Thermal and Hydrodynamic Boundary Layer

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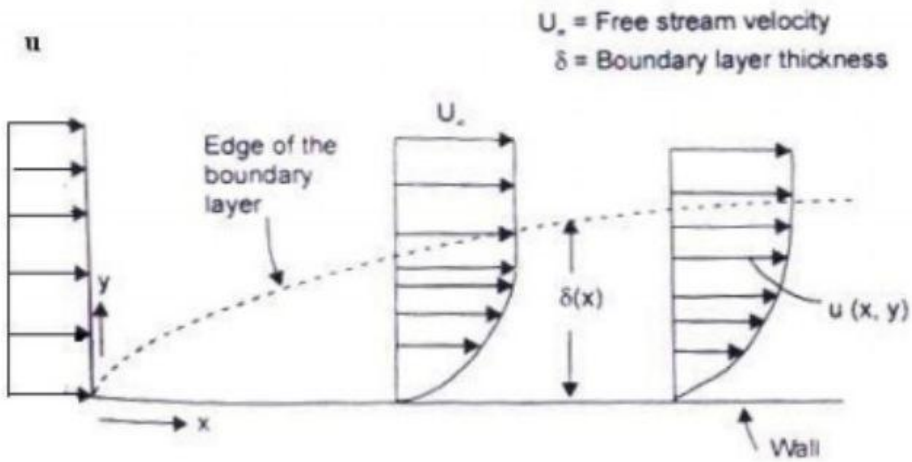
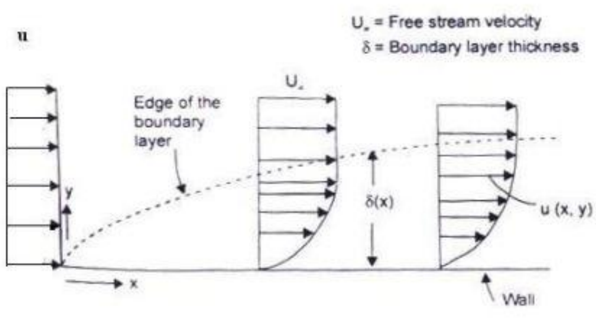


Fig 2.2: sketch of a boundary layer on a wall

Formation of a Boundary Layer: When a fluid flow, over a surface, irrespective of whether the flow is laminar or turbulent, the fluid particles adjacent to the solid surface will always stick to it and their velocity at the solid surface will be zero, because of the viscosity of the fluid.

Formation of a Boundary Layer

When a fluid flow, over a surface, irrespective of whether the flow is laminar or turbulent, the fluid particles adjacent to the solid surface will always stick to it and their velocity at the solid surface will be zero, because of the viscosity of the fluid. Due to the shearing action of one fluid layer over the adjacent layer moving at the faster rate, there would be a velocity gradient in a direction normal to the flow.



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Let us consider a two-dimensional flow of a real fluid about a solid (slender in cross-section) as shown in Fig. 2.2. Detailed investigations have revealed that the velocity of the fluid particles at the surface of the solid is zero. The transition from zero velocity at the surface of the solid to the free stream velocity at some distance away from the solid surface in the V-direction (normal to the direction of flow) takes place in a very thin layer called 'momentum or hydrodynamic boundary layer'. The flow field can thus be divided in two regions:

(i) A very thin layer in t he vicinity 0 f t he body w here a velocity gradient normal to the direction of flow exists, the velocity gradient du/dy being large. In this thin region, even a very small Viscosity μof the fluid exerts a substantial Influence and the shearing stress $\tau = \mu$ du/dy may assume large values. The thickness of the boundary layer is very small and decreases with decreasing viscosity.

(ii) In the remaining region, no such large velocity gradients exist and the Influence of viscosity is unimportant. The flow can be considered frictionless and potential.

Thermal Boundary Layer

Since the heat transfer by convection involves the motion of fluid particles, we must superimpose the temperature field on the physical motion of fluid and the two fields are bound to interact. It is intuitively evident that the temperature distribution around a hot body in a fluid stream will often have the same character as the velocity distribution in the boundary layer flow. When a heated solid body IS placed In a fluid stream, the temperature of the fluid stream will also vary within a thin layer In the immediate neighbourhood of the solid body. The variation in temperature of the fluid stream also takes place in a thin layer in the neighbourhood of the body and is termed 'thermal boundary layer'. Fig. shows the temperature profiles inside a thermal boundary layer.

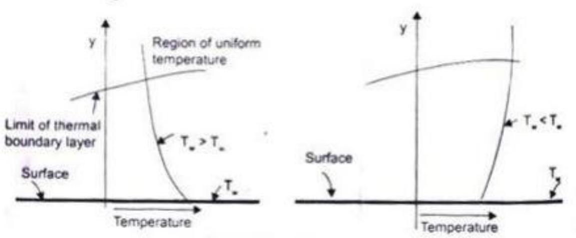

Fig: The thermal boundary layer

Hydrodynamic Boundary Layer :

One of the most important concepts in understanding the external flows is the boundary layer development. For simplicity, we are going to analyze a boundary layer flow over a flat plate with no curvature and no external pressure variation.

- Boundary layer thickness (d): defined as the distance away from the surface where the local velocity reaches to 99% of the free-stream velocity, that is u(y=d)=0.99U∞.

Somewhat an easy to understand but arbitrary definition.

- Boundary layer is usually very thin: δ/x usually $\ll 1$.

- As we have seen earlier,the hydrodynamic boundary layer is a region of a fluid flow, near a solid surface, where the flow patterns are directly influenced by viscous drag from the

  surface wall.

- $0<u<U$, $0<y<\delta$

- The Thermal Boundary Layer is a region of a fluid flow, near a solid surface, where the fluid temperatures are directly influenced by heating or cooling from the surface wall.

- $0<t<T$, $0<y<\delta_t$

- *The two boundary layers may be expected to have similar characteristics but do not normally coincide.* Liquid metals tend to conduct heat from the wall easily and

  temperature changes are observed well outside the dynamic boundary layer. Other materials tend to show velocity changes well outside the thermal layer.

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