Boundary layer separation

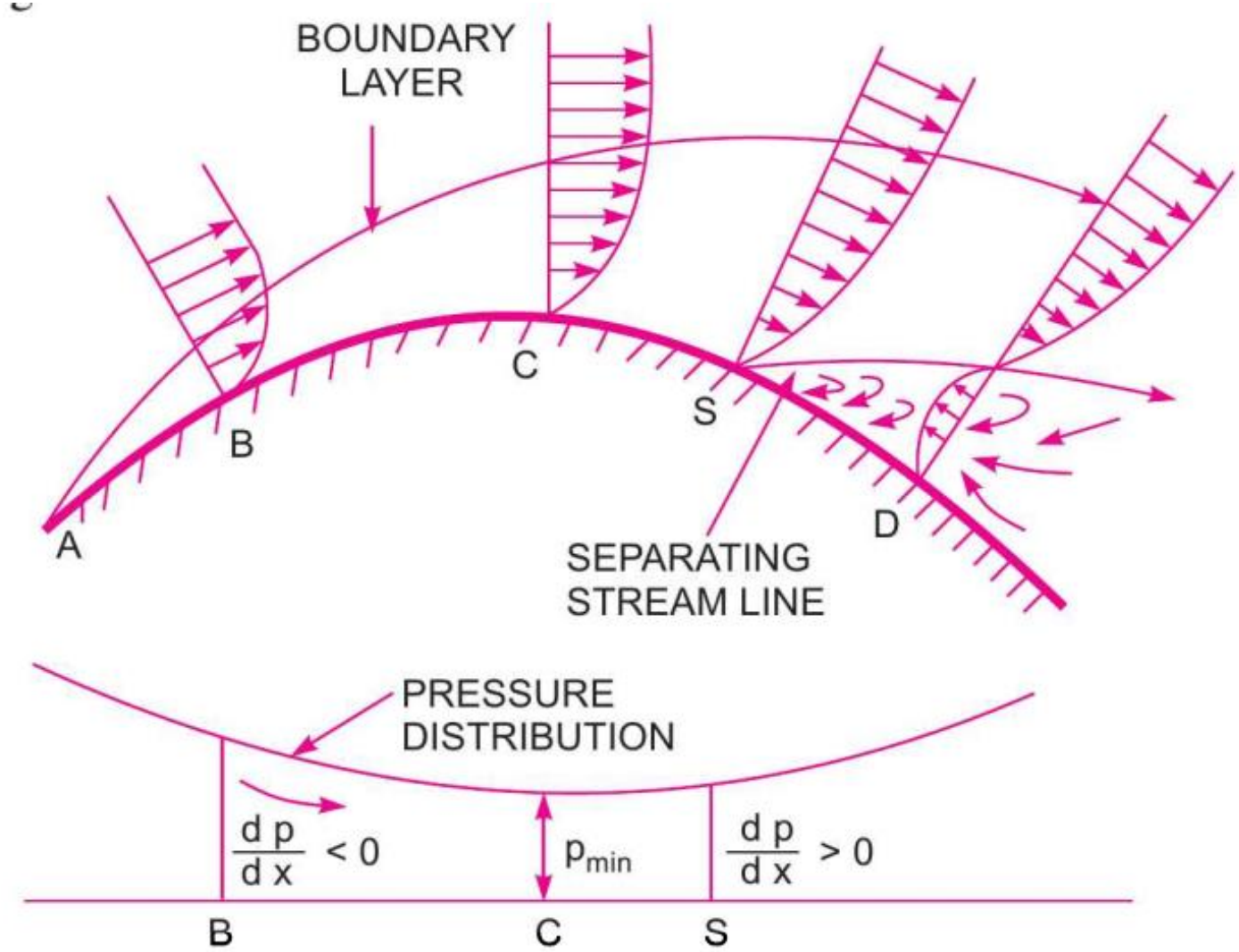


Fig. 13.7 *Effect of pressure gradient on boundary layer separation.*

Region ABC of curved surface:

- Area of the flow decreasing along the flow direction ---> Velocity increases along the flow direction ---> pressure decreases along the flow direction
- Therefore, along ABC, the pressure decreases. So $(dp/dx) < 0$ ----> Favourable pressure gradient
- Fluid is flowing from a high pressure to low pressure in this region

Region CSD of curved surface:

- Area of the flow increasing along the flow direction ---> Velocity decreases along the flow direction ---> pressure increases along the flow direction
- Therefore, along CSD, the pressure increases. So $(dp/dx) > 0$ ----> Adverse pressure gradient
- Fluid is flowing from a low pressure point to high pressure point in this region. The combined effect of the positive pressure gradient and surface resistance reduces the momentum of flow in the boundary layer in this region.
- The flow inside the boundary layer looses its momentum and a stage comes when the momentum of the fluid is unable to overcome the combined effect of positive pressure gradient and surface resistance
- The boundary layer separates from the surface at this point and the flow takes place in the reverse direction beyond this point.
- This phenomenon is called “Boundary layer separation” and the point where the flow reverses its direction is called the “Separation point”

NOTE:

- Flow separates only in the region of the adverse pressure gradient, i.e., dp/dx > 0
- Flow does not separate in the regions of favorable pressure gradient dp/dx < 0 or zero pressure gradient dp/dx = 0

3.7.2 Location of Separation Point. The separation point S is determined from the condition,

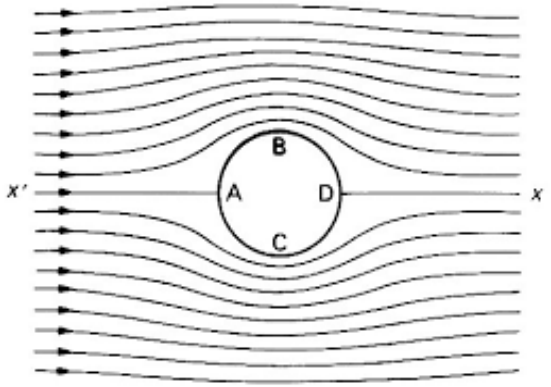
$$\left(\frac{\partial u}{\partial y}\right)_{y=0} = 0 \qquad \ldots(13.46)$$

For a given velocity profile, it can be determined whether the boundary layer has separated, or on he verge of separation or will not separate from the following conditions :

1. If $\left(\frac{\partial u}{\partial y}\right)_{y=0}$ is negative ... the flow has separated.
2. If $\left(\frac{\partial u}{\partial y}\right)_{y=0} = 0$ ... the flow is on the verge of separation.
3. If $\left(\frac{\partial u}{\partial y}\right)_{y=0}$ is positive ... the flow will not separate or flow will remain attached with the surface.

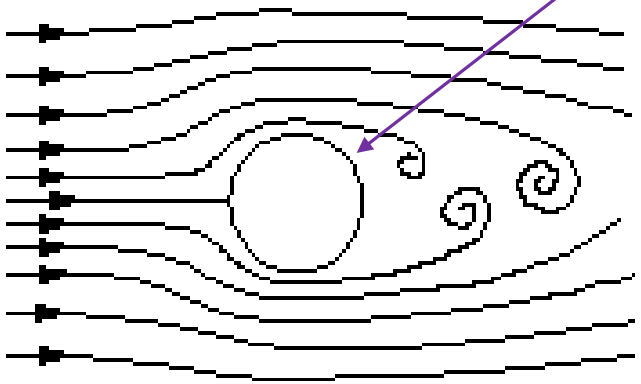
Boundary layer separation over cylinder

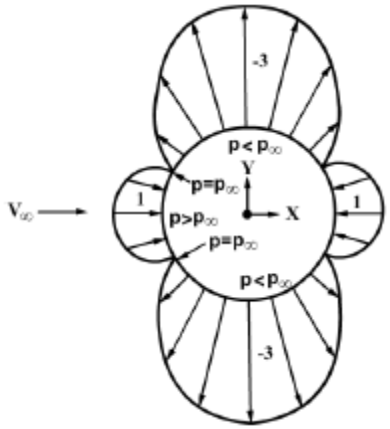
Inviscid flow (Theoretical)



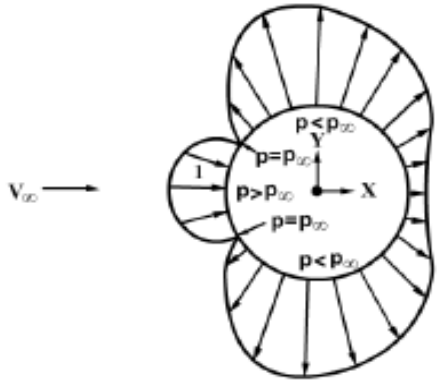
Real flow (Experimental)

Boundary layer separation

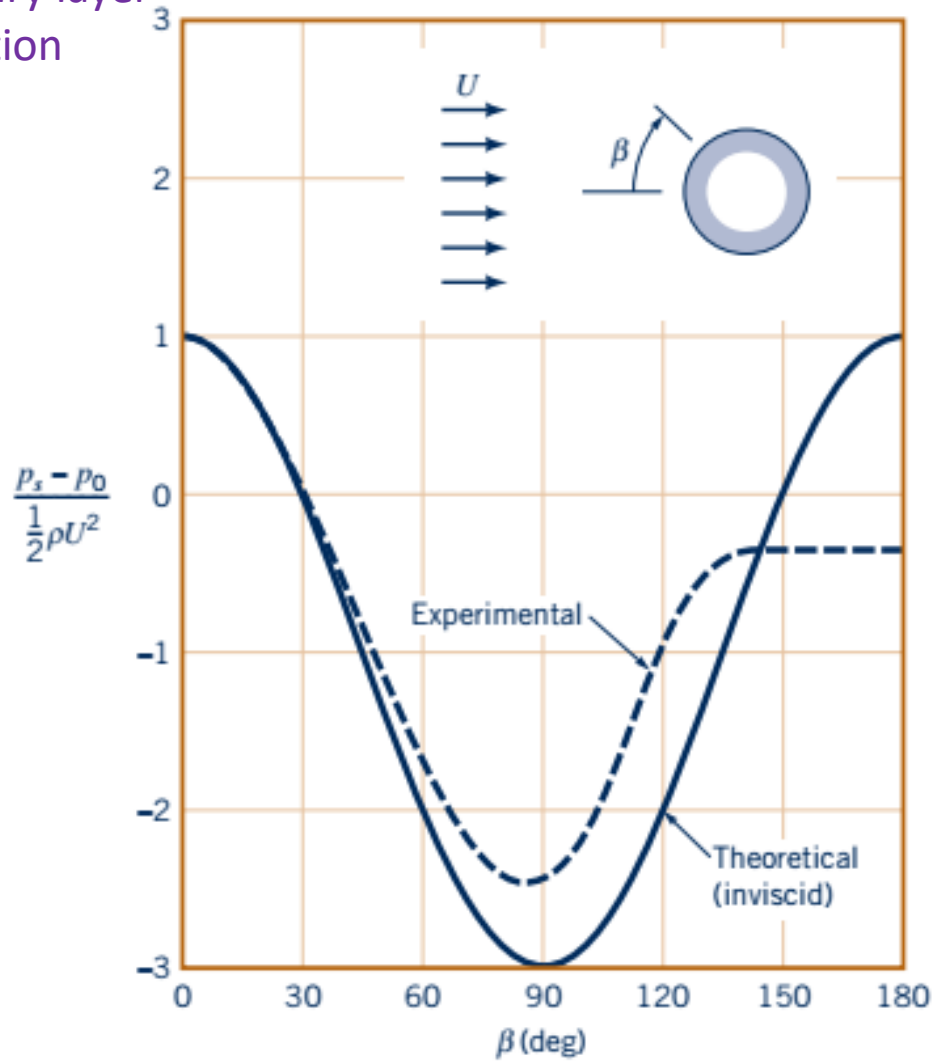




Drag = 0



Drag ≠ 0



- Boundary layer separation leads to incomplete pressure recovery on the rear side leading to Drag
- Drag that arises because of boundary layer separation is called FORM DRAG (or) PRESSURE DRAG