The Wing and Airfoil

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A little about fluids

What is a wing ?

The Airfoil
- Definitions
- Modeling a 2D wing
- Aerodynamic Stall

The 3D Wing
- Definition and Numbers

Examples of Aerodynamics
- Why Golf Balls Have Dimples
- Clark Y airfoil example

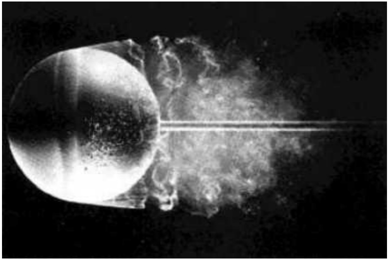
Lamaniar and Turbulent Flow

As fluids flow over an object a layer of fluid sticks to the surface and is called the boundary layer.

The layer will grow until the trailing edge of the object passes

At the beginning the fluid shears perfectly (Laminar)

layer eventually destabilizes and become very random (turbulent)



cylinder flow (video)

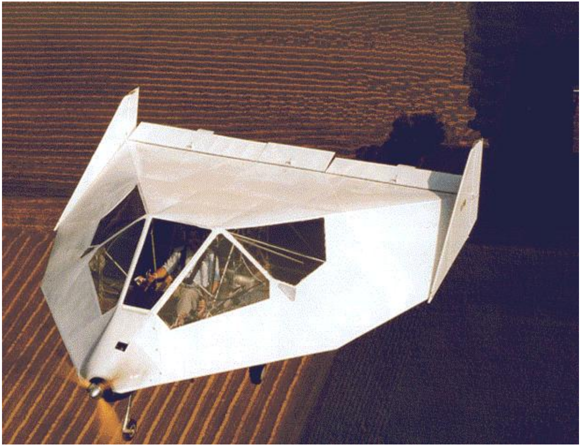
The Wing ?

OK They usually work on airplanes but what are they and what do they do ?

Flying wings and other things

The first of the B2 bombers and flying wings.

This things technically has no wings but still flys



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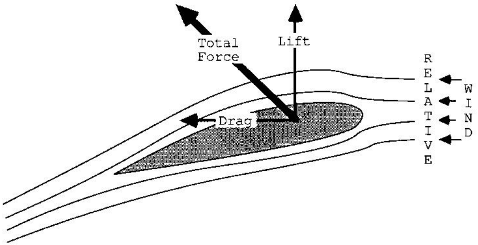
- A wing only works if a fluid moves over it.
- A wing is not magical it produces negative effects.
- ...

Lift and Drag

$$L_w = 1/2\rho V^2 S_W C_L \ \& \ D = 1/2\rho V^2 S_W C_D$$

Lift is always defined as prepender to the velocity vector **V** and induced drag parallel



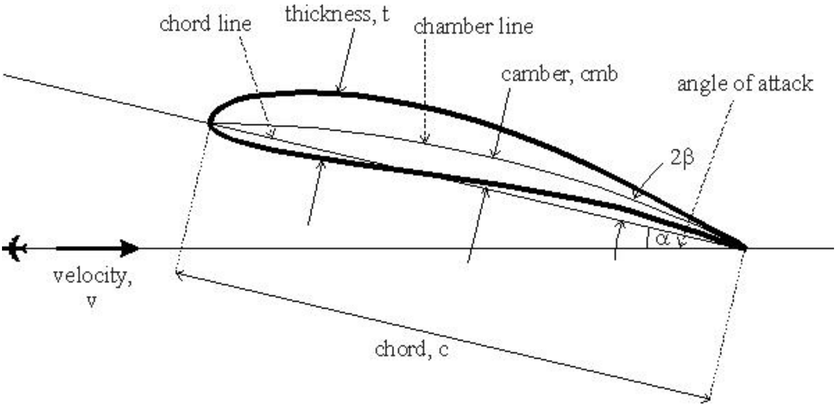
ρ is the density of air
S_W is the plan form area of the wing
C_L is the lift Coefficient C_{D_i} is the induced drag Coefficient

A wing is a lot of airfoils stuck together

The design of the wing is done in sections. The wing in cross section is called the airfoil and its shape will determine half of the aircrafts flight characteristics

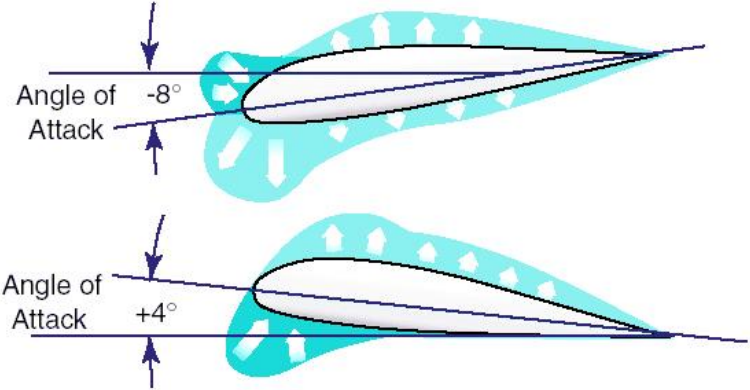
The wing in 3D is defied as how the airfoil changes along the path from the start or root to the tip.

Parts of an airfoil



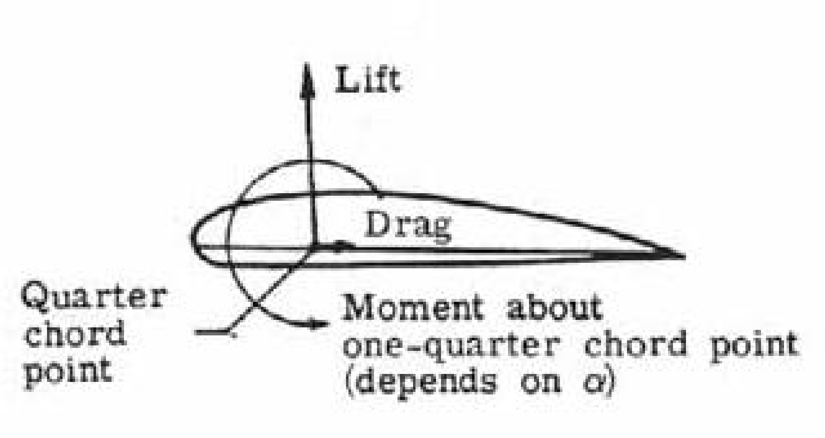
The pressure distribution on an airfoil

As air flows around a body it changes in pressure depending on its velocity these pressure variations cause a net effect of Lift however since these are not evenly distributed a moment is created on the airfoil.



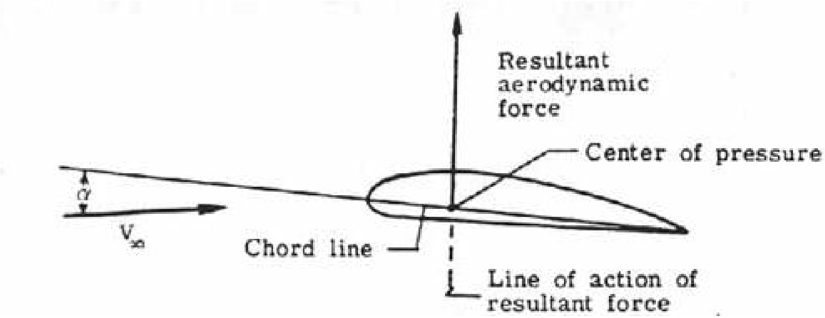
Modeling the airfoil

For convenience the quarter chord location is used to model the airfoil and the resulting moment is defined as M_{AC} or moment of the aerodynamic chord



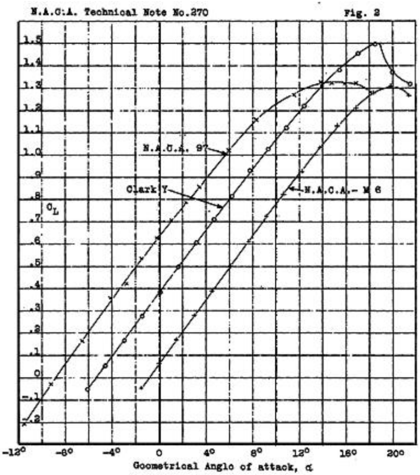
The Affect Of Alpha On C_L, C_D and M_{AC}

Changing the angle of Attack will result in a
change in the pressure distribution and therefore change C_L and M_{AC}



Airfoil Chart

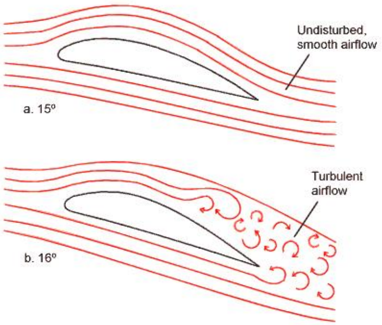
Airfoil charts are created from each airfoil ether empirically or through CFD modeling



Wing or aerodynamic stall

Wing stall or aerodynamic stall occurs when air separates from the airfoil and a large disturbance is created.

This sudden increase in drag and decrease in lift is caused by exceeding the designed angle of attack

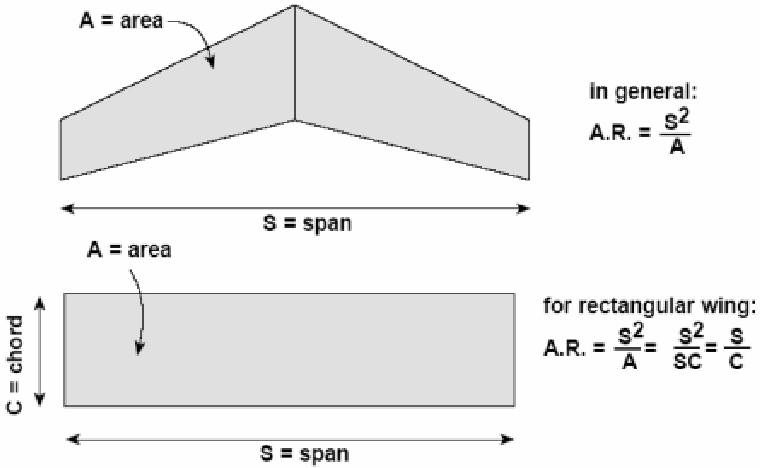


Airfoil in Stall (video)

The Wing

The wing span is defined as b measured parallel to the y axis

The chord defined perpendicular to the y axis and is defined as c



The Wing

Useful numbers to know and calculate

- The tip chord c_t
- The root chord c_o
- The taper ratio $\lambda = c_t/c_o$
- The plan form area is $S = c_{avg}b = \frac{c_o(1+\lambda)b}{2}$
- The Aspect Ratio $AR = \frac{b^2}{s_w} = \frac{2b}{c_o(1+\lambda)}$

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Drag

Drag is primarily made up of two main parts, Induced and Parasite

The first we have seen before but in 3D it bundles up into a vortex that occurs off each wing tip as the pressure leaks around the wing tip

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The second is Parasite Drag Including

- Skin friction drag
- Form or pressure drag
- interference drag
- wave Drag
- cowling drag
- etc.

examples of vortex drag

Skin friction Drag

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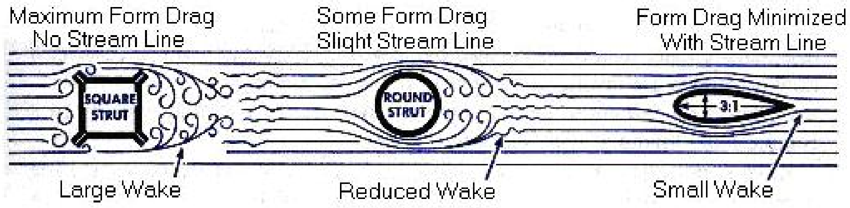
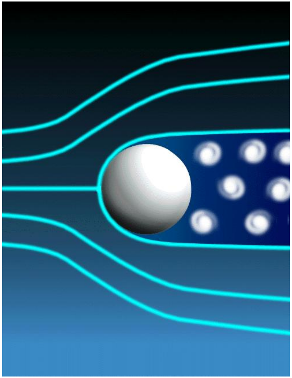


Why Golf Balls Have Dimples

laminar flow separates earlier creating a large low pressure volume behind the ball



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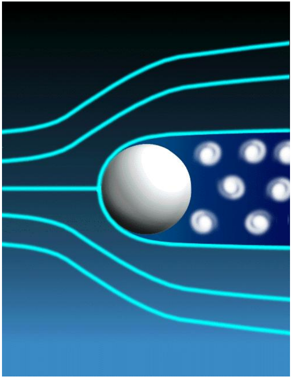
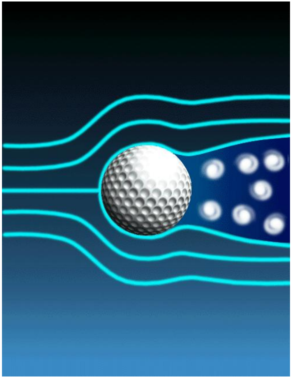


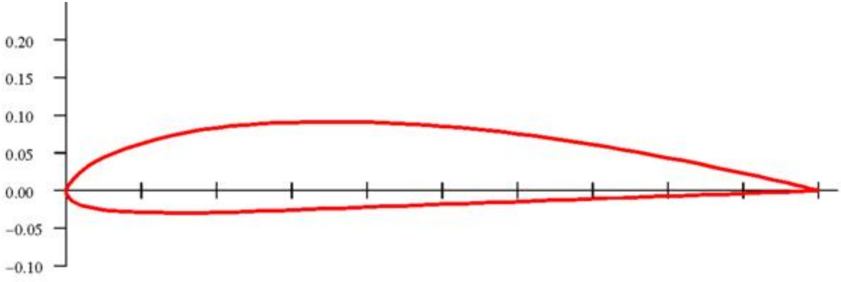
The turbulent flow (more random motion) creates less drag since it separates later.

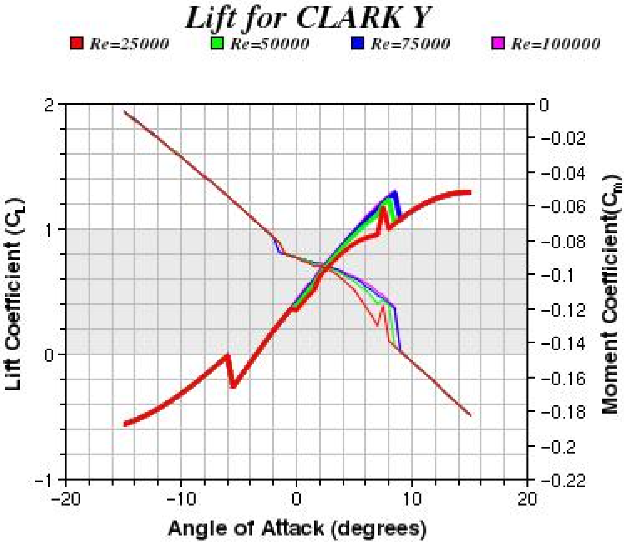


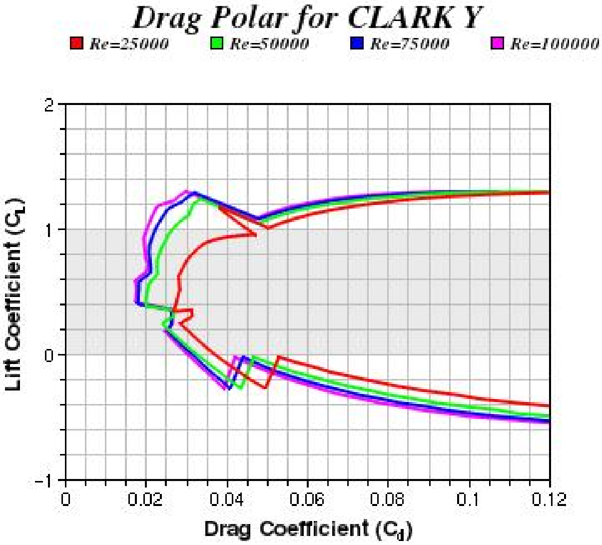
Clark Y airfoil example

Given this airfoil and the following charts what is the max and min C_L and α ?

Do the curves make sense ?




Lift for CLARK Y
Re=25000
Re=50000
Re=75000
Re=100000
Lift Coefficient (C_L)
Moment Coefficient(C_m)
Angle of Attack (degrees)
2
1
0
−1
0
−0.02
−0.04
−0.06
−0.08
−0.1
−0.12
−0.14
−0.16
−0.18
−0.2
−0.22
−20
−10
0
10
20


Drag Polar for CLARK Y
Re=25000
Re=50000
Re=75000
Re=100000
Lift Coefficient (C_L)
Drag Coefficient (C_d)
2
1
0
−1
0
0.02
0.04
0.06
0.08
0.1
0.12