 12:00
PANEL_NUM
    14
PANEL_NUM_NO_WAKE
    11
NODE_NUM
    16
AIRSPEED
0.27778000E+02
DENSITY
0.12250000E+01
PRESSURE
0.10132500E+06
MACH
0.00000000E+00
CASE_NUM
    1
0.00000000E+00
0.00000000E+00
WINGSPAN
0.20000000E+01
MAC
0.10000000E+01
SURFACE
0.20000000E+01
ORIGIN
0.00000000E+00 0.00000000E+00 0.00000000E+00
METHOD
    0
ERROR
0.10000000E-06
FARFIELD
0.50000000E+01
COLLCALC
    0
VELORDER
    2
CX
0.89704208E+01
CY
0.37879400E-06
CZ
-.17214865E-06
CL
0.00000000E+00
CM
0.00000000E+00
CN
-.24198695E-06
CDRAG
0.89704208E+01
CSIDE
0.37879400E-06
```

```

CLIFT
-.17214865E-06
FX
0.84791211E+04
FY
0.35804790E-03
FZ
-.16272026E-03
FL
0.00000000E+00
FM
0.00000000E+00
FN
-.45746719E-03
FDRAG
0.84791211E+04
FSIDE
0.35804790E-03
FLIFT
-.16272026E-03
NODES
0.10000000E+01 -.10000000E+01 0.00000000E+00
0.00000000E+00 -.10000000E+01 0.50000000E+00
0.00000000E+00 -.10000000E+01 -.50000000E+00
0.10000000E+01 -.33329999E+00 0.00000000E+00
0.00000000E+00 -.33329999E+00 0.50000000E+00
0.00000000E+00 -.33329999E+00 -.50000000E+00
0.10000000E+01 0.33329999E+00 0.00000000E+00
0.00000000E+00 0.33329999E+00 0.50000000E+00
0.00000000E+00 0.33329999E+00 -.50000000E+00
0.10000000E+01 0.10000000E+01 0.00000000E+00
0.00000000E+00 0.10000000E+01 0.50000000E+00
0.00000000E+00 0.10000000E+01 -.50000000E+00
0.10000000E+02 -.10000000E+01 0.00000000E+00
0.10000000E+02 -.33329999E+00 0.00000000E+00
0.10000000E+02 0.33329999E+00 0.00000000E+00
0.10000000E+02 0.10000000E+01 -.00000000E+00
PANELS
1 1 4 5 2 4 2
10 0
1 2 5 6 3 1 5
3 10
1 3 6 4 1 2 6
10 0
1 4 7 8 5 7 5
1 0
1 5 8 9 6 4 8
6 2
1 6 9 7 4 5 9
3 0
1 7 10 11 8 8 4
11 0
1 8 11 12 9 7 9
5 11
1 9 12 10 7 8 6
11 0
2 1 2 3 0 1 2
3 0
2 10 12 11 0 9 8
7 0
10 4 1 13 14 1 3
0 0
10 7 4 14 15 4 6
0 0
10 10 7 15 16 7 9
0 0
S
0.74539328E+00

```

```
0.66670001E+00
0.74539328E+00
0.74528146E+00
0.66659999E+00
0.74528146E+00
0.74539328E+00
0.66670001E+00
0.74539328E+00
0.50000000E+00
0.50000000E+00
0.60002999E+01
0.59994001E+01
0.60002999E+01
FF
0.65086269E+01
0.60093446E+01
0.65086269E+01
0.65083704E+01
0.60090675E+01
0.65083704E+01
0.65086269E+01
0.60093446E+01
0.65086269E+01
0.55901699E+01
0.55901699E+01
0.45123299E+02
0.45123260E+02
0.45123299E+02
NORMAL
0.44721359E+00 0.00000000E+00 0.89442718E+00
-.10000000E+01 0.00000000E+00 -.00000000E+00
0.44721359E+00 0.00000000E+00 -.89442718E+00
0.44721359E+00 0.00000000E+00 0.89442718E+00
-.10000000E+01 0.00000000E+00 -.00000000E+00
0.44721359E+00 0.00000000E+00 -.89442718E+00
0.44721359E+00 0.00000000E+00 0.89442718E+00
-.10000000E+01 0.00000000E+00 -.00000000E+00
0.44721359E+00 0.00000000E+00 -.89442718E+00
0.00000000E+00 -.10000000E+01 -.00000000E+00
0.00000000E+00 0.10000000E+01 -.00000000E+00
-.00000000E+00 0.00000000E+00 0.10000000E+01
-.00000000E+00 0.00000000E+00 0.10000000E+01
0.00000000E+00 0.00000000E+00 0.10000000E+01
L_VECTOR
-.89442718E+00 0.00000000E+00 0.44721359E+00
0.00000000E+00 0.00000000E+00 -.10000000E+01
0.89442718E+00 0.00000000E+00 0.44721359E+00
-.89442718E+00 0.00000000E+00 0.44721359E+00
0.00000000E+00 0.00000000E+00 -.10000000E+01
0.89442718E+00 0.00000000E+00 0.44721359E+00
-.89442718E+00 0.00000000E+00 0.44721359E+00
0.00000000E+00 0.00000000E+00 -.10000000E+01
0.89442718E+00 0.00000000E+00 0.44721359E+00
-.55470020E+00 0.00000000E+00 -.83205032E+00
-.55470020E+00 0.00000000E+00 0.83205032E+00
0.10000000E+01 0.00000000E+00 0.00000000E+00
0.10000000E+01 0.00000000E+00 0.00000000E+00
0.10000000E+01 0.00000000E+00 0.00000000E+00
P_VECTOR
0.00000000E+00 -.10000000E+01 0.00000000E+00
0.00000000E+00 -.10000000E+01 -.00000000E+00
0.00000000E+00 -.10000000E+01 0.00000000E+00
0.00000000E+00 -.10000000E+01 0.00000000E+00
0.00000000E+00 -.10000000E+01 -.00000000E+00
0.00000000E+00 -.10000000E+01 0.00000000E+00
0.00000000E+00 -.10000000E+01 -.00000000E+00
0.00000000E+00 -.10000000E+01 0.00000000E+00
```

```
0.83205032E+00 0.00000000E+00 -.55470020E+00
0.83205032E+00 0.00000000E+00 0.55470020E+00
0.00000000E+00 0.10000000E+01 -.00000000E+00
0.00000000E+00 0.10000000E+01 -.00000000E+00
0.00000000E+00 0.10000000E+01 0.00000000E+00
CENTER POINTS
0.50000000E+00 -.66665000E+00 0.25000000E+00
0.00000000E+00 -.66665000E+00 0.00000000E+00
0.50000000E+00 -.66665000E+00 -.25000000E+00
0.50000000E+00 0.00000000E+00 0.25000000E+00
0.00000000E+00 0.00000000E+00 0.00000000E+00
0.50000000E+00 0.00000000E+00 -.25000000E+00
0.50000000E+00 0.66665000E+00 0.25000000E+00
0.00000000E+00 0.66665000E+00 0.00000000E+00
0.50000000E+00 0.66665000E+00 -.25000000E+00
0.33333334E+00 -.10000000E+01 0.00000000E+00
0.33333334E+00 0.10000000E+01 0.00000000E+00
0.55000000E+01 -.66665000E+00 0.00000000E+00
0.55000000E+01 0.00000000E+00 0.00000000E+00
0.55000000E+01 0.66665000E+00 0.00000000E+00
VELOCITY
0.82401543E+02
0.28999931E+02
0.82401543E+02
0.94167130E+02
0.42916417E-05
0.94167130E+02
0.82401558E+02
0.28999939E+02
0.82401558E+02
0.68463623E+02
0.68463631E+02
CP
-.77997184E+01
-.89913487E-01
-.77997184E+01
-.10492030E+02
0.10000000E+01
-.10492030E+02
-.77997217E+01
-.89914061E-01
-.77997217E+01
-.50746021E+01
-.50746036E+01
DIPOLE
-.64671016E+01
0.13953703E+02
-.64670992E+01
-.74550238E+01
0.16046268E+02
-.74550247E+01
-.64671016E+01
0.13953708E+02
-.64671016E+01
-.24131084E-01
-.24130439E-01
SOURCE
0.12422699E+02
-.27778000E+02
0.12422699E+02
0.12422699E+02
-.27778000E+02
0.12422699E+02
0.12422699E+02
-.27778000E+02
0.12422699E+02
0.00000000E+00
0.00000000E+00
```

```

VELOCITY_COMP
0.73251854E+02 0.90951176E+01 -.36625927E+02
0.00000000E+00 -.28999931E+02 0.76293945E-05
0.73251854E+02 0.90951157E+01 0.36625927E+02
0.84225639E+02 -.00000000E+00 -.42112820E+02
0.00000000E+00 -.42916417E-05 -.00000000E+00
0.84225639E+02 0.20564116E-05 0.42112820E+02
0.73251869E+02 -.90951176E+01 -.36625935E+02
0.00000000E+00 0.28999939E+02 0.00000000E+00
0.73251869E+02 -.90951176E+01 0.36625935E+02
0.68463623E+02 0.00000000E+00 0.43756118E-05
0.68463631E+02 0.00000000E+00 -.12015919E-05
P_STATIC
0.97638734E+05
0.10128251E+06
0.97638734E+05
0.96366305E+05
0.10179762E+06
0.96366305E+05
0.97638727E+05
0.10128251E+06
0.97638727E+05
0.98926664E+05
0.98926664E+05
P_DYNAMIC
0.41588838E+04
0.51511005E+03
0.41588838E+04
0.54313120E+04
0.11281141E-10
0.54313120E+04
0.41588853E+04
0.51511035E+03
0.41588853E+04
0.28709514E+04
0.28709521E+04
P_MANOMETER
-.36862683E+04
-.42494514E+02
-.36862683E+04
-.49586968E+04
0.47261557E+03
-.49586968E+04
-.36862698E+04
-.42494785E+02
-.36862698E+04
-.23983359E+04
-.23983367E+04
end

```

First, let us discuss contents of results file. First set of data is same as in input file with additional PANEL\_NUM\_NO\_WAKE number that represents number of panels of type 1 and 2 (only “real” wall types). Also should be noticed that angles are in radians here. Next are coefficients and forces (airframe coordinate system) for all cases:

- CX, CY, CZ, CL, CM, CN, CDRAG, CSIDE and CLIFT (axial, side and normal force coefficients, roll, pitch and yaw moment coefficients, and drag, side force and lift coefficients)
- FX, FY, FZ, FL, FM and FN (axial, side and normal forces, roll, pitch and yaw moments, and drag, side and lift forces)

After that, we have geometry information with nodes and panels defined in same way as in input file.

Next are surfaces (S), far-field distances (FF), normal vectors (NORMAL), lengthwise vectors (L\_VECTOR), perpendicular vectors (P\_VECTOR) and center points (CENTER POINTS) for each panel and they represent geometry data.

Next is solution data for each wall panel (type 1 and 2 only) and consists of velocity field (VELOCITY), pressure coefficient (CP), doublet strength (DIPOLE), source strength (SOURCE) (in case source/doublet method is used), velocity components field (VELOCITY\_COMP), static pressure (P\_STATIC), dynamic pressure (P\_DYNAMIC) and manometer pressure (P\_MANOMETER).

We can check our results now, even though we used the simplest possible geometry.

First, since the front panels are perpendicular to the stream (in case of 0 AOA), we expect there a zero velocity and a coefficient pressure of 1. We can see that this is true for inner panel, while side panels have some velocity which is due to 3D geometry effect (part of air stream is flowing sideways).

Normal force coefficient (CZ) would increase with increase of AOA, while pitch moment decrease. This is in correlation with flat plate theory.

Axial force should be disregarded for such a simple example, while other coefficients regarding lateral behavior (due to sideslip angle) are negligible.

Now we can move to creating a bit more complex mesh for some realistic results.



## 2. SPHERE EXAMPLE

Sphere mesh data has been prepared in NASTRAN format (use sphere\_2400.bdf from importMesh/examples folder). It consist of 2400 quadrilateral elements with all coincident nodes merged and all normals pointing outwards.

First, we shall convert this file to Apame format using importMesh utility.

Command line will look like this (for Windows 32bit):

```
importMesh_win32.exe nastran sphere_2400.bdf
```

Here, “nastran” indicates that Nastran mesh file is given (for now only Nastran is supported).

Upon completion, two additional files will be created; .map map file and .inp Apame input file. Map file defines which panels and nodes refer to which element and node ID's in Nastran input file (Apame doesn't use panel and node ID's).

At this point we must add reference, flow and solver parameters to Apame input file, so please insert these lines to sphere\_2400.inp before existing geometry data:

```
APAME input file
```

```
VERSION 3.0
```

```
# FLOW PARAMETERS
```

```
# airspeed [m/s]
```

```
AIRSPEED 27.778
```

```
# air density [kg/m^3]
```

```
DENSITY 1.225
```

```
# atmospheric pressure [Pa]
```

```
PRESSURE 101325
```

```
# prandtl-glauert correction:
```

```
# 0-no correction
```

```
# *-Mach number
```

```
MACH 0
```

```
# number of cases
```

```
# angles of attack [degrees]
```

```
# sideslip angles [degrees]
```

```
CASE_NUM 1
```

```
0
```

```
0
```

```
# REFERENCE VALUES
```

```
# wing span [m]
```

```
WINGSPAN 2
```

```
# mean aerodynamic chord      [m]
MAC 1
# wing surface                 [m^2]
SURFACE 2
# reference point              [m]
ORIGIN *
0 0 0

# SOLVER PARAMETERS

# singularity method:
# 0-constant source/doublet
# 1-constant doublet
METHOD 0
# error
ERROR 0.0000001
# collocation point depth
COLLDIST 0.0000001
# "far field" coefficient
FARFIELD 5
# collocation point calculation:
# 0-approximative
# 1-accurate
COLLCALC 0
# interpolation method/order for velocity calculations:
# 0-nodal
# 1-first
# 2-second
VELORDER 2

# RESULT REQUESTS
# 0-no
# 1-yes
# RESULTS <1> or <0> (yes or no will the result file be written)
# 1 coefficients
# 2 forces
# 3 geometry
# 4 velocity
# 5 pressure
# 6 center points
# 7 dipole values
# 8 source values
# 9 velocity components
# 10 mesh characteristics
```

```
# 11 static pressure
# 12 dynamic pressure
# 13 manometer pressure
RESULTS 1
  1  1  1  1  1  1  1  1  1  1  1  1  1
# 1  2  3  4  5  6  7  8  9 10 11 12 13
```

Now we can run our input file in Apame solver using command:

```
C:\temp>apame_win32.exe sphere_2400
```

```
Date: 01/01/2010 Time: 00:00
```

```
Reading APAME input file... Done!
```

```
Job name: sphere_2400
```

```
Total number of panels:      2400
...excluding dummy panels:    2400
```

```
KEYWORD values:
```

```
Airspeed:      .27778E+02
Density:       .12250E+01
Atmospheric pressure: .10132E+06
Mach number:   .00000E+00
Wing span:    .20000E+01
Mean aerodynamic chord: .10000E+01
Wing surface: .20000E+01
Origin:       .00000E+00 .00000E+00 .00000E+00
Singularity method: constant source/doublet
Error parameter: .10000E-06
Farfield parameter: .50000E+01
Collocation calculation: approximative
Velocity interp. order: quadratic
```

```
Angles of interest [deg]:
```

```
Angles of attack:  0.0
Sideslip angles:  0.0
```

```
Calculating grid information... Done!
```

```
Time for preprocessing.....: 0.088 s
```

```
Calculating influence coefficients... Done!
```

```
Time for calculating influence coefficients.....: 0.289 s

Calculating right-hand side... Done!

Time for calculating right-hand side.....: 0.016 s

Solving system of equations... Done!

Time for solving system of equations.....: 0.342 s

Postprocessing... Done!

Time for postprocessing.....: 0.008 s

Coefficients in body reference frame:
      CX      CY      CZ      CL      CM      CN
-0.0000 -0.0000  0.0000 -0.0000 -0.0000 -0.0000

Coefficients in aerodynamic reference frame:
      CD      CK      CL
-0.0000 -0.0000  0.0000

Writing results file... Done!

Time for writing results file.....: 0.789 s

Job complete!
```

If successful, sphere\_2400.res is created which contains results data and which we will use in our Scilab (or Matlab) reader. For this reason, load reader.sci into Scilab and modify line 35 to:

```
file_name = 'sphere_2400.res'
```

and execute it by pressing Ctrl+E (may be different with different version).

Following picture representing pressure coefficient is displayed:

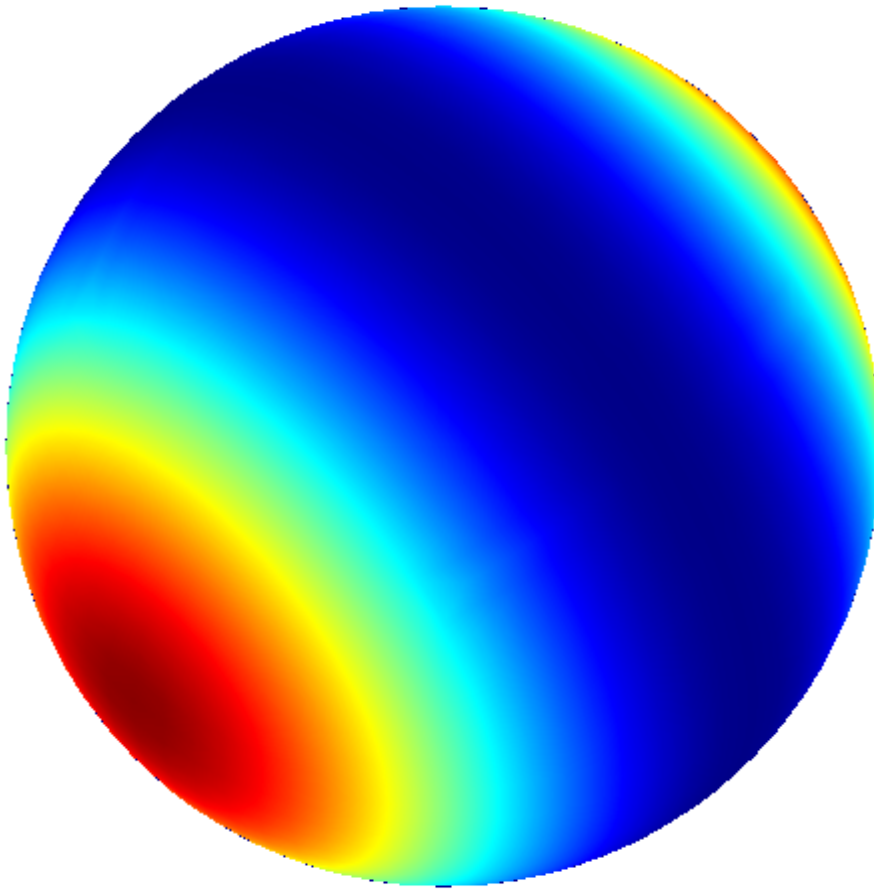


Figure 2. Pressure coefficient distribution on sphere

All data from results file is being read into Scilab and we can check pressure values. Pressure coefficients extremities for sphere potential flow can be calculated analytically and they are 1 for front and rear stagnation points and -1.25 for region where flow is fastest. By executing following commands we can check these values from Apame:

```
-->max (cp)
ans =
    0.9922865
-->min (cp)
ans =
    - 1.2492009
```

### 3. WING-FUSELAGE TEST

For this test we will use specially prepared Apame input file:

```
wake_test_fuselage_wake.inp
```

which resides in Documentation folder. This geometry is special in a way that wake panels are being shed from fuselage also. However, their strength is not the difference in strengths between upper and lower panel (from which it was shed), but same as wing wake panel strength that is nearest to fuselage (Figure 3).

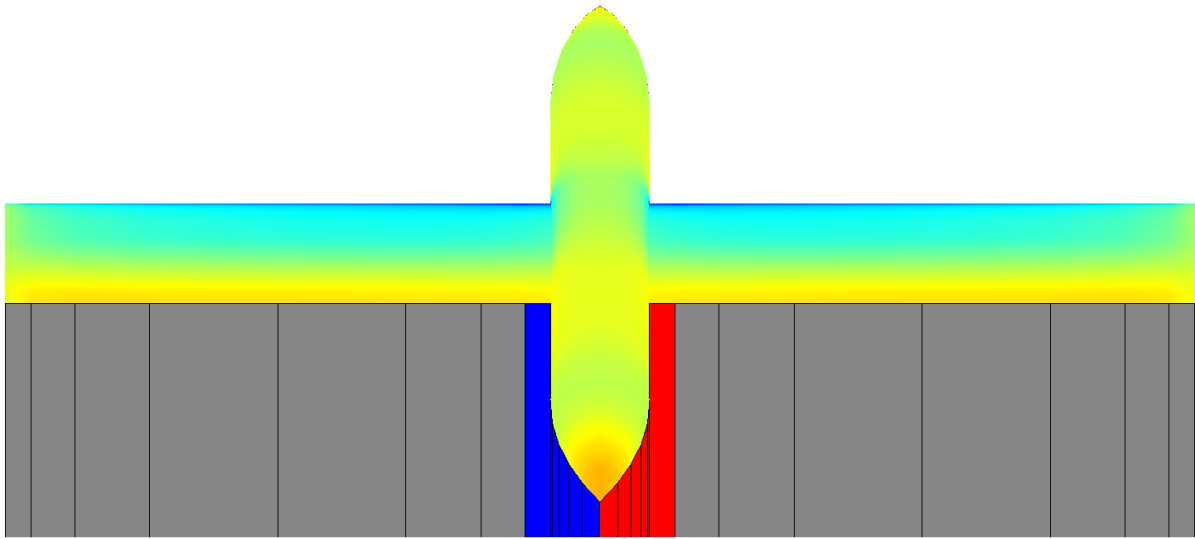


Figure 3. Wake being shed from wings and fuselage

Blue wakes all have same strength that is equal to doublet strength of a upper trailing wing panel near fuselage minus lower panel on left wing (red ones on right wing). This can be done by editing input file and applying same “neighbours” for these new wake panels (check `wake_test_fuselage_wake.inp` file, lines 4469-4478).

Another important thing to notice is that fuselage panels that are near wake must not include neighbours across wake surface. This would result in velocity interpolation error as here exists potential jump (Figure 5). If geometry is being prepared for `importMesh` utility, than panels above and below wake plane should not have same nodes (merging of nodes should not be done).

`ImportMesh` utility still doesn't have support for recognizing this sort of geometry so user will have to define it manually if he wants this feature.

Run Apame with our input file:

```
apame_win32.exe wake_test_fuselage_wake
```

After it completes, you will have .res file which you should load into Scilab (or Matlab) reader. Modify file\_name line to load our .res file, modify plot\_case = 3 to load data of third case (first case is zero degree AOA and will results in zero wake strengths) and modify geometry\_only = 0 to show wake geometry also, or 1 to show plane geometry only.

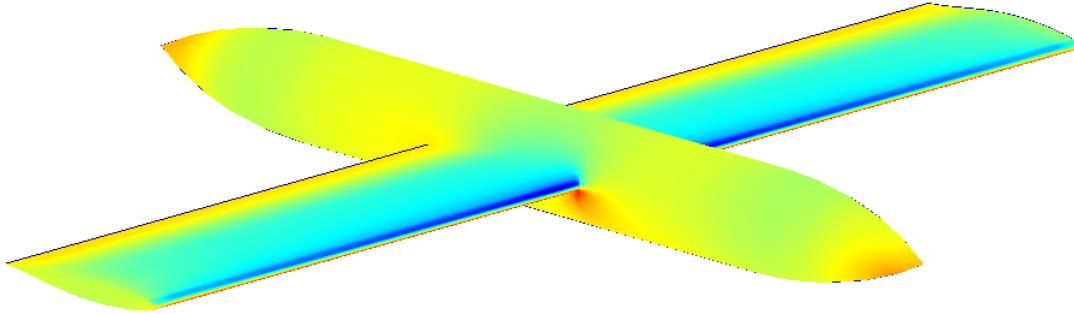


Figure 4. Pressure coefficient distribution

By applying fuselage wakes, no discontinuities in velocity or pressure will be present near the fuselage and also some amount of lift will be generated by fuselage.

If we change line 184 of Scilab reader (or line 252 of Matlab reader) to:

```
field = doublet(:,plot_case);
```

we should get picture like this:

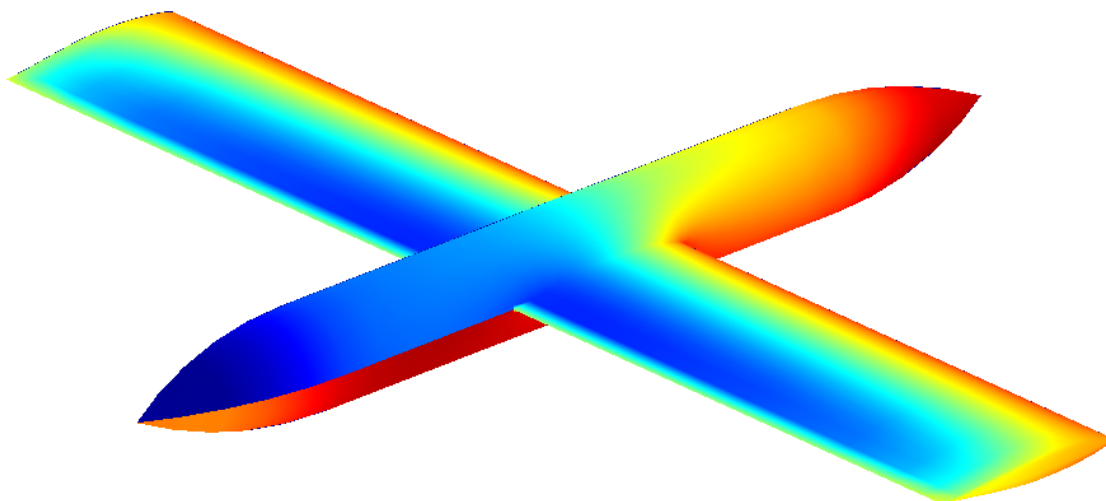


Figure 5. Doublet strength distribution

showing doublet strength discontinuity in fuselage region across wake plane. This is the reason why panels above and below wake plane should not make contact (share nodes).