

Aerodynamics: Lift on Wing

- The lift curve for a wing has smaller slope than the corresponding lift curve for an airfoil with the same airfoil cross section.
- The relationship between the two slopes is given by

$$\frac{dC_L}{d\alpha} = \eta = \frac{\eta_o}{1 + \frac{\eta_o}{\pi \mathfrak{R}}(1 + \tau)}$$

where η is the slope of a wing, η_o is the slope of the airfoil, is the *aspect ratio*, τ is a correction factor.

- The aspect ratio is defined as $\mathfrak{R} = b^2/S$ where b is the span and S is the area of the wing.

Aerodynamics: Lift and Circulation

- The lift per unit span of an airfoil can be related to the intensity of the circulatory flow or *circulation*, Γ , via *Kutta-Joukowski Theorem*

$$L' = \rho_{\infty} V_{\infty} \Gamma$$

where the L' is the lift per unit span of the wing.

- This relation shows that the lift per unit span is directly proportional to circulation.
- It is a pivotal relation in ideal incompressible flow theory often called potential flow theory.
- Thus, a major prop of the potential flow theory is to calculate circulation.

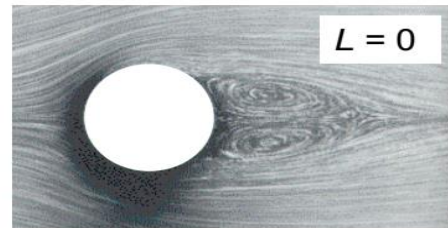
Aerodynamics: Lift and Circulation

- Example of this relation:

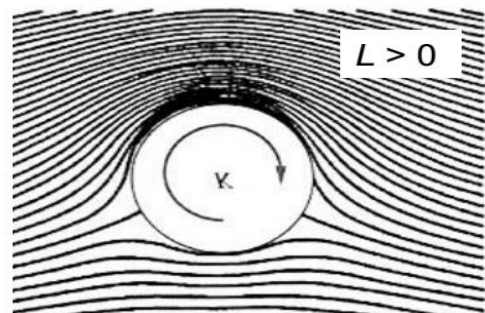
flow over a circular cylinder

- The flow around non-lifting circular cylinder is symmetric
- Hence one would expect that the pressure distribution over the top and bottom surfaces of the cylinder is also symmetric.
- This results in zero lift for the cylinder.
- However, if the cylinder rotates about its axis, then the flow field is not symmetric any more.

Flow over Non-lifting circular cylinder



Flow over lifting circular cylinder



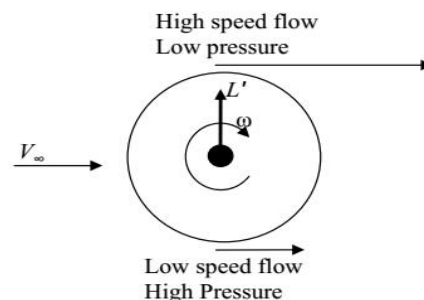
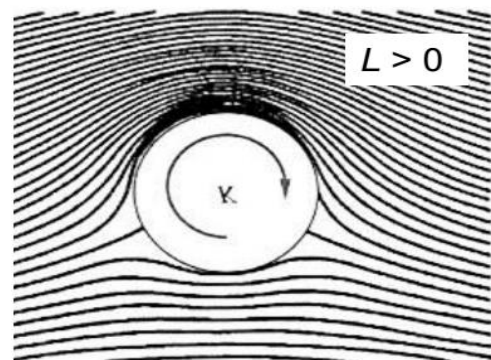
- Why do we have a lift when the cylinder rotates?

- When the cylinder rotates, this will increase the flow velocity over the top surface and decrease it on the bottom of the cylinder.
- As a result, the pressure on the top surface decreases and the pressure on the bottom surface increases (Bernoulli's equation).

$$P_{\infty} + \frac{1}{2} \rho V_{\infty}^2 = P + \frac{1}{2} \rho V^2$$

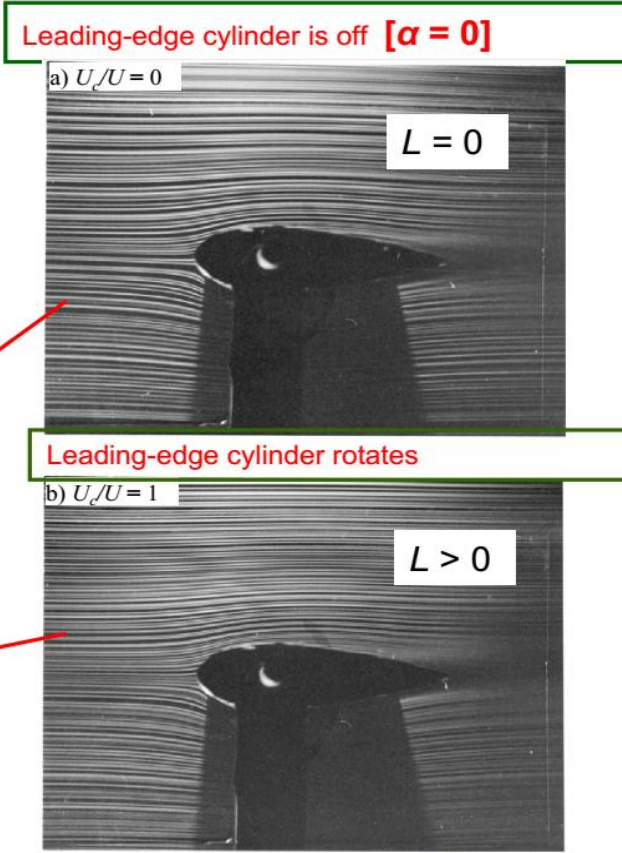
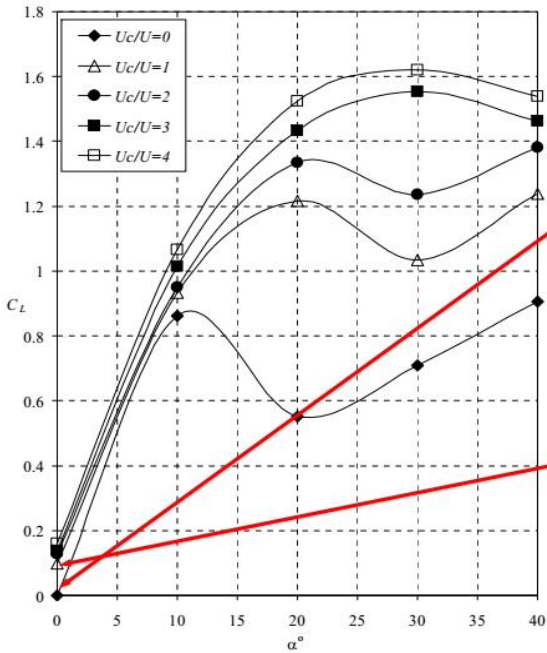
- This net imbalance of pressure will produce a finite lift as sketched in Figure. This is often called Magnus effect.

Flow over lifting circular cylinder

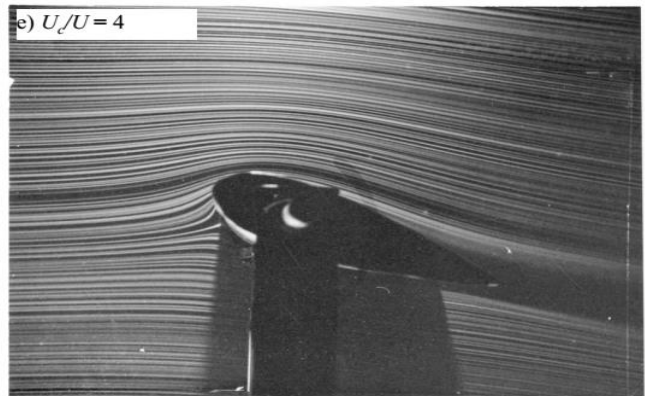
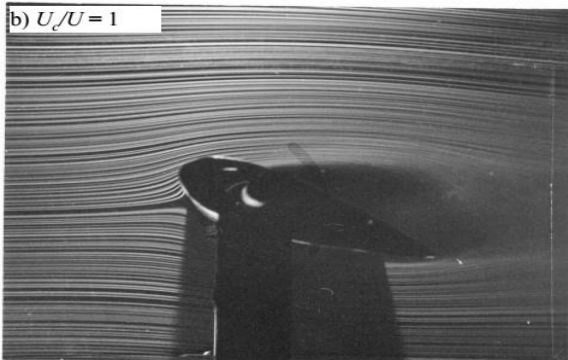
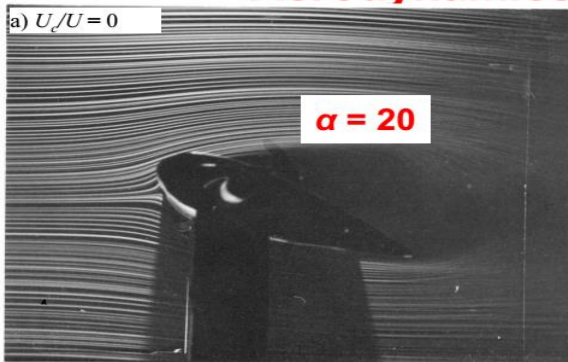


- Another Example of this relation:

flow over a airfoil with a leading-edge rotating cylinder

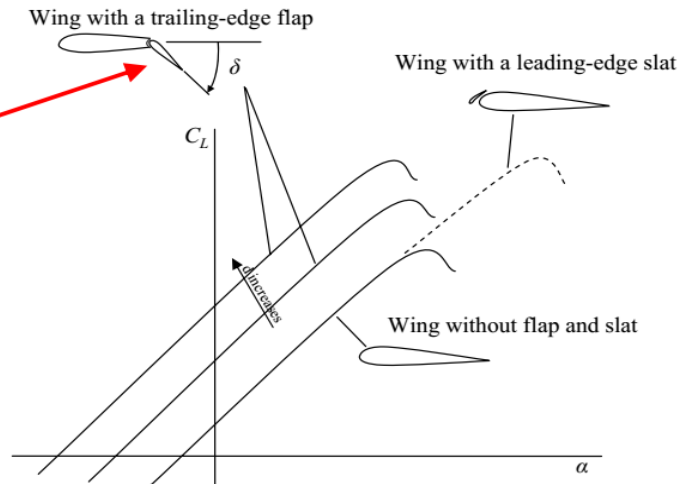


Aerodynamics: Lift and Circulation



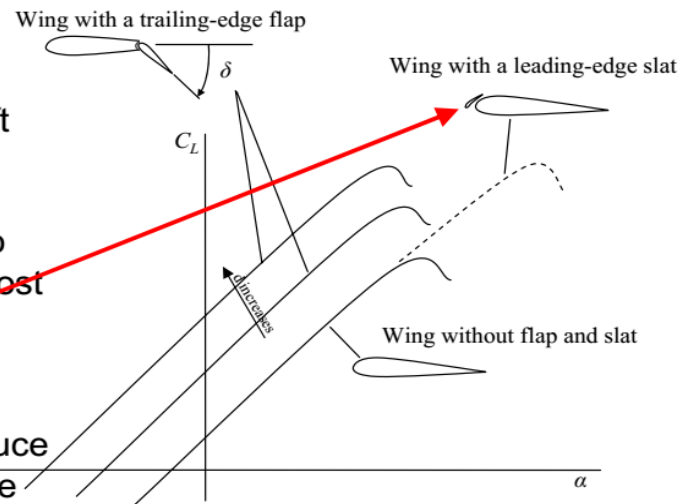
Aerodynamics: High Lift Devices

- The lifting properties of a given airfoil can be enhanced by using high lift devices as shown in the Figure 13.
- The most common of these devices is the simple flap at the trailing edge of the wing.
- When the flap is deflected downward, the camber of the airfoil is increased.
- This increase is associated with a dramatic increase in the maximum lift coefficient, $C_{L,max}$ and a shift of the zero-lift angle of attack to a more negative value for the wing.



- In some airplanes, the flap is designed not only to deflect downward but also to translate rearward which increases the wing area and hence increase the lift.

- The flap can increase the maximum lift coefficient by about 200%.
- High lift devices can also be applied to the leading edge of the wing with the most common is the leading-edge slat.
- The leading edge slat can alter the pressure distribution over the wing, reduce the pressure on the top and increase the pressure on the bottom surface. As a result, a more lift is generated on the wing.
- Another advantage of the leading-edge slat is the delay of flow separation over



the top surface of the wing to higher angles of attack and consequently delays stall of the wing. In modern aircraft a combination of leading-edge slat and trailing-flaps is common.