International Journal of Engineering Research and Reviews ISSN 2348-697X (Online)
Vol. 2, Issue 4, pp: (1-9), Month: October-December 2014, Available at: www.researchpublish.com

DESIGN, CONSTRUCTION AND TESTING OPEN CIRCUIT LOW SPEED WIND TUNNEL

[1]Bapu Joglekar, [2]Rana Manoj Mourya

[1] Research scholar, Department of Mechanical Engineering, Lakshmi Narain Collage of Technology, Bhopal, India
[2] Asst.prof., Department of Mechanical Engineering, Lakshmi Narain Collage of Technology, Bhopal, India

Abstract: **In this paper we are discussing about the Wind Tunnel and its types. The Wind Tunnel Testing Machine is used in Aerodynamic research to study the effects of Air moving past to the solid objects. This paper we discuss the Design, Construction and Testing process open circuit low speed wind tunnel. The Design of wind tunnel is very important to proper working and accuracy of result. The construction process is depending on Design parameters and quality of material. In the testing we use the pitot tube, manometer and solid object (airfoil). Solid object is representing the original shape of the object. The testing chamber is main part of wind tunnel. We calculate the velocity of fluid and drag & lift forces. It is use to experimental analysis of object. Experiment conducted after build to find drag coefficient of a shape. An impression of fluid field flow around a shape is using air.**

Keywords: **Open Circuit Wind Tunnel, Single Testing Section, Wind Tunnel Design, Industrial Design, airfoil analysis.**

1. INTRODUCTION

A wind tunnel is used in aerodynamic research to study the effects of air moving past solid objects. A wind tunnel consists of a tubular passage with the object under test mounted in the middle. Air is made to move past the object by a powerful fan system or other means. The test object, we measure aerodynamic forces, pressure distribution, or other aerodynamic-related characteristics. [1][3] The earliest wind tunnels were invented towards the end of the 19th century, in the early days of aeronautic research, when many attempted to develop successful heavier-than-air flying machines. Wind-tunnel testing was applied to automobiles, not so much to determine aerodynamic forces per se but more to determine ways to reduce the power required to move the vehicle on roadways at a given speed. In these studies, the interaction between the road and the vehicle plays a significant role, and this interaction must be taken into consideration when interpreting the test results. In an actual situation the roadway is moving relative to the vehicle but the air is stationary relative to the roadway, but in the wind tunnel the air is moving relative to the roadway, while the roadway is stationary relative to the test vehicle. Some automotive-test wind tunnels have incorporated moving belts under the test vehicle in an effort to approximate the actual condition, and very similar devices are used in wind tunnel testing of aircraft take-off and landing configurations. [2][1][14]

1.1 Measurement of Aerodynamic Force

Air velocity and pressures are measured in several ways in wind tunnels. Air velocity through the test section is determined by principle. Measurement of the dynamic pressure, the static pressure and compressible flow only. The temperature rise in the airflow. The direction of airflow around a model can be determined by tufts of yarn attached to the aerodynamic surfaces. The direction of airflow approaching a surface can be visualized by mounting threads in the airflow ahead of and aft of the test model. Air, Smoke or bubbles of liquid can be introduced into the airflow upstream of the test model, and their path around the model. Aerodynamic forces on the test model are usually measured with beam balances, connected to the test model with beams, strings or cables. The pressure distributions across the test model have historically been measured by drilling many small holes along the airflow path, and using multi-tube manometers to measure the pressure at each hole. Pressure distributions can more conveniently be measured by the use of pressure-sensitive paint, in which higher local pressure is indicated by lowered fluorescence of the paint at that point. Pressure distributions can also be conveniently measured by the use of pressure-sensitive pressure belts, a recent development in which multiple ultra-miniaturized pressure sensor modules are integrated into a flexible strip. The strip is attached to the aerodynamic surface with tape, and it sends signals depicting the pressure distribution along its surface. Pressure distributions on a test model can also be determined by performing a wake survey, in which either a single pitot tube is used to obtain multiple readings downstream of the test model, or a multiple-tube manometer is mounted downstream and all its readings are taken. The aerodynamic properties of an object cannot all remain the same for a scaled model. However, by observing certain similarity rules, a very satisfactory correspondence between the aerodynamic properties of a scaled model and a full-size object can be achieved. [12][13]

The choice of similarity parameters depends on the purpose of the test, but the most important conditions to satisfy are usually:

1.1.1 Geometric similarity

All dimensions of the object must be proportionally scaled.

1.1.2 Mach number

The ratio of the airspeed to the speed of sound should be identical for the scaled model and the actual object (having identical Mach number in a wind tunnel and around the actual object is -not- equal to having identical airspeeds) [12]

1.1.3 Reynolds number

The ratio of inertial forces to viscous forces should be kept. This parameter is difficult to satisfy with a scaled model and has led to development of pressurized and cryogenic wind tunnels in which the viscosity of the working fluid can be greatly changed to compensate for the reduced scale of the model. [13]

1.2 History

English military engineer and mathematician Benjamin Robins (1707–1751) invented a whirling arm apparatus to determine drag and did some of the first experiments in aviation theory. Sir George Cayley (1773–1857) also used a whirling arm to measure the drag and lift of various airfoils. His whirling arm was 5 feet (1.5 m) long and attained top speeds between 10 and 20 feet per second (3 to 6 m/s). However, the whirling arm does not produce a reliable flow of air impacting the test shape at a normal incidence. Centrifugal forces and the fact that the object is moving in its own wake mean that detailed examination of the airflow is difficult. Francis Herbert Wenham (1824–1908), a Council Member of the Aeronautical Society of Great Britain, addressed these issues by inventing, designing and operating the first enclosed wind tunnel in 1871. Once this breakthrough had been achieved, detailed technical data was rapidly extracted by the use of this tool. Konstantin Tsiolkovsky built an open-section wind tunnel with a centrifugal blower in 1897, and determined the drag coefficients of flat plates, cylinders and spheres. Danish inventor Poul la Cour applied wind tunnels in his process of developing and refining the technology of wind turbines in the early 1890s. Carl Rickard Nyberg used a wind tunnel when designing his Flugan from 1897 and onwards. In a classic set of experiments, the Englishman Osborne Reynolds (1842–1912) of the University of Manchester demonstrated that the airflow pattern over a scale model would be the same for the full-scale vehicle if a certain flow parameter were the same in both cases. This factor, now known as the Reynolds number, is a basic parameter in the description of all fluid-flow situations, including the shapes of flow patterns, the ease of heat transfer, and the onset of turbulence. This comprises the central scientific justification for the use of models in wind tunnels to simulate real-life phenomena. However, there are limitations on conditions in which dynamic similarity is based upon the Reynolds number alone. [14]

1.2.1 German aviation laboratory, 1935

The Wright brothers' use of a simple wind tunnel in 1901 to study the effects of airflow over various shapes while developing their Wright was in some ways revolutionary. It can be seen from the above, however, that they were simply using the accepted technology of the day, though this was not yet a common technology in America. [14]
In France, Gustave Eiffel (1832-1923) built his first open-return wind tunnel in 1909, powered by a 50 kW electric motor, at Champs-de-Mars, near the foot of the tower that bears his name. Between 1909 and 1912 Eiffel ran about 4000 tests in

his wind tunnel, and his systematic experimentation set new standards for aeronautical research. In 1912 Eiffel's laboratory was moved to Auteuil, a suburb of Paris, where his wind tunnel with a 2-metre test section is still operational today. Eiffel significantly improved the efficiency of the open-return wind tunnel by enclosing the test section in a chamber, designing a flared inlet with a honeycomb flow straightened and adding a diffuser between the test section and the fan located at the downstream end of the diffuser; this was an arrangement followed by a number of wind tunnels later built; in fact the open-return low speed wind tunnel is often called the Eiffel-type wind tunnel. [14]

Subsequent use of wind tunnels proliferated as the science of aerodynamics and discipline of aeronautical engineering were established and air travel and power were developed. The US Navy in 1916 built one of the largest wind tunnels in the world at that time at the Washington Navy Yard. The inlet was almost 11 feet (3.4 m) in diameter and the discharge part was 7 feet (2.1 m) in diameter. A 500 hp electric motor drove the paddle type fan blades. [14]

1.2.2 World War Two

In 1941 the US constructed one of the largest wind tunnels at that time at Wright Field in Dayton, Ohio. This wind tunnel starts at 45 feet (14 m) and narrows to 20 feet (6.1 m) in diameter. Two 40-foot (12 m) fans were driven by a 40,000 hp electric motor. Large scale aircraft models could be tested at air speeds of 400 mph (640 km/h). By the end of the war, Germany had at least three different supersonic wind tunnels, with one capable of Mach 4.4 (heated) airflows. A large wind tunnel under construction near Oetztal, Austria would have had two fans directly driven by two 50,000 horsepower hydraulic. The installation was not completed by the end of the war and the dismantled equipment was shipped to Modena, France in 1946 where it was re-erected and is still operated there by the ONERA. With its 8m test section and airspeed up to Mach 1 it is the largest transonic wind tunnel facility in the world. [14]

1.2.3 Post World War Two

Later research into airflows near or above the speed of sound used a related approach. Metal pressure chambers were used to store high-pressure air which was then accelerated through a nozzle designed to provide supersonic flow. The observation or instrumentation chamber ("test section") was then placed at the proper location in the throat or nozzle for the desired airspeed. Preparing a model in the Kirsten Wind Tunnel, a subsonic wind tunnel at the University of Washington The most effective way to simulative external turbulent flow is through the use of a boundary layer wind tunnel .[14]

1.3 Pressure measurements

Pressure across the surfaces of the model can be measured if the model includes pressure taps. This can be useful for pressure-dominated phenomena, but this only accounts for normal forces on the body. [12][13]

1.4 Force and Moment Measurements

With the model mounted on a force balance, one can measure lift, drag, lateral forces, yaw, roll, and pitching moments over a range of angle. This allows one to produce common curves such as lift coefficient versus angle of attack.
The force balance itself creates drag and potential turbulence that will affect the model and introduce errors into the measurements. The supporting structures are therefore typically smoothly shaped to minimize turbulence. [12][13]

1.5 Types of Wind Tunnel

Wind Tunnel can be classified on the basis of construction as-

a. Open Loop

b. Closed Loop

a. Open Circuit

In an open loop wind tunnel, there is an intake and an exhaust. There is no use for corners and long diffusers but the power needed to drive the wind-tunnel is high because of the loss of energy in the out- flowing air. The open circuit wind tunnel is the simplest and most affordable to build. In these tunnels air is expelled directly into the laboratory and typically reinvested after circulating through the lab, though some tunnels utilize instead a compressed gas source. In addition to their low costs, open circuit tunnels are also advantageous because they have are relatively immune to temperature fluctuations and large disturbances in return flow, provided that the volume of the laboratory is much greater than that of the tunnel. [5]

There are two basic types of open circuit tunnels.

(a) Suck down

(b) Blower

The two are most easily differentiated by the location of the fan. Blower tunnels are the most flexible because the fan is at the inlet of the tunnel, so the test section can be easily interchanged or modified with seriously disrupting flow. These tunnels are so forgiving that exit diffusers can often be completely omitted to allow easier access to test samples and instruments, though the omission often results in a noticeable power loss. Suck down tunnels are typically more susceptible to low frequency unsteadiness in the return flow than blowers, though some claims have been made that intake swirl is less problematic in these tunnels because it does not pass through the fan before entering the test section. [5]

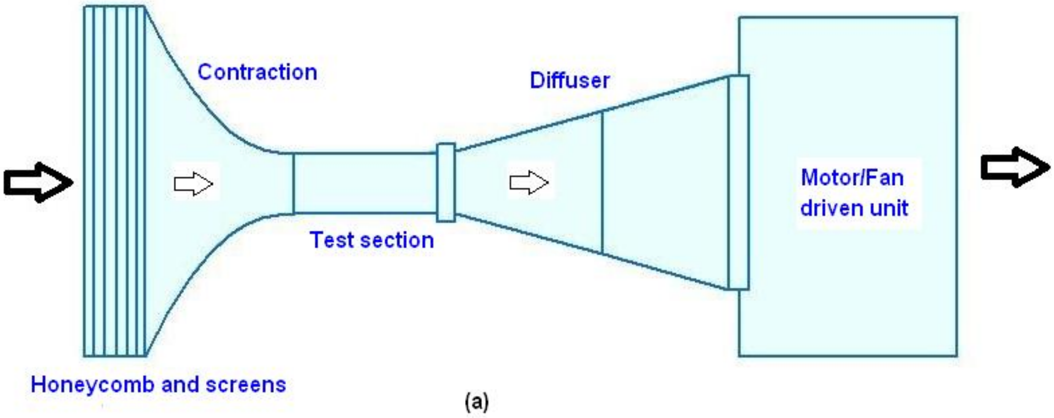

Figure 1: Open Circuit Wind Tunnel Layout

b. Closed Loop

As the name implies, closed circuit tunnels (also called closed return) form an enclosed loop in which exhaust flow is directly returned to the tunnel inlet. In a closed loop wind tunnel, the air is recalculated to improve efficiency for high speed testing. These tunnels are usually larger and more difficult to build. They must be carefully designed in order to maximize uniformity in the return flow. These tunnels are powered by axial fan(s) upstream of the test section and sometime include multistage compressors, which are often necessary to create trans-sonic and supersonic air speeds. Closed circuit wind-tunnels recirculation the air and thus normally need less power to achieve a given low speed, and, above all, facilitate the achievement of well controlled low conditions in the test section. The present, and most low-speed tunnels used for research, are of the closed circuit type. [5]

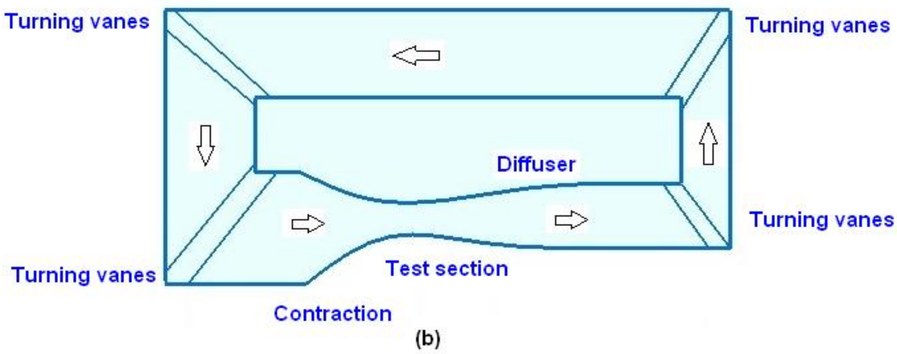

Figure 2: Closed Circuit Wind Tunnel Layout

There are many different kinds of wind tunnels.

- Low-speed wind tunnel

- High-speed wind tunnel
- Supersonic wind tunnel
- Hypersonic wind tunnel
- Subsonic and transonic wind tunnel

2. PROBLEM IDENTIFICATION

This research will focus primarily on the Design and construction process Wind tunnel, flow visualization analysis on an object and calculation of drag coefficient of an object through experiment. It is a very important part to analysis of any part or Design. The cost of wind tunnel is very high. So it is not possible to everyone purchase it easily. My purpose is to resolve primarily problem of making wind tunnel and modify the Design of wind tunnel. My focus is to develop wind tunnel for educational and research purpose. According to previous research study I was found some important area that create problem for making wind tunnel.

2.1 In the wind tunnel mostly Honeycomb and screens are rectangular shape. The purpose of the inlet and settling chamber is to align and smooth the air flow before it enters the contraction that follows. It creates some difficulty to construct it. The assembly of honeycomb is critical. Because the honeycomb works to distribute the fluid proper direction. The honeycomb is creating by many little blocks. [4][5][8][9]

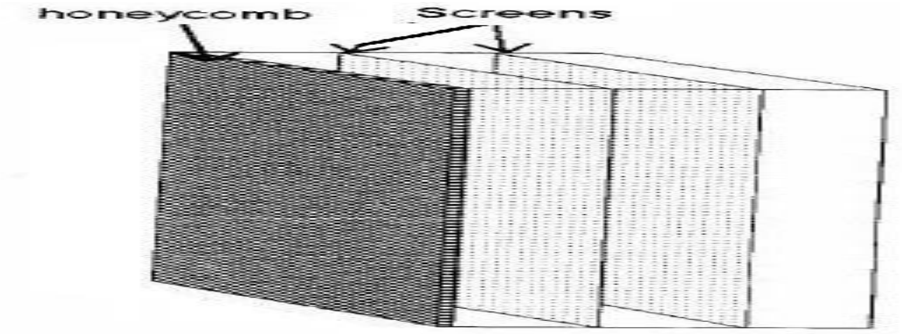

Figure 3: Honeycomb and screens

2.2 The fabricant of Construction chamber is too critical. The resign is its shape. The purpose of the contraction is to smoothly accelerate the air exiting the (larger) inlet/settling chamber and direct it into the (smaller) test section. In the process, turbulence intensity is further reduced, as the overall mean velocity increases while near-instantaneous variations in velocity are little affected. Thus, within reason the larger the entry: exit area ratio of the contraction, the better, with ratios of 6:1 to 9:1 generally recommended for tunnels of comparable design. [4][5][8][9]

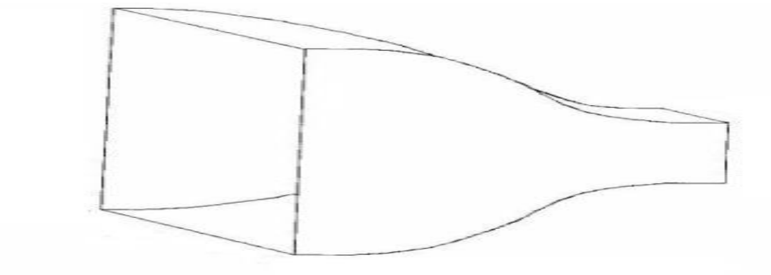

Figure 4: Construction chamber

2.3 The basic formula of Design Testing chamber is not clear. They use different size of testing chambers. According to my research the design of wind tunnel is depend the ratio of honeycomb and screens & construction chamber. The test section is, obviously, where objects are placed for testing, and thus is the portion of the wind tunnel where the air flow is desired to be most uniform. The ratio of width to height of a test section is generally chosen with the intended purpose of the wind tunnel in mind. [4][5][8][9]

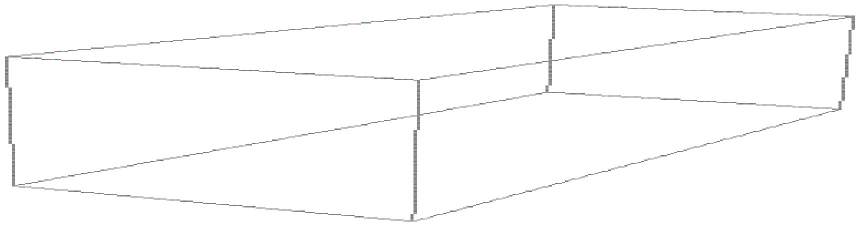

Figure 5: Testing chamber

2.4 The biggest problem I identify the Diffuser is fixed. We cannot set it different angels to find the effect comparison before and after result. The purpose of the diffuser is to allow the air exiting the test section to expand and gradually slow down, thus reducing the dynamic pressure (kinetic energy) and increasing the static pressure. This reduces the current drawn by the fan motor or, alternatively, allows a higher speed to be achieved for a given motor/fan size and current draws. The angle included by the diffuser walls is generally limited to approximately 5° – maximum pressure recovery actually occurs at a somewhat greater angle, but the boundary layer is close enough to separation that the flow through the diffuser and hence the entire tunnel may become unsteady. This small angle combined with the desire to limit the overall length of a wind tunnel generally leads to an inlet: outlet area ratio of less than the value of three needed to recover 95% of the static pressure. [4][5][8][9]

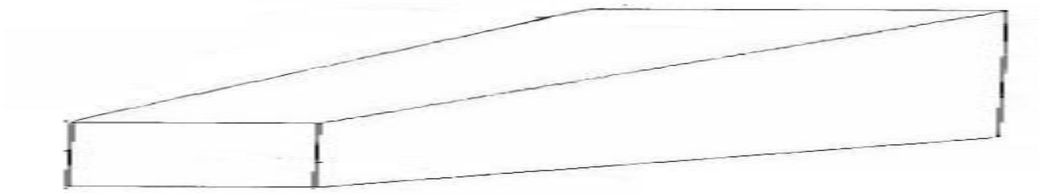

Figure 6: Diffuser

2.5 The Motor/Fan drive unit are fixed the diffuser section. It creates vibration. It creates problem to calculate the actual readings. The digital reading meter is not available easily and it is too costly. [4][5][8][9]

2.6 The casting and faberication of wind tunnel is very expensive. The material and equapement are not available easily. [8]

3. PROPOSED METHODOLOGY

The common of all wind tunnels they worked on Bernoulli’s theory and Venturi effect. Bernoulli's principle thus says that a rise (fall) in pressure in a flowing fluid must always be accompanied by a decrease (increase) in the speed, and conversely, if an increase (decrease) in, the speed of the fluid results in a decrease (increase) in the pressure. This is at the heart of a number of everyday phenomena. [5][6][11]

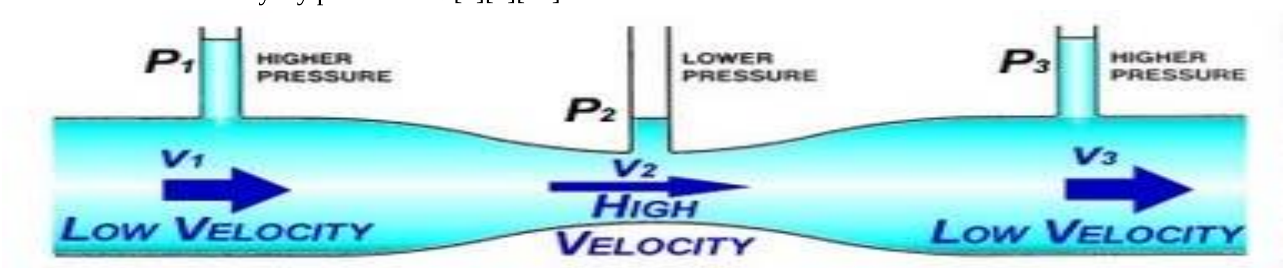

Figure 7: Principle Bernoulli’s theory

$$\frac{p_1}{\rho g}+\frac{u_1^2}{2g}+z_1=\frac{p_2}{\rho g}+\frac{u_2^2}{2g}+z_2$$

Eq-3.1

According to the laws governing fluid dynamics, a fluid's velocity must increase as it passes through a constriction to satisfy the principle of continuity, while its pressure must decrease to satisfy the principle of conservation of mechanical energy. Thus any gain in kinetic energy a fluid may accrue due to its increased velocity through a constriction is negated by a drop in pressure. [11][12][13]

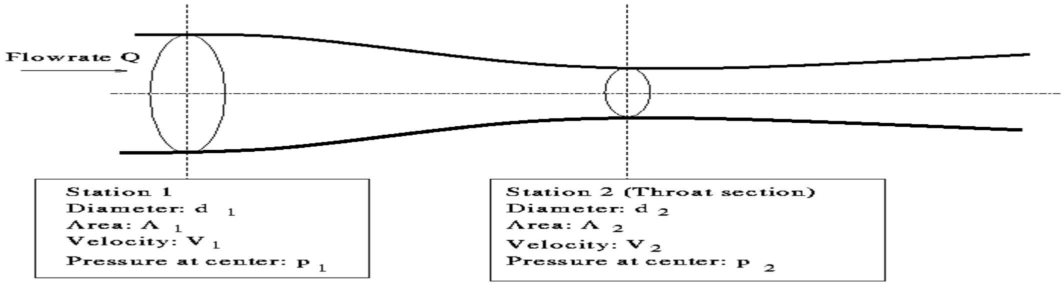

Figure 8: Principle Venturi effect

$$p_1 - p_2 = \frac{\rho}{2}\left(v_2^2 - v_1^2\right)$$ Eq-3.2

Flow rate

$$Q = v_1 A_1 = v_2 A_2$$

$$p_1 - p_2 * h1 = \frac{\rho}{2}(v_2^2 - v_1^2)$$ Eq-3.2

Then,

$$Q = A_1 \sqrt{\frac{2}{\rho} \cdot \frac{(p_1 - p_2)}{\left(\frac{A_1}{A_2}\right)^2 - 1}} = A_2 \sqrt{\frac{2}{\rho} \cdot \frac{(p_1 - p_2)}{1 - \left(\frac{A_2}{A_1}\right)^2}}$$

Eq-3.3

3.1 Layout of Open Circuit Low Speed Wind Tunnel

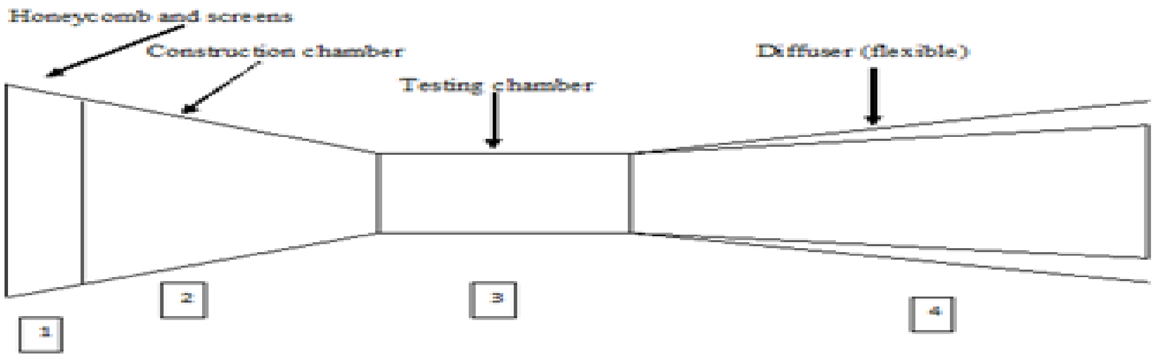

Figure 9: Wind tunnel layout

Table No: 1

S.No	Section's	All dimensions are in mm.		
		Length	Height	width
1.	Honeycomb and screens	152.4	736.6	736.6
2.	Construction chamber	609.6	609.6	609.6
3.	Testing chamber	609.6	304.8	304.8
4.	Diffuser	1219.2	431.8	431.8

Figure 10: Assemble of wind tunnel

3.2 Two meager Instruments who are very helpful to experimental analysis is Pitot tube and Piezometer. Use to this we find stagnation pressure, static pressure, and dynamic pressure. All of part to find the Head drag & lift forces and velocity of fluid. [6][12][13]

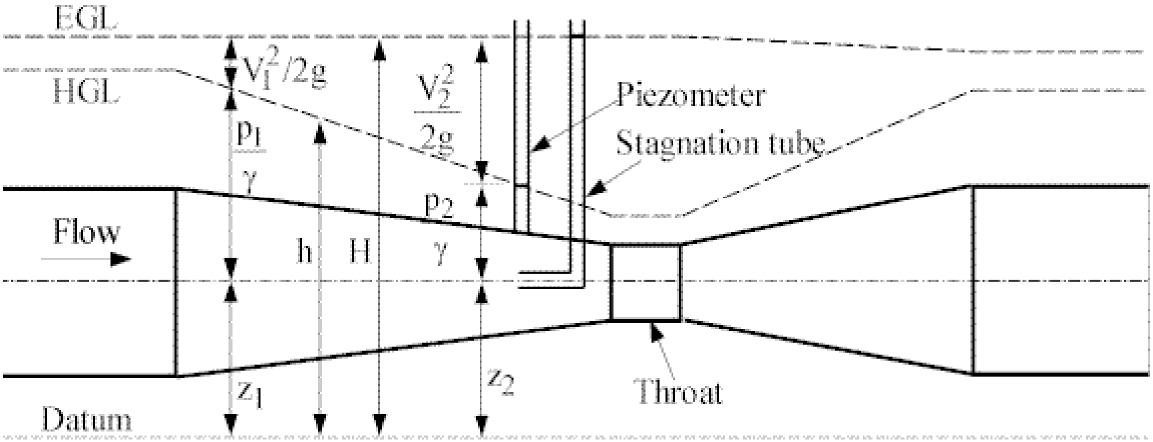

Figure 11: Working principle of wind tunnel

The drag coefficient c_d is defined as:

$$c_\mathrm{d} = \frac{F_\mathrm{d}}{\frac{1}{2}\rho v^2 A}$$ Eq- 3.4

Where:

F_d Is the drag force, which is by definition the force component in the direction of the flow velocity?

ρ Is the mass density of the fluid?

v Is the speed of the object relative to the fluid and

A Is the reference area.

The lift coefficient C_L is defined by

$$C_\mathrm{L} = \frac{L}{\frac{1}{2}\rho v^2 S} = \frac{2L}{\rho v^2 S} = \frac{L}{qS}$$, Eq-3.5

where L is the lift force, ρ is fluid density, v is true airspeed, S is plan form area and q is the fluid dynamic pressure. [6][7][10][12][13]

4. CONCLUSION

Wind tunnel is a testing or analysis setup of solid objects. The Design of low speed open circuit wind tunnel is some different to other wind tunnel. Its diffuser is flexible. We set the diffuser different angle. The construction of machine is low cost and Design is very easy. It's using materials easily available in the market. The machine is useful to educational and research purpose. Design is easy to read and construction and study the flow visualization of an object. The study of fundamental design process is resolve. To get an impression of fluid flow around a scale model of a real object. Use to it calculates the drag coefficient of the object design.

REFERENCES

[1] Nguyen Quoc Y "Designing, Constructing, And Testing A Low – Speed Open – Jet Wind Tunnel "www.ijera.com ISSN: 2248-9622, Vol. 4, Issue 1(Version 2), January 2014, pp.243-246

[2] Ishan.M.Shah, S. A. Thakkar, K. H. Thakkar, Bhavesh A. Patel " Performance Analysis on Airfoil Model in Wind Tunnel Testing Machine (WTTM) " (IJERA) ISSN: 2248-9622 www.ijera.com Vol. 3, Issue 4, Jul-Aug 2013, pp.2094-2103

[3] Md. Arifuzzaman, Mohammad Mashud "Design Construction and Performance Test of a Low Cost Subsonic Wind Tunnel" (IOSRJEN) e-ISSN: 2250-3021, p-ISSN: 2278-8719, www.iosrjen.org Volume 2, Issue 10 (October 2012), PP 83-92

[4] Ranjan Basak, Debojyoti Mitra, Asis Mazumdar "Design of Various Components of an Open Circuit Blower Tunnel without Exit Diffuser " International Journal of Advances in Science and Technology, Vol. 2, No.6, 2011

[5] Mansi Singh, Neha Singh & Sunil Kumar Yadav "Review of Design and Construction of an Open Circuit Low Speed Wind Tunnel" Volume 13 Issue 5 Version 1.0 Year 2013Online ISSN: 2249-4596 Print ISSN: 0975-5861 Publisher: Global Journals Inc. (USA)

[6] Kalpesh Vaghela "Optimization of Roof fairing angle to reduce the Aerodynamic Drag of Heavy Duty Truck" (IJETCAS) ISSN (Print): 2279-0047 ISSN (Online): 2279-0055

[7] Jean-Luc Aider • Jean-Franc¸ois Beaudoin • Jose´ Eduardo Wesfreid "Drag and lift reduction of a 3D bluff-body using active vortex Generators" Published online: 16 October 2009! Springer-Verlag 2009 Exp Fluids (2010) 48:771–789 DOI 10.1007/s00348-009-0770-y

[8] Andrew R. Coggan, Ph.D. "The Coggan Low Speed Wind Tunnel: Design, Dimensions, and Operating Characteristics" Coggan LSWT-November 2011

[9] Josué Njock Libii "Wind Tunnels in Engineering Education" Indiana University-Purdue University Fort Wayne USA

[10] G. Dimitriadis Wind Tunnel Tests on Road Vehicles Experimental Aerodynamic Lecture 7:

[11] Miguel A. González Hernández, Design Methodology for a Quick and Low-Cost Wind Tunnel http://dx.doi.org/10.5772/54169

[12] Fluid dynamics - Equation of continuity and Bernoulli's principle. Lecture 4 Dr Julia Bryant

[13] Wind Tunnels and Experimental Fluid Dynamics Research Edited by Prof. Jorge Colman Lerner ISBN 978-953-307-623-2 Hard cover, 709 pages Publisher InTech Published online 27, July, 2011

[14] Aviation Science & Development at Farnborough "History and Learning Briefings No. 13 - The Farnborough Wind Tunnels" & _Wikipedia