Subsonic Airfoils

W.H. Mason

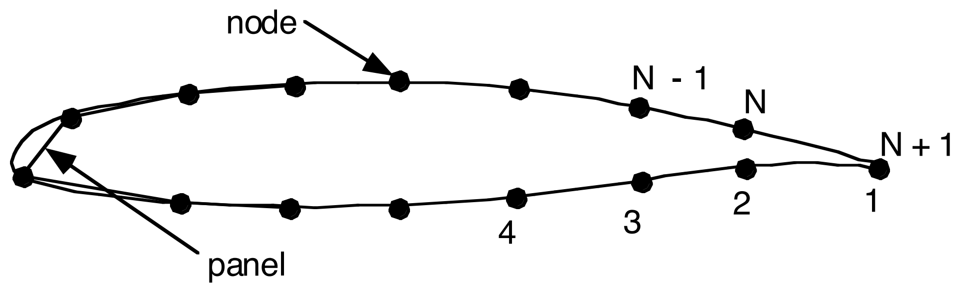
Configuration Aerodynamics Class

Most people don't realize that mankind can be divided into two great classes: those who take airfoil selection seriously, and those who don't.

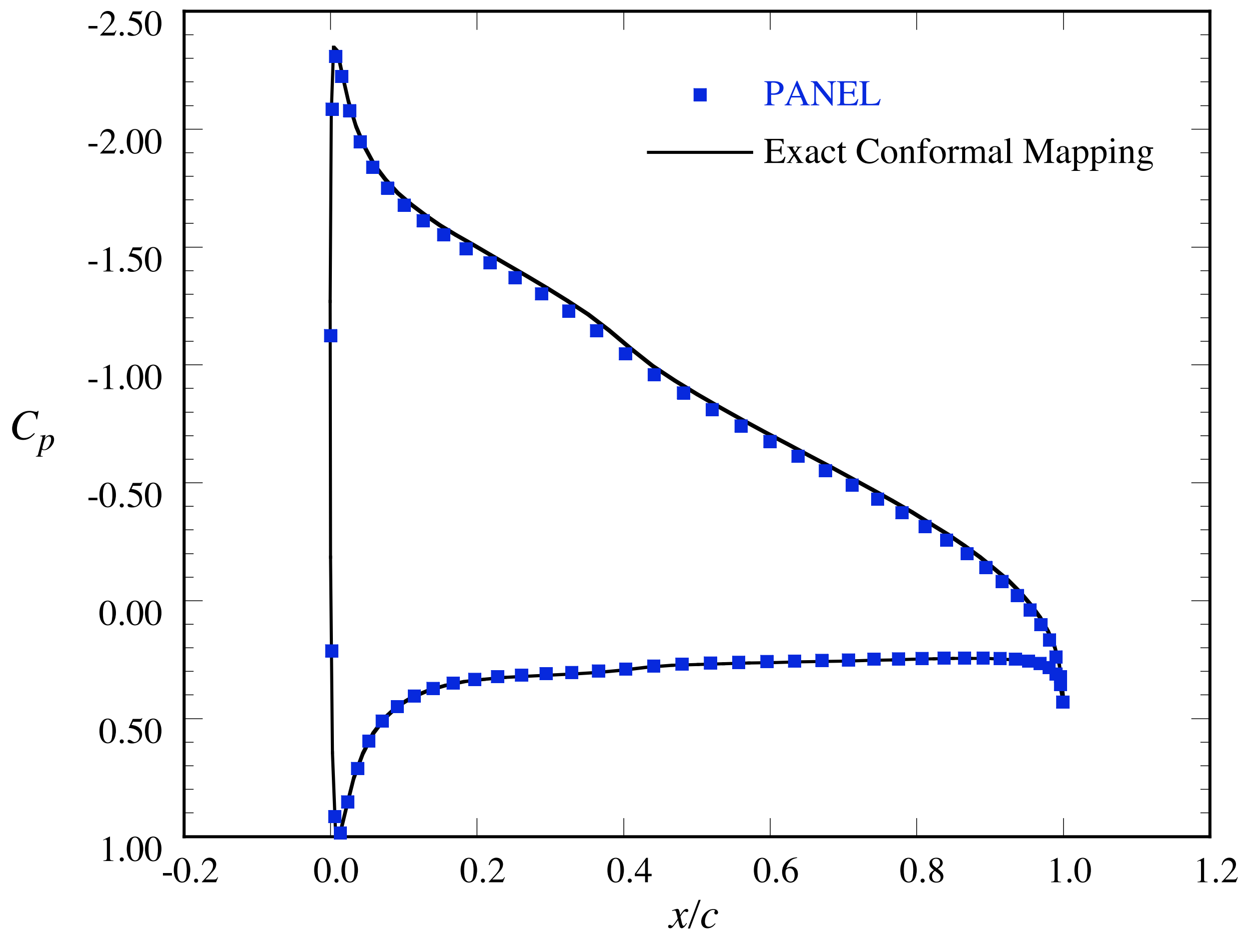
Peter Garrison, *Flying*, Sept. 2002

Typical Subsonic Methods: Panel Methods

- For subsonic inviscid flow, the flowfield can be found by solving an integral equation for the potential on the surface
- This is done assuming a distribution of singularities along the surface, and finding the "strengths" of the singularities
- The airfoil is represented by a series of (typically) straight line segments between "nodes", and the nonpenetration boundary condition is typically satisfied at control points
- Some version of a Kutta condition is required to close the system of equations.



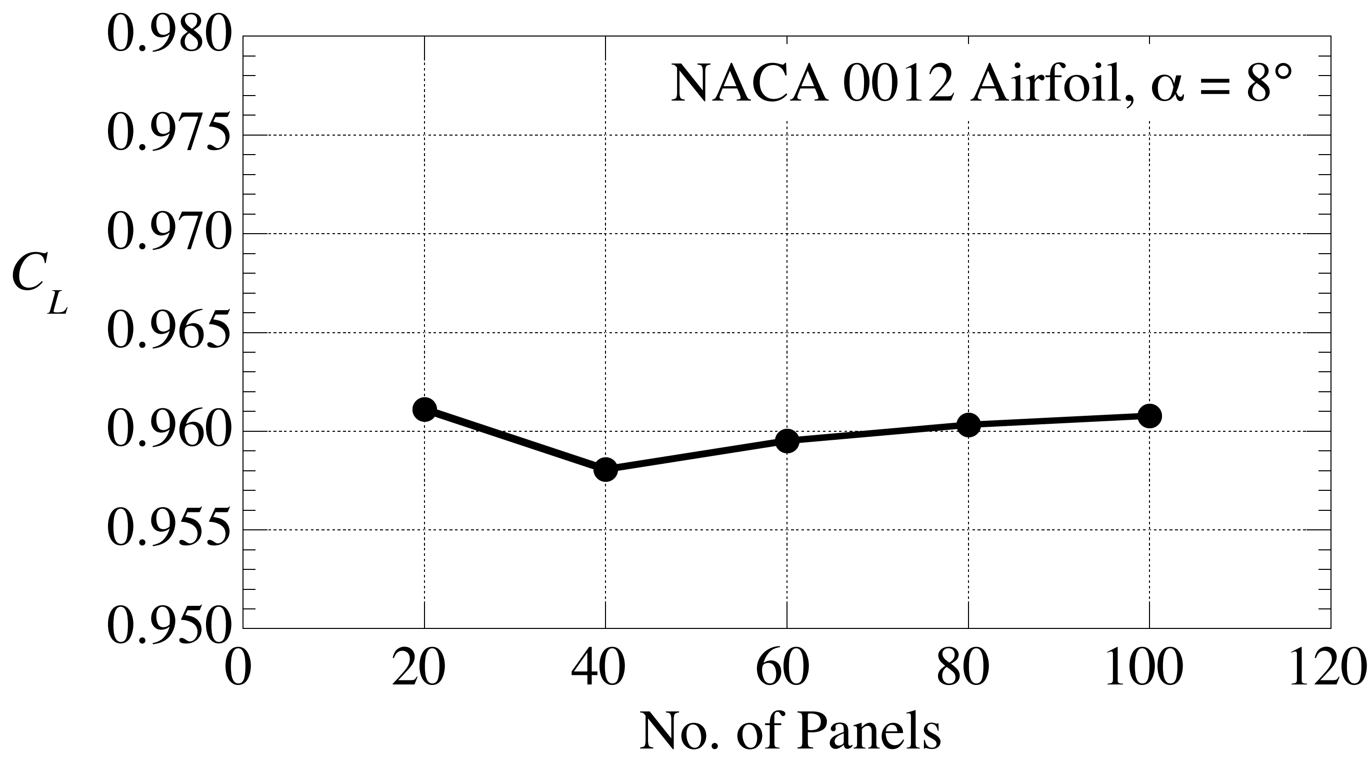
Comparison of Panel Method Pressure Distribution with Exact Conformal Transformation Results



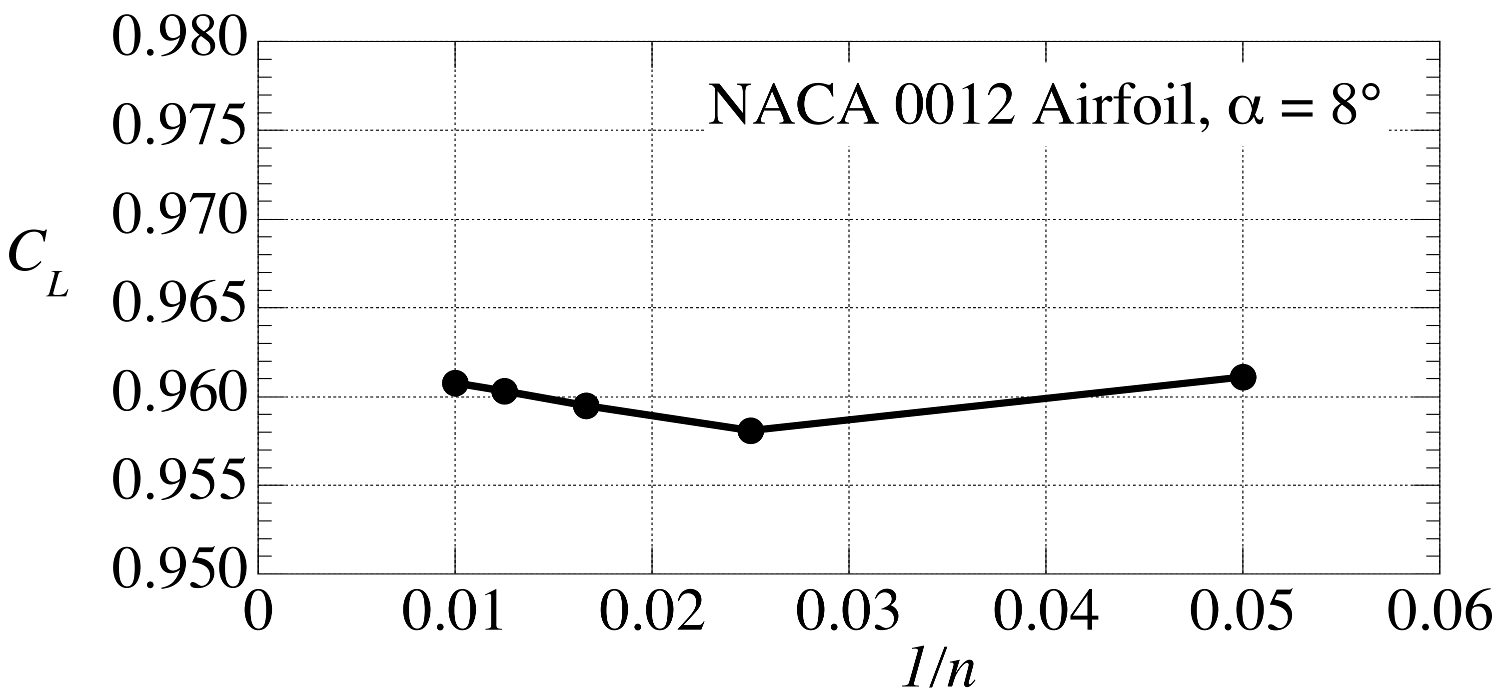
XFOIL's inviscid calculations use a panel method

The conformal mapping solution is from Antony Jameson

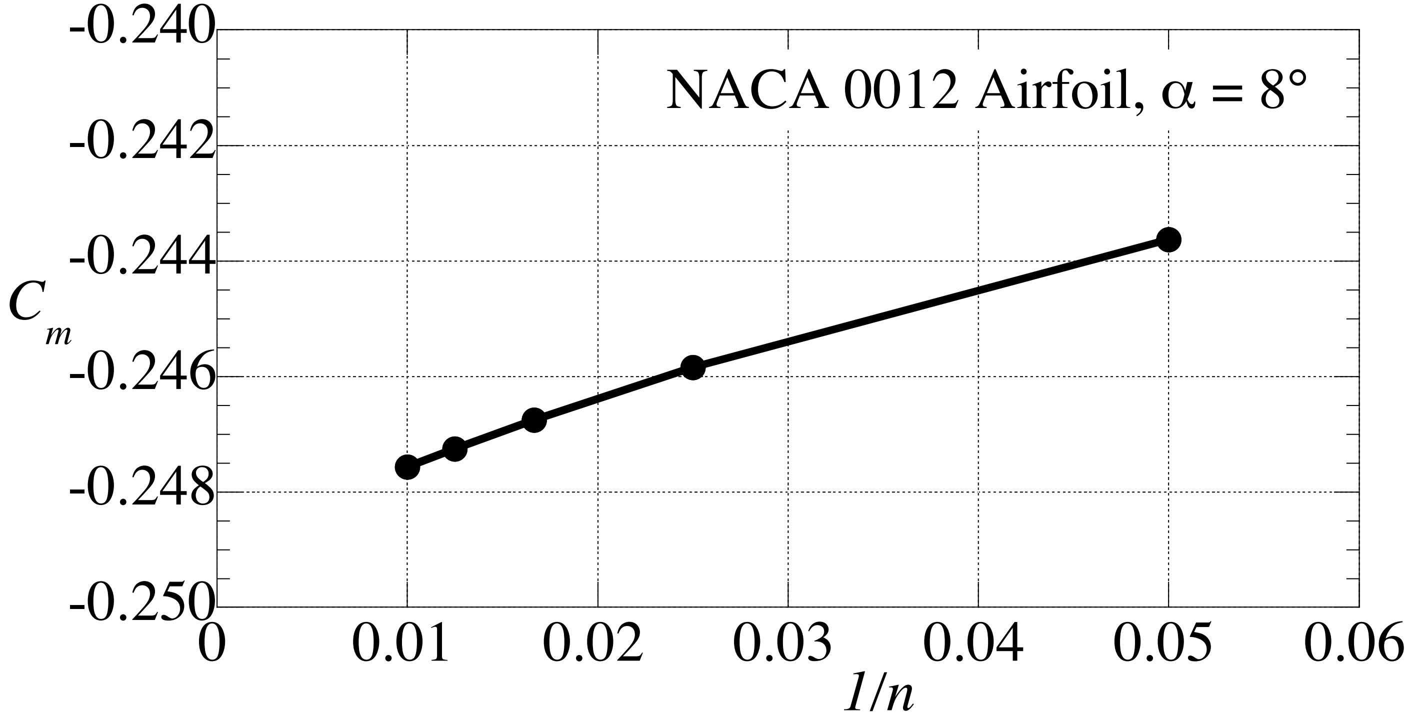
Convergence with increasing numbers of panels



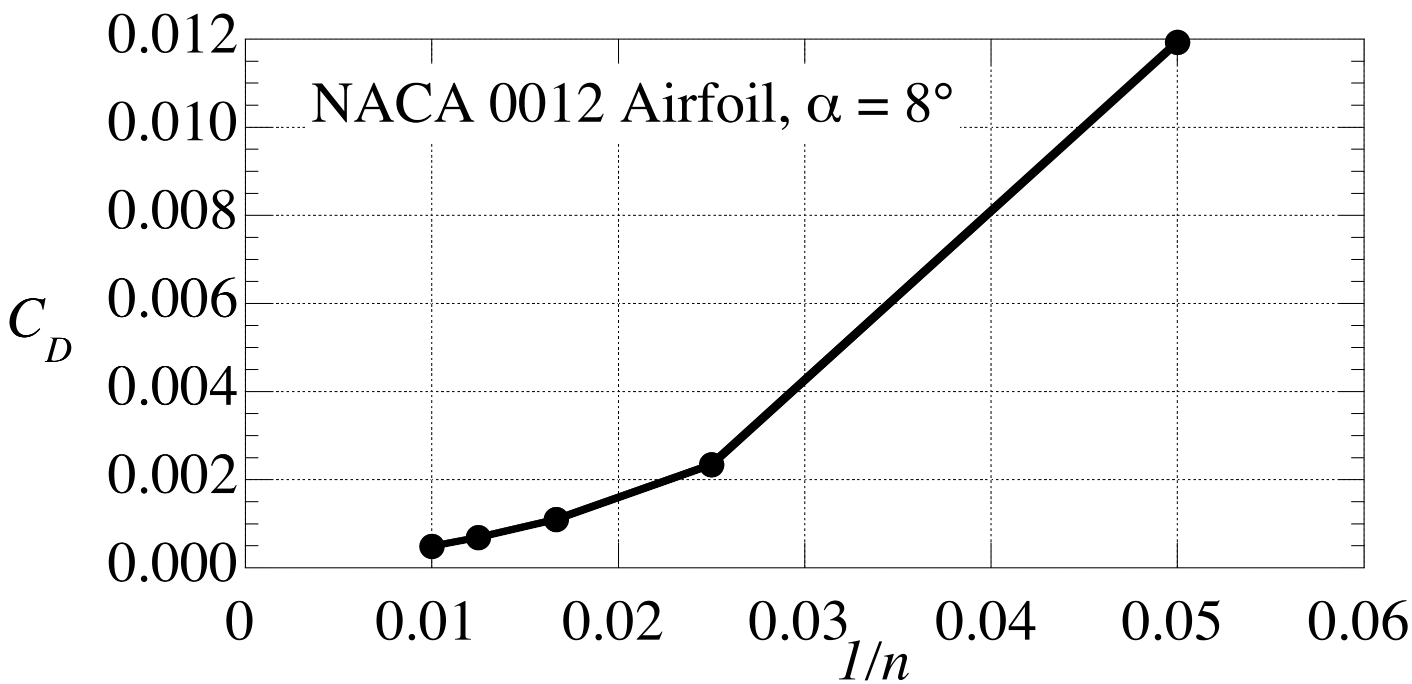
A better way to examine convergence: Lift



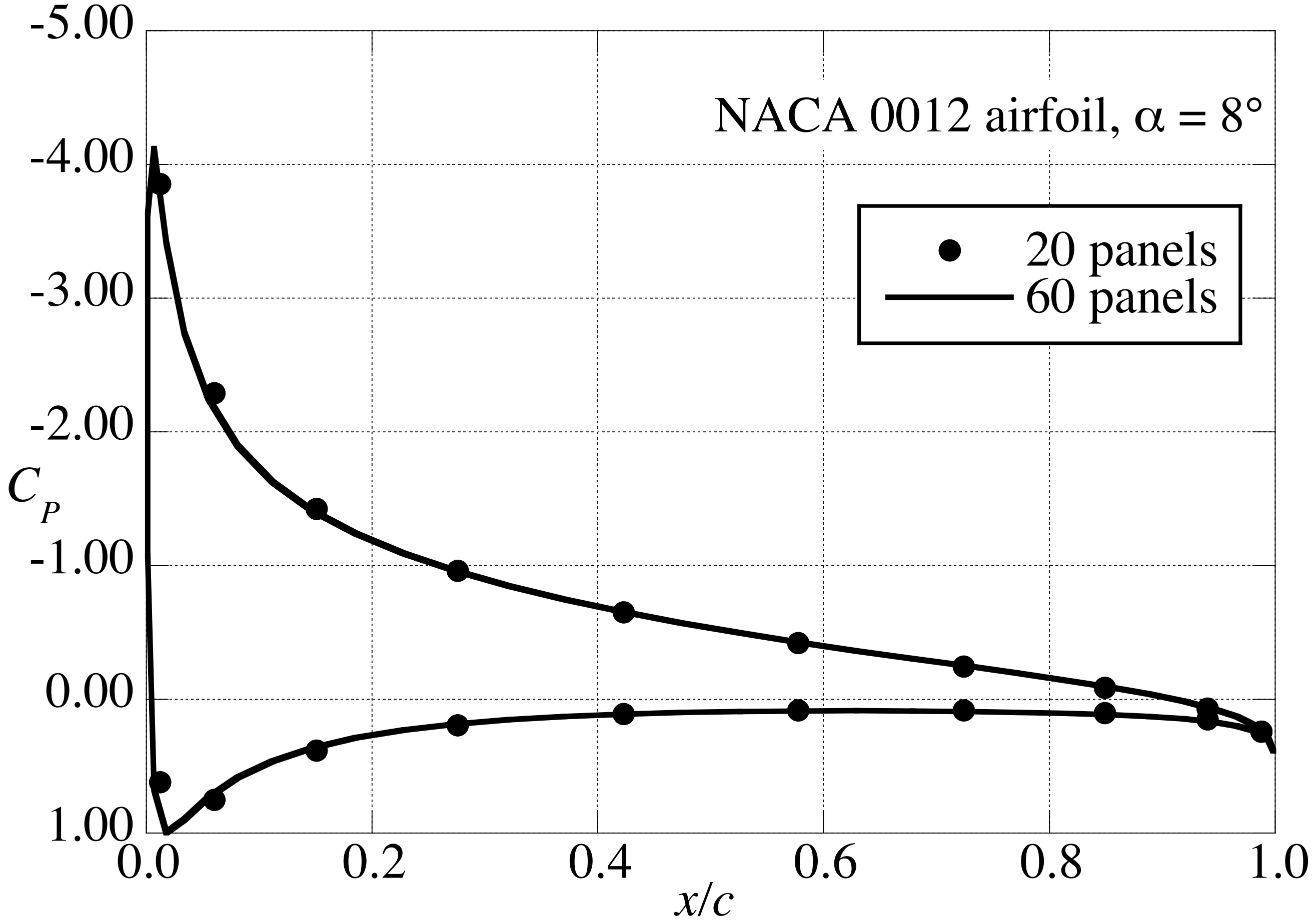
Convergence with Panels: Moment



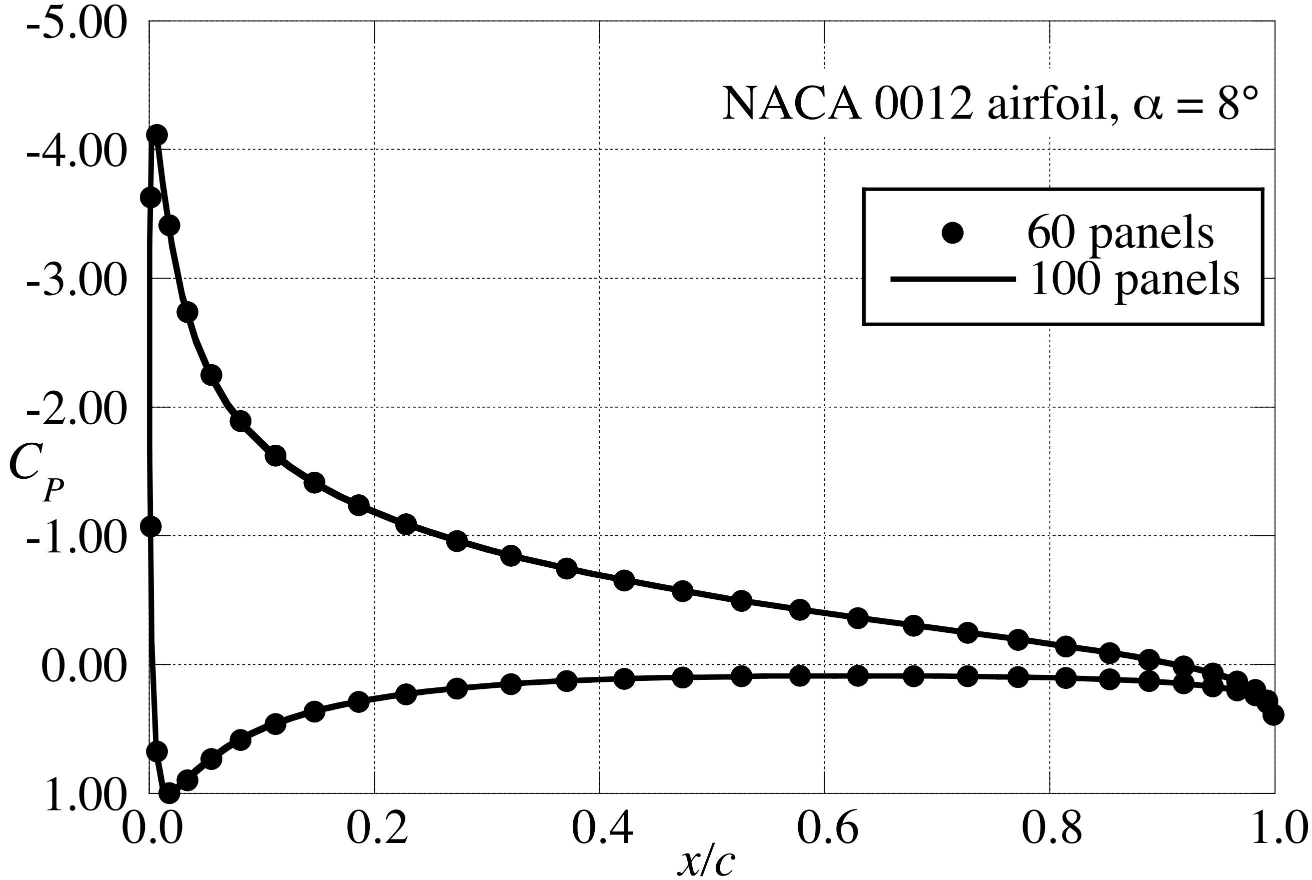
Convergence with Panels: Drag



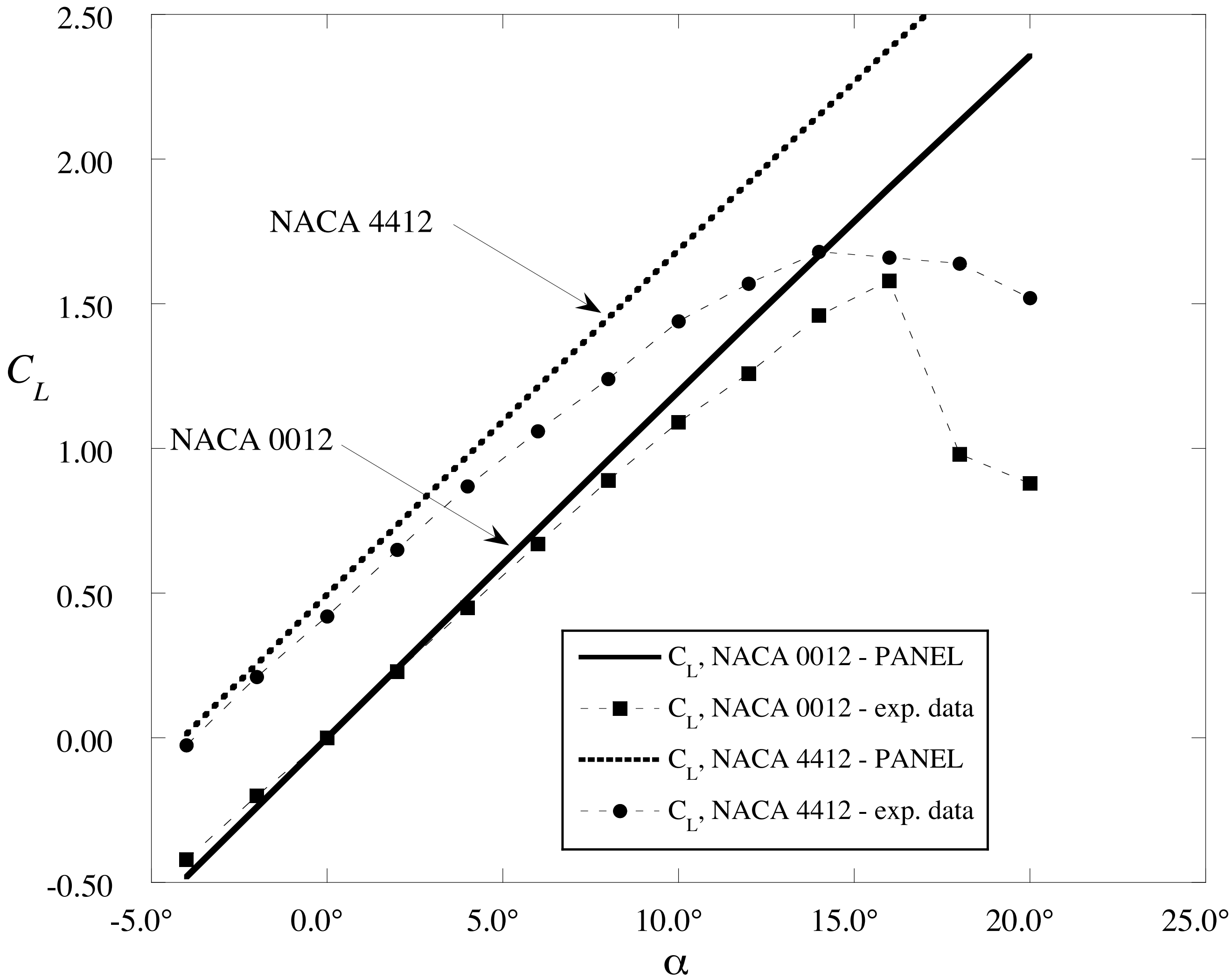
Pressures: 20 and 60 panels



Pressures: 60 and 100 panels

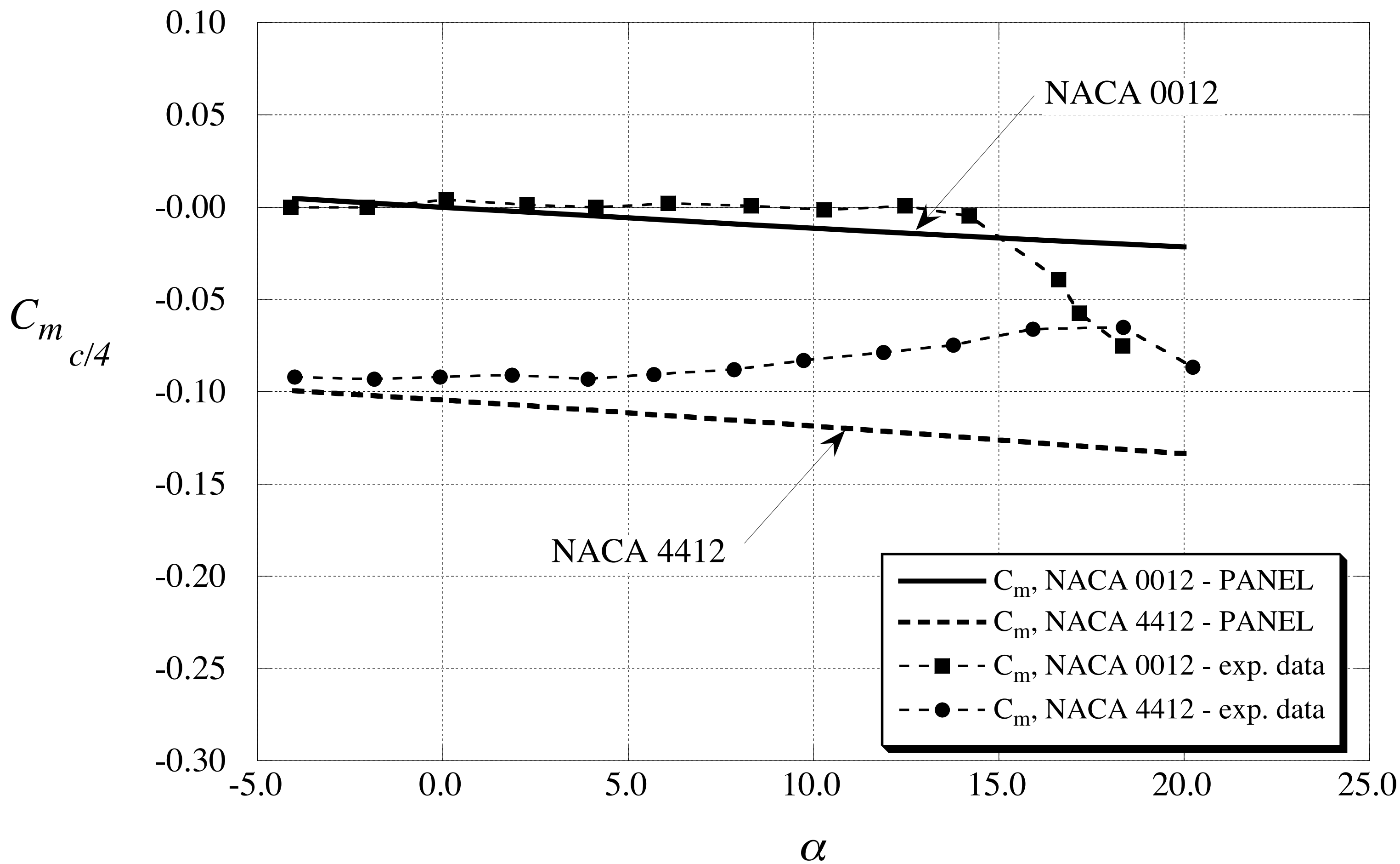


Comparison with WT Data: Lift
- recall: panel methods are inviscid! -

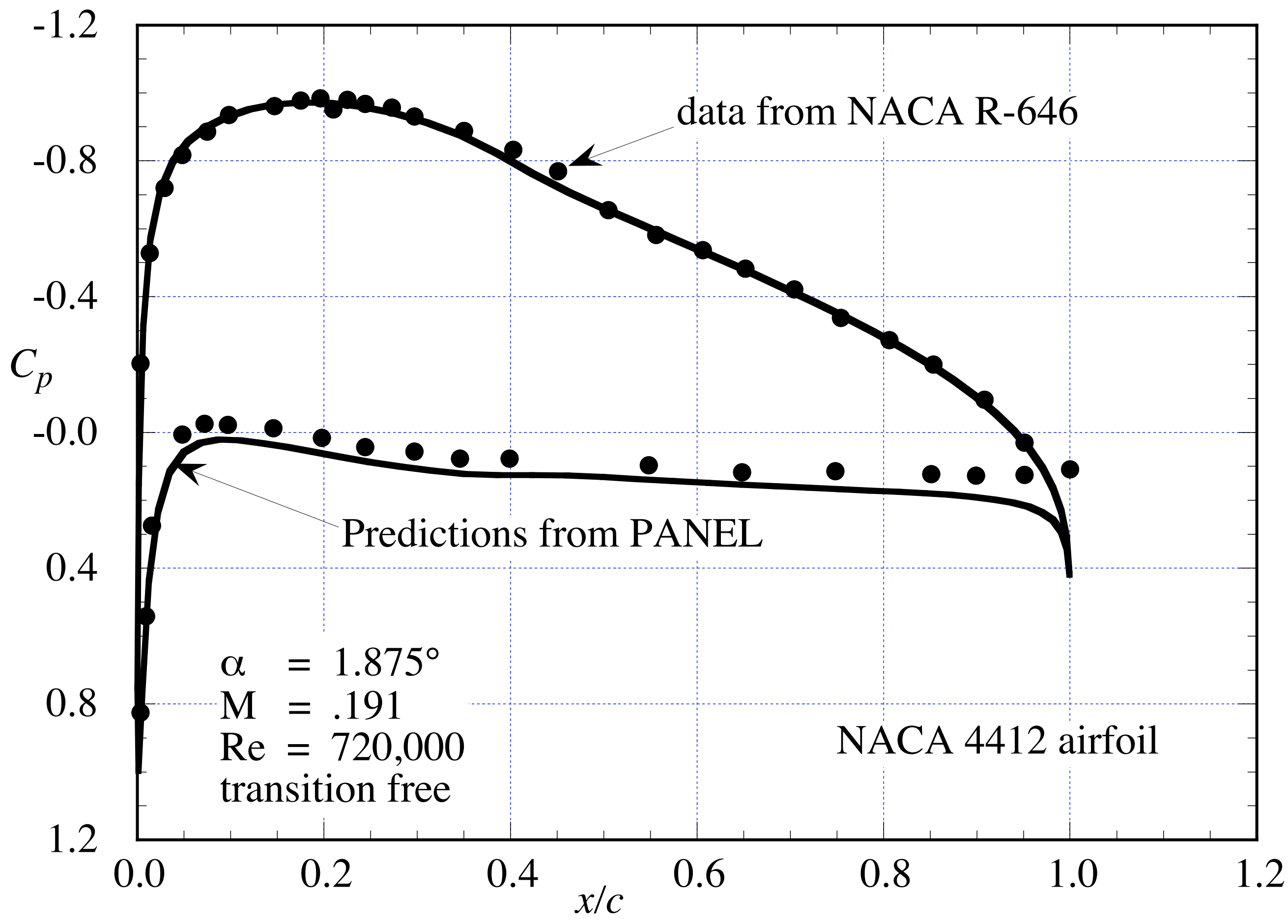


Comparison with Data: Pitching Moment

- about the quarter chord -



Comparison of inviscid prediction with WT Pressure Distribution

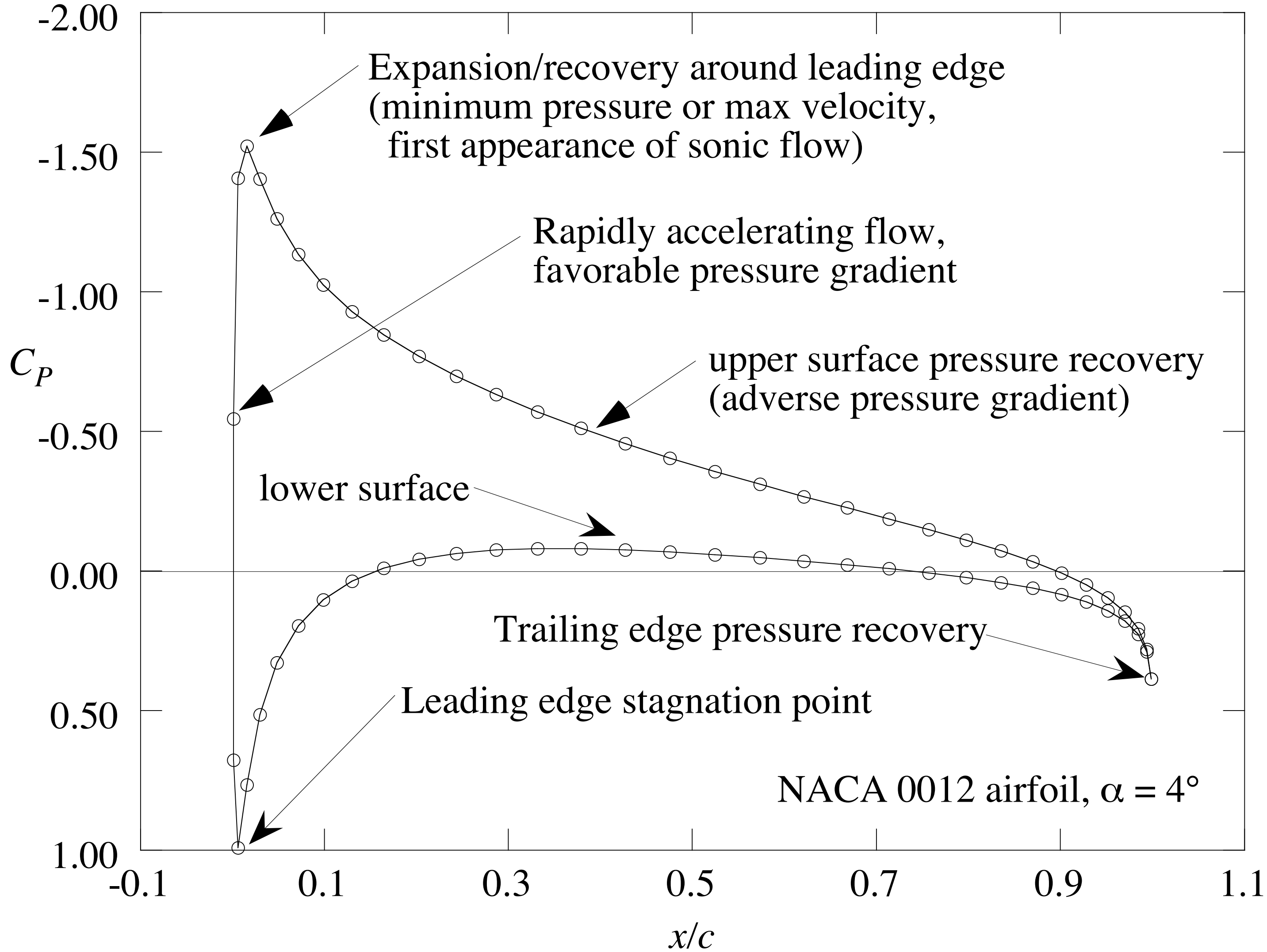


Note viscous "relief" (loss) of full pressure recovery at the trailing edge

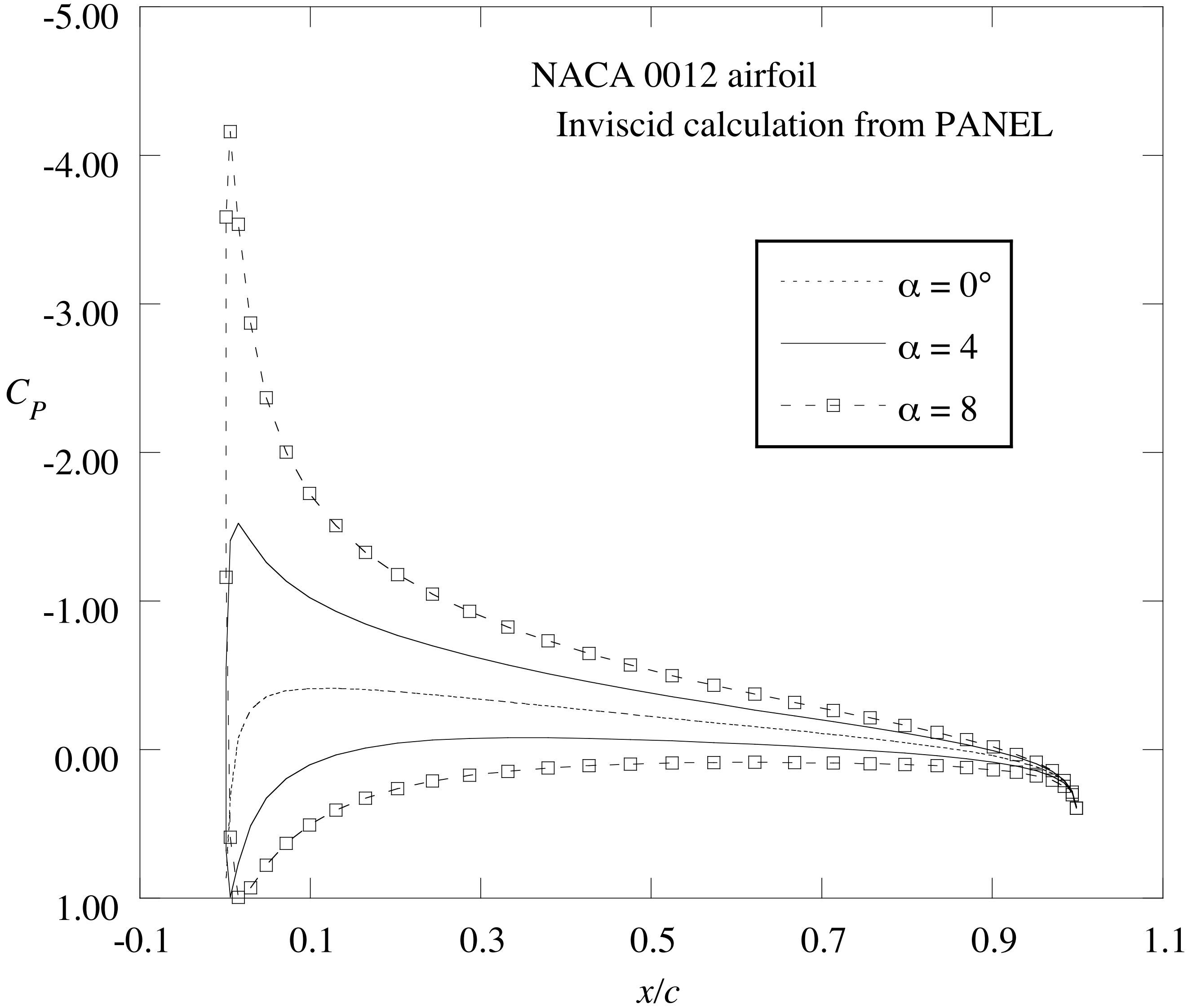
XFOIL: the code for subsonic airfoils

- Panel Methods: Inviscid!
- Couple with a BL analysis to include viscous effects
- The single element viscous subsonic airfoil analysis method of choice: XFOIL
  - by Prof. Mark Drela at MIT
- Link available from my software site

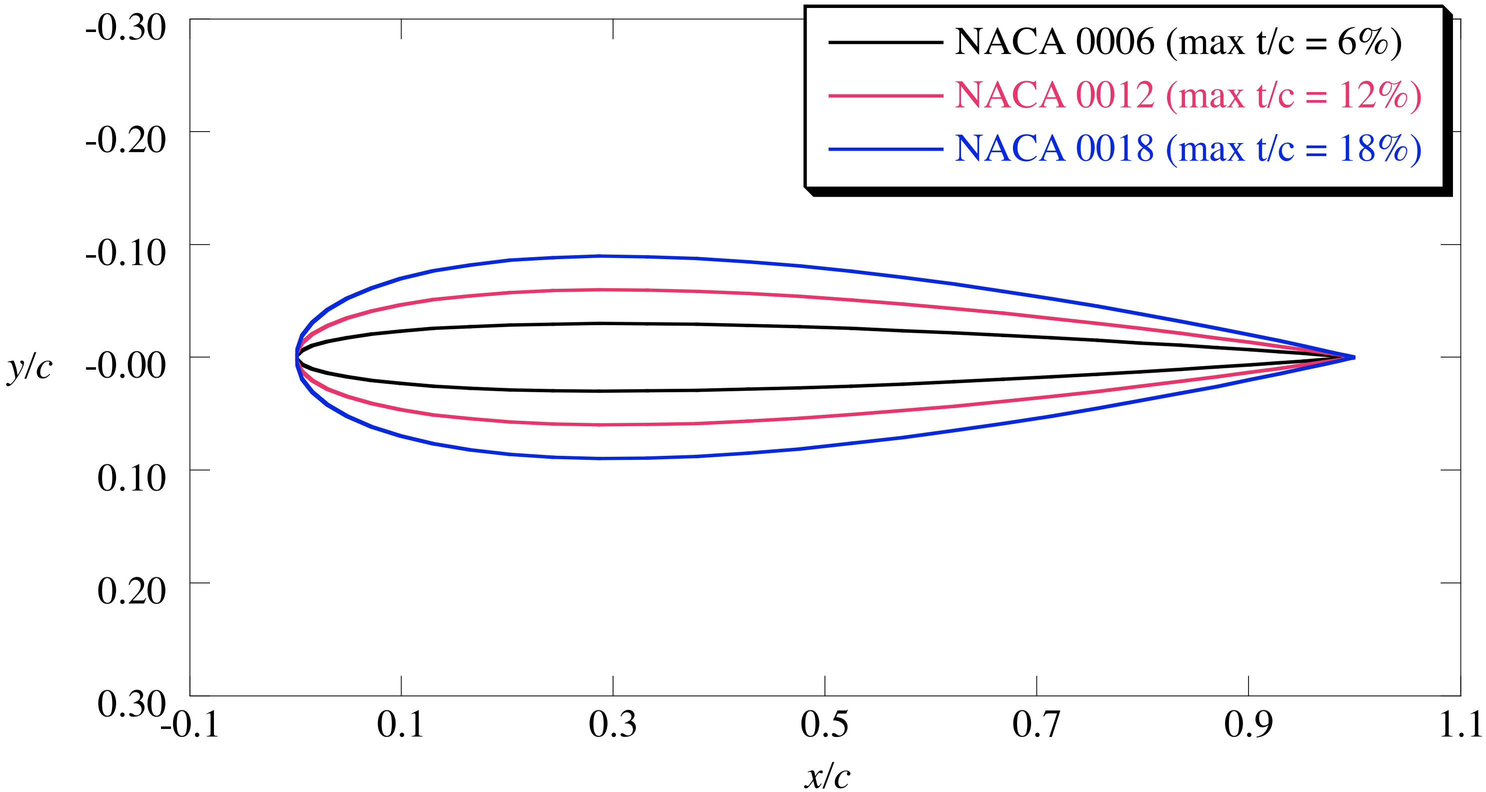
Airfoil pressures: What to look for



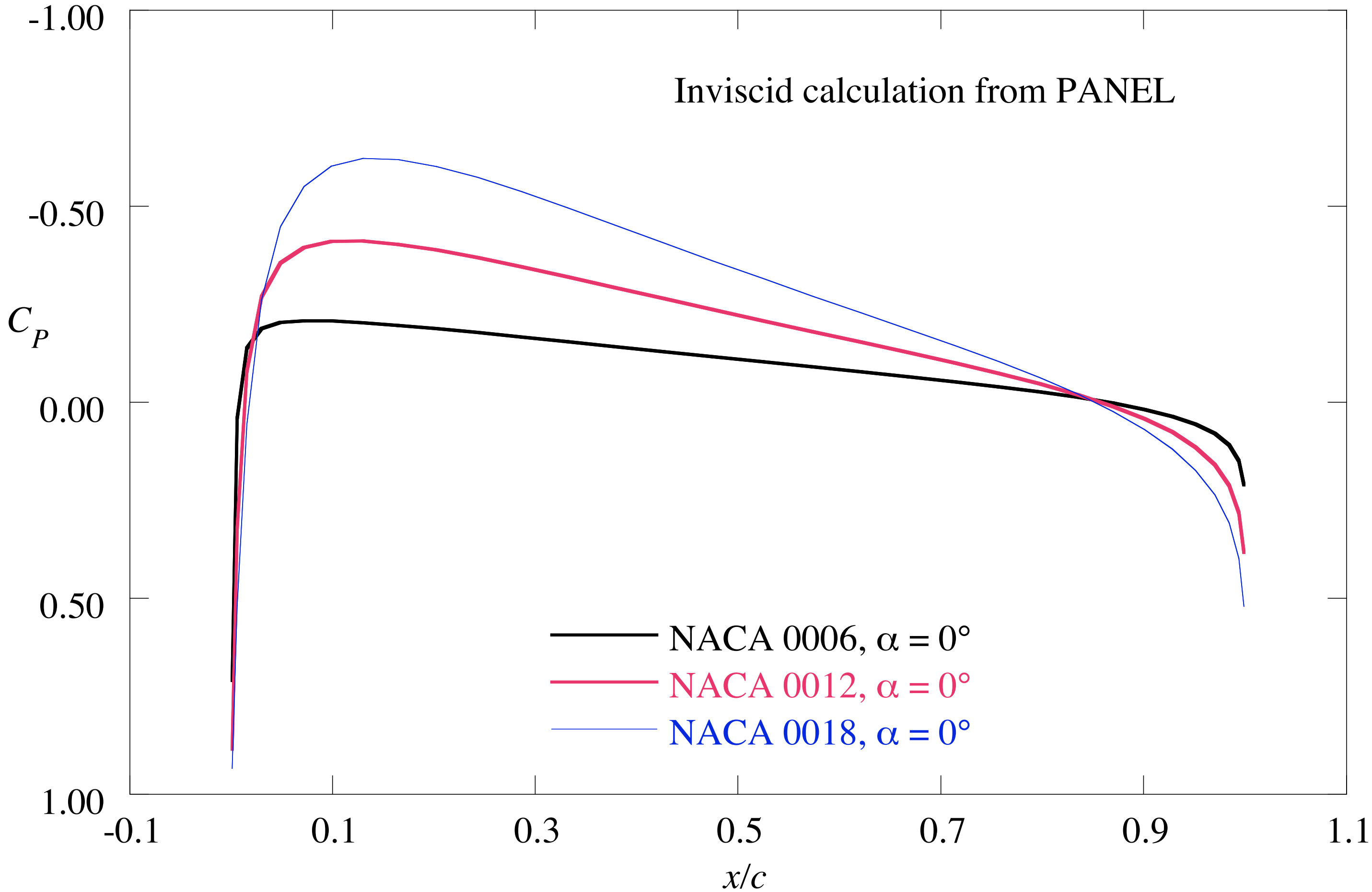
Effect of Angle of Attack



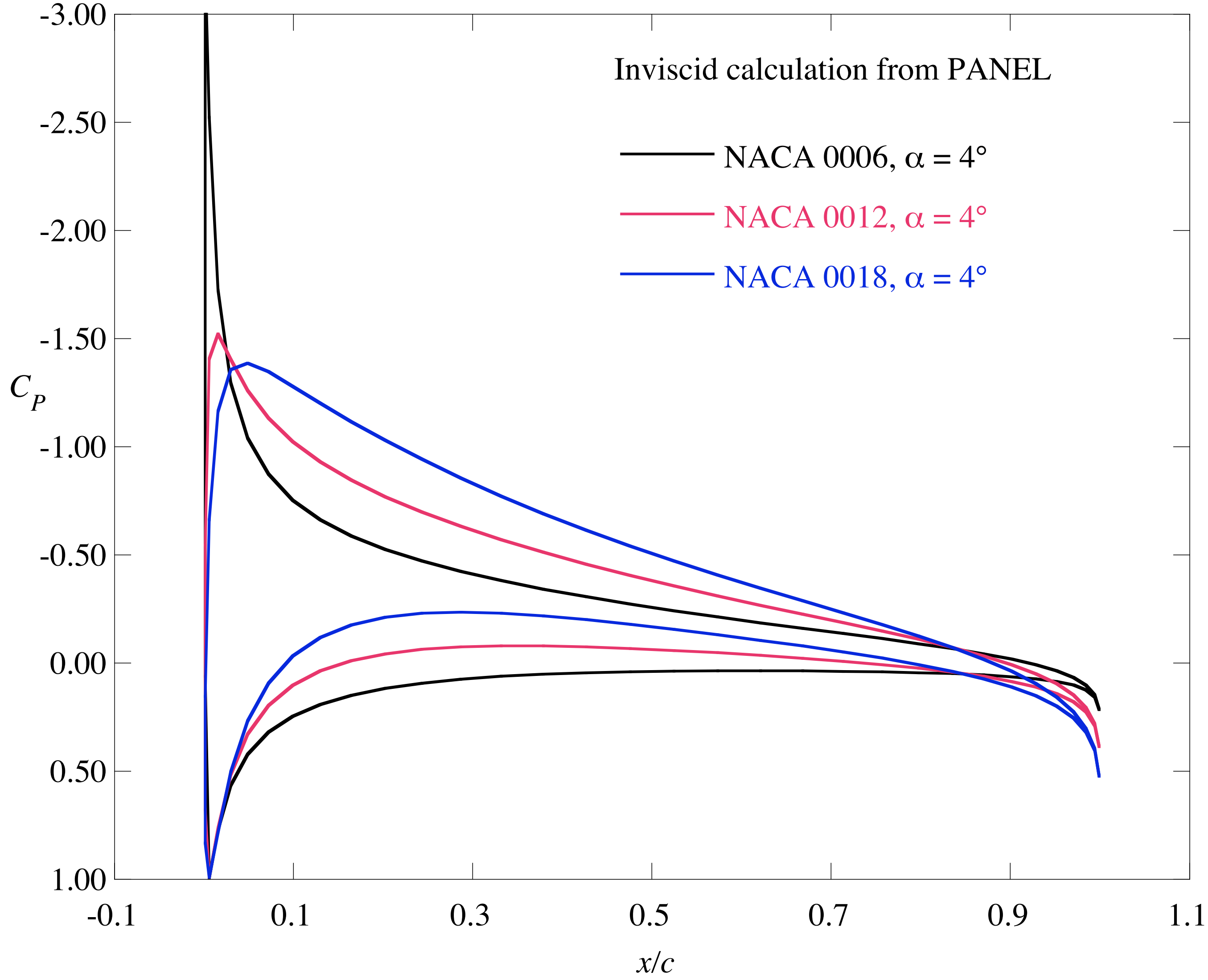
Comparison of NACA 4-Digit Airfoils
0006, 0012, 0018



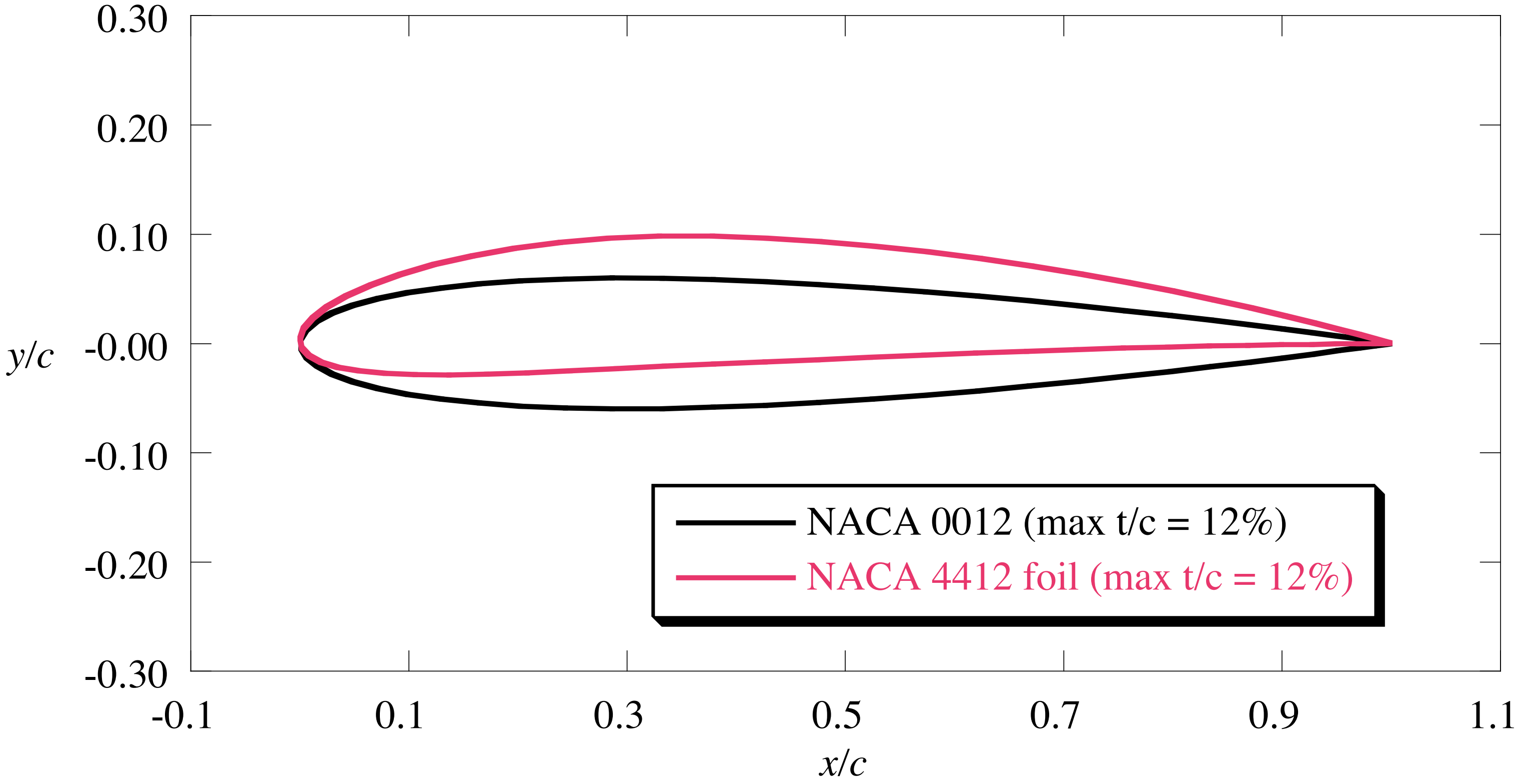
Thickness Effects on Airfoil Pressures
Zero Lift Case



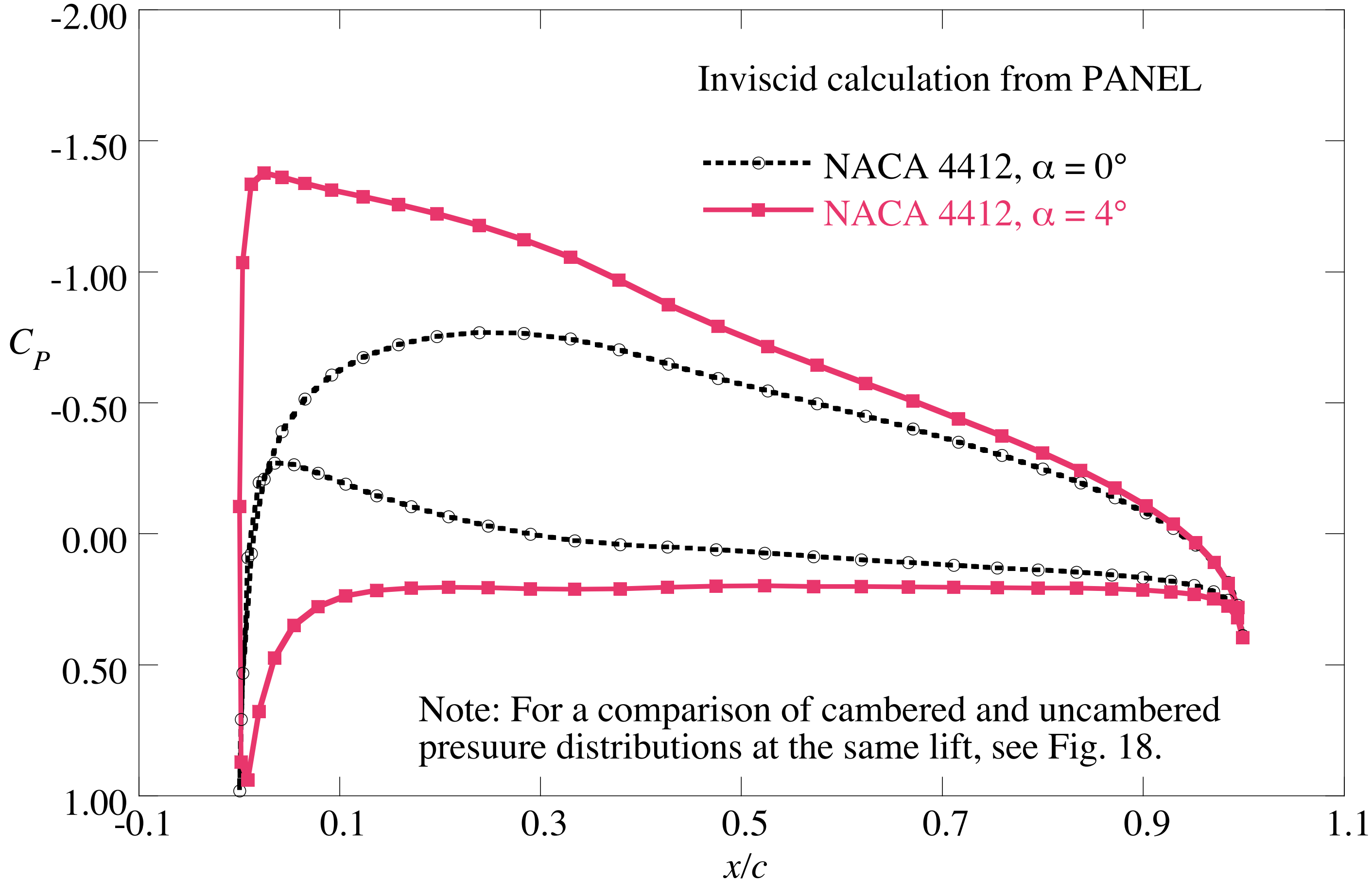
Thickness Effects on Airfoil Pressures, $C_L = 0.48$



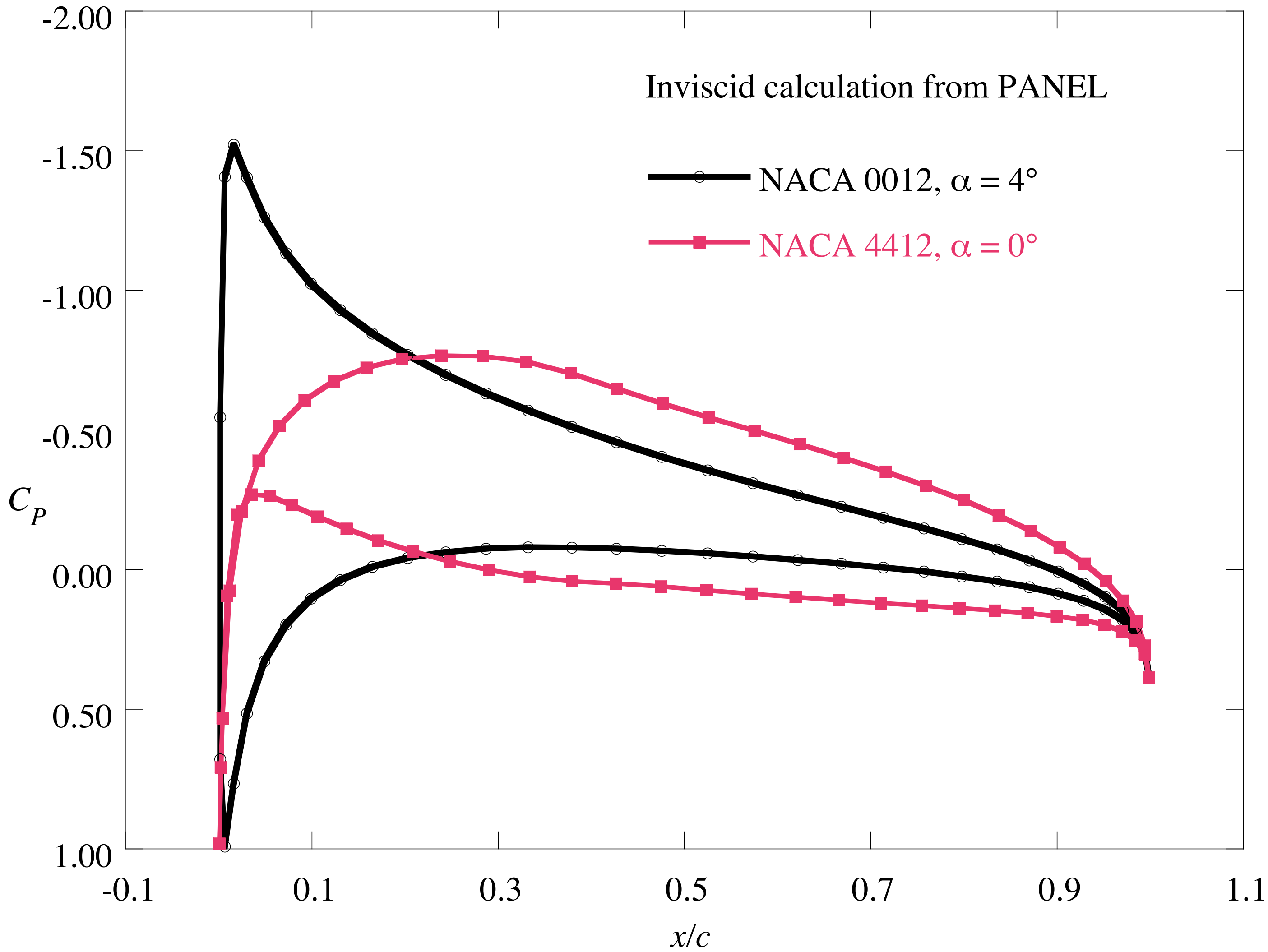
Comparison of NACA 4-Digit Airfoils the 0012 and 4412



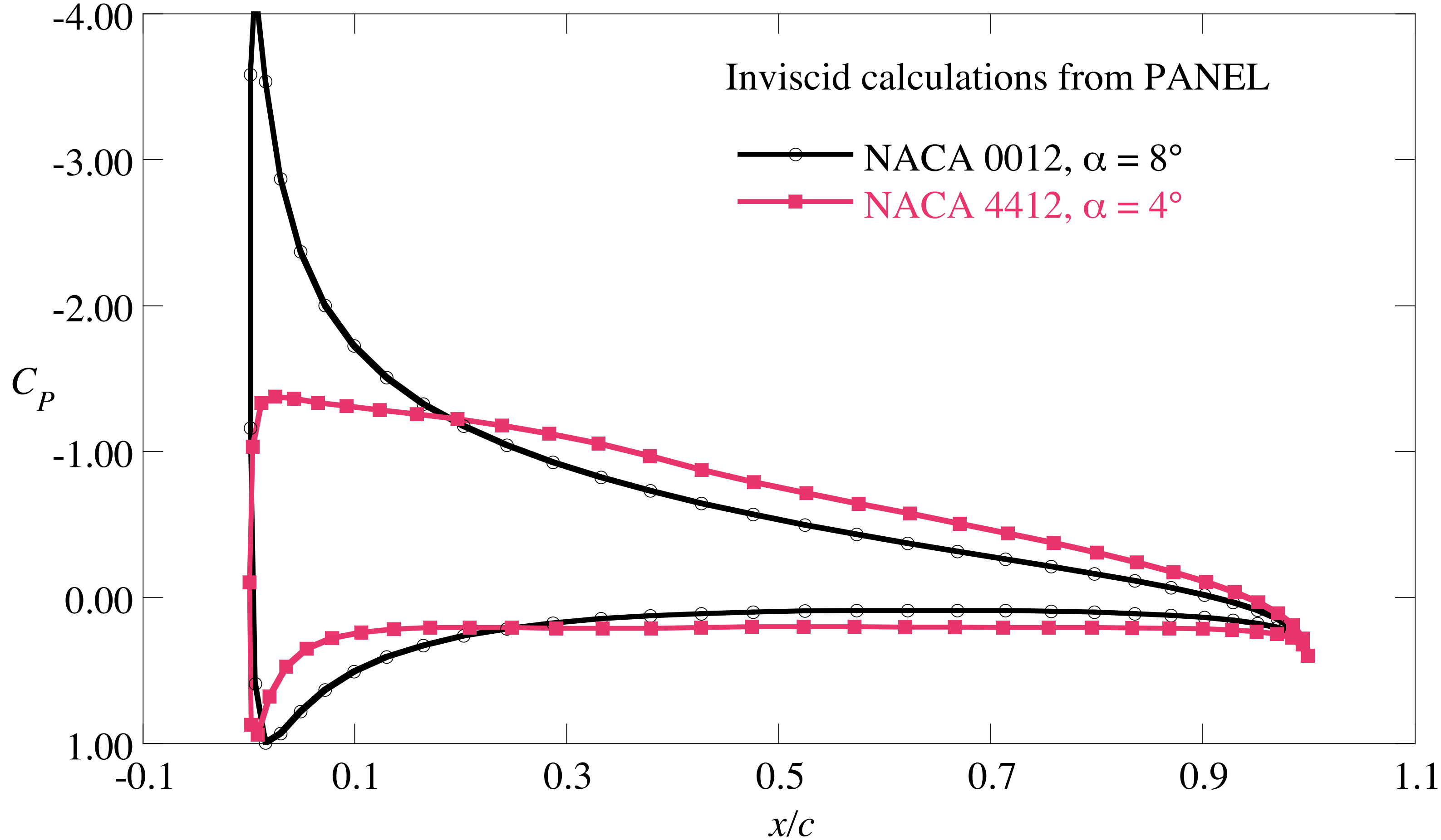
Highly Cambered Airfoil Pressure Distribution - NACA 4412 -



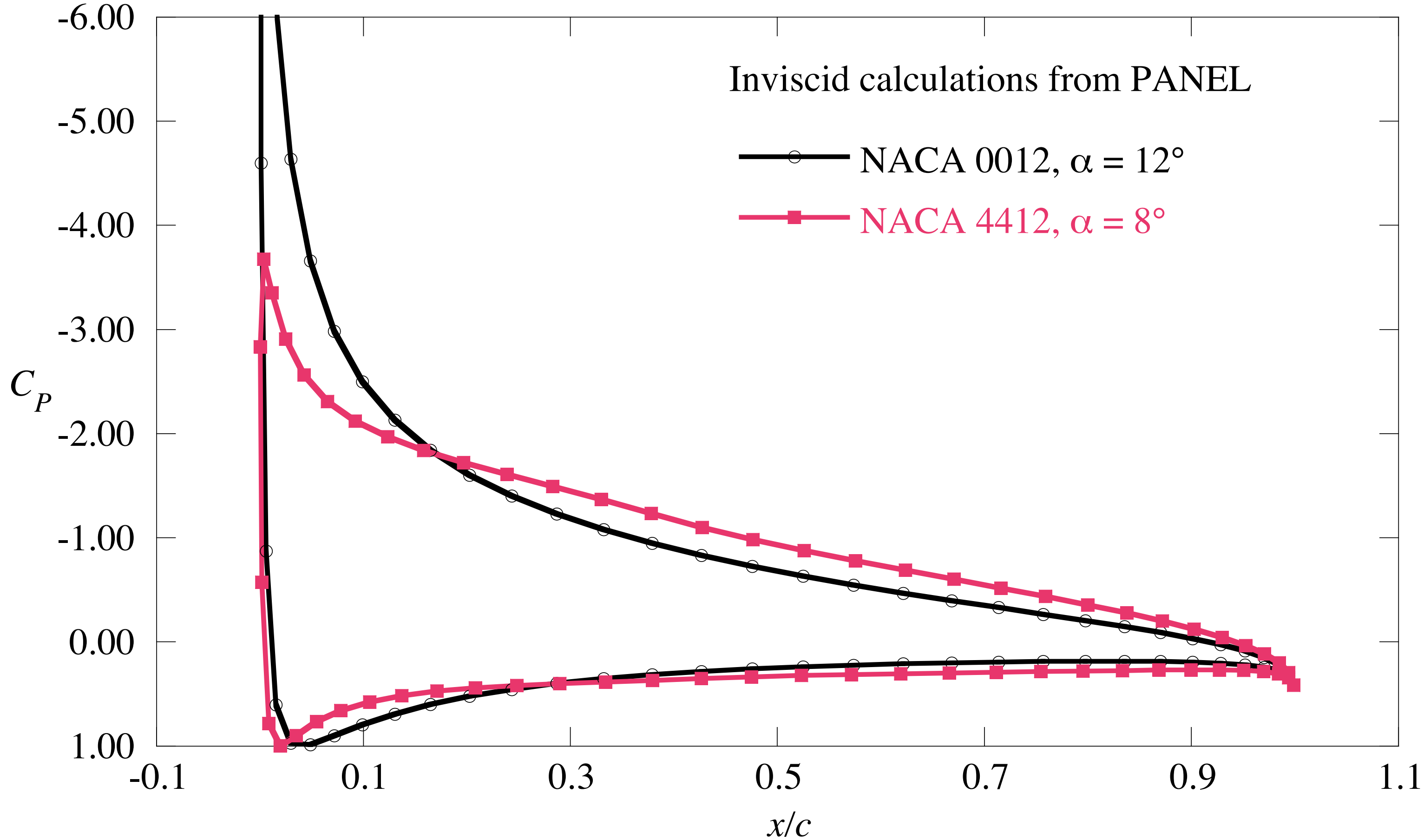
Camber Effects on Airfoil Pressures, $C_L = 0.48$



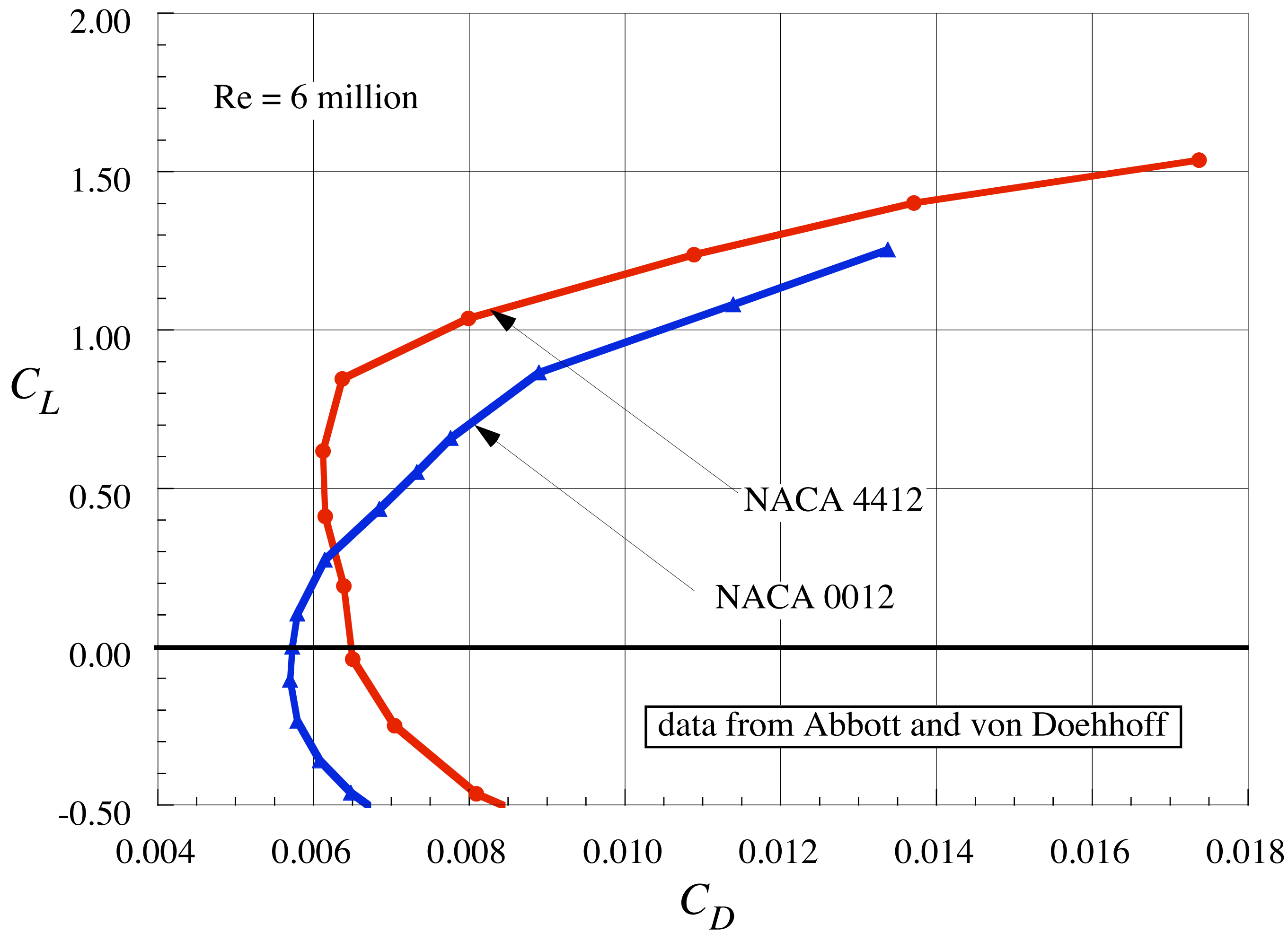
Camber Effects on Airfoil Pressures, $C_L = 0.96$



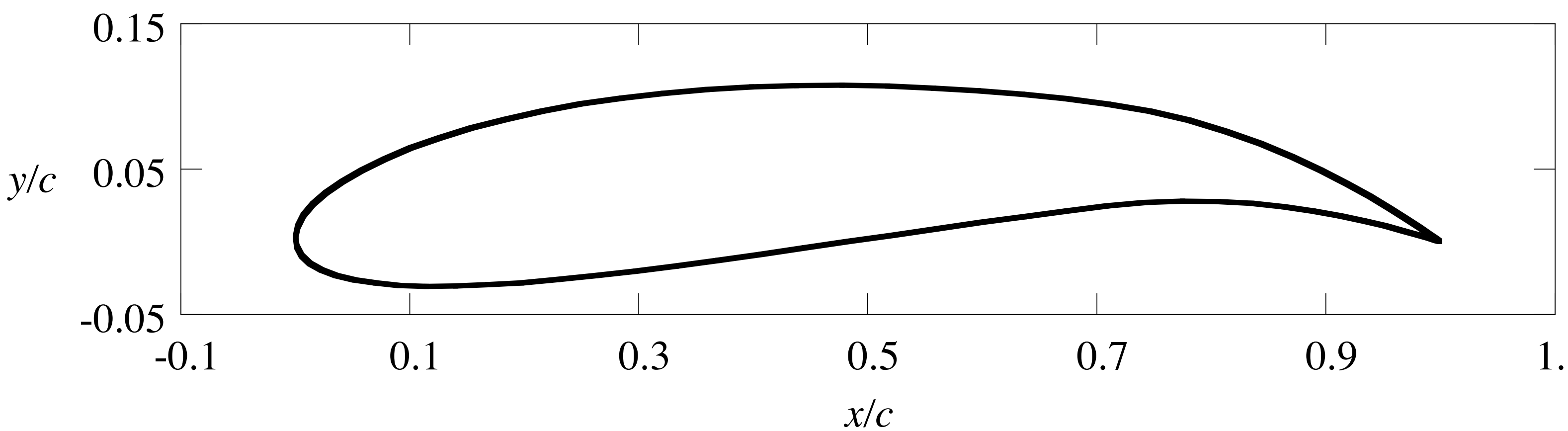
Camber Effects on Airfoil Pressures, $C_L = 1.43$



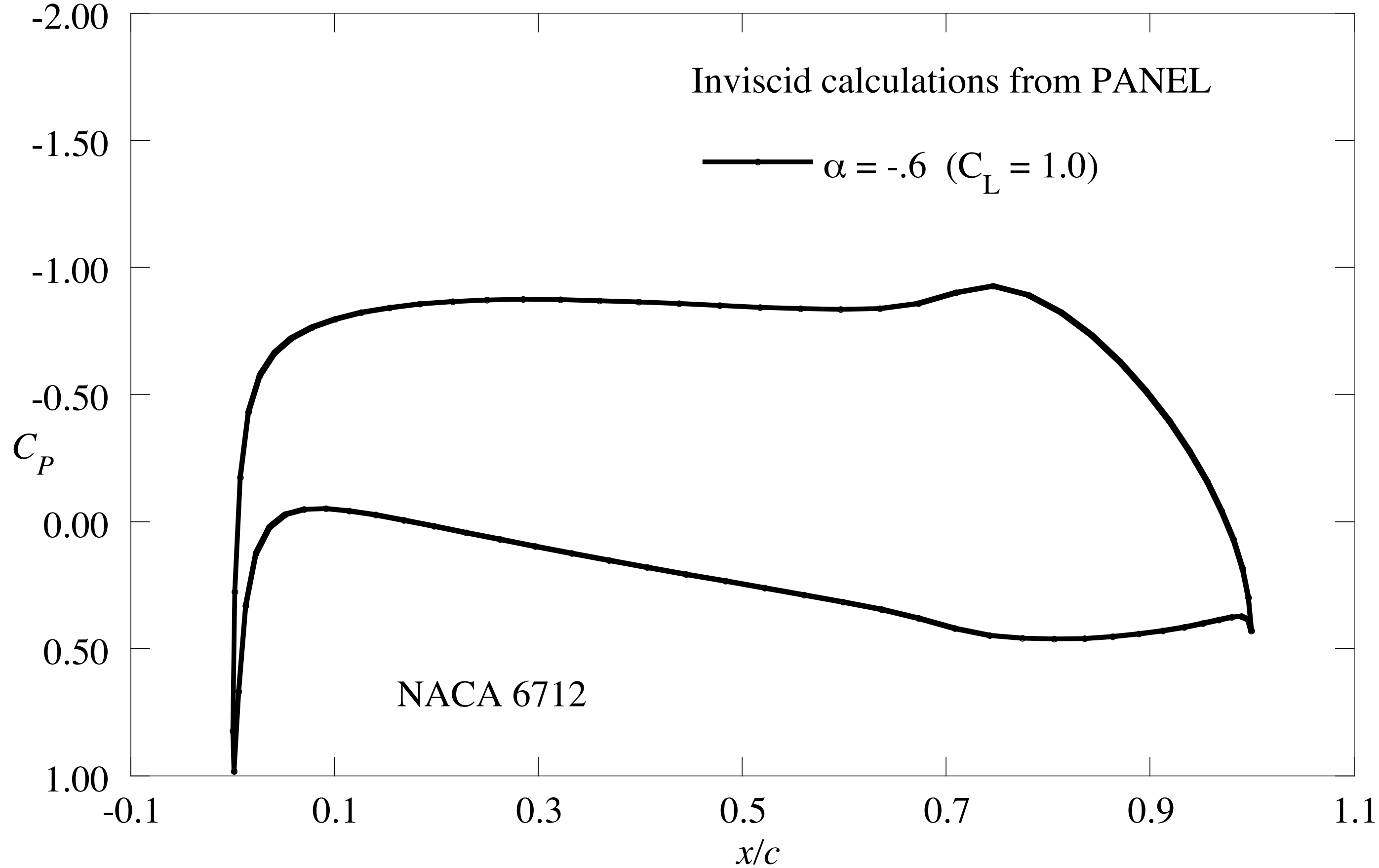
For Completeness: Drag Data
Effect of Camber



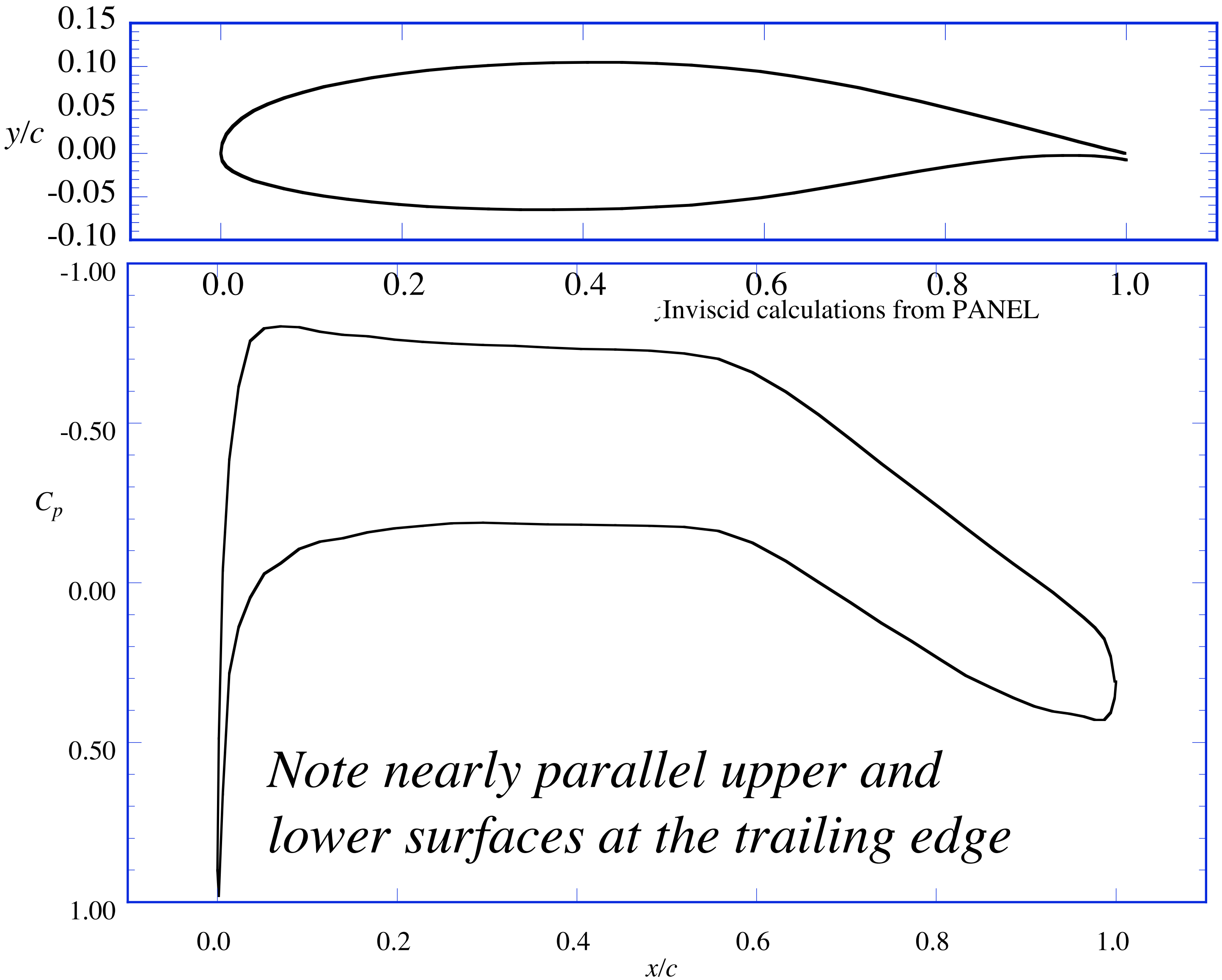
NACA 6712 Airfoil
- Heavy Aft Camber Geometry -



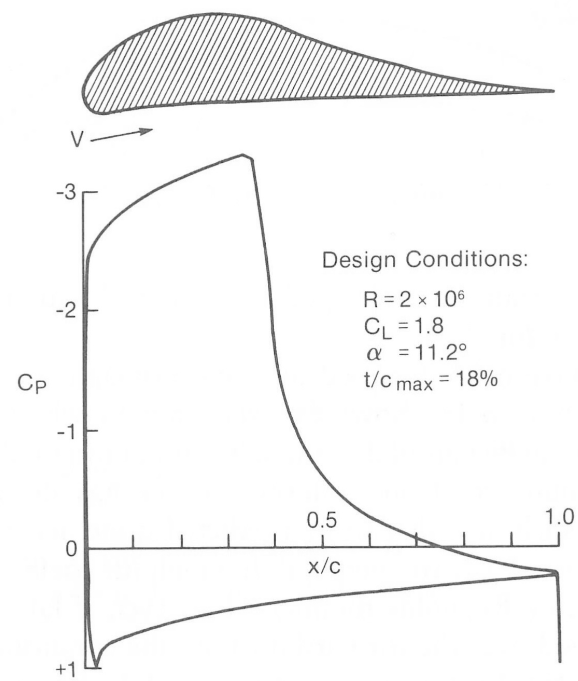
NACA 6712 Airfoil
- Heavy Aft Camber, Pressure Distribution -



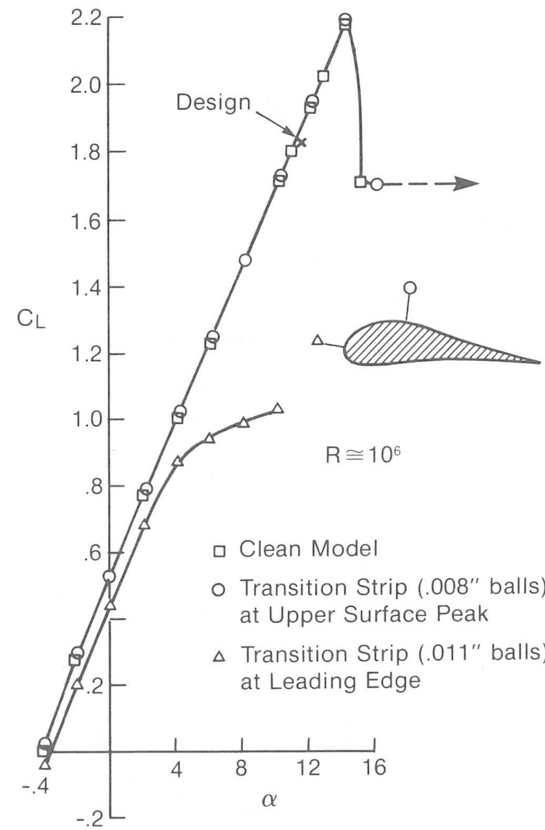
Whitcomb GA(W)-1 Airfoil



Liebeck's Hi-Lift Airfoil: Geometry and Lift
- note shape of pressure recovery -



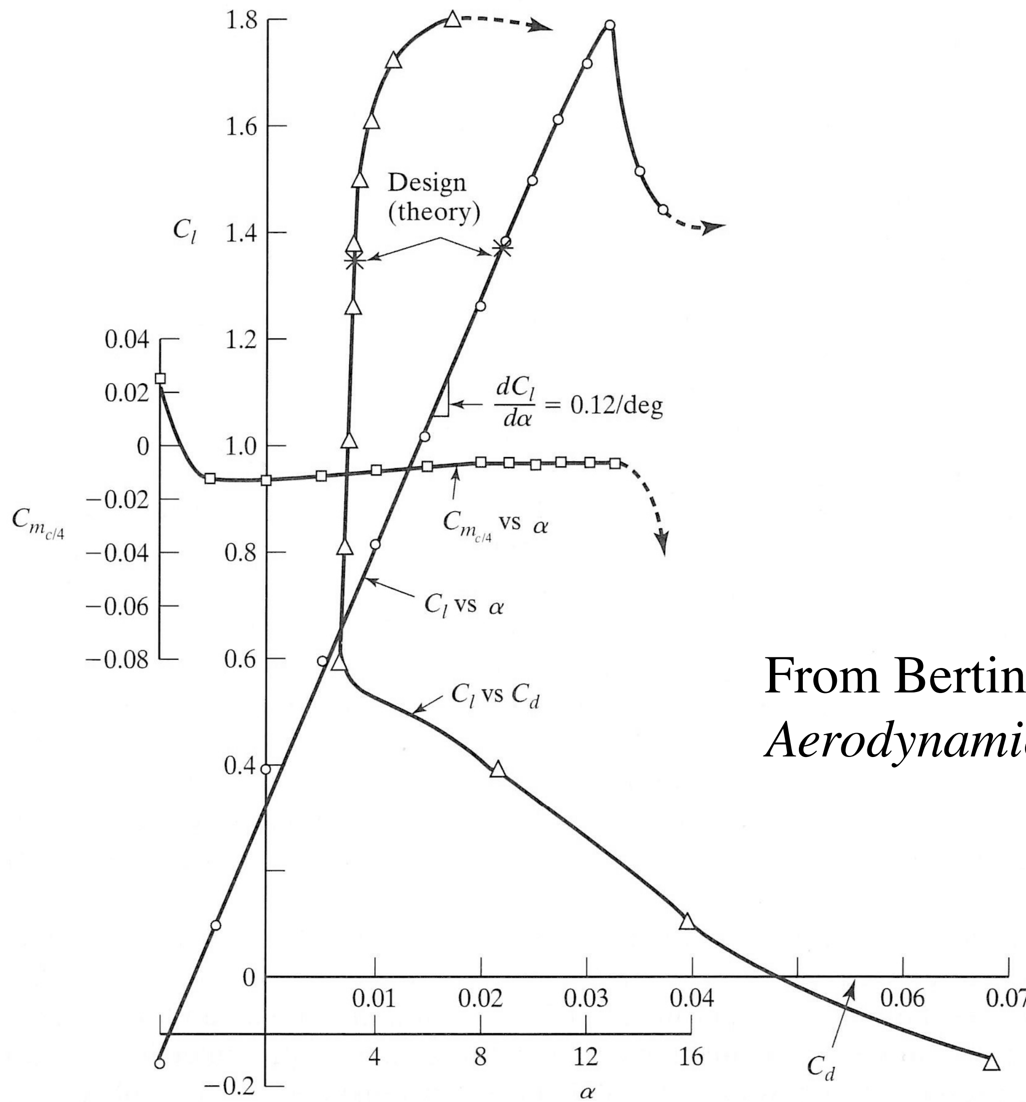
3.19a. Laminar rooftop airfoil, geometry and pressure distributio



3.19b. Laminar rooftop airfoil, lift curves showing the effect of transition strips. (From R. H. Liebeck, "Wind Tunnel Tests of Two Airfoils Designed for High Lift without Separation in Incompressible Flow," Rep. MDC-J5667/01, McDonnell Douglas Aircraft Co., Aug. 1972. With permission of the author.)

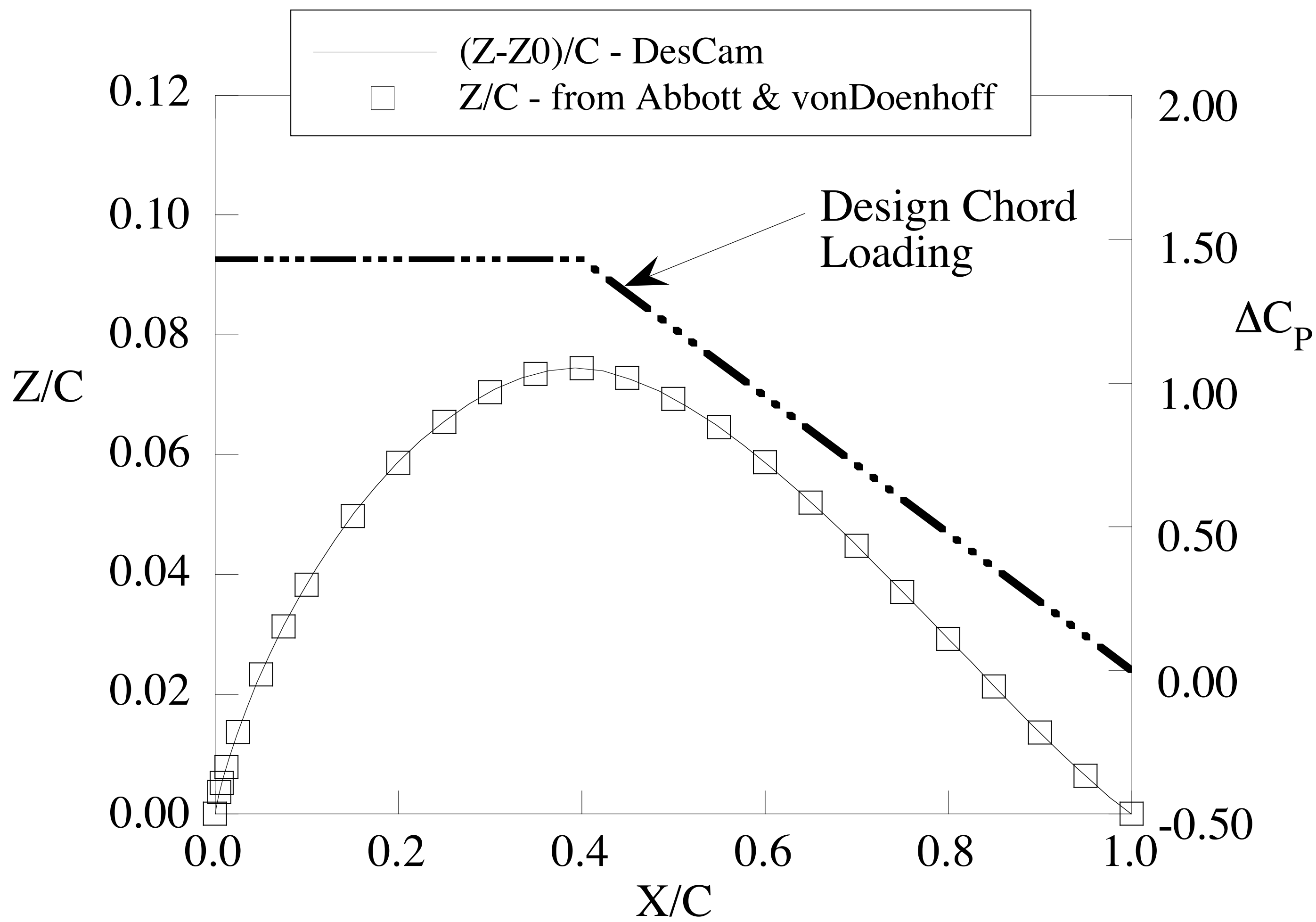
From R.T. Jones, *Wing Theory*

Liebeck's Hi-Lift Airfoil: Drag



From Bertin,
Aerodynamics for Engineers

Camberline Design: DesCam



Airfoil Selection

Issues:

- Cruise C_L, and C_{Lmax}, don't forget C_{m0}
  - -large LE radius?
  - -Near parallel trailing edge closure
- Profile Drag: Laminar flow?
  - – Tailor pressure distribution
- Thickness for low weight and internal volume
- Tails: often symmetric, 6 series foils picked

Study Abbott and von Doenhoff (both) as a start

To Conclude

You have the tools to do single element airfoil design