

Airfoil Analysis: XFOIL

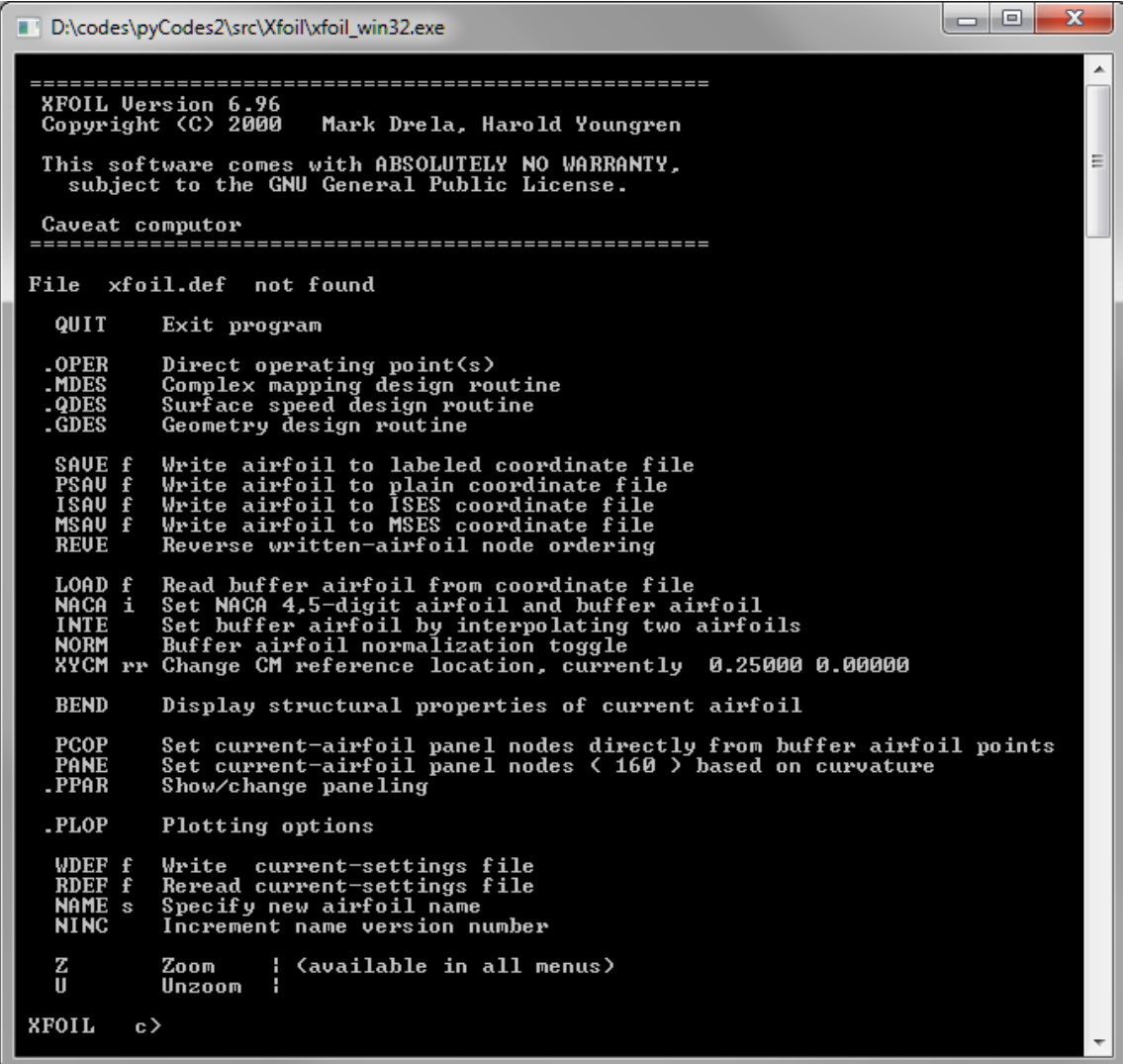
- Viscous (or inviscid) analysis of an existing airfoil, allowing
 - forced or free transition
 - transitional separation bubbles
 - limited trailing edge separation
 - lift and drag predictions just beyond CL_{max}
 - Karman-Tsien compressibility correction
 - fixed or varying Reynolds and/or Mach numbers
- Airfoil design and redesign by interactive modification of surface speed distributions, in two methods:
 - Full-Inverse method, based on a complex-mapping formulation
 - Mixed-Inverse method, an extension of XFOIL's basic panel method
- Airfoil redesign by interactive modification of geometric parameters such as
 - max thickness and camber, highpoint position
 - LE radius, TE thickness
 - camber line via geometry specification
 - camber line via loading change specification
 - flap deflection
 - explicit contour geometry (via screen cursor)
- Blending of airfoils
- Writing and reading of airfoil coordinates and polar save files
- Plotting of geometry, pressure distributions, and multiple polars
- <http://web.mit.edu/drela/Public/web/xfoil/>



XFOIL Interface

- XFOIL is an interactive program for the design and analysis of subsonic isolated airfoils.
- Analysis is performed using text user's interface (keyboard input).

NOTE: input command will be shown using
Magenta bold monospace font



```
D:\codes\pyCodes2\src\Xfoil\xfail_win32.exe

=====
XFOIL Version 6.96
Copyright (C) 2000 Mark Drela, Harold Youngren

This software comes with ABSOLUTELY NO WARRANTY,
subject to the GNU General Public License.

Caveat computer
=====

File xfoil.def not found

QUIT      Exit program

.OPER      Direct operating point(s)
.MDES      Complex mapping design routine
.QDES      Surface speed design routine
.GDES      Geometry design routine

SAVE f     Write airfoil to labeled coordinate file
PSAU f     Write airfoil to plain coordinate file
ISAU f     Write airfoil to ISES coordinate file
MSAU f     Write airfoil to MSES coordinate file
REVE       Reverse written-airfoil node ordering

LOAD f     Read buffer airfoil from coordinate file
NACA i     Set NACA 4,5-digit airfoil and buffer airfoil
INTE       Set buffer airfoil by interpolating two airfoils
NORM       Buffer airfoil normalization toggle
XYCM rr    Change CM reference location, currently 0.25000 0.00000

BEND       Display structural properties of current airfoil

PCOP       Set current-airfoil panel nodes directly from buffer airfoil points
PANE       Set current-airfoil panel nodes < 160 > based on curvature
.PPAR      Show/change paneling

.PLOP      Plotting options

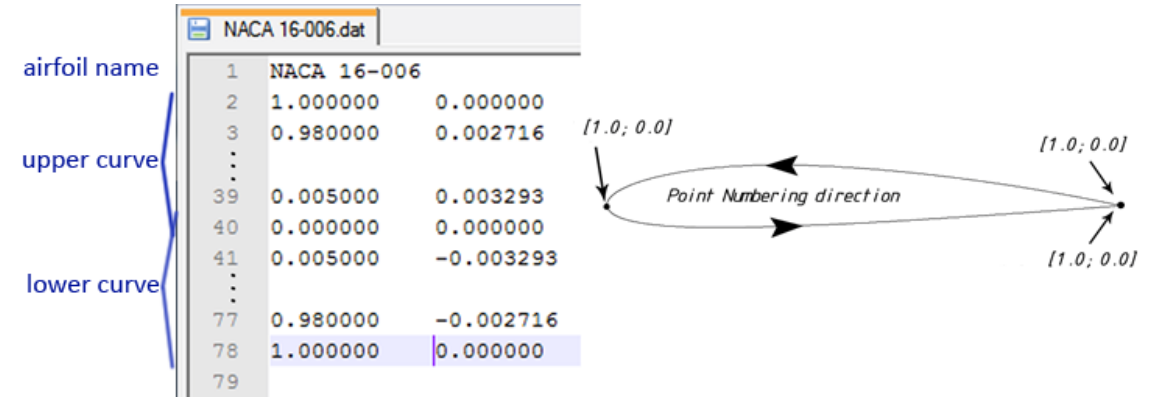
WDEF f     Write current-settings file
RDEF f     Reread current-settings file
NAME s     Specify new airfoil name
NINC       Increment name version number

Z          Zoom      ! <available in all menus>
U          Unzoom    !

XFOIL  c>
```

Load Airfoil

- Load airfoil from text file
 - **LOAD filename.txt**
 - filename.txt – name of the coordinates file
- Use NACA 4-series airfoil
 - **NACA XXXX**
 - XXXX – 4 digit code for NACA airfoil (example 2312)



NOTE:

In XFOIL, the X and Y coordinate delimiter is Space, not tab.

Analysis

- **OPER** – direct analysis routine
- **?** – will produce list of available commands

```
D:\codes\pyCodes2\src\Xfoil\Xfoil_win32.exe
.OPERi  c> ?

<cr>      Return to Top Level
!         Redo last ALFA,CLI,CL,ASEQ,CSEQ,UELS

Uisc r    Toggle Inviscid/Viscous mode
UPAR      Change BL parameter(s)
Re r      Change Reynolds number
Mach r    Change Mach number
Type i    Change type of Mach,Re variation with CL
ITER      Change viscous-solution iteration limit
INIT      Toggle BL initialization flag

Alfa r    Prescribe alpha
CLI r     Prescribe inviscid CL
CL r      Prescribe CL
ASEq rrr  Prescribe a sequence of alphas
CSeq rrr  Prescribe a sequence of CLs

SEQP      Toggle polar/Cp(x) sequence plot display
CINC      Toggle minimum Cp inclusion in polar
HINC      Toggle hinge moment inclusion in polar
Pacc i    Toggle auto point accumulation to active polar
PGET f    Read new polar from save file
PWRT i    Write polar to save file
PSUM      Show summary of stored polars
PLIS i    List stored polar(s)
PDEL i    Delete stored polar
PSOR i    Sort stored polar
PPlo ii   Plot stored polar(s)
APlo ii   Plot stored airfoil(s) for each polar
ASET i    Copy stored airfoil into current airfoil
PREM ir   Remove point(s) from stored polar
PNAM i    Change airfoil name of stored polar
PPAX      Change polar plot axis limits

RGET f    Read new reference polar from file
RDEL i    Delete stored reference polar

GRID      Toggle Cp vs x grid overlay
CREF      Toggle reference Cp data overlay
FREF      Toggle reference CL,CD.. data display

CPx       Plot Cp vs x
CPU       Plot airfoil with pressure vectors (gee wiz)
UPlo      BL variable plots
ANNO      Annotate current plot
HARD      Hardcopy current plot
SIZE r    Change plot-object size
CPMI r    Change minimum Cp axis annotation

BL i      Plot boundary layer velocity profiles
BLC       Plot boundary layer velocity profiles at cursor
BLWT r    Change velocity profile scale weight

FMOM      Calculate flap hinge moment and forces
FNEW rr   Set new flap hinge point
UELS rr   Calculate velocity components at a point
DUMP f    Output Ue,Dstar,Theta,Cf vs s,x,y to file
CPWR f    Output x vs Cp to file
CPMN      Report minimum surface Cp
NAME s    Specify new airfoil name
NINC      Increment name version number

.OPERi  c>
```

Set Analysis Parameters

- **VISC** – toggle viscous/inviscid mode
- If viscous mode is enabled, need to enter Reynolds number
- **Mach** – set Mach number to account for compressibility effect.
- **PACC polar.txt** – enables accumulation of polar to text file. All analysis runs will be stored to polar.txt textfile

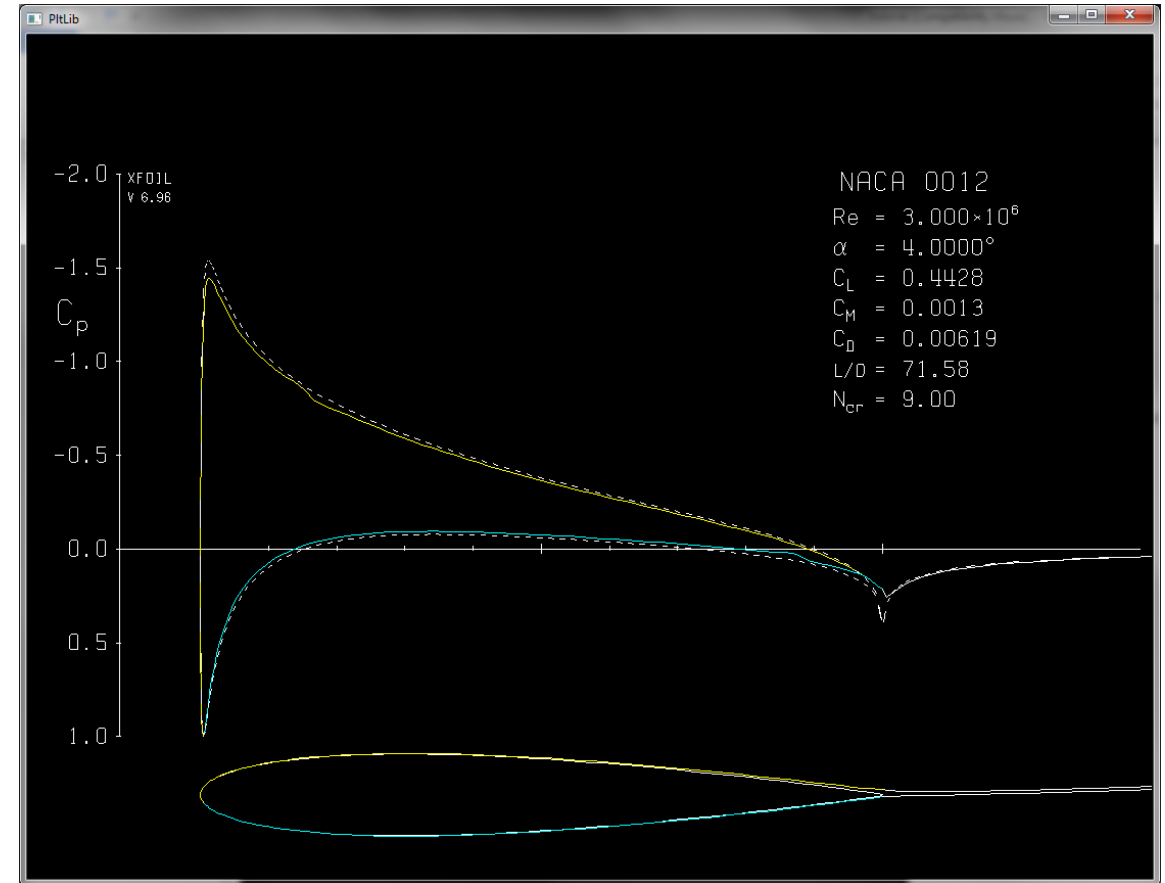
Analysis at Given α

- **ALFA 4** – runs analysis of current airfoil at given angle of attack.

Solid line – viscous
pressure distribution

Dashed - inviscid

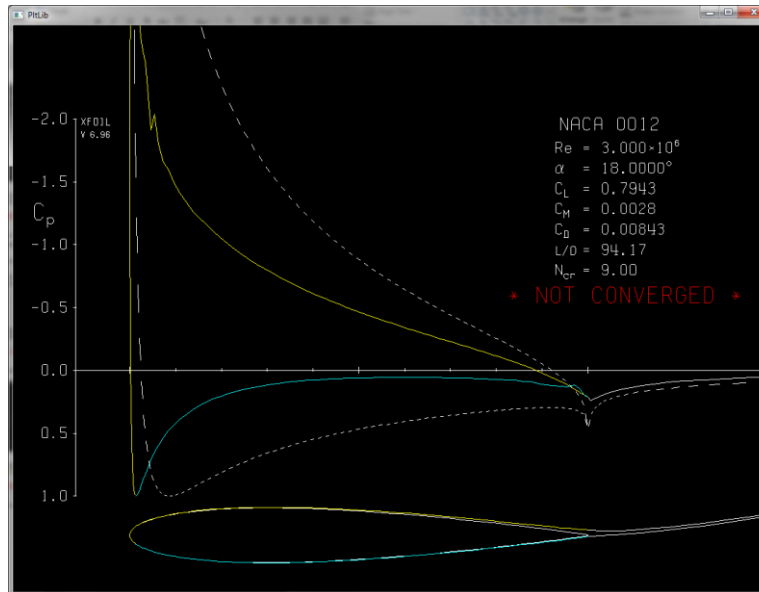
- **CPWR filename.txt** – saves C_p vs. x/c distribution to text file



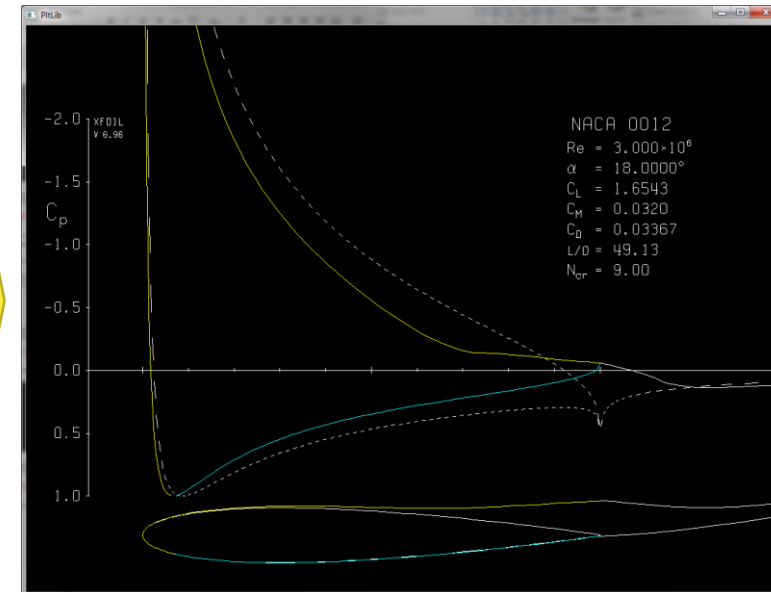
Improve Convergence

- **ITER** – set number of iterations if XFOIL failed to converge

ALFA 18 – not converged

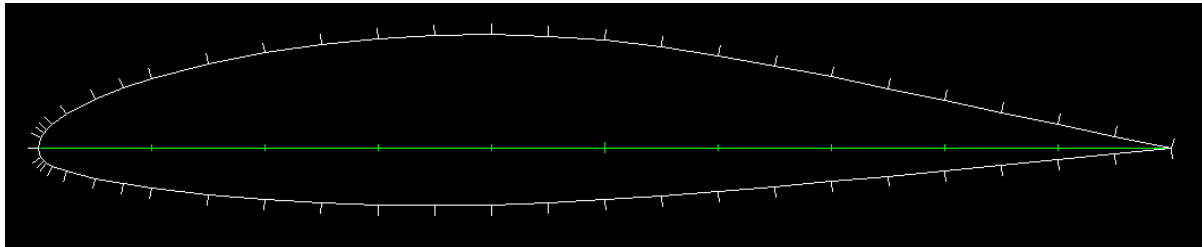


ITER 50 – set number of iterations to 50
ALFA 18 – converged

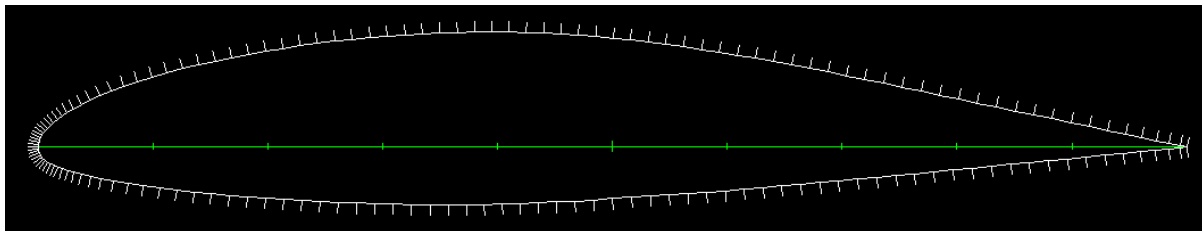


Smooth Airfoil

- **PANE** – automatically smooth airfoil if number of points is too low
 - Xfoil determines number of points required to



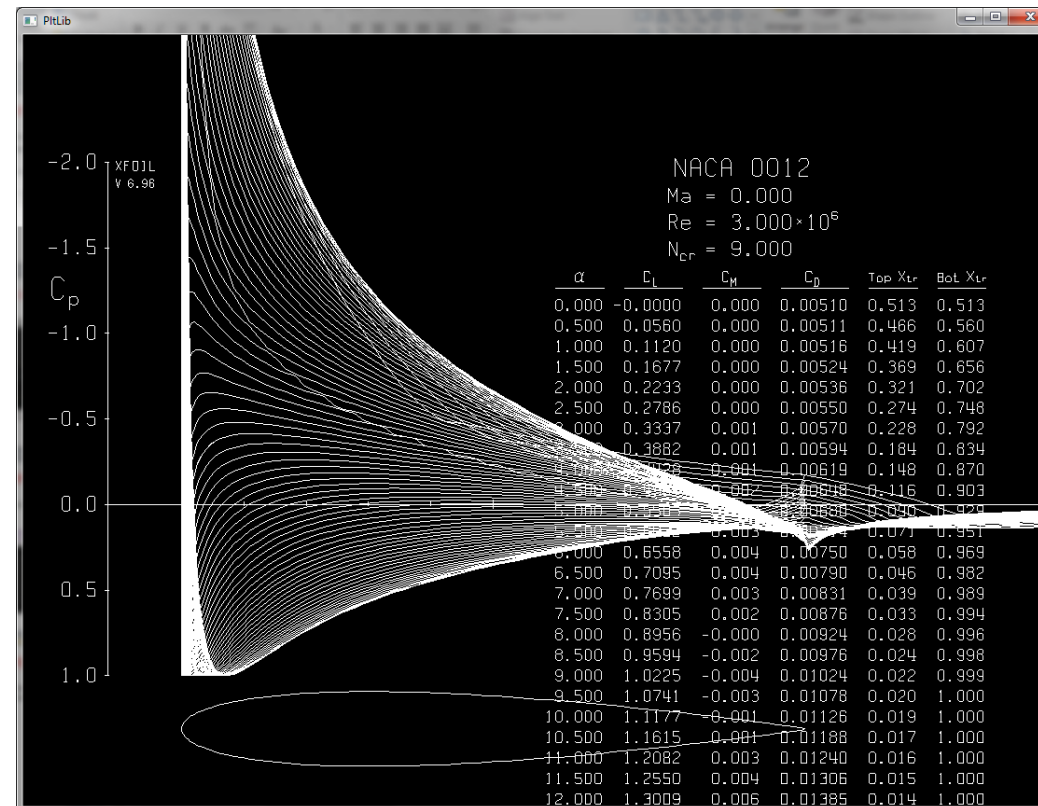
Airfoil loaded from
text file



Smoothed airfoil

Run for Series of Angles of Attack

- **ASEQ 0 20 0.5** – runs XFOIL for sequence of angles of attack from 0 to 20 with 0.5-degree increment



Run Case

- Run XFOIL.exe
- **LOAD GA37A315.txt** – load airfoil from text file
- **OPER** – enter analysis routine
- **VISC 3000000** – enable viscous flow analysis and set Reynolds number to 3×10^6
- **Mach 0.3** – set Mach number to 0.3
- **PACC newPolar.txt** – enable results accumulation to text file
- **“Enter”** – press enter to disable dump file
- **ASEQ 0 20 0.5** – run analysis at angles of attack from 0 to 20 with 0.5 degree increment
- **PACC** – disable polar accumulation
- **“Enter”** – go to one level up
- **QUIT** – exit the program