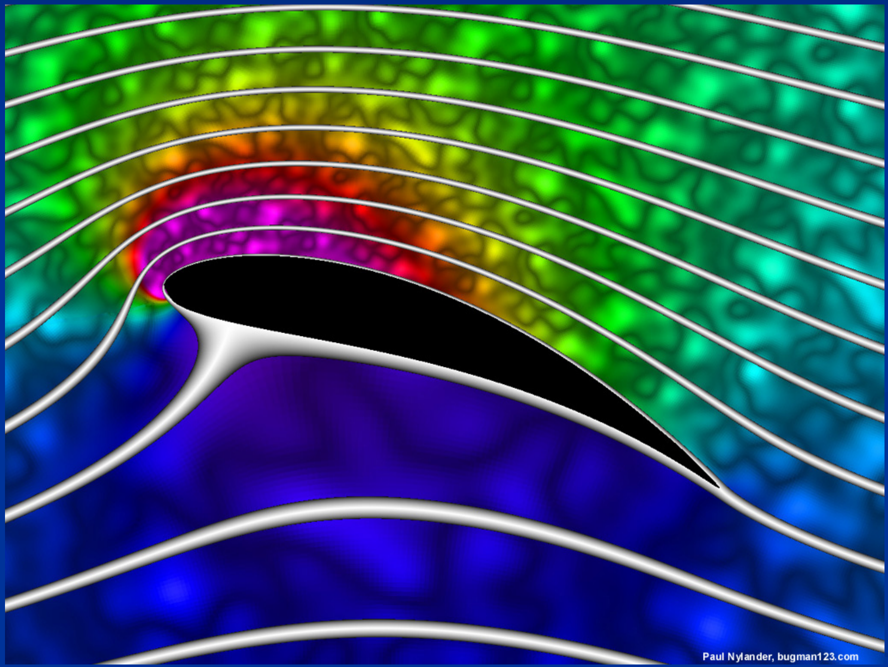
Aerodynamic Characteristics of a NACA 4412 Airfoil



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Scholar's Day
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Baylor University
Engineering & Computer Science

Overview

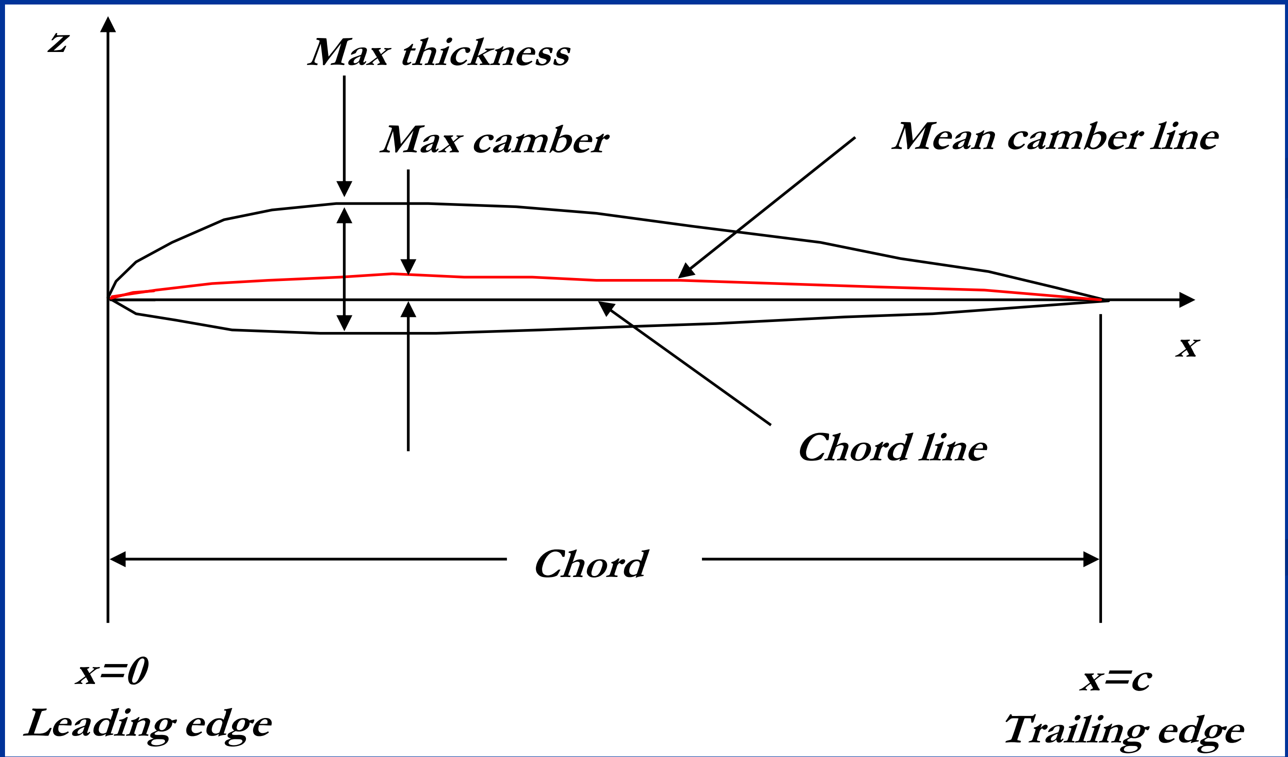
- Objective
- Theory
- Apparatus
- Experimental Comparison
- Results
- Summary
- Recommendations

Objective

- Study the lift and drag forces on a NACA 4412 airfoil
- Resolve discrepancy in wind tunnel data
- Develop experimental techniques for an airfoil
- Compare wind tunnel data
  - Force Balance to Pressure Distribution
  - Baylor data to published NACA data

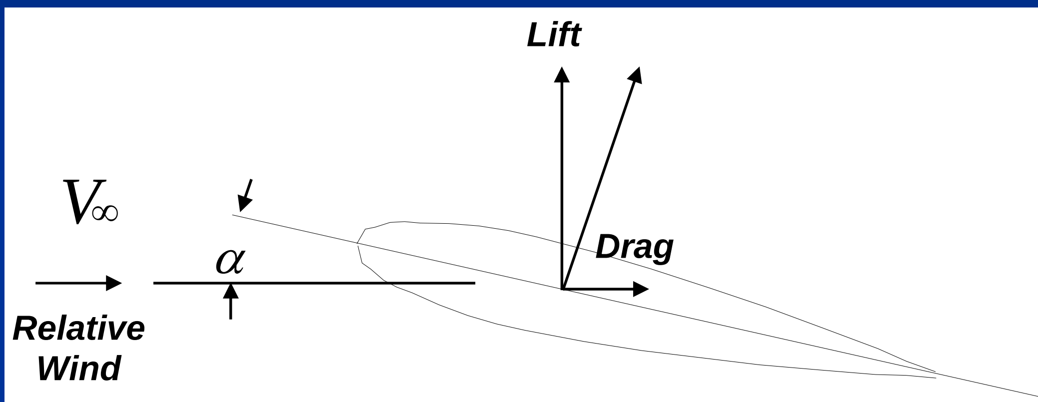
NACA 4412 Airfoil

- 4 digit code used to describe airfoil shapes
- 1st digit - maximum camber in percent chord
- 2nd digit - location of maximum camber along chord line (from leading edge) in tenths of chord
- 3rd and 4th digits - maximum thickness in percent chord
- NACA 4412 with a chord of 6”
  - Max camber: 0.24” (4% x 6”)
  - Location of max camber: 2.4” aft of leading edge (0.4 x 6”)
  - Max thickness: 0.72” (12% x 6”)



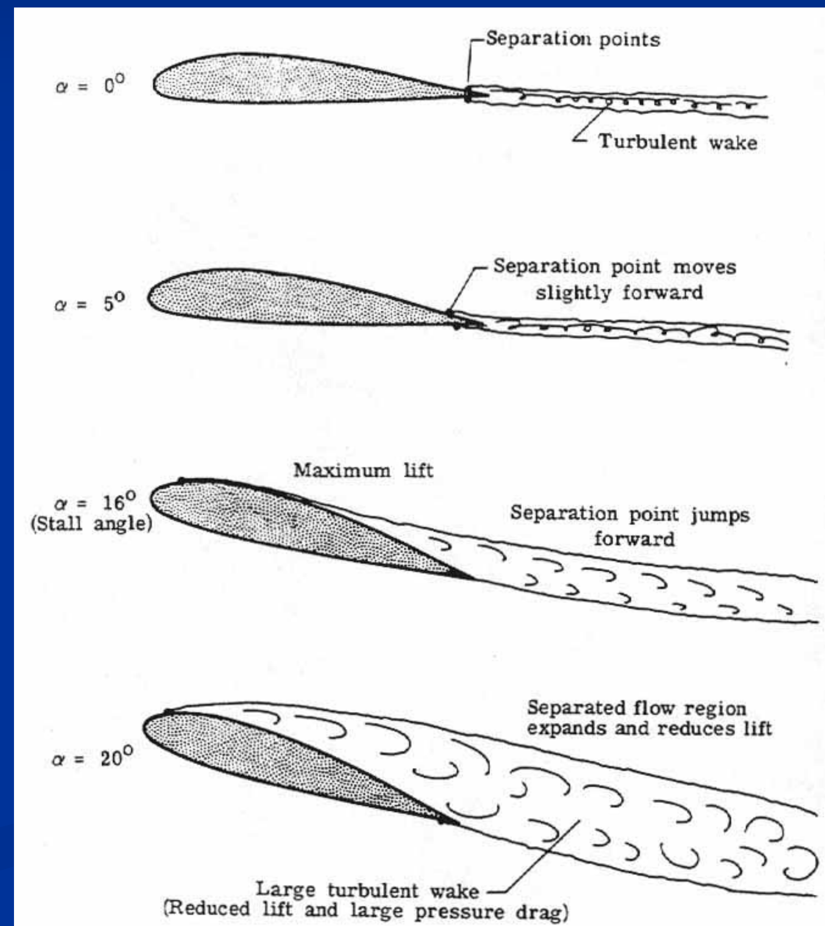
Theory

Lift, Drag and Angle of Attack



$$\text{Reynolds Number} = \text{Re} = \frac{\rho V c}{\mu} = \frac{Momentum}{Viscous}$$

Stall Angle



Theory

Direct Method (Force Balance)

$$C_l = \frac{L}{\frac{1}{2}\rho V^2 S} \qquad C_d = \frac{D}{\frac{1}{2}\rho V^2 S}$$

Relates lift and drag forces to the velocity

Pressure Distribution (Pressure Ported Airfoil)

$$C_P = \frac{P_{Local} - P_{Stat}}{P_{Dyn}}$$

Relates local pressure on an airfoil to the velocity

$$C_X = \int_{-\frac{y}{c}}^{\frac{y}{c}} (C_{PF} - C_{PA})\, d(\frac{y}{c}) \qquad C_Y = \int_0^1 (C_{PL} - C_{PU})\, d(\frac{x}{c})$$

$$C_l = C_Y \cos\alpha - C_X \sin\alpha \qquad C_d = C_Y \sin\alpha + C_X \cos\alpha$$

Experimental Apparatus

Baylor University Wind Tunnel

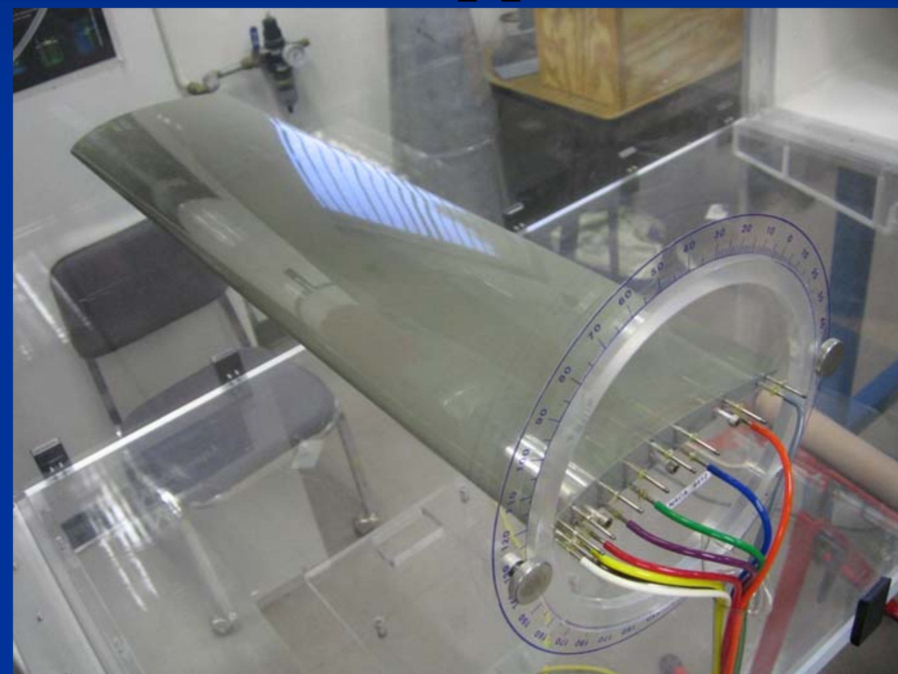
24” by 24” Test Section | Test Range: 0 – 150 ft/s | Open loop tunnel

Experimental Apparatus

Force Balance

-8 to 20 Degrees

Pressure Tapped Airfoil



18 pressure ports
-18 to 20 Degrees

Both NACA 4412 airfoils are 24" wide with a 6" chord length

Experimental Comparison

NACA

- Re = 3,000,000
- 54 pressure ports
- Variable density wind tunnel
- 24” chord length

Baylor University

- Re = 150,000
- 18 pressure ports
- Constant density wind tunnel
- 6” chord length

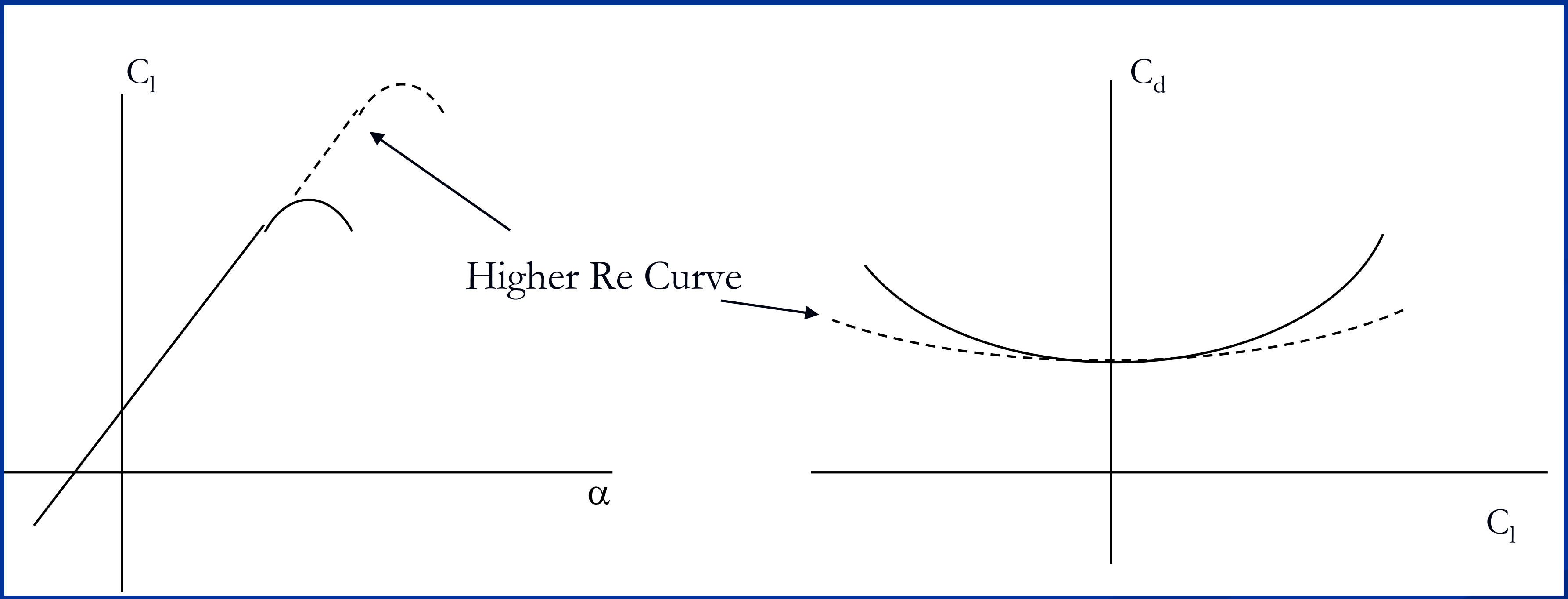
Results

- Stall angle
  - 11 degrees for 150,000 Re (Baylor)
  - 15 degrees for 3,000,000 Re (NACA)
- Lift coefficient agrees within 2% of NACA published data
- Noticeable inaccuracies in drag coefficient data from the pressure ported airfoil
- Drag coefficient is Re dependent

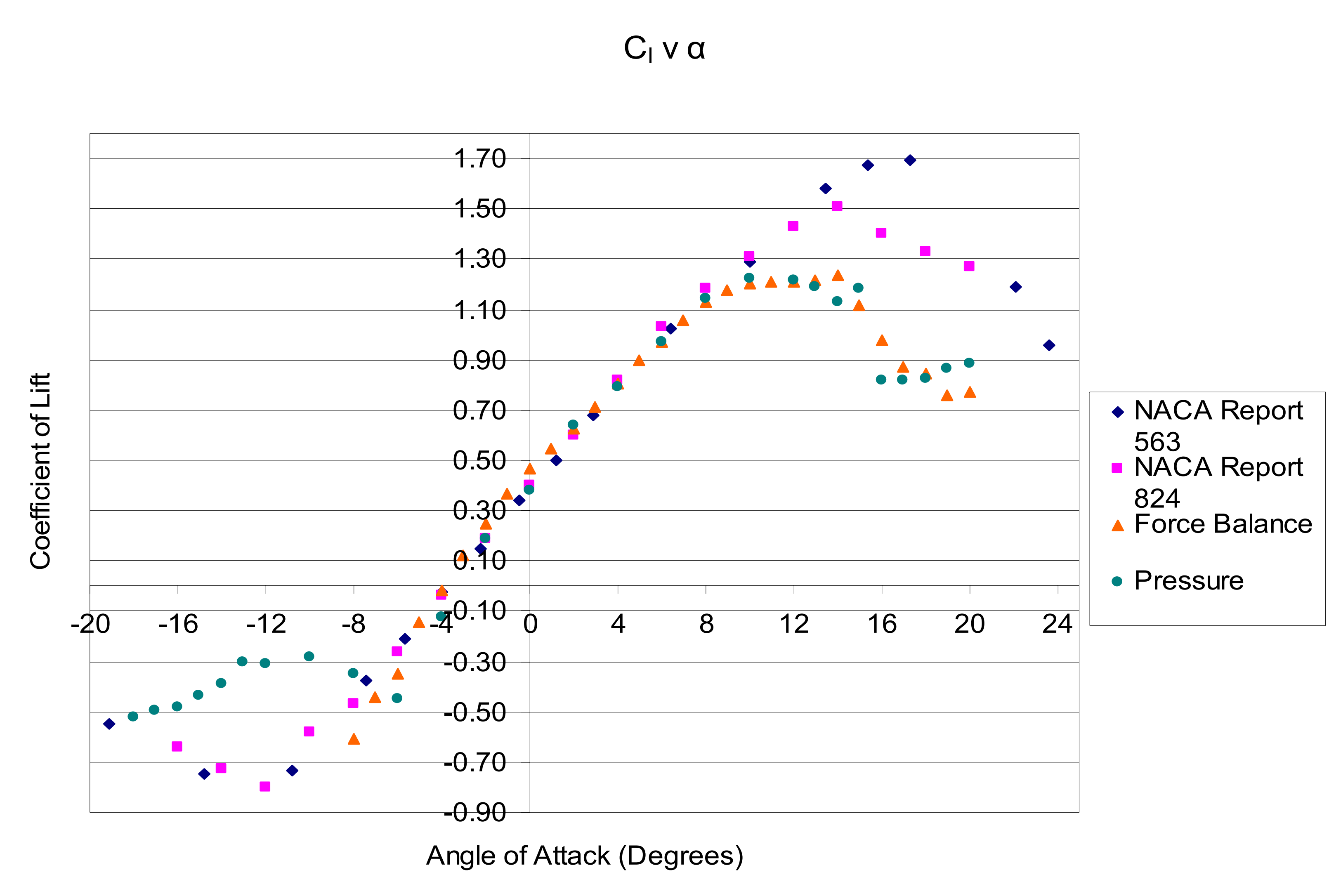
Aerodynamic Curves

Lift Curve

Drag Curve

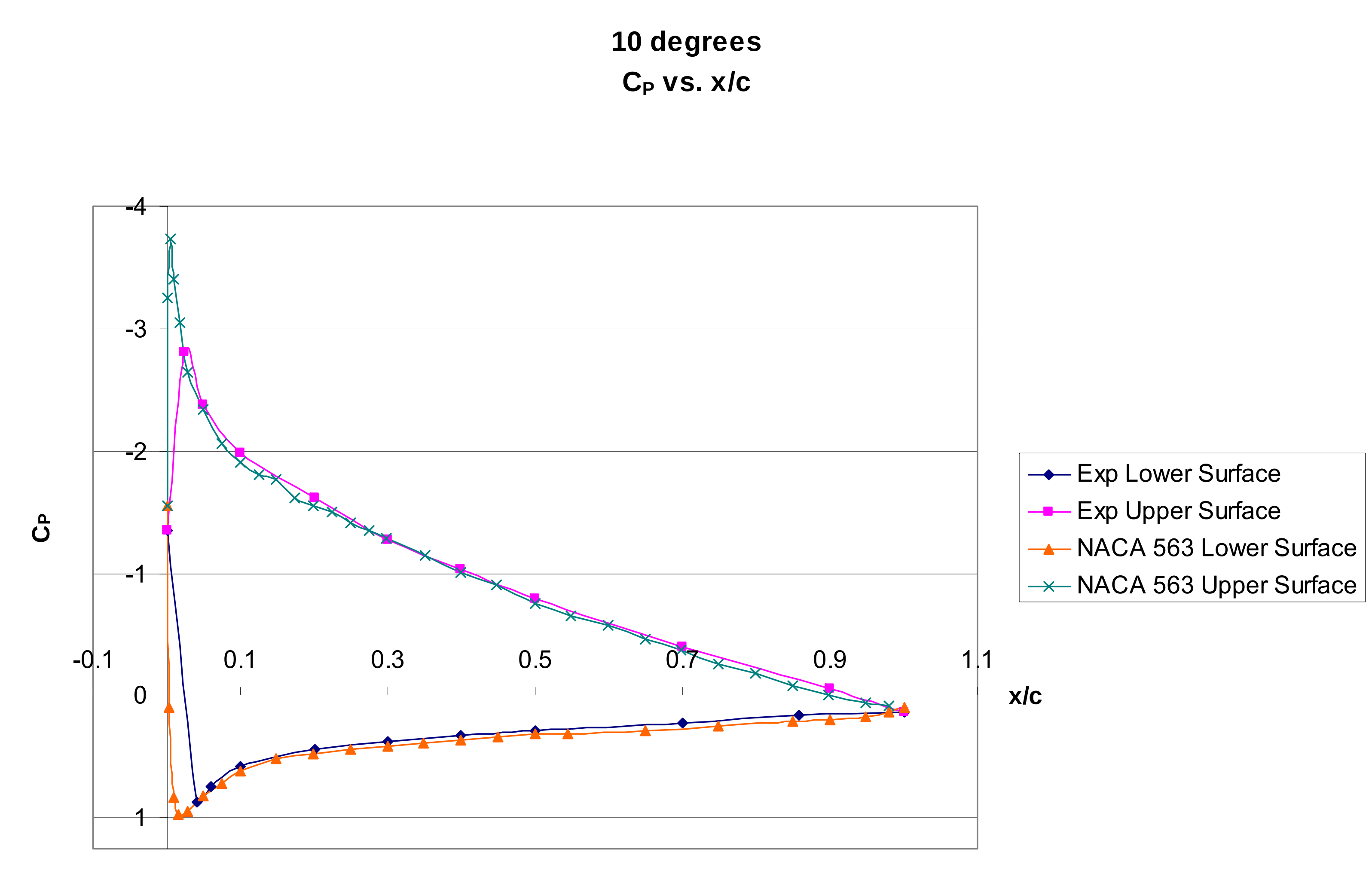


Lift Curve

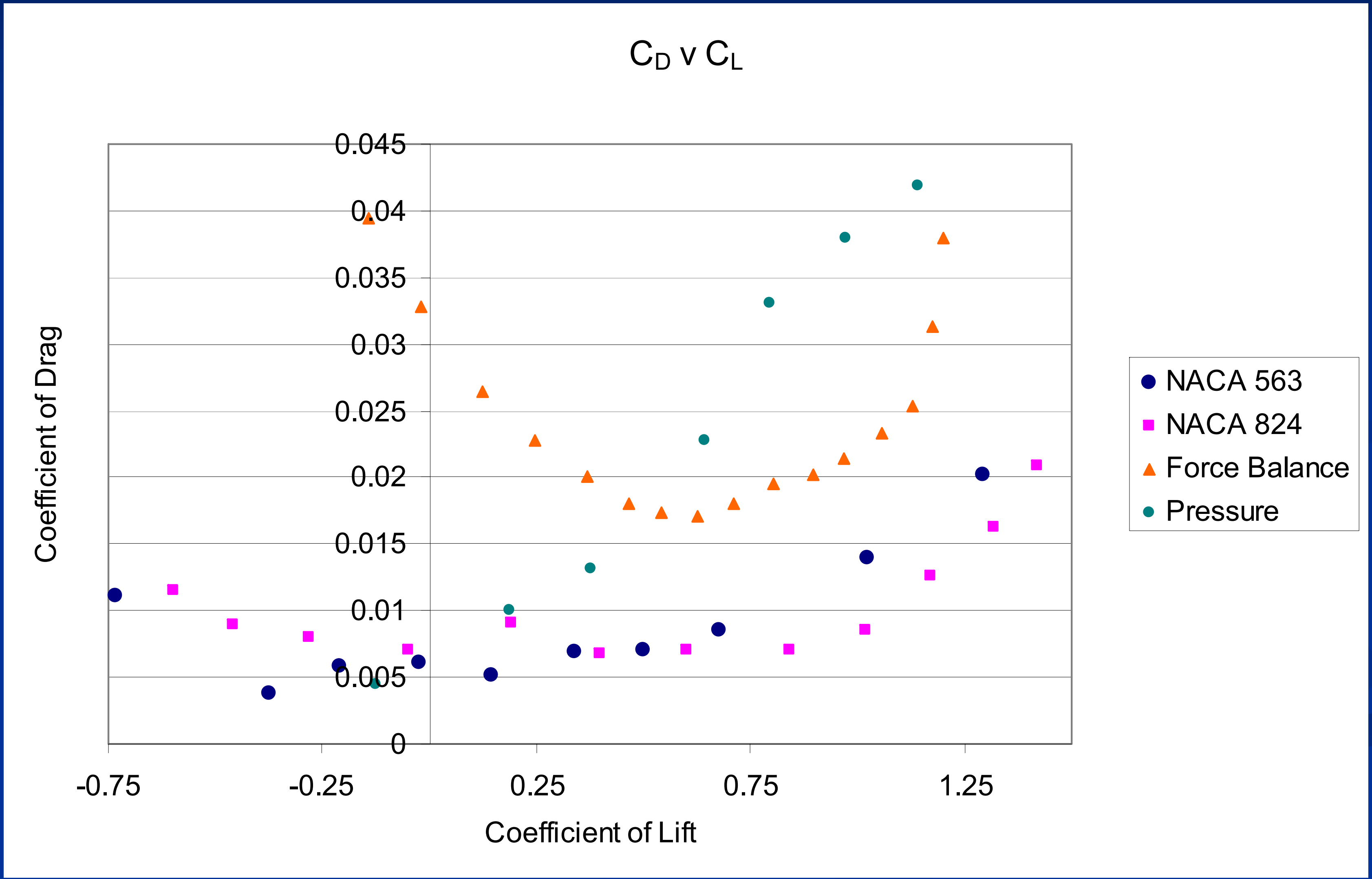


C_l v α
Coefficient of Lift
Angle of Attack (Degrees)
1.70
1.50
1.30
1.10
0.90
0.70
0.50
0.30
0.10
-0.10
-0.30
-0.50
-0.70
-0.90
-20
-16
-12
-8
-4
0
4
8
12
16
20
24
NACA Report 563
NACA Report 824
Force Balance
Pressure

Lift Pressure Distribution

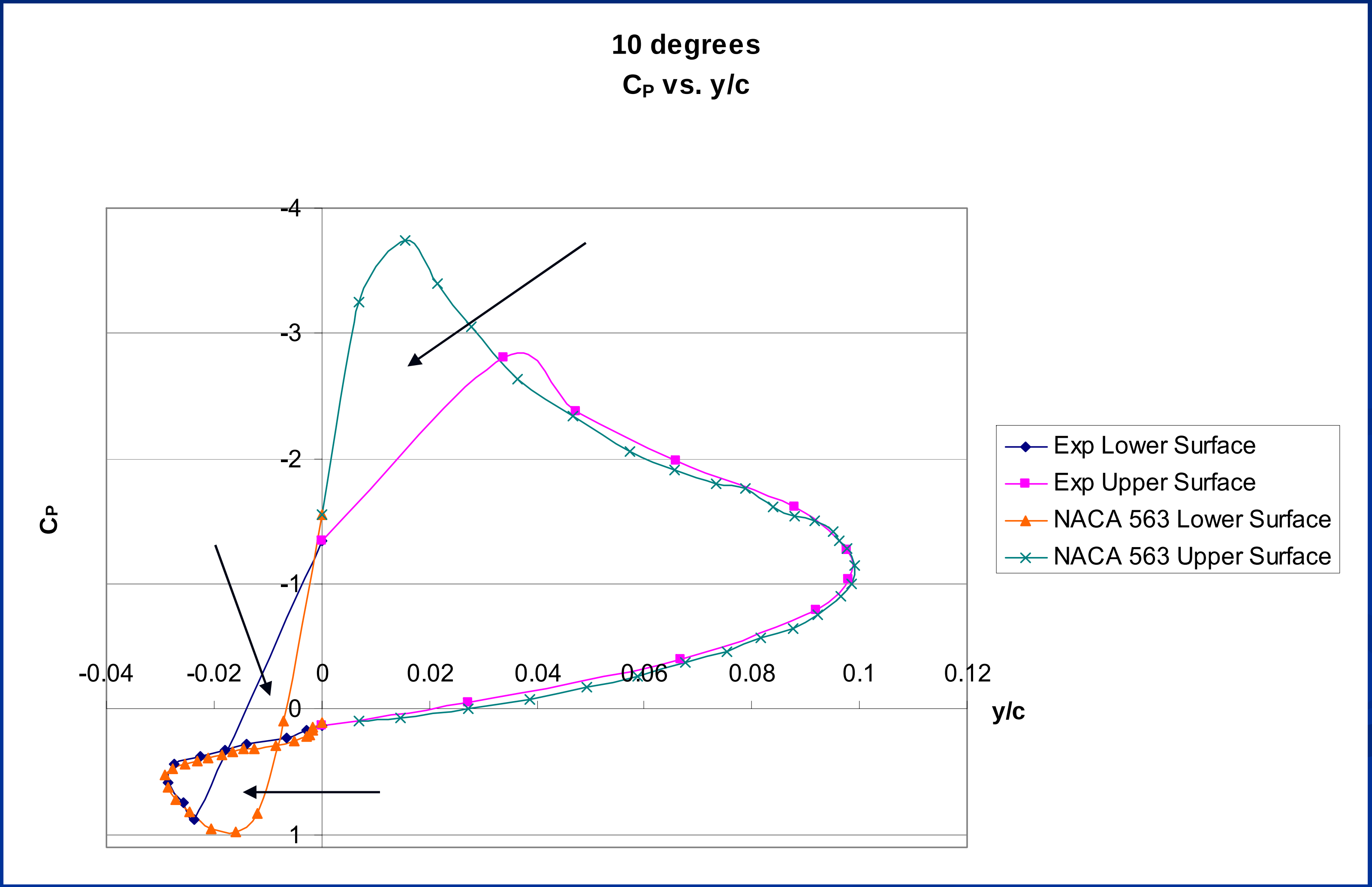


Drag Curve

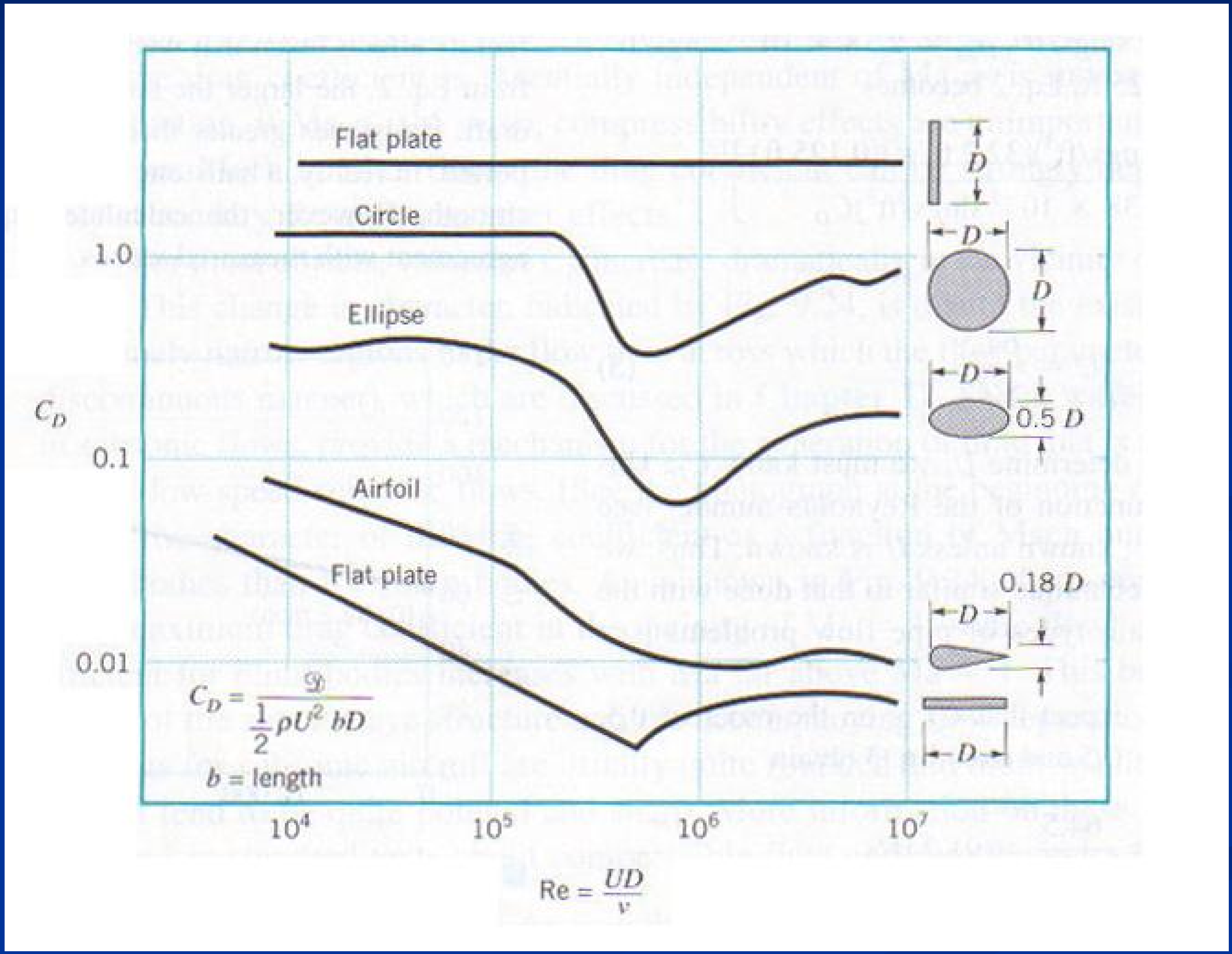


C_D v C_L
Coefficient of Drag
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
-0.75
-0.25
0.25
0.75
1.25
Coefficient of Lift
NACA 563
NACA 824
Force Balance
Pressure

Drag Pressure Distribution



C_D vs. Reynolds Number



Munson, B. R., Young, D. F., and Okiishi, T. H., 2006, *Fundamentals of Fluid Mechanics*

Summary

- Objectives
  - Study airflow over an airfoil
  - Resolve discrepancy in previous wind tunnel data
  - Compare wind tunnel data
- Results
  - Stall angle is a function of the Reynolds number
  - Lift coefficient relates closely to published data
  - Insufficient pressure ports to accurately map the pressure distribution for drag coefficient
  - Drag coefficient highly dependent on Reynolds number

Recommendations

- Further experiments
  - NACA 0012 (Double the pressure ports)
  - Utilize Baylor's 3D printer
- Develop lift and drag curves for future experiments to reference

Questions