APAME – Aircraft panel method

Documentation/Tutorial

(Document still in development...)

APAME version 2.2

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Preface

The goal of this document is to show the user how to use APAME software on series of examples. We shall start with some basic models, go trough the coupling with Scilab as a preprocessor and ending with complex aircraft configuration.

APAME was initially available in engineering packages Matlab, Scilab and Octave, however, I have decided to make APAME as a standalone executable and chosen Fortran for that number crunching operation. This standalone executable is easily called from other tools such as Matlab and Scilab.

Since APAME is open-source project, I will promote usage of Scilab instead of Matlab for writing preprocessing and post-processing routines.

Keywords: potential flow, panel method, aircraft configuration, Fortran, Matlab, Scilab, Octave

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1. BASIC EXAMPLE

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

Geometry will represent a simple wing containing three panels along airfoil and three panels spanwise, totaling in nine panels. This means four nodes along airfoil and four nodes spanwise, totaling in sixteen nodes (Figure 1.).

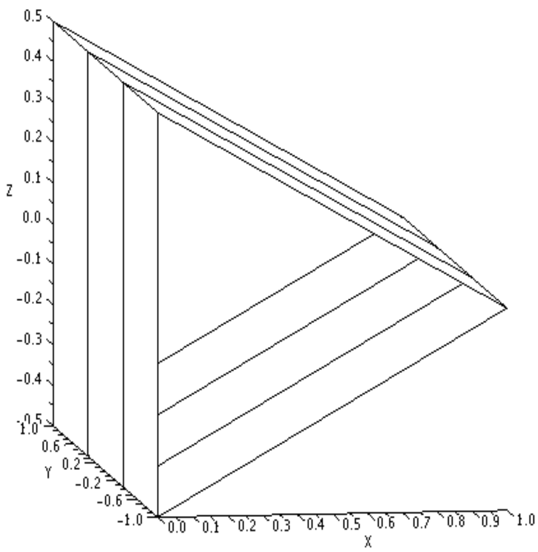

Figure 1. Simple geometry

Input file looks like this:

```
APAME input file
VERSION 2.2


# 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
# angle of attack             [degrees]
ALFA 4
-2 0 2 4
# sideslip angle              [degrees]
BETA 1
0
```

```
# REFERENCE VALUES

# wing span                 [m]
WINGSPAN 2
# mean aerodynamic chord    [m]
MAC 1
# wing surface              [m^2]
SURFACE 2
# 1-find and use aerodynamic
#   center
# 0-values that follow will
#   be used as reference point
#                           [m]
FIND_AC 0
0 0 0


# SOLVER PARAMETERS

# singularity method:
#   0-constant source/doublet
#   1-constant doublet
METHOD 0
# trailing wake distance    [m]
WAKE 1000
# error
ERROR 0.0000001
# "far field" coefficient
FARFIELD 5
# collocation point calculation:
#   0-approximative
#   1-accurate
COLLCALC 0
# interpolation order for velocity calculations:
#   1-first
#   2-second
VELORDER 1
# interpolation method:
#   0-directional
#   1-surface
VELOMETH 0


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

```
# 12 mesh characteristics
# 13 static pressure
# 14 dynamic pressure
# 15 manometer pressure
RESULTS 1
  1  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 14 15


# GEOMETRY

# components

# <KEYWORD> <number of components>
# maximum row and column number of components
# <'name'> <row number of nodes> <column number of nodes> <lifting
component>

# WARNING! Do not split or reorder following lines !!!
KOMP 1
4 4
'simple wing' 4 4 1
1      1      1      1
0      0      0      0
0      0      0      0
1      1      1      1
-1 -0.3333 0.3333 1
-1 -0.3333 0.3333 1
-1 -0.3333 0.3333 1
-1 -0.3333 0.3333 1
0      0      0      0
-0.5   -0.5   -0.5   -0.5
0.5    0.5    0.5    0.5
0      0      0      0
# 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 version is different from the solver, 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.
- Next are values of flow parameters; AIRSPEED and DENSITY need not to be explained, they are in meters per second and kilograms per cubic meter.
- 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 then 0.3 Mach.
- ALFA is angle of attack (AOA) in degrees and can be a single value or a set of values. Next to keyword ALFA is number of angles of attack that will be entered in the following line. Same is with BETA – sideslip angle. Also important to notice here is that stating more AOA's or sideslip angles has small slowing down effect on solver (for 3840 panels, if we calculate for 4 AOA's instead of 1, time for solving increases to only 150%).
- Next are reference values. They are needed for coefficients calculation. WINGSPAN and SURFACE are known wing parameters, while MAC is mean aerodynamic chord. FIND_AC parameter controls weather aerodynamic center is to be found, or values that follow will be used as reference point. APAME solver iteratively, within 10 iterations, tries to find aerodynamic center. If it fails to converge, following values from the input file will be used.
- Next are defined solver parameters. First one, METHOD, is most important and selects type of singularities used. 0 is for constant source/constant doublet combination, and 1 is for constant doublet only. Constant source/constant doublet combination gives much finer results at the expense of a slightly more time needed for calculation. This difference in time could be as much as double for smaller models, but shrinks for larger models.
- WAKE parameter is a length of trailing wake. This wake represents three-dimensional Kutta condition and, for now, only flat wake is available in APAME. Other types would include flat wake that stays parallel to free stream and rolled-up wake created using wake relaxation technique or similar. Each technique, other than flat wake, would require changing influence coefficient matrix for each case. This results in excessive speed penalties and would be avoided for fast optimizations in first stage even if APAME solver would include those routines.
- 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.
- 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 approximative or accurate collocation point calculation. Accurate calculation calculates panel's center of weight, whereas approximative 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.
- Following keyword VELORDER enables first or second interpolation order for velocity calculation. Second order is more accurate and results in slightly more time for results calculation. Still, this time is far less then time for influence coefficients calculation and time for solving the system of equations.
- Keyword VELOMETH enables directional or surface velocity calculation. Directional method calculates local velocities separately (longitudinal and lateral direction of panel distribution), while surface method finds second order surface from local doublet strengths and then its derivatives in local coordinate system.
- 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 ones for results that we want, they are:
  1. coefficients of complete configuration
  2. forces of complete configuration
  3. coefficients by components
  4. forces by components
  5. pressure distribution for all cases
  6. velocity distribution for all cases
  7. geometry (node coordinates from input file)
  8. collocation nodes (coordinates of nodes that are in center of panels)
  9. doublet strengths
  10. source strengths (if constant doublet method is used, warning is displayed if source strengths are requested)
  11. velocity components (just like under number 6, but in x,y and z direction)
  12. mesh characteristics:
      - panel surfaces
      - far field factors
      - normals (x,y and z direction)
      - longitudinal unit vectors (x,y and z direction)

- lateral unit vectors (x,y and z direction)
- perpendicular unit vectors (x,y and z direction)

13. static pressure
14. dynamic pressure
15. manometer pressure

each integer must exist, whether 1 or 0.

- Finally, we get to define of our geometry. First keyword KOMP states number of components that form our configuration. **After this line there should be no comment or empty lines**. Next line states maximum row and column number of all components.
- Before we enter geometry, we need to define numbering convention. Geometry is defined with nodes which are structured so that panels can be automatically defined. For a wing (and every other lifting surface) columns represent panel nodes along airfoil, while rows represent panel nodes along span. For non-lifting components this is irrelevant. For a wing, first node with indexes (1.1) is located on a trailing edge, lower surface at the wing tip. This means that we could unfold lower surface of our wing over the leading edge and it would resemble our matrices.
- Next line in our input file states component name under apostrophe signs, row number of nodes, column number of nodes and integer which states component as lifting (1) or non-lifting (0).
- Next, we enter X coordinates of nodes followed by Y and Z coordinates, as we discussed earlier.
- If there should be more components, next one would follow with its name, row column number...
- 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, apame22_32.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;

```
./apame22_64
```

If case apame22_64 is not executable (which can happen after downloading file over the Internet), one can change it into executable with command:

```
chmod 755 apame22_64
```

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

```
sudo cp apame22_64 /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$ ./apame22_64

 ========================================================
 =                                                      =
 =             APAME - Aircraft Panel Method            =
 =______________________________________________________=
 =                                                      =
 =               3D potential flow solver               =
 =                                                      =
 =                     Version: 2.2                     =
 =                                                      =
 ========================================================

 Please enter input file without .INP extension: simple

 Date: 03/07/2009  Time: 17:08

 Reading APAME input file... Done!

     Total panel number is:       9

     KEYWORD values:
         Airspeed:                    27.778
         Density:                      1.225
         Atmospheric pressure:    101325.
         Mach number:                  0.000
```

```
        Wing span:                    2.000
        Mean aerodynamic chord:       1.000
        Wing surface:                 2.00
        Find aerodynamic center:      0
        Origin:                       0.00   0.00   0.00
        Calculation method:           0
        Wake length:               1000.
        Error parameter:              0.1E-06
        Farfield parameter:           5.000
        Collocation calculation:      0
        Velocity interp. order:       1
        Velocity interp. method:      0
        Number of components:         1

    Angles of interest [deg]:
        Angles of attack:  -2.0   0.0   2.0   4.0
        Sideslip angles:    0.0

Calculating grid information... Done!

    Time for pre-processing:   0.176 s

Calculating influence coefficients... Done!

    Time for calculating influence coefficients:   0.000 s

Solving system of equations... Done!

    Time for solving system of equations:   0.000 s

Calculating results data... Done!

    Time for results calculation:   0.000 s

    Calculated coefficients:
            CX       CY       CZ       CL       CM       CN
         5.1574  0.0000 -0.2575  0.0000  0.0965  0.0000
         5.1805  0.0000  0.0000  0.0000  0.0000  0.0000
         5.1574  0.0000  0.2575  0.0000 -0.0965  0.0000
         5.0882  0.0000  0.5136  0.0000 -0.1926  0.0000

Start writing APAME results file... Done!

Job complete!
```

We can also notice there are two file new files in folder; 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, except for the info on finding aerodynamic center which we did not request).

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: 04/07/2009  Time: 08:08
AIRSPEED
0.27778000E+02
```

```
DENSITY
0.12250000E+01
PRESSURE
0.10132500E+06
MACH
0.00000000E+00
ALFA
         4
-.34906585E-01 0.00000000E+00 0.34906585E-01 0.69813170E-01
BETA
         1
0.00000000E+00
WINGSPAN
0.20000000E+01
MAC
0.10000000E+01
SURFACE
0.20000000E+01
FIND_AC
         0
ORIGIN
0.00000000E+00 0.00000000E+00 0.00000000E+00
METHOD
         0
WAKE
0.10000000E+04
ERROR
0.10000000E-06
FARFIELD
0.50000000E+01
COLLCALC
         0
VELORDER
         1
VELOMETH
         0
KOMP
         1
         3            3
CX
0.51574316E+01 0.51805434E+01 0.51574316E+01 0.50882087E+01
CY
0.00000000E+00 0.00000000E+00 0.00000000E+00 0.00000000E+00
CZ
-.25745037E+00 -.25828669E-06 0.25745100E+00 0.51364702E+00
CL
-.19371502E-06 -.96857512E-07 0.64571672E-07 0.00000000E+00
CM
0.96543819E-01 0.12914334E-06 -.96544079E-01 -.19261765E+00
CN
-.64571672E-07 -.14528626E-06 -.11300043E-06 -.22600085E-06
FX
0.48749648E+04 0.48968110E+04 0.48749648E+04 0.48095332E+04
FY
0.00000000E+00 0.00000000E+00 0.00000000E+00 0.00000000E+00
FZ
-.24335010E+03 -.24414062E-03 0.24335071E+03 0.48551514E+03
FL
-.36621094E-03 -.18310547E-03 0.12207031E-03 0.00000000E+00
FM
```

```
0.91256226E+02 0.12207031E-03 -.91256470E+02 -.18206821E+03
FN
-.12207031E-03 -.27465820E-03 -.21362305E-03 -.42724609E-03
'simple wing'
         1
         4            4
X
0.10000000E+01 0.10000000E+01 0.10000000E+01 0.10000000E+01
0.00000000E+00 0.00000000E+00 0.00000000E+00 0.00000000E+00
0.00000000E+00 0.00000000E+00 0.00000000E+00 0.00000000E+00
0.10000000E+01 0.10000000E+01 0.10000000E+01 0.10000000E+01
Y
-.10000000E+01 -.33329999E+00 0.33329999E+00 0.10000000E+01
-.10000000E+01 -.33329999E+00 0.33329999E+00 0.10000000E+01
-.10000000E+01 -.33329999E+00 0.33329999E+00 0.10000000E+01
-.10000000E+01 -.33329999E+00 0.33329999E+00 0.10000000E+01
Z
0.00000000E+00 0.00000000E+00 0.00000000E+00 0.00000000E+00
-.50000000E+00 -.50000000E+00 -.50000000E+00 -.50000000E+00
0.50000000E+00 0.50000000E+00 0.50000000E+00 0.50000000E+00
0.00000000E+00 0.00000000E+00 0.00000000E+00 0.00000000E+00
COLX
0.50000000E+00 0.50000000E+00 0.50000000E+00
0.00000000E+00 0.00000000E+00 0.00000000E+00
0.50000000E+00 0.50000000E+00 0.50000000E+00
COLY
-.66665006E+00 0.00000000E+00 0.66665000E+00
-.66665006E+00 0.00000000E+00 0.66665000E+00
-.66665006E+00 0.00000000E+00 0.66665000E+00
COLZ
-.25000000E+00 -.25000000E+00 -.25000000E+00
0.00000000E+00 0.00000000E+00 0.00000000E+00
0.25000000E+00 0.25000000E+00 0.25000000E+00
CX_COMP
0.51574316E+01 0.51805434E+01 0.51574316E+01 0.50882087E+01
CY_COMP
0.00000000E+00 0.00000000E+00 0.00000000E+00 0.00000000E+00
CZ_COMP
-.25745037E+00 -.25828669E-06 0.25745100E+00 0.51364702E+00
CL_COMP
-.19371502E-06 -.96857512E-07 0.64571672E-07 0.00000000E+00
CM_COMP
0.96543819E-01 0.12914334E-06 -.96544079E-01 -.19261765E+00
CN_COMP
-.64571672E-07 -.14528626E-06 -.11300043E-06 -.22600085E-06
FX_COMP
0.48749648E+04 0.48968110E+04 0.48749648E+04 0.48095332E+04
FY_COMP
0.00000000E+00 0.00000000E+00 0.00000000E+00 0.00000000E+00
FZ_COMP
-.24335010E+03 -.24414062E-03 0.24335071E+03 0.48551514E+03
FL_COMP
-.36621094E-03 -.18310547E-03 0.12207031E-03 0.00000000E+00
FM_COMP
0.91256226E+02 0.12207031E-03 -.91256470E+02 -.18206821E+03
FN_COMP
-.12207031E-03 -.27465820E-03 -.21362305E-03 -.42724609E-03
S
0.74539328E+00 0.74528146E+00 0.74539328E+00
0.66670001E+00 0.66659999E+00 0.66670001E+00
```

```
0.74539328E+00 0.74528146E+00 0.74539328E+00
FF
0.65086269E+01 0.65083704E+01 0.65086269E+01
0.60093446E+01 0.60090675E+01 0.60093446E+01
0.65086269E+01 0.65083704E+01 0.65086269E+01
N1_VECTOR
0.44721359E+00 0.44721359E+00 0.44721359E+00
-.10000000E+01 -.10000000E+01 -.10000000E+01
0.44721359E+00 0.44721359E+00 0.44721359E+00
N2_VECTOR
0.00000000E+00 0.00000000E+00 0.00000000E+00
0.00000000E+00 0.00000000E+00 0.00000000E+00
0.00000000E+00 0.00000000E+00 0.00000000E+00
N3_VECTOR
-.89442718E+00 -.89442718E+00 -.89442718E+00
0.00000000E+00 0.00000000E+00 0.00000000E+00
0.89442718E+00 0.89442718E+00 0.89442718E+00
U1_VECTOR
-.89442718E+00 -.89442718E+00 -.89442718E+00
0.00000000E+00 0.00000000E+00 0.00000000E+00
0.89442718E+00 0.89442718E+00 0.89442718E+00
U2_VECTOR
0.00000000E+00 0.00000000E+00 0.00000000E+00
0.00000000E+00 0.00000000E+00 0.00000000E+00
0.00000000E+00 0.00000000E+00 0.00000000E+00
U3_VECTOR
-.44721359E+00 -.44721359E+00 -.44721359E+00
0.10000000E+01 0.10000000E+01 0.10000000E+01
-.44721359E+00 -.44721359E+00 -.44721359E+00
P1_VECTOR
0.00000000E+00 0.00000000E+00 0.00000000E+00
0.00000000E+00 0.00000000E+00 0.00000000E+00
0.00000000E+00 0.00000000E+00 0.00000000E+00
P2_VECTOR
0.10000000E+01 0.10000000E+01 0.10000000E+01
0.10000000E+01 0.10000000E+01 0.10000000E+01
0.10000000E+01 0.10000000E+01 0.10000000E+01
P3_VECTOR
0.00000000E+00 0.00000000E+00 0.00000000E+00
0.00000000E+00 0.00000000E+00 0.00000000E+00
0.00000000E+00 0.00000000E+00 0.00000000E+00
O1_VECTOR
0.00000000E+00 0.00000000E+00 0.00000000E+00
0.00000000E+00 0.00000000E+00 0.00000000E+00
0.00000000E+00 0.00000000E+00 0.00000000E+00
O2_VECTOR
0.99999994E+00 0.99999994E+00 0.99999994E+00
0.10000000E+01 0.10000000E+01 0.10000000E+01
0.99999994E+00 0.99999994E+00 0.99999994E+00
O3_VECTOR
0.00000000E+00 0.00000000E+00 0.00000000E+00
0.00000000E+00 0.00000000E+00 0.00000000E+00
0.00000000E+00 0.00000000E+00 0.00000000E+00
CP
          1
-.39930072E+01 -.49510136E+01 -.39930091E+01
0.97109812E+00 0.97934222E+00 0.97109807E+00
-.37659492E+01 -.46327710E+01 -.37659492E+01
          2
-.38847342E+01 -.47978601E+01 -.38847361E+01
```

```
0.98719680E+00 0.10000000E+01 0.98719686E+00
-.38847342E+01 -.47978601E+01 -.38847351E+01
          3
-.37659492E+01 -.46327686E+01 -.37659502E+01
0.97109807E+00 0.97934204E+00 0.97109818E+00
-.39930077E+01 -.49510136E+01 -.39930091E+01
          4
-.36372280E+01 -.44565463E+01 -.36372309E+01
0.92288035E+00 0.91746926E+00 0.92288041E+00
-.40902381E+01 -.50914855E+01 -.40902405E+01
V
          1
0.62070045E+02 0.67763596E+02 0.62070057E+02
0.47224145E+01 0.39924817E+01 0.47224178E+01
0.60642300E+02 0.65926804E+02 0.60642300E+02
          2
0.61393364E+02 0.66885941E+02 0.61393375E+02
0.31431139E+01 0.40461478E-05 0.31431084E+01
0.61393364E+02 0.66885941E+02 0.61393372E+02
          3
0.60642300E+02 0.65926788E+02 0.60642307E+02
0.47224154E+01 0.39924970E+01 0.47224107E+01
0.62070049E+02 0.67763596E+02 0.62070057E+02
          4
0.59817764E+02 0.64887329E+02 0.59817783E+02
0.77140694E+01 0.79801092E+01 0.77140646E+01
0.62671490E+02 0.68558701E+02 0.62671505E+02
DIPOLE
          1
-.71063533E+01 -.82073517E+01 -.71063566E+01
0.13941394E+02 0.16035473E+02 0.13941395E+02
-.58279729E+01 -.66958299E+01 -.58279734E+01
          2
-.64711041E+01 -.74561315E+01 -.64711075E+01
0.13949889E+02 0.16045246E+02 0.13949893E+02
-.64711041E+01 -.74561329E+01 -.64711056E+01
          3
-.58279710E+01 -.66958251E+01 -.58279753E+01
0.13941396E+02 0.16035471E+02 0.13941396E+02
-.71063547E+01 -.82073545E+01 -.71063557E+01
          4
-.51777382E+01 -.59273658E+01 -.51777420E+01
0.13915910E+02 0.16006161E+02 0.13915915E+02
-.77329435E+01 -.89485731E+01 -.77329464E+01
SOURCE
          1
0.13282224E+02 0.13282224E+02 0.13282224E+02
-.27761078E+02 -.27761078E+02 -.27761078E+02
0.11548039E+02 0.11548039E+02 0.11548039E+02
          2
0.12422699E+02 0.12422699E+02 0.12422699E+02
-.27778000E+02 -.27778000E+02 -.27778000E+02
0.12422699E+02 0.12422699E+02 0.12422699E+02
          3
0.11548039E+02 0.11548039E+02 0.11548039E+02
-.27761078E+02 -.27761078E+02 -.27761078E+02
0.13282224E+02 0.13282224E+02 0.13282224E+02
          4
0.10659310E+02 0.10659310E+02 0.10659310E+02
-.27710335E+02 -.27710335E+02 -.27710335E+02
```

```
0.14125566E+02 0.14125566E+02 0.14125566E+02
VX
          1
0.55497478E+02 0.60609600E+02 0.55497490E+02
0.00000000E+00 0.00000000E+00 0.00000000E+00
0.54227623E+02 0.58966724E+02 0.54227623E+02
          2
0.54895988E+02 0.59824604E+02 0.54896000E+02
0.00000000E+00 0.00000000E+00 0.00000000E+00
0.54895988E+02 0.59824604E+02 0.54895992E+02
          3
0.54227623E+02 0.58966713E+02 0.54227631E+02
0.00000000E+00 0.00000000E+00 0.00000000E+00
0.55497486E+02 0.60609600E+02 0.55497490E+02
          4
0.53493179E+02 0.58036991E+02 0.53493195E+02
0.00000000E+00 0.00000000E+00 0.00000000E+00
0.56031353E+02 0.61320766E+02 0.56031364E+02
VY
          1
0.16515386E+01 0.25034572E-05 -.16515337E+01
-.31411970E+01 -.71527359E-06 0.31411958E+01
0.13018178E+01 0.35763674E-06 -.13018171E+01
          2
0.14775776E+01 0.25034572E-05 -.14775727E+01
-.31431139E+01 -.28610943E-05 0.31431084E+01
0.14775797E+01 0.10729102E-05 -.14775777E+01
          3
0.13018135E+01 0.32187306E-05 -.13018070E+01
-.31411912E+01 0.00000000E+00 0.31411915E+01
0.16515408E+01 0.71527347E-06 -.16515394E+01
          4
0.11244692E+01 0.28610939E-05 -.11244636E+01
-.31354547E+01 -.35763678E-05 0.31354477E+01
0.18234897E+01 0.21458204E-05 -.18234855E+01
VZ
          1
0.27748739E+02 0.30304800E+02 0.27748745E+02
-.35261989E+01 -.39924817E+01 -.35262046E+01
-.27113811E+02 -.29483362E+02 -.27113811E+02
          2
0.27447994E+02 0.29912302E+02 0.27448000E+02
0.00000000E+00 0.28610227E-05 -.38146970E-05
-.27447994E+02 -.29912302E+02 -.27447996E+02
          3
0.27113811E+02 0.29483356E+02 0.27113815E+02
0.35262055E+01 0.39924970E+01 0.35261989E+01
-.27748743E+02 -.30304800E+02 -.27748745E+02
          4
0.26746590E+02 0.29018496E+02 0.26746597E+02
0.70481052E+01 0.79801092E+01 0.70481033E+01
-.28015676E+02 -.30660383E+02 -.28015682E+02
P_STAT
          1
0.99437844E+05 0.98985070E+05 0.99437844E+05
0.10178395E+06 0.10178785E+06 0.10178395E+06
0.99545156E+05 0.99135477E+05 0.99545156E+05
          2
0.99489016E+05 0.99057453E+05 0.99489016E+05
0.10179156E+06 0.10179762E+06 0.10179156E+06
```

```
0.99489016E+05 0.99057453E+05 0.99489016E+05
          3
0.99545156E+05 0.99135484E+05 0.99545156E+05
0.10178395E+06 0.10178785E+06 0.10178395E+06
0.99437844E+05 0.98985070E+05 0.99437844E+05
          4
0.99605992E+05 0.99218766E+05 0.99605984E+05
0.10176116E+06 0.10175861E+06 0.10176116E+06
0.99391891E+05 0.98918688E+05 0.99391891E+05
P_DYNA
          1
0.23597729E+04 0.28125417E+04 0.23597739E+04
0.13659485E+02 0.97631950E+01 0.13659503E+02
0.22524617E+04 0.26621353E+04 0.22524617E+04
          2
0.23086013E+04 0.27401592E+04 0.23086023E+04
0.60509887E+01 0.10027429E-10 0.60509677E+01
0.23086013E+04 0.27401592E+04 0.23086021E+04
          3
0.22524617E+04 0.26621340E+04 0.22524624E+04
0.13659491E+02 0.97632694E+01 0.13659462E+02
0.23597732E+04 0.28125417E+04 0.23597739E+04
          4
0.21916262E+04 0.25788489E+04 0.21916274E+04
0.36447956E+02 0.39005314E+02 0.36447910E+02
0.24057258E+04 0.28789309E+04 0.24057271E+04
P_MANO
          1
-.18871573E+04 -.23399260E+04 -.18871583E+04
0.45895609E+03 0.46285239E+03 0.45895605E+03
-.17798462E+04 -.21895198E+04 -.17798462E+04
          2
-.18359858E+04 -.22675435E+04 -.18359867E+04
0.46656458E+03 0.47261557E+03 0.46656461E+03
-.18359858E+04 -.22675435E+04 -.18359863E+04
          3
-.17798462E+04 -.21895186E+04 -.17798467E+04
0.45895605E+03 0.46285229E+03 0.45895612E+03
-.18871576E+04 -.23399260E+04 -.18871583E+04
          4
-.17190106E+04 -.21062332E+04 -.17190120E+04
0.43616763E+03 0.43361026E+03 0.43616766E+03
-.19331102E+04 -.24063154E+04 -.19331113E+04
end
```

First, let us discuss contents of results file. First informations, airspeed, density... are taken from input file, although angles are in radians here. Next are coefficients and forces (airframe coordinate system) for complete configuration (all components summed) and for all cases:

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

Next are informations for each component separately. For each component following order of data is written:

- Component geometry – coordinates of nodes; X, Y and Z
- Collocation node coordinates; COLX, COLY and COLZ
- Aerodynamic coefficients (airframe coordinate system); CX_COMP, CY_COMP, CZ_COMP, CL_COMP, CM_COMP and CN_COMP
- Aerodynamic forces (airframe coordinate system); FX_COMP, FY_COMP, FZ_COMP, FL_COMP, FM_COMP and FN_COMP
- Next are mesh characteristics:
  - S – panel surfaces
  - FF – far field factors
  - N1_VECTOR, N2_VECTOR,N3_VECTOR normal vector components in x,y and z directions
  - U1_VECTOR, U2_VECTOR,U3_VECTOR longitudinal vector components in x,y and z directions
  - P1_VECTOR, P2_VECTOR,P3_VECTOR lateral vector components in x,y and z directions
  - O1_VECTOR, O2_VECTOR,O3_VECTOR perpendicular vector components in x,y and z directions
- Pressure distribution; CP. In case of multiple AOA's or sideslip angles, data is written for each case defined by case number, in our situation there are four block of data for each angle of attack
- Velocity distribution; V. Same rules for case numbers (here, and for next values) applies as for CP
- Doublet strengths; DIPOLE
- Source strengths (in case of constant doublet/constant source method); SOURCE
- Velocity components; VX,VY and VZ
- Static pressure; P_STAT
- Dynamic pressure; P_DYNA
- and finally, Manometer pressure; P_MANO

Pressure, velocity and the rest of panel data are given at collocation nodes (for each panel), not each node!

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 airstream is flowing sideways).

Normal force coefficient (CZ) increases 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. USING APAME SOLVER WITH APAME-WCS

APAME-WCS is wing coefficients solver in which user can define basic wing parameters and calculate its coefficients (derivatives) for longitudinal behavior. Wing is simple trapezoidal, swept with geometric and aerodynamic twist. User can use external airfoil data defined through file, or use internal van de Vooren airfoil generator (based on Katz, Plotkin; Low Speed Aerodynamics).

APAME-WCS is written in Scilab and all processor-intensive tasks are basically in APAME solver. Since all of the required operations (pre and post-processing) can be easily done in Scilab, other languages (such as Matlab) are not supported from now on. Scilab is free software similar to Matlab and available at http://www.scilab.org/.

Open Scilab and change current directory to:

```
<apame_install_dir>/apame_V2.2/WCS
```

Here, you open apame_wcs.sci Scilab script.

Modify following lines accordingly:

```
// geometry
span = 5;               // wing span                    [m]
croot = 1;              // root chord length            [m]
ctip = 0.3;             // tip chord length             [m]
tipAL = -3*pi/180;      // tip angle of attack          [degrees]
lambda14 = 30*pi/180;   // wing sweep (1/4 wing)        [degrees]
mode = 1;                     // 0=external file, 1=van de Vooren airfoil
(internal)
if mode == 0
    r_foil = "66415_60.DAT";    // root airfoil data
    t_foil = "66415_60.DAT";    // tip airfoil data
elseif mode == 1
    thickness_r = 0.05;         // thickness of root airfoil
    trailing_angle_r = 15;      // trailing angle of root airfoil
    thickness_t = 0.03;         // thickness of tip airfoil
    trailing_angle_t = 12;      // trailing angle of tip airfoil
end

// solver parameters
method = 0;             // singularity method: 0=const sourc/doubl, 1=const
doubl
farpoint = 1000;        // farpoint distance for trailing wake  [m]
err = 1E-07;            // error
farfieldfaktor = 5;     // "far field" distance in longer panel diagonal
collcalc = 1;            // collocation point calculation: 0=approximative,
1=accurate
velorder = 1;           // interpolation order: 1-first, 2-second
velometh = 1;           // interpolation method: 0-directional, 1-surface
Mp = 15;                // number of panels on halfspan
if mode == 1
    N = 60;             // number of panels on airfoil
end

// flow parameters
V = 27.778;                 // reference speed          [m/s]
AL = [0 2 4]*pi/180;        // angle of attack          [degrees]
ro = 1.225;                 // air density              [kg/m^3]
p_ref = 101325;             // atmospheric pressure     [Pa]
mach = 0;                   // prandtl-glauert correction: 0=no correction,
*=Mach number
find_ac = 0;                  // 1=find aerodynamic center, 0=use following
values
origin = [0 0 0];           // reference point
```

Most of the values required for calculation are already known from APAME input file except for the first ones which define simple wing geometry. They need not be explained here as they are all known values and explained in script.

News here is van de Vooren airfoil generator (Scilab routine) and external file selector in case user wants to use his own airfoil data. Van de Vooren airfoil is not practical for any use, however creates airfoil for which analytical solution of potential flow is available and therefore could be of interest in testing our solutions. External data is simple ASCII file with point coordinates in two columns; x and z (please check one of those file inside WCS folder).

Also, it is important to modify lines 134 and 136 according to your system and available APAME solver executables. Here, it is assumed that executables are located in default places.

At the end of the script, at line 157 and 159, we choose which field shall we display graphically, in this case leave cp for pressure coefficient distribution.

When you have completed editing apame_wcs.sci Scilab script, you will execute it by clicking to Execute → Load into Scilab, or by pressing Ctrl+l. If successful, following text and figure should be displayed:

```
Preparing input file time in seconds:

   0.193

APAME solver time in seconds:

   1.396

Lift coefficient slope Cl_alfa=

   4.747439

Lift coefficient at zero AOA Cl_alfa_0=

 - 0.0517790

Lift coefficient at minimum drag Cl_minCd=

 - 0.0502643

Oswald coefficient e=

   1.020871

Moment coefficient slope Cm_alfa=

 - 4.3301501

Moment coefficient at zero angle of attack Cm_alfa_0=

   0.0632430

Time for post-processing in seconds:

   0.577
```

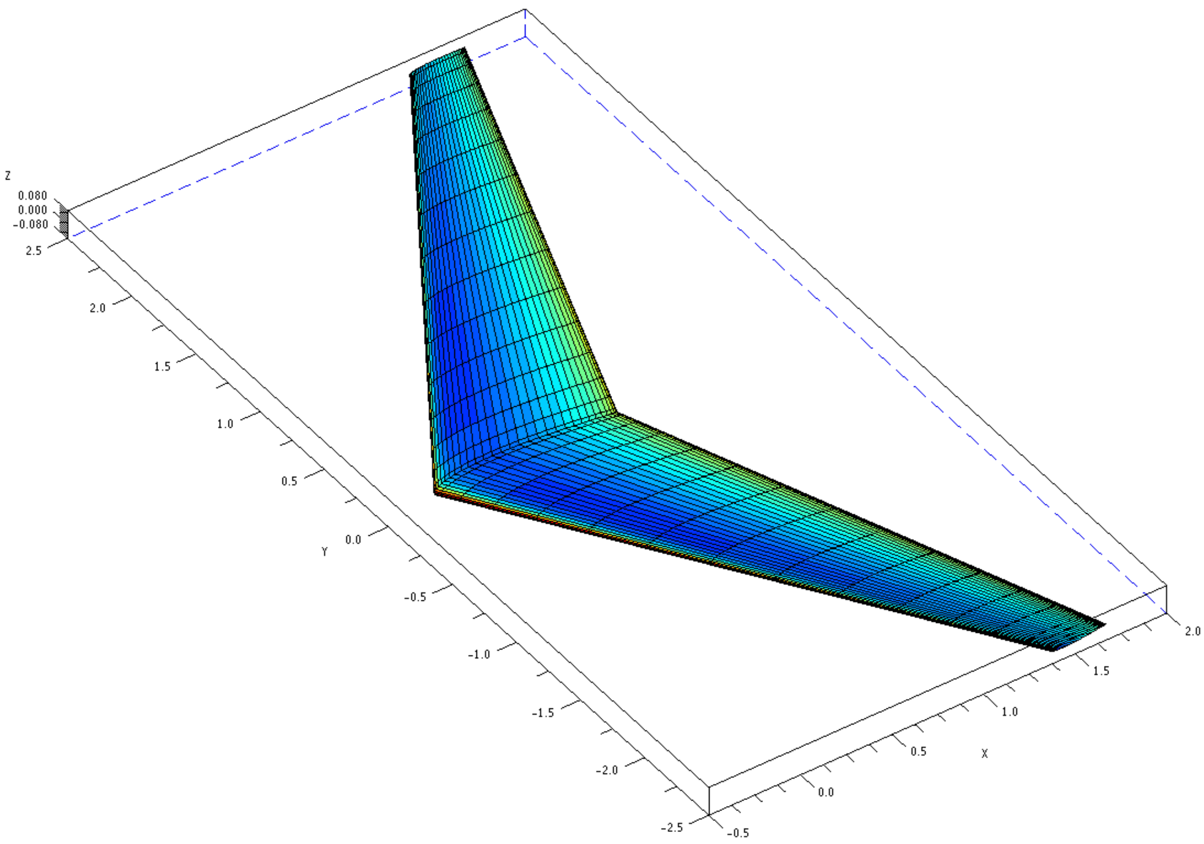

Figure 2.1 Pressure distribution for simple wing