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Effect of Roughness on Boundary Layer Using Flat Plate

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***Abstract*—Flow characteristics over a rough flat plate are studied through an experiment, carried out in the laboratory using a low speed wind tunnel. Velocity reading are taken at equal intervals over the flat plate (wood surface glued with a 40 grade emery paper) over a free stream velocity of 12.3m/s. Velocity profiles are plotted at different sections along the longitudinal length, which ultimately give the boundary layer over that section. The boundary layer thickness ranges from 3.2mm to 50.2mm. The boundary layer growth gives a brief idea of fluid flow over a flat surface. Comparison between four rough flat plates gives a better understanding of boundary layer. Analysis of boundary layer gives a better idea for design of aerodynamic objects.**

***Keywords*- boundary layer, roughness, flat plate, velocity profile.**

I. Introduction

Boundary layer is a layer adjacent to a 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.

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In the first part of experiment, the study was based on the fact that reading was taken with some obstruction like 40 grades in approaching flow. 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 important 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. Schubauer [1] analyzed the laminar boundary layer oscillation and stability of flow by mathematical model.

Donald [2] measured the boundary layer on smooth flat plate in supersonic flow. Messiter [3] proposed a boundary flow near the trailing edge of a flat plate. Cook [4] placed a elliptic wedge in front of air flow, means roughness and barriers are placed in wind tunnel. Takeshi and Hibi [5] placed a three dimensional steep hill model in wind tunnel and studied the velocity profile in all three planes. M Jens [6] studied turbulent boundary layer in a flat plate. Lushchik [7] analyzed transition to turbulent flow in boundary layer on a flat plate in the presence of negative pressure gradient. Bert and Peter [8] put aerodynamically different position of the cyclist and did analysis in CFD. They put full scale model in the wind tunnel. Kazuki and Nagayama [9] developed a numerical simulation technique for unsteady turbulent dispersion over a complicated terrain. P.K. Singh [10] 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 between 10 to 25 m/s.

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 are done on the objects to find the effects on them due to the air stream. The photograph of the testing section is shown in Fig. 2.

Fig. 1 Photograph of Low Speed Wind Tunnel

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. Four different surface roughness' are taken in the current study, namely 40, 50, 60 and 120 Grade. The value of the grain size in 40, 50, 60 and 120 Grade is 375, 348, 290 and 125µm 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. 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. 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.

Fig. 2 Photograph of the Test Section

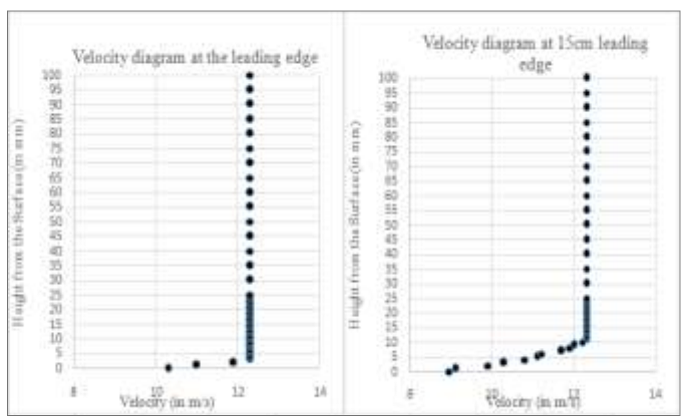
III. Discussion & Result

For a given free stream velocity, velocity profiles data are taken throughout the testing section where the rough flat plates are positioned. Speed of this low speed wind tunnel used here, is less than 25 m/s. The boundary layer thickness is in the range of 3.2-50.2 mm (of 40 grade rough emery paper), which was expected for rough flat plate at some fixed velocity in the low speed wind tunnel.

Here using four different types of roughness' .It means the boundary layer thickness is also different in these roughness used flat plates. All these plates are putting horizontally with respect to bed. There is no variation in the velocity magnitude in the lateral direction at a particular section and at the same level. We are performing this result on 50 cm from 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 profiles changes along the length of the flat plate. Initially the velocity profiles have 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.

We are plotted velocity profiles as got the result in digital veloci manometer in m/s. here in this paper we are using 8 sections in the longitudinal direction (fig.3). With the help of these velocity profiles we are plotted a boundary layer of 40 grade roughness emery paper (fig.4). As we plotted 40 grade boundary layer, similarly plotted 50 grade, 60 grade, 120 grade rough flat plate (fig.5).

As we decreased the roughness of the emery paper, means grain size diameter decreased. Therefore main stream flow faces less resistance and thickness of the boundary also decreased. As we increase the roughness of the flat plate the boundary layer thickness also increased. Velocity profiles in the longitudinal directions has been carried out to measure the velocity at different sections.



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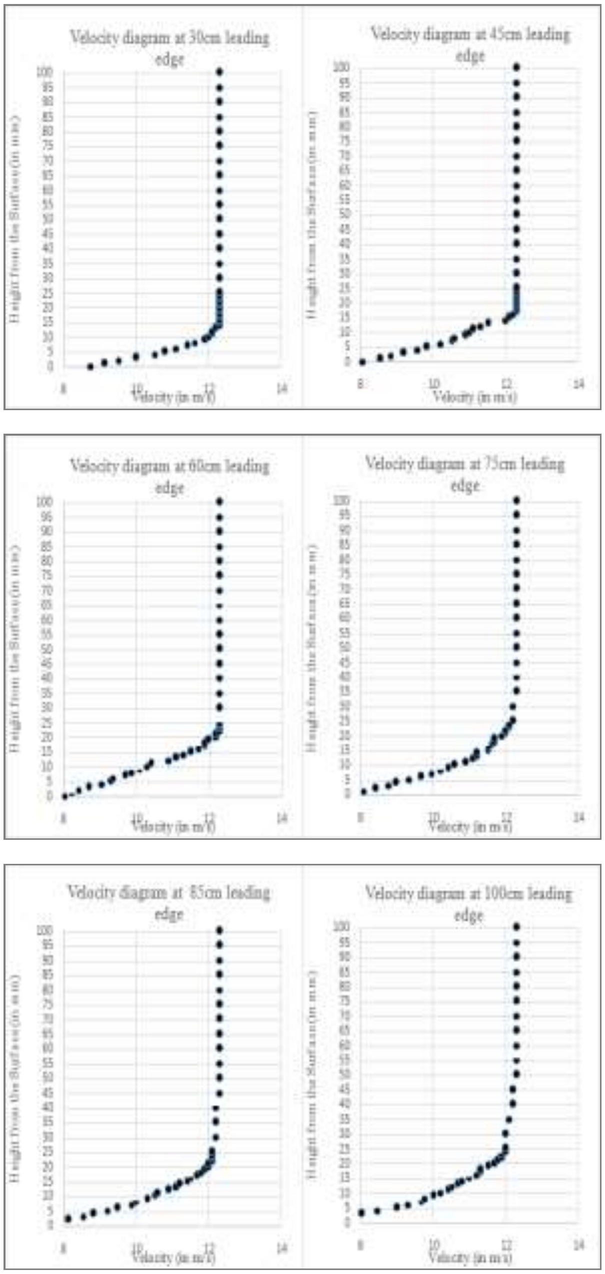

Fig. 3 Velocity Profile Plots for 40 Grade.

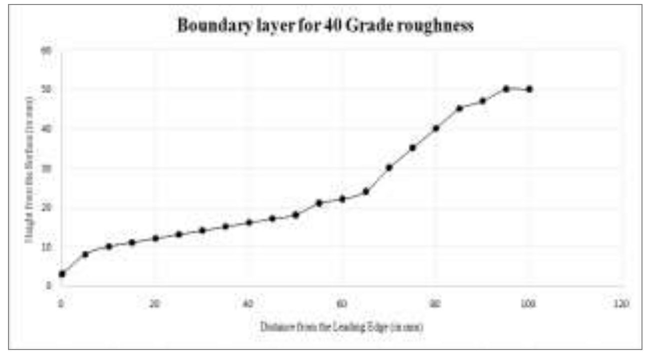

Fig.4 Boundary Layer Graph for 40 Grade

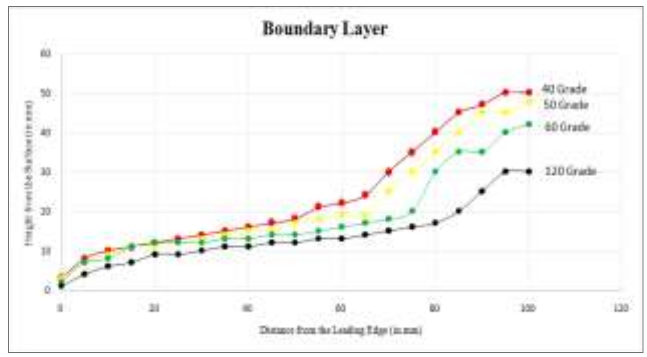

Fig.5 Boundary Layers

IV. Conclusions

The following conclusions can be presented in this work:

1. 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.
2. Test conducted on rough flat plates gave a better understanding of boundary layers and the design. Study of Comparison between boundary layer of different – different roughness is easy.
3. The velocity profiles gave a clear view of variation which took place along the length of the rough flat plate.
4. There is no variation in the velocity magnitude in the lateral direction at a particular section and at the same level.
5. There is a clear transition from laminar to turbulent flow through transition region. The laminar region and the turbulent region can be easily differentiated by the transition zone. Tangent at each and every point of the boundary layer will be different from others.
6. Uses of different grades 40,50,60 and directly 120 grades gives a clear picture of boundary layer thickness close to each-other.

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