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Effect of Mainstream Velocity and Roughness on Velocity Profile on Flat Surface in Turbulent Boundary Layer Zone

Arunima Singh[1], A.Kumar[2]
[1, 2]*(Department of Civil Engineering, National Institute of Technology, Rourkela, India)*

ABSTRACT: *Turbulence is the chaotic and seemingly random motion of fluid parcels. Turbulence has mechanical and convective origins. Here the Wind tunnel experiment was conducted to study the effects of surface roughness on the turbulent boundary layer flow over a flat plate surface at zero angle of incidence. To study the variation of main stream velocity on velocity profile at a particular distance from the leading edge, a graph of velocity versus vertical distance from the surface has been plotted. And it has been observed that the velocity is significantly influenced by the mainstrem velocity and the roughness of the surfaces.*
Keywords – *Boundary layer, Flat plate, Roughness, Turbulence, Velocity profile*

I. INTRODUCTION

We experience wind turbulence in everyday life. It affects all the structures and objects within the atmospheric boundary. Turbulence is the chaotic and seemingly random motion of fluid parcels. Turbulence has mechanical and convective origins. Shear forces cause mechanical turbulence while buoyant instabilities (due to the intermingling of fluid parcels with different densities) cause convective turbulence. Atmospheric turbulence differs from turbulence generated in a laboratory or in pipe flow. In the atmosphere, convective turbulence co-exists with mechanical turbulence. Roughness is a component of surface quality. It is quantified by the vertical deviations of an actual surface from its model form. Each of the roughness parameters is calculated using a formula for describing the surface. Although these parameters are generally considered to be "well known" a standard reference describing each in detail is Surfaces and their Measurement. Roughness is often closely related to the friction and wear properties of a surface. In turbulent flow, the boundary layer is defined as the thin region above the surface of a body in which viscous effects are important. The boundary layer allows the fluid to stick at the surface and thus having the velocity of the surface and to increase towards the mainstream.

The study by Cheryl Klipp (2007), a variety of atmospheric boundary layer parameters are observed as a function of wind direction in both urban and suburban settings in Oklahoma City, Oklahoma, derived from measurements during the Joint Urban 2003 field campaign. The research of Shuyang Cao, Tetsuro Tamura (2005) showed the Wind tunnel experiments to study the effects of surface roughness on the turbulent boundary layer flow over a two-dimensional steep hill, accompanied by a relatively steady and large separation, sometimes called a separation bubble. R. A. Antonia, P-A. Krogstad (2000) described the classical treatment of rough wall turbulent boundary layers consists in determining the effect, the roughness has on the mean velocity profile. Flow of a viscous fluid over a solid surface encounters frictional forces, which retard the motion of the fluid in a thin layer close to the wall. The development of this layer is a major contributor to flow resistance on streamlined geometries and is of great importance in many engineering problems. The concept of a boundary layer is largely due to Prandtl in 1904, as reported by White (1974), who displayed that the effects of friction within the fluid are significant only in a very thin layer close to the surface. The use of boundary layer theory has many important applications, such as the calculation of flow separation and skin friction drag.

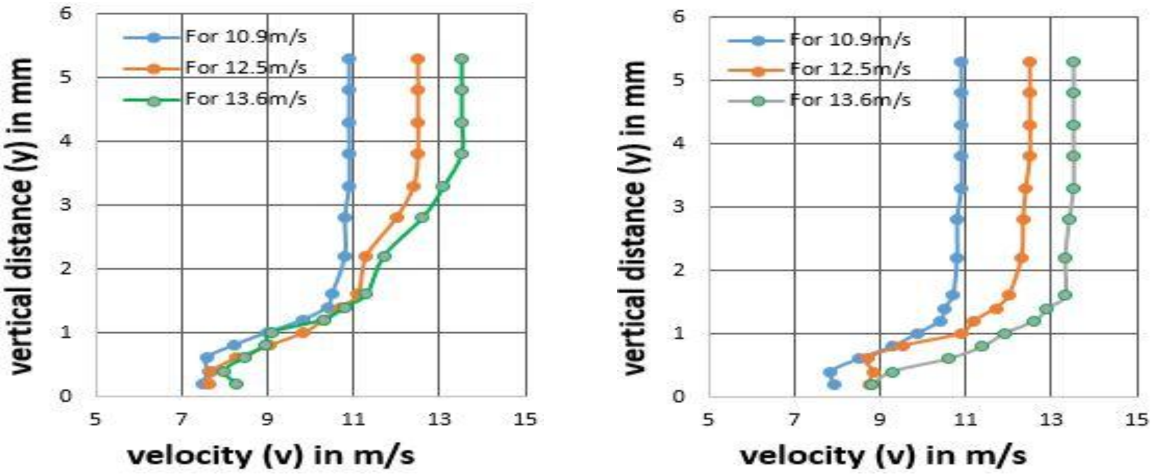
II. EXPERIMENTAL SET-UP

The set-up consists of a low speed wind tunnel air moving inside. The wind tunnels are used to study the aerodynamic behavior of an object. Researchers use wind tunnels to learn more about any air moving or wind influenced objects. The wind tunnel used in this project is a low speed wind tunnel in the Hydraulic Machines Laboratory located at National Institute of Technology, Rourkela, Odisha. The wind tunnel is able to produce a wind velocity of up to 45 m/s. The experimental variables include three constant free stream velocities of 10.9, 12.5 and13.6m/s on flat plates of 40 and 60 grade roughness. Emery papers of 40 grade to produce a roughness projection of 375µm and that of for 60 grade, 290µm were used in the experiment. All the experiments were carried out at room temperature (25^0 to 27^0C). A total of 17 numbers of sections at the intervals of 5 cm were taken along the centre-line of the flat plate. At a particular section, velocity measurement along vertical height at an interval of 2 mm and up to a height of maximum velocity were recorded in the turbulent region. The same procedure was repeated for varying sections and varying incoming main stream velocities. The observation data were used for plotting of graphs and further studies. Some of the principal equipment used to carry out the experiment are, Digital Veloci-Manometer, Telescopic pitot-tube, Special trolley arrangement and Tachometer.

III. RESULTS AND DISCUSSIONS

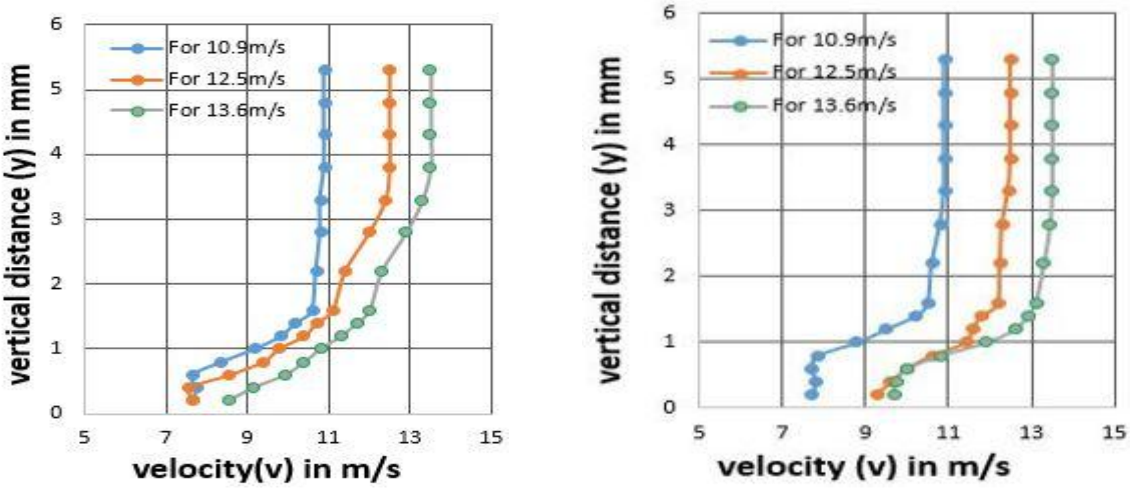
To study the variation of main stream velocity on velocity profile at a particular distance from the leading edge, a graph of velocity versus vertical distance from the surface has been plotted (Fig.1). The same has been repeated at various sections in turbulent boundary layer zones (Fig 2 and 3), and velocity profiles at different sections from the leading edge have plotted for three mainstream velocities (Fig. 4, 5 and 6). Then the variations of profiles due to different roughness with respect to mainstream velocities were also observed by the plots at a section for all two roughness grades for a constant free stream velocity.

3.1 Velocity Variations At Different Sections For All The Main Stream Velocities



GRADE 40 GRADE 60

Fig.1. At x=70cm



GRADE 40 GRADE 60

Fig.2. At x=80cm

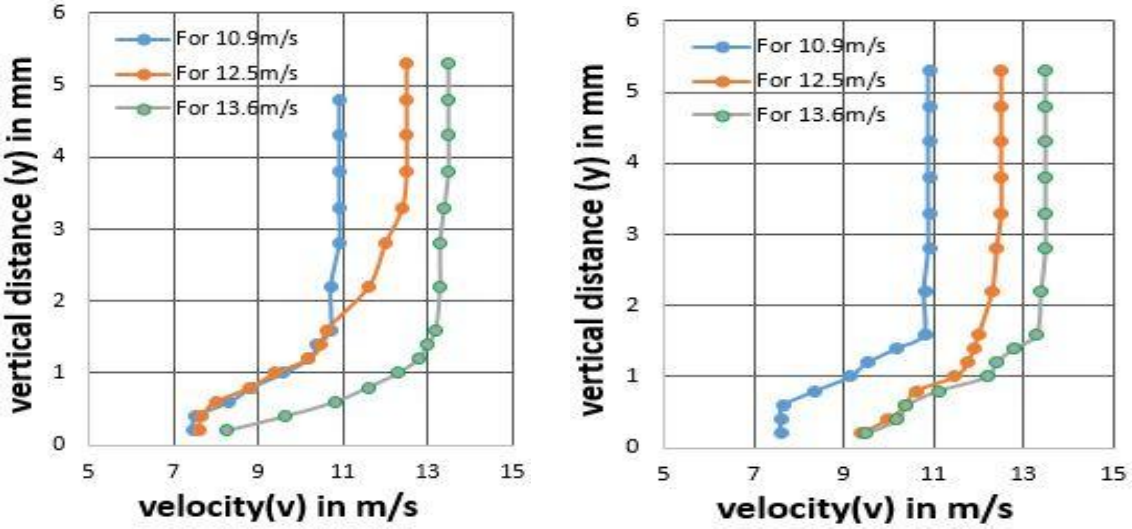


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Fig.3. At x=90cm

3.2 Velocity Varitions At Different Sections For All The Roughness

V=10.9m/s V=12.5m/s V=13.6m/s

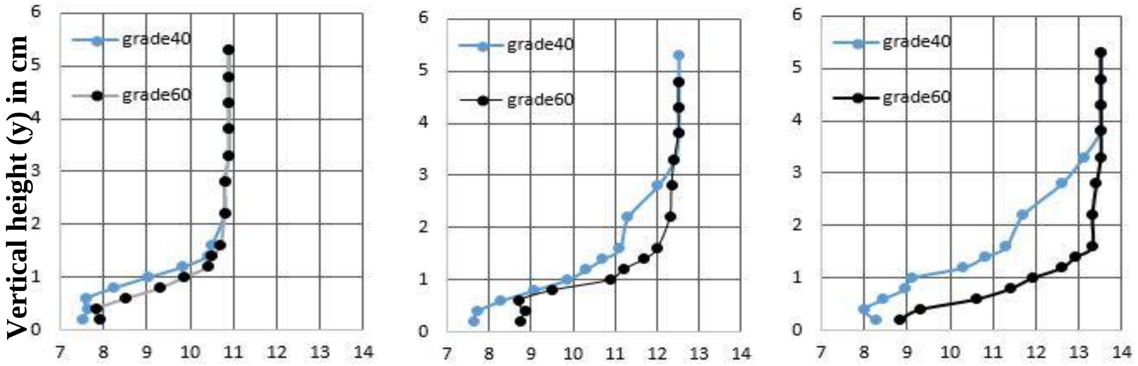

Fig.4. At x=70cm Variation of velocity profiles for different roughness

V=10.9m/s V=12.5m/s V=13.6m/s

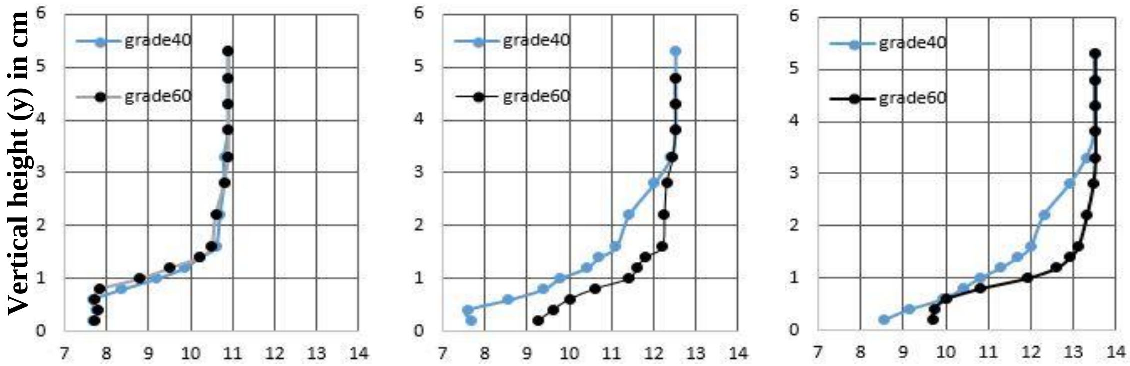

Fig.5. At x=80cm Variation of velocity profiles for different roughness

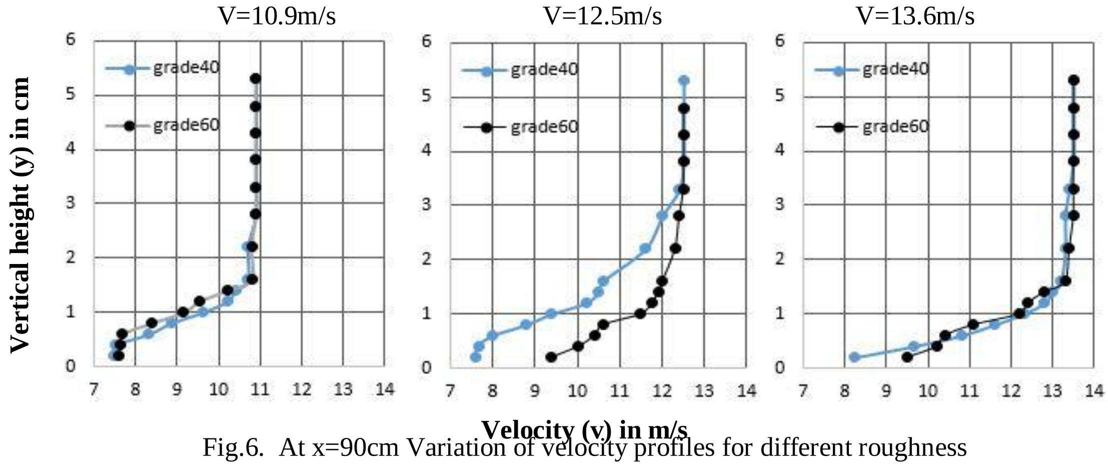

Fig.6. At x=90cm Variation of velocity profiles for different roughness

IV. CONCLUSION

From the analysis of the experimental data and plots, the following conclusions have been derived:

- The velocity is significantly influenced by the mainstrem velocity and the roughness of the surfaces.
- At a particular location from the leading edge, the velocity has been found to increase with mainstream velocity.
- For the given distance from the leading edge and at constant mainstrem velocity, the velocity has also been found to decrease with increase in roughness of the surface.

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