DESIGN AND FABRICATION OF A BENCH MOUNTED CLOSED LOOP WIND TUNNEL

Gp. Capt. Abdus Salam (1), Dr. M. A. Taher Ali (2),
S. M. Anwarul Aziz (3), Asif Iqbal (4), Md. Mijanur Rahman (5), Istaqur Rahman (6)

(1) Head of the Department, Aeronautical Engineering Department, MIST.
(2) Former Professor, Mechanical Engineering Dept., Bangladesh University of Engineering & Technology (BUET).
(3) (4) (5) (6) Level-4 students, Aeronautical Engineering Department, MIST.

ABSTRACT

A Bench-mountedclosed loop wind tunnel has been designed and fabricated to study the air flow characteristics and its effects on different models at different flow conditions. Thefabricated wind tunnel is sub-sonic nature with operating velocity from 0 to 18 m/s. The wind tunnel could be used to carry out research on different model for laminar and turbulent flow conditions .The wind tunnel is powered by two similar co-rotating axial flow fans and the air velocity could be varied by varying the fan speed. The wind tunnel consists of a test section, bell mouth nozzle, bends, guide vanes and fan section. An ATMega16 microcontroller based Data Acquisition Card (DAQ)has been incorporatedhere to measurepressure through pressure sensors. Steady state flow condition could be attained from the wind tunnel within short period of time to easily explain the flow parameterswhile carrying out the experiments.

KEY WORDS: Floor mounted wind tunnel,bench mounted wind tunnel,fabrication, instrumentation, LabVIEW.

1.0 INTRODUCTION

A wind tunnel is a basic apparatus to carry out study of airflow under different boundary conditions and aerodynamic characteristics on different model of airfoils, cylinders, blocks etc.The floor mounted wind tunnels are generally expensive and require huge floor space. More so, they generate noise level of 75-80 dB, which creates difficulties to collect data during carrying out experiment on models. Bench mounted whereas,the wind tunnel is the less expensive, portable and generates less noise. This type of wind tunnel facilitates easy demonstration to the students during carrying out experiments. By using this wind tunnel, students could analysis and investigate the data of different aerodynamic models and could make a full scale structureafter analyzing the data.

2.0 DIFFERENT TYPES OF WIND TUNNEL

Thecommonlyused two types of wind tunnels areclosed loop and Open type wind tunnels. In a closed loop wind tunnel, the same air is re-circulated within the duct whereas, in an open type one the room air is used only once and released back into the room again. In the open type, the room air enters into the wind tunnel through its bell mouth entry and any variation of the room air quality/velocity affects the flow in its test section,such as it wouldbecome difficult to get the steady state flow condition from an open circuit wind tunnel. In theclosed loop wind tunnel the steady state flow could be attained and maintained due to its controlled entry condition. In the open type one, certain mass of room air is acceleratedfrom zero velocity to the steady state velocity of the test section and is discharged back intothe room with nearly the same velocity. While in the closed loop one, the air with nearly the same velocity circulates through the wind tunnel. In this case, the energy provided by the fans is due to overcome the friction and energy needed to run the closed loop wind tunnel is much less than that of the open type one. Again in the open type wind tunnel, the air is discharged freely into the room, generating noise which is difficult to control. While in the closed loop wind tunnel, there is no scope of generation of sound due free discharge. More so, the sound generated by fan could be absorbed by incorporation of silencers.

Considering all the above facts, a closed loop wind tunnel has been designed and fabricated. The layout of the wind tunnel is shown in figure 1.

achieve the requirevelocity. A guide van section has been used to the second fan deflects the discharge air velocity of the first fan to an angle which would be tangential to the inlet of second fan.

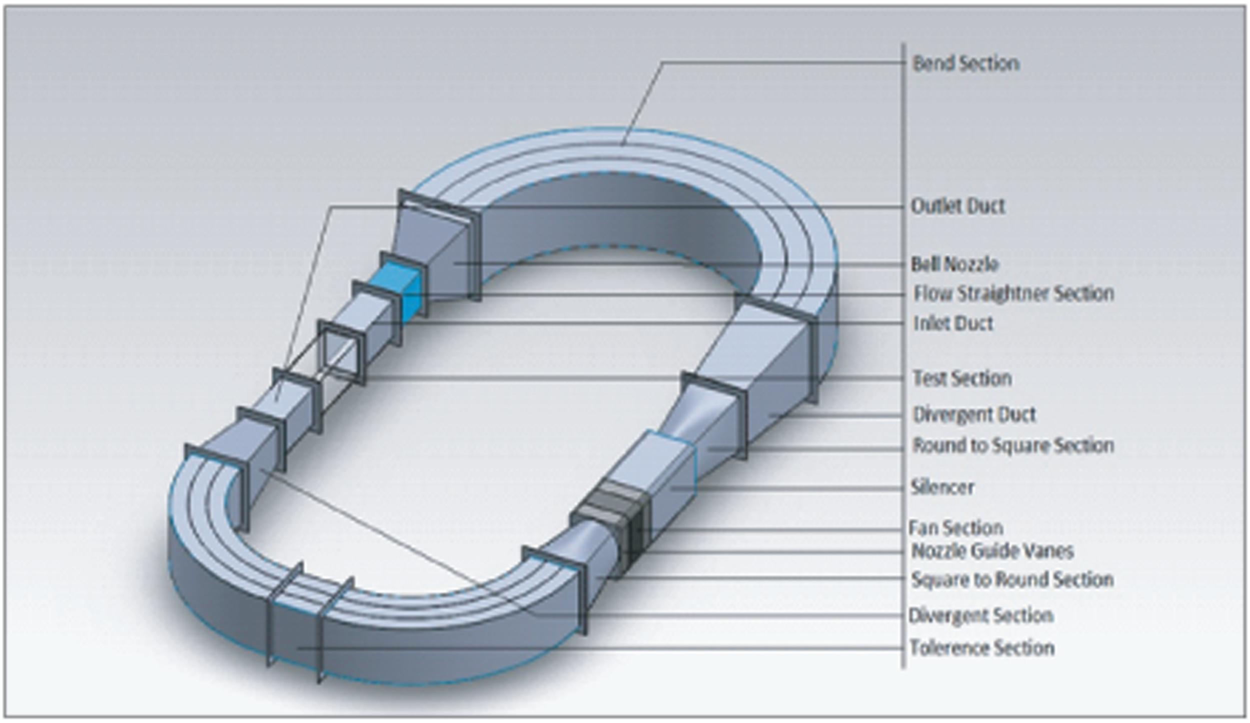


Figure 1: A closed type wind tunnel

3.0 FABRICATION

The designed closed loop wind tunnel would be light and tough. The 18 gauge MS sheet has been used to manufacture its different components.Its test section has been made from plexi glass and 20 mm MS sheet has been used for flanges. Different components have beenassembled with screws and Gaskets has been used in between the flanges to make the wind tunnel airtight. Finally the whole setup has been painted Grey color. Total length and width of the wind tunnel are 1750 mm and 640 mm respectively.

The main components of the designed wind tunnelare the axial fan-section & nozzle guide vanes, bell mouth nozzle, bend section and testsection.

(a) Fan Section & Nozzle Guide Vanes:

The fan section will generate air flow through the wind tunnel in the axial direction.Electrically driven axial fans has been chosen in producing high wind velocity at low pressure head. Two fixed blade co-rotating fans of the same size have been installed in series for higher head to overcome friction and to This will reduce loss and provide stable flow.

(a) (b)

Figure 2: (a) Fan (b) guided vane

(b) Bell Mouth Nozzle:

The bell mouth nozzle has been used at delivery side of the plenum chamber. The nozzle has inlet section of 200 X 200 mm2 and outlet section of 100 X 100 mm2. The reduction of sectional flow area has been obtained by generating a convergent profileto attain maximum flow velocity of the wind tunnel. This profile ensures minimum loss and provides stream line flow.

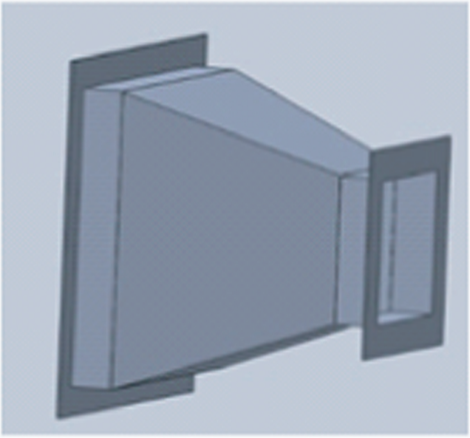


Figure 3: Bell mouth nozzle

(c) Bend Section:

Bend sections have beenused to bring the wind tunnel in closed loop shape. Air passing through the corners of these bends causes significant flow energy losses due to the change of direction and differential flow velocity. As such, guided vanes will direct the flow smoothly and evenly distributing the flow over whole sectional area and reducing the loss.

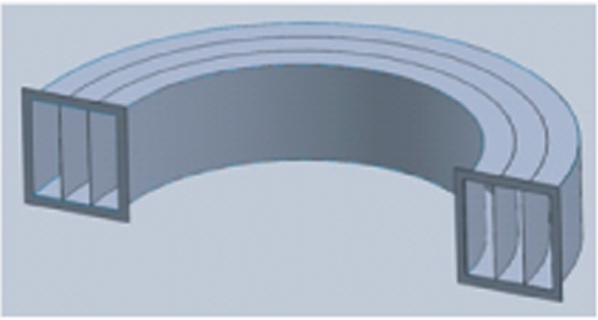


Figure 4: Bend section with guided vanes

(d) The Test Section:

Test section is the place where modelshave been placed to carry out study. The squared test section has been made of plexi-glass of 15 mm thick. The test models could be easily seen through the flexi-glass, the flow could be visualized by generating smoke on to the test object. One side of the test section has been detachable to allow opening of the test section to insert the test specimens. Screws have been used at four corners to join this side with the main section. Several holes have been made throughout the section to insert different instrumentations, like pitot tubes, hot wire probes etc. Again a wheel mechanism, including a protector has been incorporated with the test section for changing the angle of attack of the test objects. To break down large eddies generated at the discharge of the fan and to minimize the level of turbulence, a flow straightener was used at the inlet of the entry duct of the test section. The flow straighter breaks down large eddies, reduces tangential component of any circulative flow and ensure axial streamline flow to the test section.The length, width and height of the test section are 250 x 100 x 100 mm^3.

4.0 INSTRUMENTATIONS:

(a) Pitot Tube:

Pitot tubes are differential pressure flow meters, which are basically used to measure flow velocity. It is used to determine the airspeed of an aircraft and to measure air and gas velocities in laboratories and in industrial applications. The pitot tube is used to measure the local velocity at a given point in the flow stream and not the average velocity in the pipe or conduit.

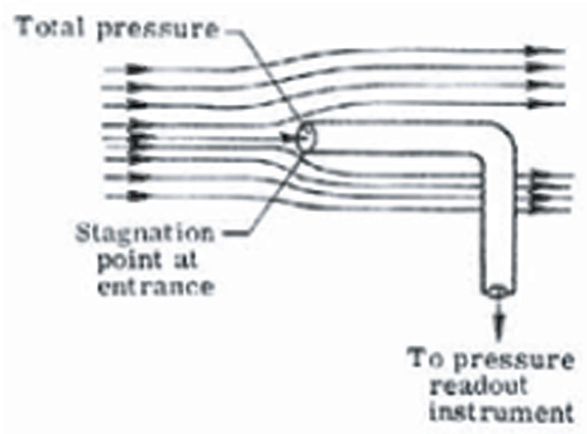


Figure 4: Pitot tube

The Pitot tube measures the Stagnation pressure of the fluid. The measured stagnation pressure canbe used to determine the fluid velocity. By applying Bernoulli's equation, air velocity could be calculated as described below:

Stagnation pressure = Static Pressure + Dynamic Pressure

It could be expressed as,

$$Pt = Ps + \left(\frac{\rho V^2}{2}\right)$$

Or, $V = \sqrt{\dfrac{2\,(Pt\text{-}Ps)}{\rho}}$

This equation is only applicable for the incompressible fluid.

Where, V = Fluid Velocity;

Pt = Stagnation or Total Pressure;

Ps = Static Pressure

ρ = Fluid Density

(b) Pressure Transducer:

A pressure transducermeasures pressure from differ tapping holes of an object. It generates an electric signal, usually voltage, as a function of the pressure imposed on a point surface of an object.

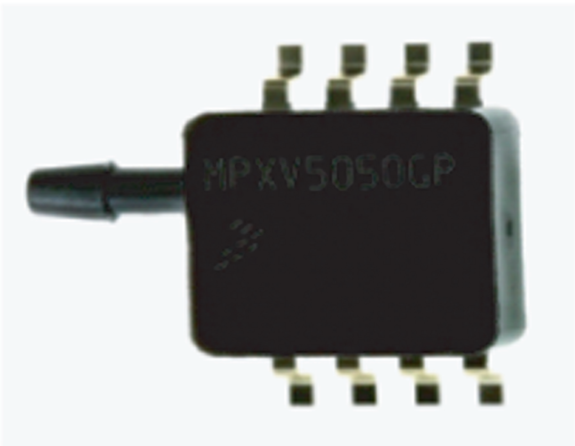


Figure 5: Pressure transducer

Forthis project, MPXV5050GP pressure sensor has been used to measure pressure. Thiscould measure pressure from 0 KPa to 50 KPa and it can withstand up to 200 KPa.

(c) Data Acquisition System (DAQ) for wind tunnel:

Data acquisition is the process of sampling signals that measure the physical conditions and converting the resulting samples into digital numeric values that could be manipulated by a computer. Data acquisition systems typically convert analog waveforms into its digital values for processing.

The components of the data acquisition systems include the following :

- Sensors that convert physical parameters in to electrical signals.
- Signal conditioning circuitry to convert sensor signals into a form that could be converted to digital values.
- Analog-to-digital converters which convert conditioned sensor signals to digital values.

Specialized software has been used for building large-scale data acquisition systems like EPICS. Graphical programming environments include ladder logic, Visual C++, Visual Basic, and LabVIEW.

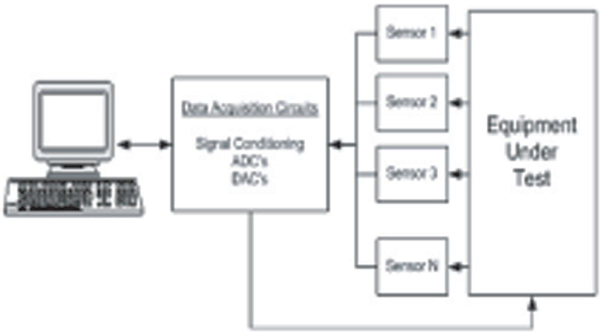
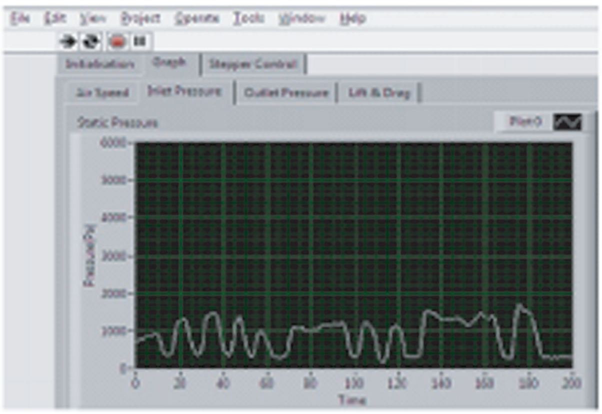


Figure 6: DAQ system

(a)



(b)

Figure 7: Graphical Representation of (a) Airspeed (m/s) and (b) Pressure (Pa) in LabVIEW.

To read data from the DAQ, Lab VIEW have been used which is an interactive graphical programing language. A PC can have several COM ports like COM1, COM2 ... COMn etc. and inLabVIEW, the specific COM port has been defined which could communicate with the AT mega16.

After running the program spontaneous data from pressure sensor have been shown in figure 7.

(d). Precision Potentiometer:

Precision potentiometerhas been incorporated at the wind tunnel which could be used to calculate the lift and drag forceby measuring the position displacement of the object. A pot has been attached to mechanical fixtures and components to measure displacement positions. The housingtypically mounts to a stationary reference frame, while the shaft couples to a moving element. The inputmotioncould be coupled directly or indirectly to the pot's shaft.

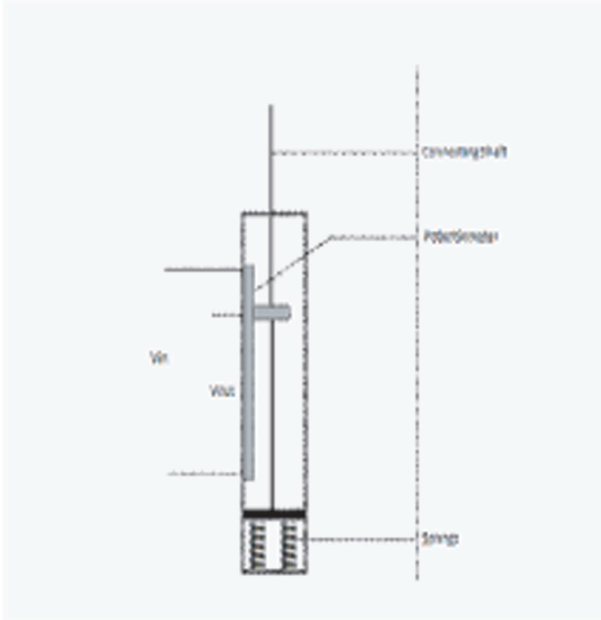
Integrating a pot into a measurement system requires consideration of various design issues, includingthe impact of the pot's physical characteristics, error sources, space restrictions, and wire-routing. Thepot's shaft type and bearings are also to be taken into consideration and protected against excessive loading.

Considering all this, a mechanical housing has been built for the potentiometer to calculate the linear displacement of the test object. The housing includes a connecting shaft, a plate suspended by springs to holdthe shaft. The spring suspended base would keep the shaft at a fixed height and allowing it to be at default or 'zero' position before carry out every reading.

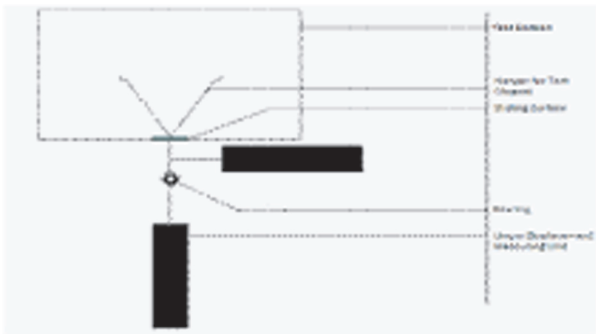
The potentiometer requires a input voltage of 5V. The output voltage V_{out} is measured and sent to the microcontroller as an ADC input. The output voltage could be measured by the formula-

$$\text{Output Voltage} = \text{abc\_value} * \frac{\textit{input voltage}}{255}$$

With this output, the linear displacement could be measured and the force applied on the shaft could be calculated easily.



(a)



(b)

Figure 8: (a) Precision Potentiometer with mechanical housing (b) Test section with Precision Potentiometer having mechanical housing to calculate Lift and Drag.

The whole mechanism has been attached with the test section in both vertical and horizontal direction, where the vertical directionprovides the lift data and the horizontal direction provides drag data.

5.0 EXPERIMENT CAPABILITIES

(a) Lift and Drag Coefficient Measurement:

The instrumental setup on the test section could be used to calculate the linear displacement of the test object to measure lift and drag forces and then send it to the PC through the DAQ. Lift coefficient Cl and drag coefficient C_d could be calculated by the formula,

$$C_l = \frac{L}{\frac{1}{2}\rho v^2 s} \quad \text{and} \quad C_d = \frac{D}{\frac{1}{2}\rho v^2 s}$$

Where,

L = Lift Force

D = Drag Force

ρ = Air Density

V = Free Stream Velocity

S = Surface Area of the object

The free stream velocity (V) at the test section is obtained automatically from the dynamic pressure of the air which is being sensed by the pressure sensors. Density of air (ρ) is constant as the air is incompressible.

(b). Wall Shear Stress Measurement:

Fluid normally crates a boundary layer while moving through a closed tunnel or on a flat surface. Boundary layer is created due to the shear stress created by the wall on the flow field and the viscosity of the fluid. By measuring velocities at 2 point near the boundary of the field, wall shear stress (τ) could be measured by the formula,

$$\frac{u_{max} - u}{\sqrt{\frac{\tau}{\rho}}} = 5.75 \log_{10} \left(\frac{H}{y}\right)$$

Where,

u_{max} = Velocity at the center of the test section

u = Velocity at a distance 'y' from the wall

H = Height of the center point from the wall

ρ = Air Density

(c). Discharge through the Test Section:

The velocity changes with the height from the wall due to boundary layer. So the average velocity $(\overline{U})$ at any section could be calculated by using the formula,

$$\frac{u - \overline{U}}{\sqrt{\frac{\tau}{\rho}}} = 5.75 \log_{10} \frac{y}{H} + 3.75$$

Where,

τ = Wall shearing stress calculated by IV(b)

u = Velocity at a distance 'y' from the wall

H = Height of the center point from the wall

ρ = Air Density

So, the discharge (Q) through the test section could be calculated by,

$$\mathbf{Q = A \times \overline{U}}$$

Where, A is the area of the test section and $\overline{U}$ is the average flow velocity.

(d). Head Loss due to Friction:

A volume of energy is required to shift through a pipe by create pressure difference. A portion of that energy is usually loss due to overcome the resistance to flow. This resistance to flow is called head loss which is caused by friction. This head loss (h_f) could be measured by,

$$h_f = \frac{f L V^2}{D \times 2g}$$

Where, f = Friction Factor = $\frac{2\tau}{\rho \overline{U}^2}$

L = Length of the test section

D = Total Height of the test section

6.0 CONCLUSION

The designed close loop wind loop wind tunnel will provide basic experimental capability to measure flow velocity, velocity profile, growth of boundary layer, flow around different objects, lift and drag force etc. With advance measurement technique, it could be used to investigate the complex flow structure of specialized flow field.

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