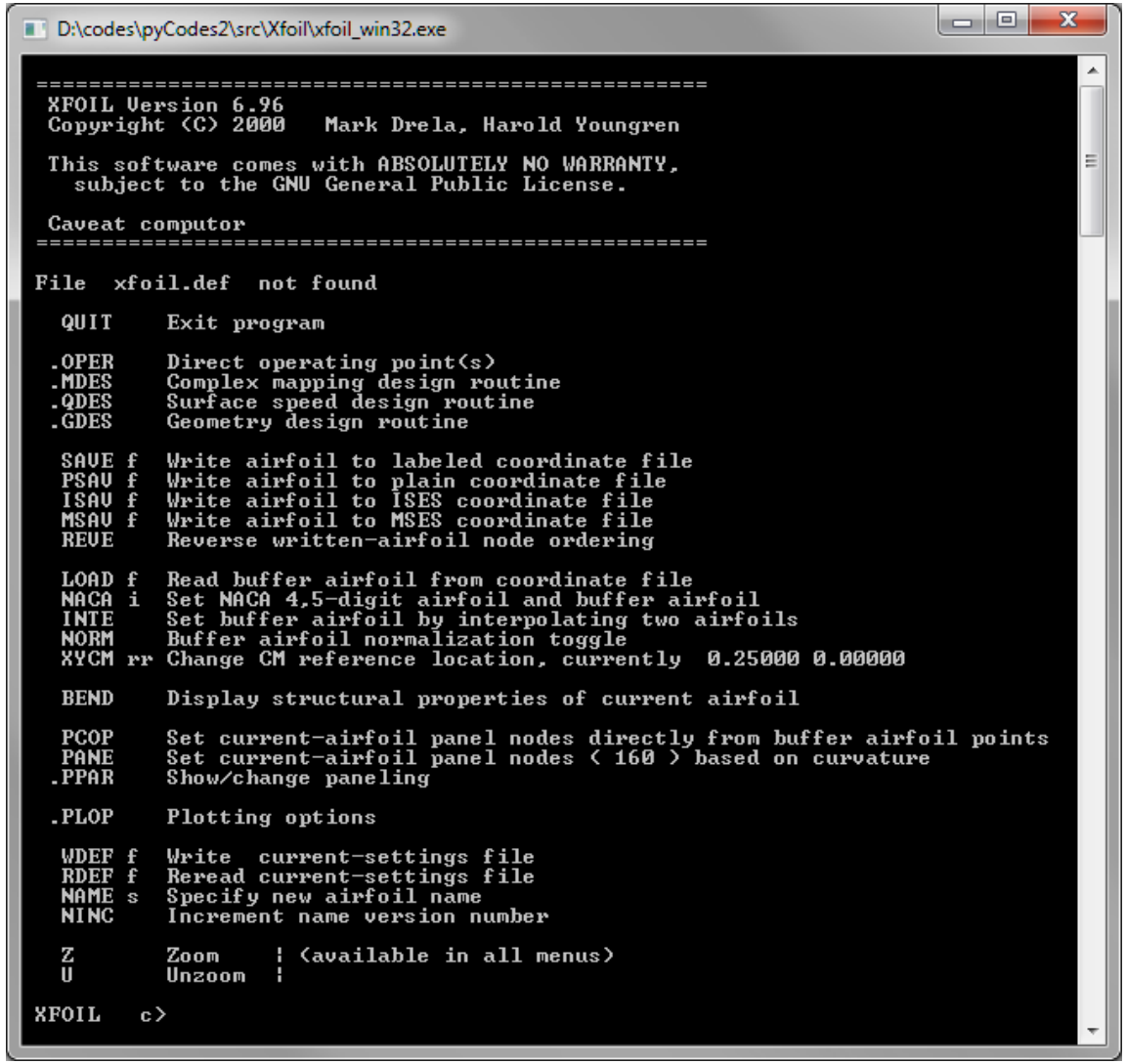
# Airfoil Analysis: XFOIL


- 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 CLmax
  - 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

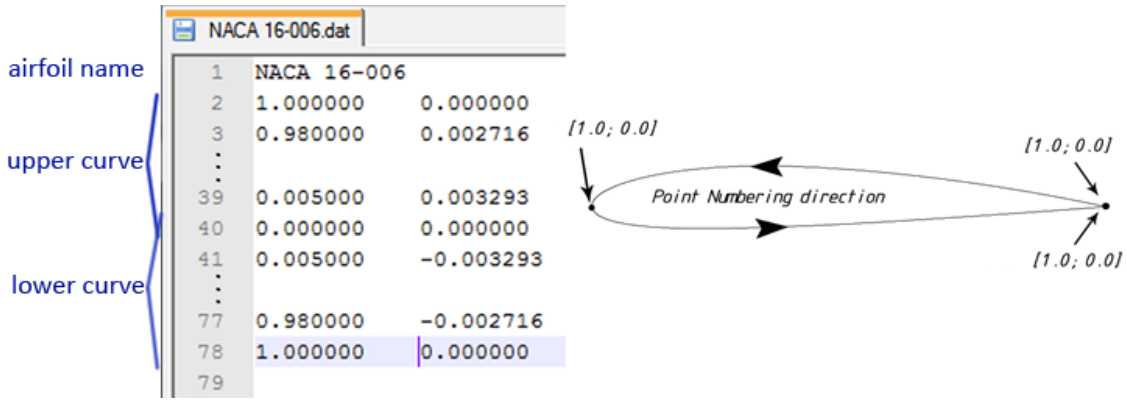
- XFOIL is an interactive program for the design and analysis of subsonic isolated airfoils.
- Analysis is performed using text user's interface (keyboard input).




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

# 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

# Set Analysis Parameters

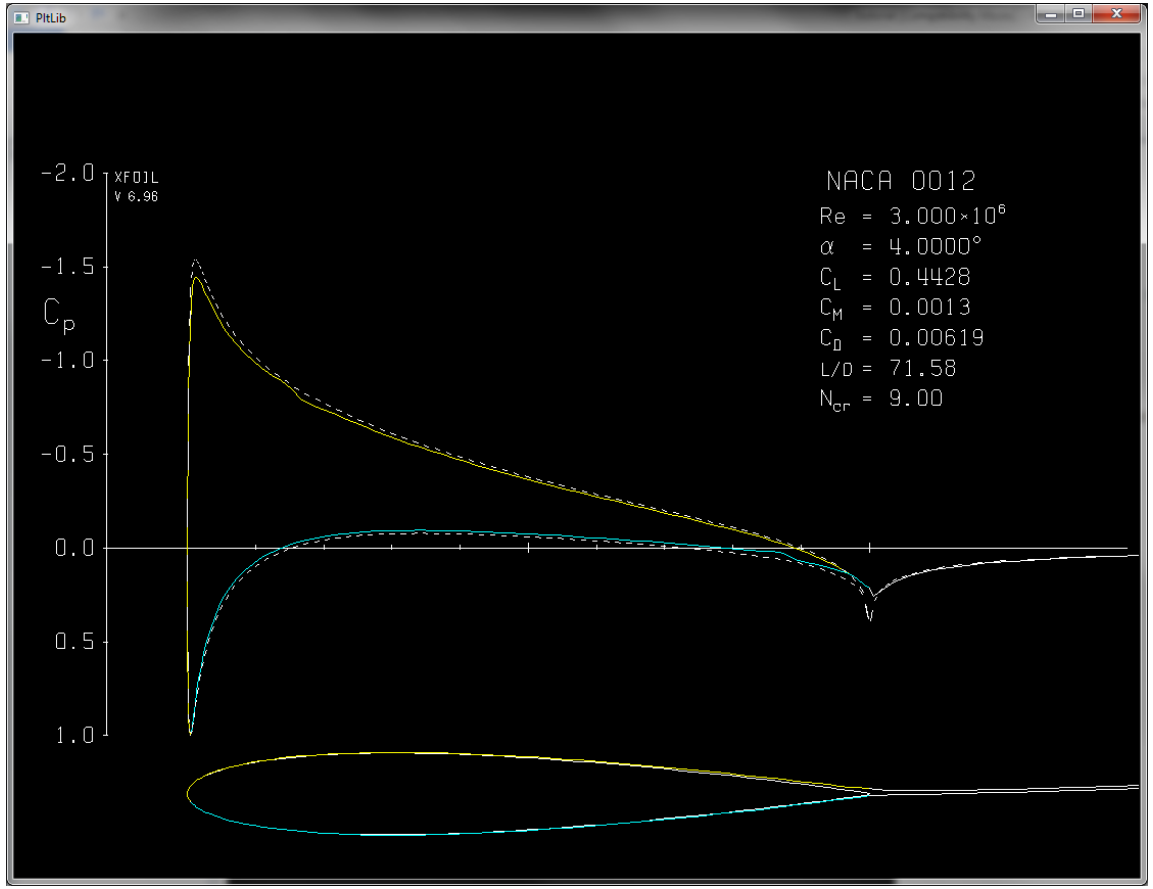
- `VISC` – toggle viscous/inviscid mode
- If viscous mode is enabled, need to enter Reynolds number
- `Mach` – set Mach number to account for compressibility effect.
- `PACC polar.txt` – enables accumulation of polar to text file. All analysis runs will be stored to polar.txt textfile

# Analysis at Given α

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

Solid line – viscous pressure distribution

Dashed - inviscid

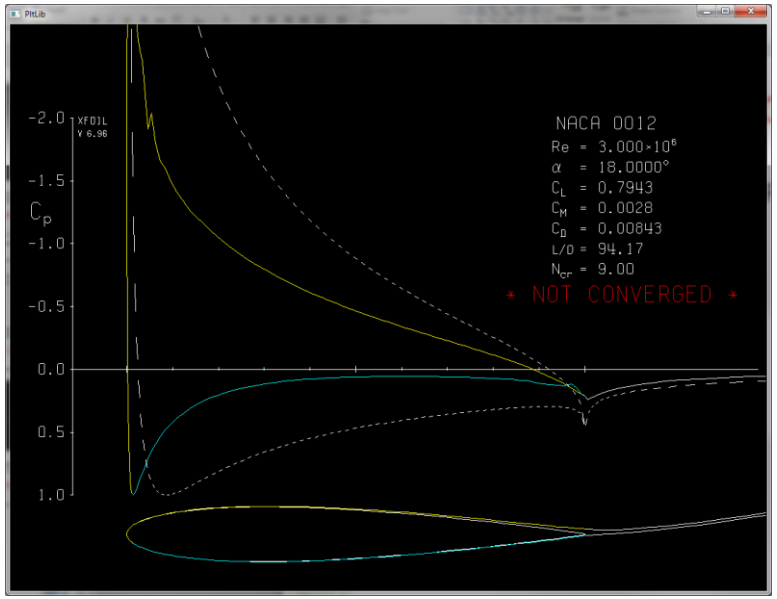



- **`CPWR filename.txt`** – saves $C_P\ vs.\ x/c$ distribution to text file

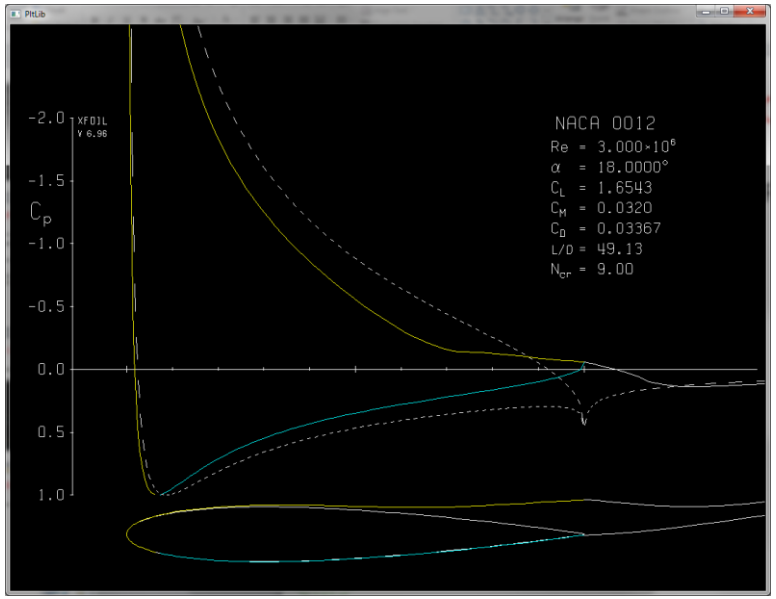
# Improve Convergence

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

**ALFA 18** – not converged

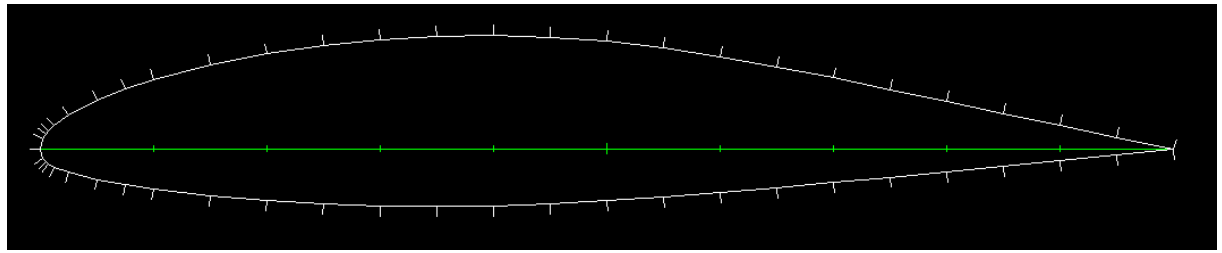



**ITER 50** – set number of iterations to 50
**ALFA 18** – converged

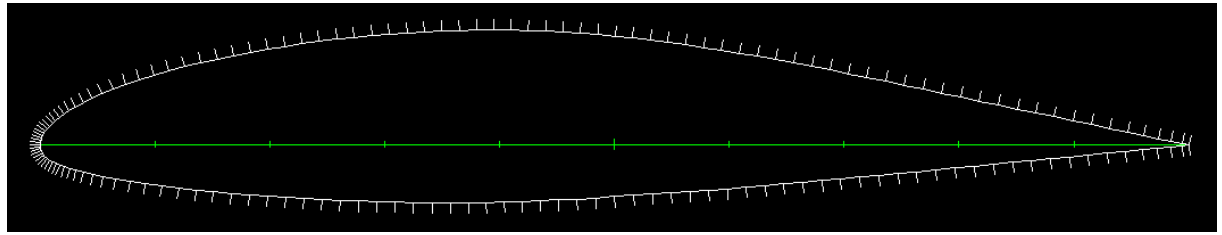


# Smooth Airfoil

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



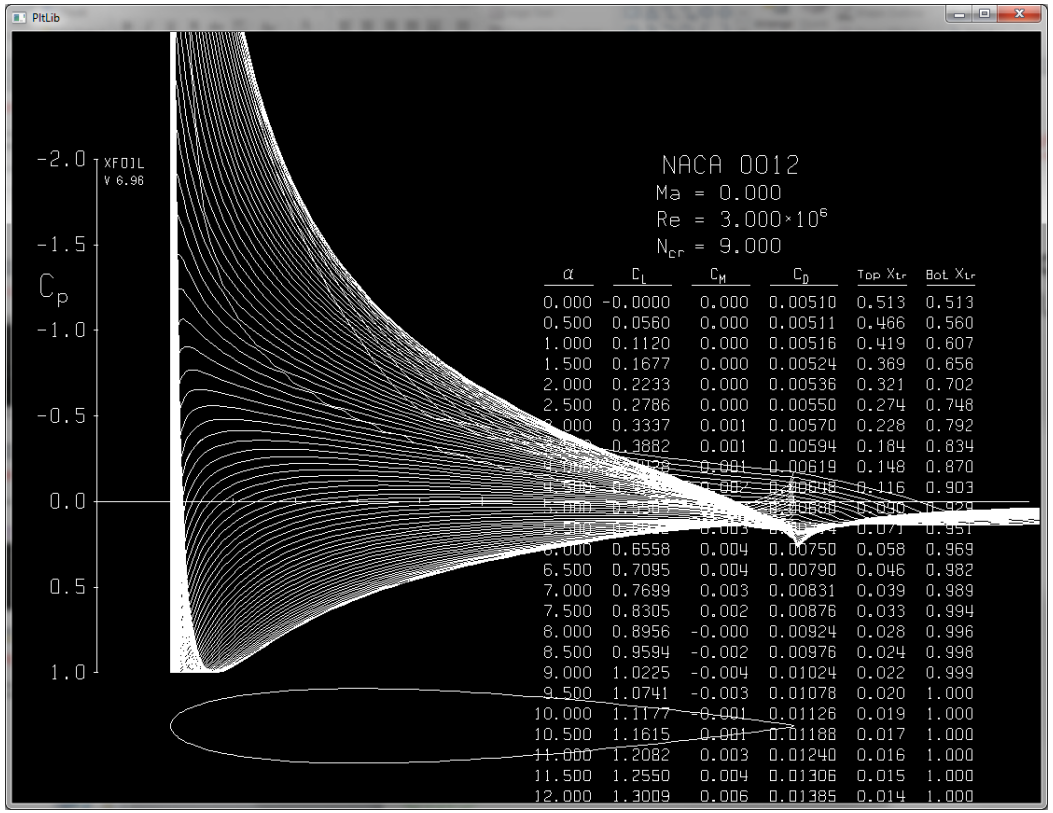
Airfoil loaded from text file



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




| α | $C_L$ | $C_M$ | $C_D$ | Top $X_{tr}$ | Bot $X_{tr}$ |
|---|---|---|---|---|---|
| 0.000 | -0.0000 | 0.000 | 0.00510 | 0.513 | 0.513 |
| 0.500 | 0.0560 | 0.000 | 0.00511 | 0.466 | 0.560 |
| 1.000 | 0.1120 | 0.000 | 0.00516 | 0.419 | 0.607 |
| 1.500 | 0.1677 | 0.000 | 0.00524 | 0.369 | 0.656 |
| 2.000 | 0.2233 | 0.000 | 0.00536 | 0.321 | 0.702 |
| 2.500 | 0.2786 | 0.000 | 0.00550 | 0.274 | 0.748 |
| 3.000 | 0.3337 | 0.001 | 0.00570 | 0.228 | 0.792 |
| 3.500 | 0.3882 | 0.001 | 0.00594 | 0.184 | 0.834 |
| 4.000 | 0.4428 | 0.001 | 0.00619 | 0.148 | 0.870 |
| 4.500 | 0.4970 | 0.002 | 0.00648 | 0.116 | 0.903 |
| 5.000 | 0.5510 | 0.003 | 0.00684 | 0.090 | 0.929 |
| 5.500 | 0.6048 | 0.003 | 0.00714 | 0.071 | 0.951 |
| 6.000 | 0.6558 | 0.004 | 0.00750 | 0.058 | 0.969 |
| 6.500 | 0.7095 | 0.004 | 0.00790 | 0.046 | 0.982 |
| 7.000 | 0.7699 | 0.003 | 0.00831 | 0.039 | 0.989 |
| 7.500 | 0.8305 | 0.002 | 0.00876 | 0.033 | 0.994 |
| 8.000 | 0.8956 | -0.000 | 0.00924 | 0.028 | 0.996 |
| 8.500 | 0.9594 | -0.002 | 0.00976 | 0.024 | 0.998 |
| 9.000 | 1.0225 | -0.004 | 0.01024 | 0.022 | 0.999 |
| 9.500 | 1.0741 | -0.003 | 0.01078 | 0.020 | 1.000 |
| 10.000 | 1.1177 | -0.001 | 0.01126 | 0.019 | 1.000 |
| 10.500 | 1.1615 | 0.001 | 0.01188 | 0.017 | 1.000 |
| 11.000 | 1.2082 | 0.003 | 0.01240 | 0.016 | 1.000 |
| 11.500 | 1.2550 | 0.004 | 0.01306 | 0.015 | 1.000 |
| 12.000 | 1.3009 | 0.006 | 0.01385 | 0.014 | 1.000 |

# 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 $3 \times 10^6$
- `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