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# Effect Of Inclination On Boundary Layer In A Low Speed Wind Tunnel On Different Roughness'

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**ABSTRACT**
The boundary layer of a flowing fluid is the thin layer close to the wall. For the basic understanding of flow characteristics over a flat plate, the experiment was carried out in the laboratory using a low speed wind tunnel. In a flow field viscous stresses are very prominent within this layer due to existence of velocity gradient. Velocity reading at 21 locations over the flat plate (wood surface with stacked on a 40 grade and 60 grade emery paper) with a free stream velocity (U) and with the concept of 0.99U velocity profile is plotted at different locations of working section length. The inclination of flat plate gives a better idea of free steam bodies for the purpose of design. The boundary layer thickness of the boundary layer ranges from 2.2mm to 59.2mm.The boundary layer growth over the rough flat plate was found out with the help of velocity profiles at different locations. The boundary layer growth gives a brief idea of fluid flow over a flat surface. Comparison of rough flat plates with different inclination gives a better understanding of boundary layer.
***Keywords* -** boundary layer, roughness, flat plate, velocity profile, inclination of plate.

## I. INTRODUCTION

Boundary layer is a layer adjacent to the surface where viscous effects are important. When real fluid flows past a solid body or a solid wall, the fluid particles adhere to the boundary and condition of no slip occurs. This means that the velocity of fluid close to the boundary will be same as that of boundary. If the boundary is not moving the velocity of fluid at the boundary will be zero. Further away from the boundary, the velocity will be increase gradually and as a result of this variation of velocity, the velocity gradient will exist. The velocity of fluid increases from zero velocity on the stationary boundary to the free stream velocity of the fluid in the direction normal to the boundary. The extent of atmospheric boundary layer (ABL) thickness is quite high and all types of structures lies with atmospheric boundary layer thickness. To conduct wind tunnel experiments on the small scale replica of a structure (civil, mechanical or any), it is necessary that the models should lie within boundary layer zone. But in wind tunnel the boundary layer thickness is very small and hence constant attempts have been made by different researchers to increase boundary layer thickness by different means.

In the first part of experiment the study was based on the fact that reading was taken with some obstruction like 40 grade in approaching flow with 0 degree (horizontal position) and 5 degree inclination. With these reading velocity profile were plotted and then growth of boundary layer were also drawn. In the second part of experiment reading were taken in presence of less rough flat plates and the thickness of boundary layer is decreased in comparison to previous cases. This is because obstruction helps in the generation of vortex formation and consequent turbulence.

Boundary layer study is of utmost importance for stability and design point of view. Much work has been done by many researchers in this field out of which those related to the present work has been described as follows. In [1], author analyzed the laminar boundary layer oscillation and stability of flow by mathematical model.

In [2], author measured the boundary layer on smooth flat plate in supersonic flow. In [3], author proposed a boundary flow near the trailing edge of a flat plate. in [4], author placed an elliptic wedge in front of air flow i.e. roughness and barriers are placed in wind tunnel. In [5], authors suggested a three dimensional steep hill model in wind tunnel and studied the velocity profile in all three planes. In [6], authors studied turbulent boundary layer in a flat plate. In [7], author analyzed transition to turbulent flow in boundary layer on a flat plate in presence of negative pressure gradient. In [8], authors put aerodynamically different position of the cyclist and did analysis in CFD. They put full scale model in the wind tunnel. In [9], authors developed a numerical simulation technique for unsteady turbulent dispersion over a complicated terrain. In [10], authors developed mathematical model in heat and mass transfer in a flat plate and put an inclined plate in the viscous medium.

## II. Experimental Setup

For carrying out research on boundary layer study a Low Speed Wind Tunnel is built in the Hydrodynamics Laboratory of NIT Rourkela as shown in Fig 1. The speed of air in this wind tunnel can be varied from 10 to 25 m/s.

Fig 1: Photograph of Low Speed Wind Tunnel

The wind tunnel consists of a testing section somewhere in the central region where the velocity variation in the air stream is nearly uniform. The dimensions of the various components of the wind tunnel are given in Table 1.

Experimental models are placed here to carry out studies done on the objects to find the effect of the air stream on them. The photograph of the testing section is shown in Fig 2.

Table 1: Dimensions of Wind Tunnel Components

| Components | Length | Inlet (m) | Outlet (m) |
|---|---|---|---|
| Effuser | 1.3 m | 2.1 X 2.1 | 2.1 X 2.1 |
| Test Section | 8 m | 0.6 X 0.6 | 0.6 X 0.6 |
| Diffuser | 5m | 0.6 | 1.3 |

To study the effect of boundary layer flat plates of length 100cm and width 50cm with different surface roughness is considered. Two different surface roughnesses are taken in the current study, namely 40 and 60 Grade. The value of the grain size in 40 and 60 Grade is 375 μm and 290 μm respectively. For the current study; 21 positions along the length of the plate are considered for velocity measurement in the vertical direction. However data for 8 such sections at 15 cm interval from the leading edge are considered in this paper Fig 4. At each such section, velocity data is taken initially at 1mm interval and later the interval is increased to 5mm when the free surface velocity is achieved.

Measurements are taken with a Telescopic Pitot Tube which is connected to a Digital Veloci Manometer shown in Fig 3. The pitot-tube is moved across the testing section throughout the length of the flat plate. The pitot-tube is held in the appropriate position and the corresponding velocity is taken directly by the digital manometer. Some wedges are used to give the inclination of rough flat plate.

Fig 2: Photograph of the Test Section


Fig 3: Photographs of Digital Veloci Manometer

## III.Discussion and Result

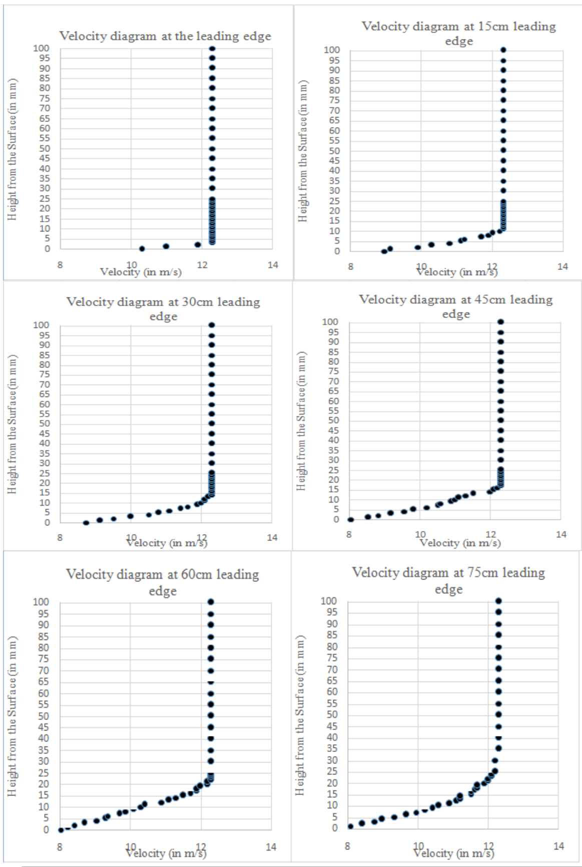
For a given free stream velocity, velocity profiles data are taken throughout the testing section where the rough flat plates are positioned. Speed of the low speed wind tunnel used here is less than 25 m/s. The boundary layer thickness is in the range of 2.2-59.2 mm (of 40 grade and 60grade rough emery paper) with 0 and 5 degree inclination which was expected for rough flat plate at some fixed velocity in the low speed wind tunnel.

Here two different types of roughnesses with two different inclinations have been used. It means the boundary layer thickness is also different in these roughnesses. These plates are put horizontally and with 5 degree inclination with respect to bed. There is no variation in the magnitude of the velocity in the lateral direction at a particular section and at the same level. The readings have been taken for the lateral side at the distance of 50 cm on the leading edge. The boundary layer of the rough flat plate grows as the length is increased and tends to have great tangent as the velocity increases. Velocity profile changes along the length of the flat plate. Initially the velocity profiles has steeper gradient compared to the velocity profiles at end ones. Tangent at each and every point of the boundary layer will be different from others.

Velocity profiles have been plotted according to the velocity readings as obtained from digital veloci manometer in m/s. Here 8 sections have been used in the longitudinal direction as shown in Fig 4. With the help of these velocity profiles, boundary layer of 40 grade roughness emery paper has been plotted in horizontal position as shown in Fig 4. As 40 grade boundary layer has been plotted in 0 degree, similarly 40 grade with 5 degree of inclination has been plotted using some wedges in Fig 5. With the help of velocity profile of 40 grades with 0 degree and 5 degree, boundary layers has been plotted as shown in Fig. 6. Similar plots have been obtained for 60 grade rough flat plate in 0 degree and 5 degree of inclinations as shown in Fig 7, Fig 8 and Fig 9. Finally for the comparison of all four boundary layers a graph has been plotted in Fig 10.

As the roughness of the emery paper is decreased, the grain size diameter decreases. Therefore main stream flow faces less resistance and thickness of the boundary also decreases. As we increase the inclination of the flat plate the boundary layer thickness also increases.

Velocity profile in the longitudinal direction has been carried out to measure the velocity at different sections.



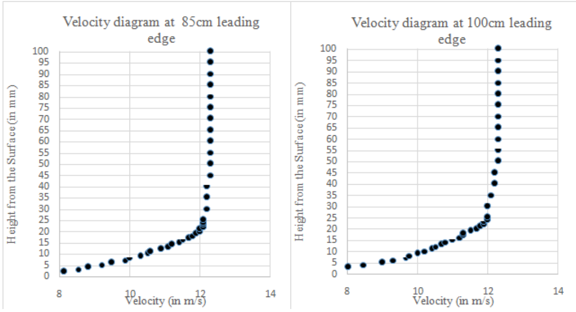




Fig 4: Velocity Profile Plots for 40 Grade at horizontal level.

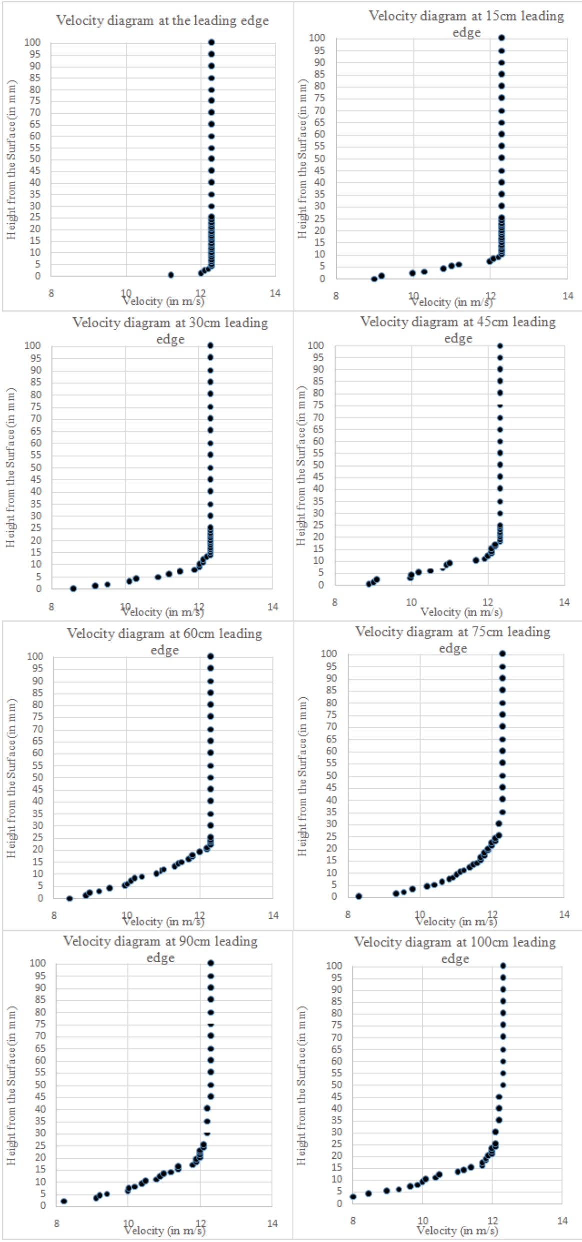



Fig 5: Velocity Profile Plots for 40 Grade at 5° inclination

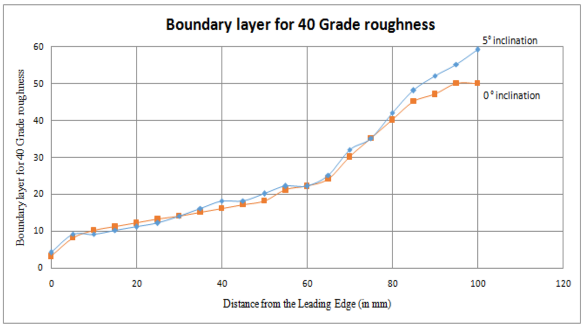



Fig 6: Boundary Layer Graph for 40 Grades

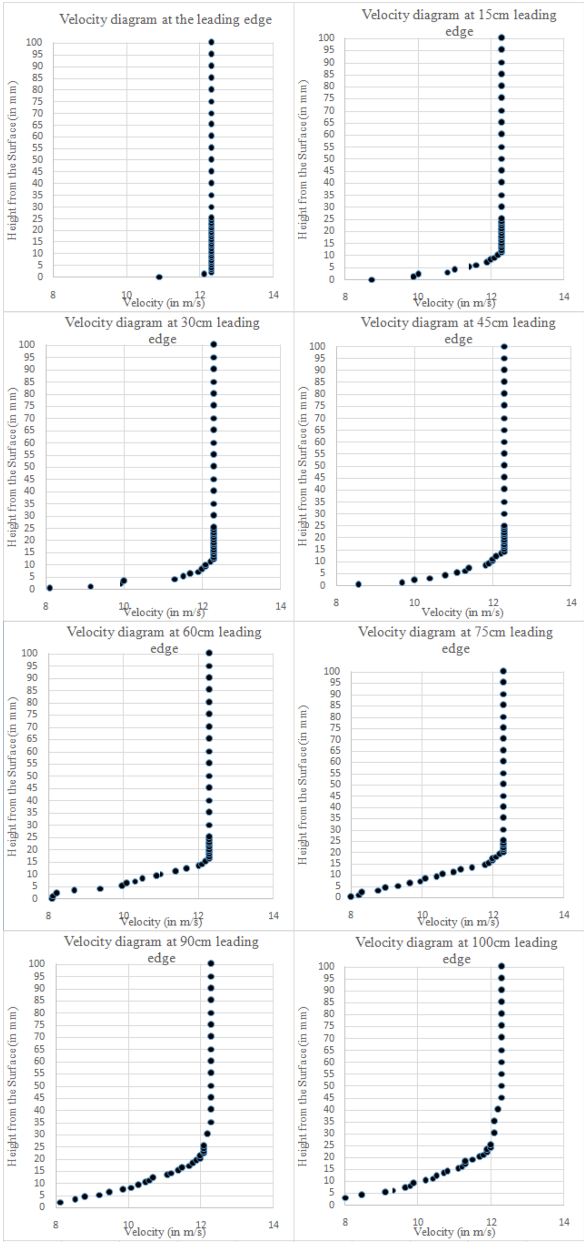



Fig 7: Velocity Profile Plots for 60 Grade at horizontal level

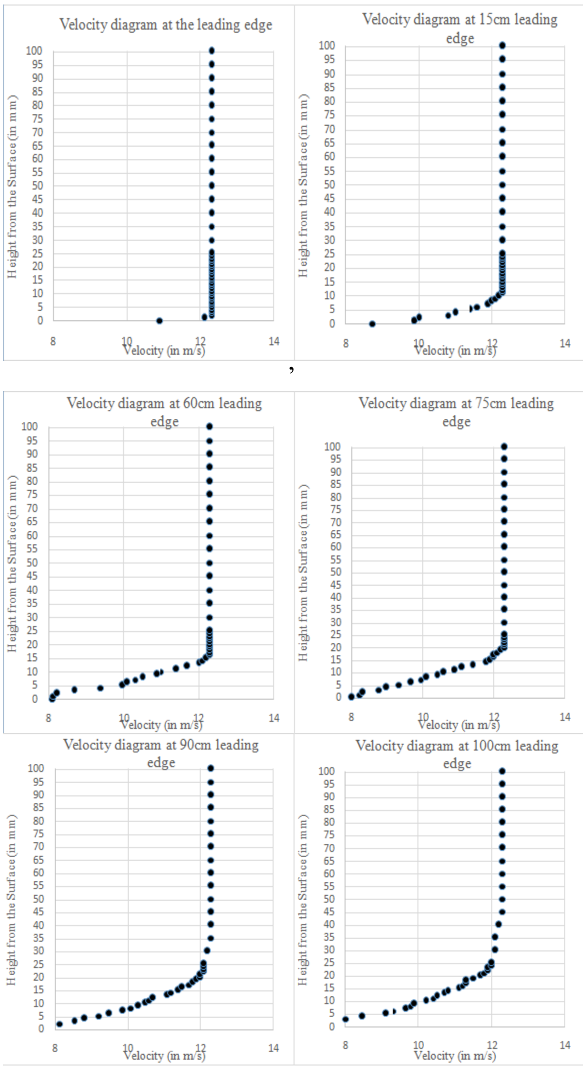



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Fig 8: Velocity Profile Plots for 60 Grade at 5° inclination

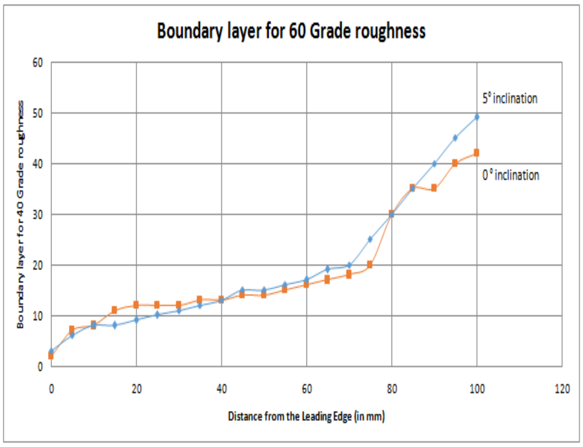


Fig 9: Boundary Layer Graph for 60 Grades

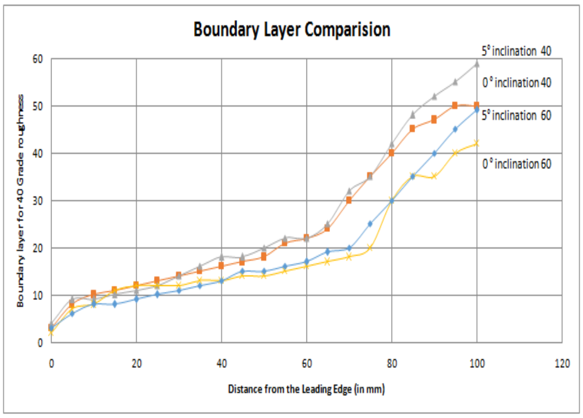


Fig 10: Boundary Layer Graphs

## IV. Conclusion

The following conclusions can be presented by this work:

- From the velocity profile graphs, it is observed that profiles have steeper gradient near the leading edge as to the profiles generated in the latter section.
- Tests conducted on different rough flat plates gave a better understanding of boundary layers and the design. Study of Comparison between boundary layers of different – different roughness is easy.
- The velocity profiles gave a clear view of variation which took place along the length of the rough flat plate.
- There is no variation in the velocity magnitude in the lateral direction at a particular section and at the same level.
- By increasing the inclination from the horizontal; boundary layer thickness also increases.
- Tangent at each and every point of the boundary layer will be different from others.
- Uses of different grades 40, 60 and inclinations give a clear picture of boundary layer thickness close to each-other.

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