Turbulence Intensity Estimations by Utilising Hot Wire Anemometer

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Abstract— **Wind tunnels with uniform velocity profiles and low turbulence are utilized to align air velocity sensors, for example, anemometers and Pitot tubes among others. These wind velocity sensors are utilized as a part of cases such as, eolic turbines towers, meteorological stations, doctor's facilities, and so forth. To make alignments with high exactness and precision it is important a Wind tunnels with low turbulence (under 0.4%) and uniform velocity profile in the test segment. This review exhibits a portrayal of the low turbulence wind tunnel of the Anemometry Lab of BMSCE, in which the adjustments are done in the release of the wind tunnel and the working reach is from 5 m/s up to 25 m/s. Turbulence power under 0.4% will gotten.**

Keywords—**Wind Tunnel, Anemometry, Turbulence.**

I. INTRODUCTION

A. Turbulence:

Most of applications in engineering require relative flow of fluid around objects of interest. For example flow of gas inside combustion chamber of a gas turbine or an IC engine, fluid flowing around automobiles, smoke generating out of smokestack, contrails of jet etc. are few examples. In general fluid flow is turbulent in nature; laminar flow is an exception for example flows inside a journal bearing of high viscosity fluid.

B. Origins of Turbulence

Turbulence is result of instabilities in the laminar flow. As long as the Reynolds number of the flow is low, viscous forces dominates inertial forces and the flow is laminar. As the Reynolds number increase a number of sort of unsteadiness set in and results in secondary, tertiary instabilities and changeover to completely developed turbulent flow sets in. This phenomenon occurs at all the places in the flow field and is instantaneous, however since the numerical point of vision the transitions from one flow regime to another with increasing Reynolds number is believed to be a manifestation of generic structural changes of the mathematical objects called phase flow and attractors in the phase space through bifurcations in a given flow geometry.

Turbulence is thought of as fluctuations of parameters like velocity, density, pressure etc. in the fluid flow. Since the flow is random the behaviour of flow parameters is also random. A typical turbulent velocity profile is shown in Figure 1

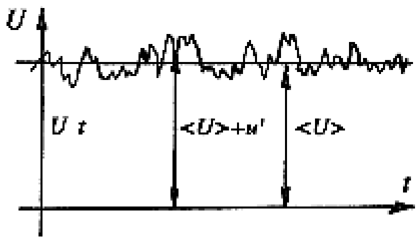

Fig1: Velocity at a point in a turbulent flow as a function of time.

C. Why Study Turbulence?

Various different techniques are existing to characterise turbulence, the existing literature is very large. These techniques can be classified based on their basic ideology, scheme structure, choice of function and limitations.

1. Laser Doppler anemometry (LDA),
2. Particle image Velocimetry (PIV),
3. Constant temperature anemometer (CTA),
4. Aeroprobe.

Are few techniques that have been extensively used to characterise the turbulence formed in wind tunnel facility. In the present work Constant Temperature Anemometer (CTA) is used to characterize the wind tunnel that is existing at BMSCE.

II. METHODS USED FOR CALIBRATION

All Wind Tunnels are to be calibrated before performing any model testing. This calibration includes

1. Range of fluid speeds that are possible in the tunnel
2. The amount of turbulence (Turbulence Intensity) for the fluid in the test section
3. The width of the frontier layer in the test section.

In the present work, the wind tunnel is being characterized by measuring velocities using

(i) Pitot tube
(ii) Measurement of turbulence intensity by using Constant Temperature Hot Wire Anemometer.

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III. MEASUREMENT OF VELOCITY PROFILE BY USING PITOT TUBE

Pitot is a thin tube adjusted to the flow and it can gauge nearby velocity by methods for pressure contrasts. It has side divider gaps to quantify the static pressure Ps in the moving flow and an opening in the front to measure the stagnation pressure P0, where the flow is announced to zero velocity.

Rather than measuring P0 and PS independently, it is standard to quantify their distinction with say transducer (electronic manometer), gives speed straightforwardly. Pitot tube configuration is shown in fig2.

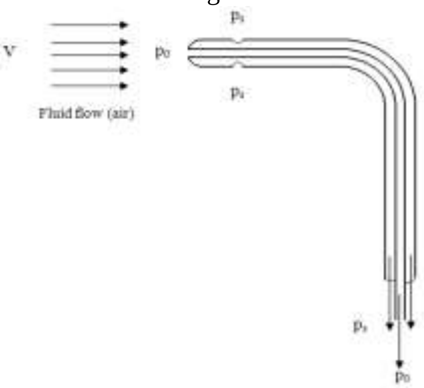

Fig 2: Pitot tube configuration

A. *Measurement of velocity profile*

Following are some points undertaken to measure velocity profile.

1. In order to measure the velocities at different points, the wind tunnel test section was divided in to 81 grid points (9 rows and 9 columns).
2. Single channel manometer is used to measure the velocities at particular points.
3. First we have to fix the pitot tube to the X-Y traverse at the exit plane of the test section as shown in the figure below.
4. Then connect the tubes of the pitot tube to the monometer ports like, connect tube which measures static pressure to the to the positive port and another tube that measures stagnation pressure to the negative port respectively.
5. Then set the zero adjustment modes at the manometer.
6. Then put to measure mode, and then turn the wind tunnel on.
7. Then take the readings for different velocities like 5,10,15,20 & 25m/s at all 81 points of the test section.
8. Used electronic monometer software to take the readings directly into the pc.
9. The velocity variation at different points will be compared with turbulence factor.

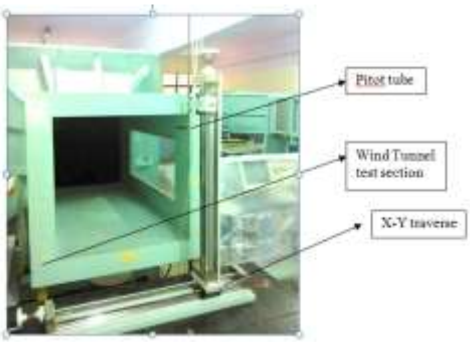

Fig 3: Taking readings using pitot tube positioned at 9x9 gridsection points for different velocities

IV. TURBULENCE INTENSITY ESTIMATIONS BY UTILISING HOT WIRE ANEMOMETER

Numerous examinations in flow issues include estimation of vacillation and mean velocities including high spatial resolutions. The hot wire anemometer procedure which utilizes a little detecting component having a low reaction time, high sensitivity and negligible flow impedance is a standout amongst the most appropriate methods for measuring turbulence in fluids.

The CTA anemometer workings on the source of convective heat transfer from a heated sensor to the neighbouring fluid, the heat transmit being mainly associated to the fluid velocity. By means of extremely fine sensors to the surrounding fluid, the heat exchange being principally identified with the fluid velocity. By utilizing fine wire sensors set in the fluid and electrons with servo loop method.

Constant Temperature Hot Wire Anemometers (HWCTA-AMB717) designed by Sunshine Measurements using modern integrated chips is adaptable, precise and appropriate for research job. Below table1 shows the readings obtained by keeping the hot wire anemometer at the centre point i.e. (5, 5) of the test section.

At centre point of the test section (5,5)					
RPM	E	U	(E/4)2	√U	SD
0	2.83	0	0.5	0	0
158	2.852	5	0.5083	2.236	0.016
279	3.19	10	0.636	3.1622	0.025
423	3.423	15	0.7323	3.8729	0.032
547	3.551	20	0.7881	4.4721	0.04
671	3.68	25	0.8464	5	0.067

Table1: Voltage (E/4)2 and Velocity (√U) values for the centre point (5, 5)

Below figure 4 shows the graphical representation of the slope created by plotting Voltage against different Velocities at the test section (5, 5).

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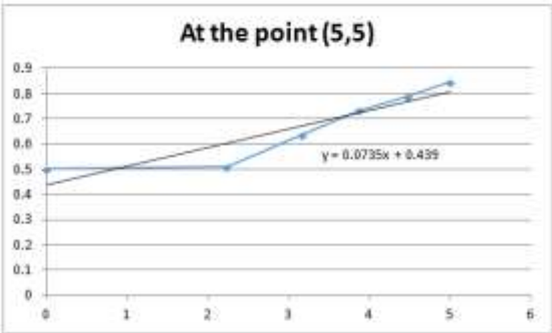

Figure 4: Slope created by plotting a graph of Velocity ($\sqrt{U}$) on x- axis and Voltage $\left(\frac{E}{4}\right)^2$ on y-axis

Let us consider the equation Y=mx+C
In the above slope let A=0.439
B=0.0735

Formulae used:

$$U = \left[\frac{\left(\frac{E}{4}\right)^2 - A}{B}\right]^2$$

$$S = \frac{B}{\left[4 \times \left(\frac{E}{4}\right)^2 \times \sqrt{U}\right]}$$

$$e = \frac{SD}{4 \times AC\ GAIN}$$

$$U^I = \frac{e}{s}$$

$$T = \frac{U^I}{U}$$

By taking the centre point value in the test section for different velocities we will get a turbulence intensity factor 'T'.

T=0.039%

V.RESULTS

Following graph obtained from Mat lab software that illustrates the effect of velocity variations at different rpm and velocities at 9X9 grids, at the outlet plane of the test section. This is shown in fig 5.

Further numerical simulations are carried out using FLUENT using K-epsilon turbulence model for the speeds where experiments are carried out. This is shown in fig 6.

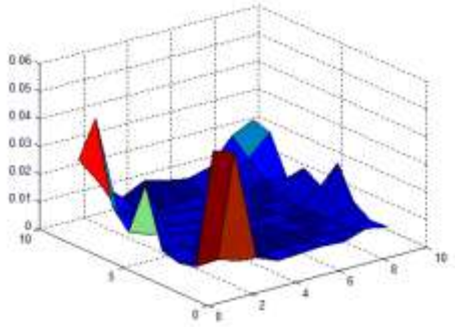

Fig 5: Mat lab graph for velocity variation at 25m/s velocity

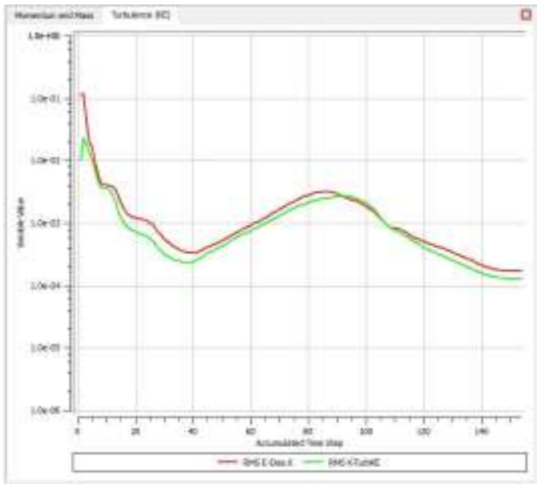

Fig 6: K-epsilon turbulence model for velocity 25m/s

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