Bharath

INSTITUTE OF HIGHER EDUCATION AND RESEARCH

Declared as **Deemed-to-be-University** u/s 3 of the UGC Act, 1956

B.Tech – Aerospace Engineering

U20ASCJ01 – Fluid Mechanics for Aerospace Engineers

Lab Manual

Vision of the Institute

"Bharath Institute of Higher Education & Research (BIHER) envisions and constantly strives to provide an excellent academic and research ambience for students and members of the faculties to inherit professional competence along with human dignity and transformation of community to keep pace with the global challenges so as to achieve holistic development."

Mission of the Institute

- To develop as a Premier University for Teaching, Learning, Research, and Innovation on par with leading global universities.
- To impart education and training to students for creating a better society with ethics and morals.
- To foster an interdisciplinary approach in education, research and innovation by supporting lifelong professional development, enriching knowledge banks through scientific research, promoting best practices and innovation, industry driven and institute-oriented cooperation, globalization and international initiatives.
- To develop as a multi-dimensional institution contributing immensely to the cause of societal advancement through spread of literacy, an ambience that provides the best of international exposures, provide health care, enrich rural development and most importantly impart value based education.
- To establish benchmark standards in professional practice in the fields of innovative and emerging areas in engineering, management, medicine, dentistry, nursing, physiotherapy and allied sciences.
- To imbibe human dignity and values through personality development and social service activities.

B.Tech- Aerospace Engineering

Vision of the Department

Department of Aeronautical Engineering will endeavour to accomplish worldwide recognition with a focal point of Excellence in the field of Aeronautics by providing quality Education through world class facilities, enabling graduates turning out to be Professional Experts with specific knowledge in Aeronautical & Aerospace engineering.

Mission of the Department

- To be the state of art Teaching and Learning center with excellent infrastructure and empowered Faculties in Aeronautical & Aerospace Engineering.
- To foster a culture of innovation among students in the field of Aeronautics and Aerospace with updated professional skills to enhance research potential for sponsored research and innovative projects.
- To Nurture young individuals to be knowledgeable, skillful, and ethical professionals in their pursuit of Aeronautical & Aerospace Engineering.

B.Tech- Aerospace Engineering

Program Educational Objectives Statements (PEO)

PEO 1: Demonstrate a solid grasp of fundamental concepts in Mathematics, Science, and Engineering, essential for effectively addressing engineering challenges within the Aerospace industry.

PEO 2: Involve in process of designing, simulating, fabricating, testing, and evaluating in the field of Aerospace.

PEO 3: Obtain advanced skills to actively engage in research and development endeavors within emerging domains, while also pursuing further education opportunities.

PEO 4: Demonstrate efficient performance both as independent contributors and as valuable team members in diverse multidisciplinary projects.

PEO 5: Embrace lifelong learning and career advancement while adapting to the evolving social demands and needs.

B.Tech- Aerospace Engineering

Programme Outcomes (PO's)

PO1: Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and Engg. Specialization to the solution of complex engineering problems.

PO2: Problem analysis: Identify, formulate, research literature, and analyze engineering problems to arrive at substantiated conclusions using first principles of mathematics, natural, and engineering sciences.

PO3: Design/development of solutions: Design solutions for complex engineering problems and design system components, processes to meet the specifications with consideration for the public health and safety, and the cultural, societal, and environmental considerations.

PO4: Conduct investigations of complex problems: Use research-based knowledge including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

PO5: Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

PO6: The engineer and society: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal, and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

PO7: Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

PO8: Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

PO9: Individual and teamwork: Function effectively as an individual, and as a member or leader in teams, and in multidisciplinary settings.

PO10: Communication: Communicate effectively with the engineering community and with society at large. Be able to comprehend and write effective reports documentation. Make effective presentations and give and receive clear instructions.

PO11: Project management and finance: Demonstrate knowledge and understanding of engineering and management principles and apply these to one's own work, as a member and leader in a team. Manage projects in multidisciplinary environments.

PO12: Life-long learning: Recognize the need for and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

B.Tech- Aerospace Engineering

Program Specific Outcomes (PSO) - R2020

PSO1: Design and analyze aerospace components/systems for aerospace industries.

PSO2: Acquire the concepts of spacecraft attitude dynamics for the prediction of spacecraft motion.

Course Outcomes (COs)

Course Outcomes (COs)

CO1	**Explain** the properties of different fluids and Fluid Characteristics **(Understand)**
CO2	**Describe** the Incompressible Inviscid Flows and Elementary Flows **(Understand)**
CO3	**Describe** the non-dimensional parameters used in airflow. **(Understand)**
CO4	**Describe** the nature of Boundary layer separation over a bluff and slender body. **(Understand)**
CO5	**Determine** the geometric features of airfoils with the help of conformal transformations. **(Apply)**
CO6	**Acquire** data using the conservation laws to determine the coefficient of discharge of a venturimeter and Orificemeter. **(Manipulation)**
CO7	**Carry out** the pressure distribution of a symmetric airfoil using subsonic wind tunnel **(Imitation)**
CO8	**Perform** the Bernoulli's test to show the sum of kinetic, potential and pressure energy of fluid is same at any point in the tube. **(Precision)**

Mapping/Alignment of COs with PO & PSO

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	H	H								H		H	H	
CO2	H	H										H	H	
CO3	H	H										H	H	
CO4	H	H								H		H	H	
CO5	H	H										H	H	
CO6	H	H			L			H	H	H		H	H	
CO7	H	M							M			L	H	M
CO8	H	M							M	L		H	H	M

(Tick mark or level of correlation: H-High, M-Medium,L-Low)

LIST OF EXPERIMENTS:

S.No	Name of Experiment	Course Outcome
1.	Determination of coefficient of discharge of Venturimeter.	CO6,CO7,CO8
2.	Determination of coefficient of discharge of Orifice meter.	CO6,CO7,CO8
3.	Verification of Bernoulli’s theorem.	CO6,CO7,CO8
4.	Calibration of Subsonic wind tunnel.	CO6,CO7,CO8
5.	Estimation of Pressure distribution on circular cylinder.	CO6,CO7,CO8
6.	Estimation of Pressure distribution of symmetric airfoil.	CO6,CO7,CO8

EXP NO : 1 DATE :	**DETERMINATION OF COEFFICIENT OF DISCHARGE OF VENTURIMETER.**

AIM:

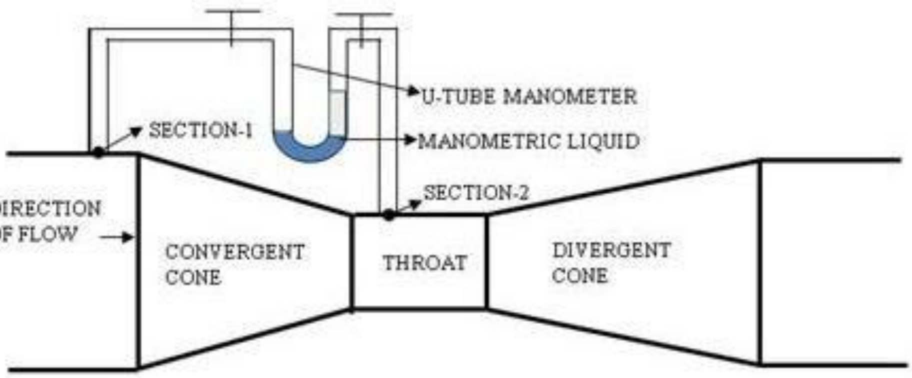
To study the variation of Cd (Coefficient of discharge) and discharge.

APPARATUS USED:

Venturimeter, U-tube manometer (Hg), stop clock, V-notch and hook gauge.

THEORY:

A Venturemeter is a device used used for measuring the rate of flow of fluid flowing through a pipe. It is based on the principle of Bernoulli's theorem. It consists of three parts they are Convergent cone, throat, Divergent cone. Convergent cone has a total inclined angle of 21hI and length approximately equal to 2.7 (D/d) the length of the throat is equal to 'd' diameter. Divergent cone has a total inclined angle of throat 6~.



PROCEDURE:

1. Before starting the experiment note down the inlet and throat diameter and also crest level of

V-notch.

2. Release the air trapped in the manometer tube by opening the air valves.

3. Using the control valve allow the water to flow through Venturimeter at the uniform rate.

4. Note down the manometer reading on both the limbs and convert into meter for water.

5. Note down the final reading of V-notch and calculate the discharge using the formula $Q_{act} = 1.417 \times Hv^{5/2} m^3/s$.

6. Calculate the theoretical discharge Q_{th} using formula $Q_{th} = a_1a_2/(\sqrt{a12 - a22}) \times \sqrt{2ghm3} /s$

7. Finally calculate the coefficient of discharge of a Venturimeter using the formula $cd = Q_{act} / Q_{th}$.

OBSERVATION:

1. d_1 = diameter of pipe =

2. d_2 = diameter of throat =

3. a_1 = area of pipe =

4. a_2 = area of throat =

TABULAR COLUMN:

OBSERVATIONS AND CALCULATIONS:

Plan area of the tank A =

Sl. no	Time for 10cm rise of water level (s)			Actual discharge A cm^3/s	Differential head in cm. of mercury			Differential head in cm. of water.	Theoretical discharge Q_{th}, cm^3/s.	Coefficient of discharge C_{od}
	t_1	t_2	t_m		h_1	h_2	h_1- h_2 H_{ug}			
1										
2										
3										
4										
5										

RESULT:

Coefficient of discharge of Venturimeter C_d =

EXP NO : 2 DATE :	DETERMINATIONS OF COEFFICIENT OF DISCHARGE OF ORIFICE METER.

AIM:

To determine the coefficient of discharge (C_d) using the orifice meter.

APPARATUS REQUIRED:

a) Measuring tank of Size 0.6 x 0.6 x 0.8 meter with overflow arrangement,gauge glass, scale arrangement and a drain valve.

b) Stop Watch.

c) Orifice meters fitted onto horizontal pipes of diameters 20mm, 25mmand 40mm with pressure tapping's and gate valves to regulate flow rate.

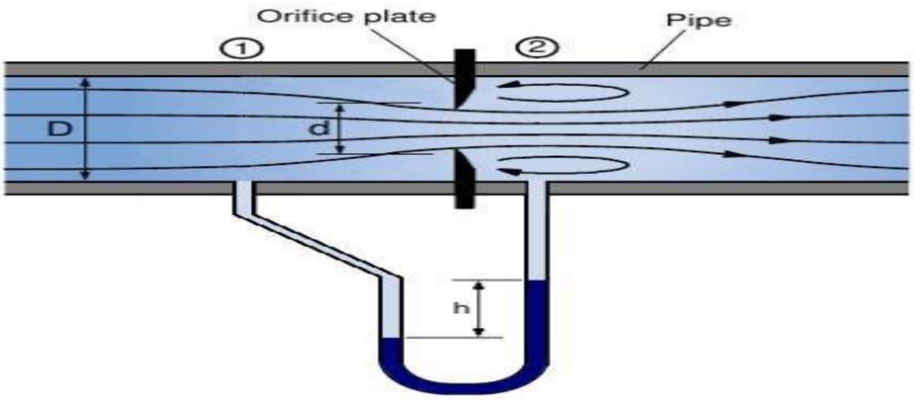
d) Differential mercury manometer with wooden scale of 1m length andscale graduations of 1mm to measure the loss of head.

e) The orifice diameter corresponding to the pipe diameters are as follows:

Sr no	Pipe diameter(mm)	Orifice diameter(mm)
1	20	13.41
2	25	16.77
3	40	26.83

THEORY:

An orifice meter or orifice plate is a device used for measuring the rate offlow of a fluid through a pipe. It works on the same principle as a venturimeter. It consists of a flat circular plate which has a circular sharp edged hole called orifice. It is an opening in the side or bottom of a vessel or a tank through whichliquid will flow under the condition that the liquid surface is always above the topedge of the opening. The orifice diameter is 0.5 times the diameter of the pipe. Adifferential manometer is connected at section 1 which is at a distance of about 1.5 to 2 times the pipe diameter upstream from the orifice plate, and at section 2,which is at a distance of about half the diameter of the orifice on the downstreamside from the orifice plate. The basic principle on which a orifice meter works isthat by reducing the cross sectional area of the flow of passage, a pressure difference between the two sections is developed and the measurement of the pressure difference enables the determination of the discharge through pipe. However, an orifice meter is a cheaper arrangement for discharge measurement through pipes and its installation requires a smaller length as compared to venturimeter.



FORMULAE:

$$Q_{th} = \frac{A_1 A_2}{\sqrt{A_1^2 - A_2^2}} \sqrt{2gH_w}$$

Where

A_1 – The area at inlet side in

cm^2 A_2 – The area at throat in

cm^2

H_w – Head difference in the manometer, converted to cm of waterg –

Acceleration due to gravity (9.81 m/sec^2)

Coefficient of discharge is given by

$$C_d = \frac{Q_a}{Q_{th}}$$

OBSERVATIONS:

CO-FFICIENT OF DISCHARGE :

Sl No	Mnometer readings in (cm) H_{Hg}		Head loss in cm of water $h=(H_1-H_2)$	Time taken for 10 cm rise of water in sec (t)	Actual discharge (Q_a) in cm^3/sec	Theoritical discharge (Q_t) in cm^3/sec	Co-efficient of discharge (C_d)
	H_1	H_2					
1							
2							
3							
4							
5							

PROCEDURE:

(i) Close the valves of inlet pipe, Orifice meter pipe line and manometer.

(ii) The gate valve of the pipeline selected for the experimentation is opened.

(iii) The needle valves of the corresponding manometer & Orifice meterare opened.

(iv) Adjust the control valve kept at the exit side of the Orifice to a desiredflow rate and maintain the flow.

(v) Note down the readings of manometer & time for 10cm rise inmeasuring tank.

(vi) Adjust the gate valve and repeat the experiment.

RESULT:

The coefficient of discharge of the Orifice meter C_d =

EXP NO : 3 DATE :	VERIFICATION OF BERNOULLI’S THEOREM.

AIM:

To understand the Bernoulli’s theorem through an experiment.

APPARATUS REQUIRED:

Bernoulli’s Apparatus Controlling valve at inlet and outlet, Discharge Measuring Tank, Scale, Stopwatch etc.

FORMULA:

Total Energy = $P/\rho g + V^2/2g + Z$ = cons

Where $P/\rho g$ = Pressure energy, $V^2/2g$ = Kinetic energy, Z = Potential energy.

THEORY:

Kinetic energy: The kinetic energy of an object is the energy which it possesses due to its motion. It is defined as the work needed to accelerate a body of a given mass from rest to its stated velocity. Having gained this energy during its acceleration, the body maintains this kinetic energy unless its speed changes. The same amount of work is done by the body in decelerating from its current speed to a state of rest.

Potential energy: The potential energy is the energy of an object or a system due to the position of the body or the arrangement of the particles of the system. The SI unit for measuring work and energy is the joule (symbol J). If the work of forces of this type acting on a body that moves from a start to an end position is defined only by these two positions and does not depend on the trajectory of the body between the two, then there is a function known as a potential that can be evaluated at the two positions to determine this work. Furthermore, the force field is defined by this potential function, also called potential energy.

Pressure energy: Pressure in a fluid may be considered to be a measure of energy per unit volume or energy density. For a force exerted on a fluid, this can be seen from the definition of pressure. Pressure in a fluid can be seen to be a measure of energy per unit volume by means of the definition of work. This energy is related to other forms of fluid energy by the Bernoulli equation.

Bernoulli’s theorem: Bernoulli's principle can be derived from the principle of conservation of energy. This states that, in a steady flow, the sum of all forms of mechanical energy in a fluid along a streamline is the same at all points on that streamline. This requires that the sum of kinetic energy and potential energy remain constant. Thus an increase in the speed of the fluid occurs proportionately with an increase in both its dynamic pressure and kinetic energy, and a decrease in its static pressure and potential energy. If the fluid is flowing out of a reservoir, the sum of all forms of energy is the same on all streamlines because in a reservoir the energy per unit volume (the sum of pressure and gravitational potential ρ g h) is the same everywhere.

PROCEDURE:

1. Open the measuring tank valve fully, to keep the tank empty. Close the outlet valve.

2. Open the inlet valve and let water rise to some height ‘h1’ in the inlet tank. Measure this height on the piezometer.

3. Now open the outlet valve slightly and maintain height $h2 < h1$ to maintain the flow rate.

4. Thus adjust the outlet valve fill the water level remains constant at ‘h’, and also readings on each of the piezometer.

5. Check if reading is correctly written. Close the measuring tank valve. Measure the discharge, i.e. note rise in water level in 5 or 10 sec., write these and also measure and note length and breadth of the tank. This completes on run. Take at least three runs by changing the discharge.
6. Note down the area of the conduit at various gauge points.

7. Open the supply valve and adjust the flow so that the water level in the inlet tanks remains constant.

8. Measure the height of water level (above an arbitrarily selected suitable plane) in different remains constant.

9. Measure the discharge of the conduit with the help of measuring tank.

10. Repeat steps 2 to 4 for two more discharges.

11. Plot graph between total energy and distance of gauge points starting from u/s side of conduit.

TABULATION:

Area of pipe (a) (m2)	**Time for 10cm rise of water (sec)**	**Actual discharge Qact =AH/t (m3 /sec)**	**Velocity = Qact/a (m/sec)**	**Velocity head V^2 /2g (m)**	**Pressure head P/ρg (m)**	**Datum head (Z) (m)**	**Total head P/ρg + V^2 /2g + Z (m)**

1. Actual discharge:

$$Qact = AH/t$$

2. Velocity:

$$Qact/a =$$

3. Velocity head:

$$V^2 /2g =$$

4. Total head:

$$P/\rho g + V^2/2g + Z = \text{constant}$$

GRAPH:

The graphs of pressure head, velocity head and total head are drawn at various cross-sections, taking the cross-section area on X-axis.

RESULT:

The total energy of a streamline, while the particle moves from one point to another. Bernoulli's theorem for an incompressible fluid flow is verified.

EXP NO : 4 DATE :	**CALIBRATION OF A SUBSONIC WIND TUNNEL**

AIM:

To calibrate the subsonic wind tunnel by preparing a calibration chart drawn between motor speeds (RPM) and test section velocity.

APPARATUS REQUIRED:

Subsonic Wind Tunnel, Manometer, Pitot - static tube mounted in the Test Section.

THEORY:

The calibration of wind tunnel is done to measure the tunnel speed, which can be measured through Pitot-static tube. The tunnel speed is the mean speed at the test section when the tunnel is empty. The tunnel speed is measured in terms of the difference between a total head and a static pressure reading. Calibration also ensures the uniformity of flow parameters in the region to be used for model testing.

PROCEDURE:

1. Check the wind tunnel for any loose parts.
2. Set the reading of the velocity indicator to zero before starting the wind tunnel.
3. Run the tunnel at a particular speed and note down the actual velocity Va from the air velocity indicator and manometer Δh by pressing the up arrow of the velocity indicator.
4. Repeat the process by running at different speeds
5. Gradually shut down the wind tunnel.
6. Calculate the velocity of air flow as per the formula given below.
7. Draw the calibration chart between calculated Flow velocity and Motor Speed.

FORMULA:

$$P_T – P_S = \frac{1}{2} \rho V^2$$

Where,

P_T - Total Pressure of tunnel, N/m2

P_s - Static pressure of tunnel, N/m2

ρ - Density of Air, Kg/m3

V - Velocity of Air Flow

$P_T = P_a - P_\infty$, this is because it is an open tunnel

P_a = ambient pressure

(Thus total pressure in the tunnel remains constant irrespective of speed of flow in Tunnel, only the static pressure of the tunnel varies)

$$\frac{2(p_T - p_S)}{\rho} = \frac{2\Delta p}{\rho} = V^2 \Rightarrow V = 129.7\sqrt{h_T - h_S} = 129.7\sqrt{\Delta h}$$

Where, Δh = manometer differential height in mm Density of air is taken as 1.125 x 103 Kg/m3.

$$V = 129.7\sqrt{\Delta h(mm)}$$

$$\text{Percentage Error} = \frac{(V_a - V_c)}{V_a} \times 100$$

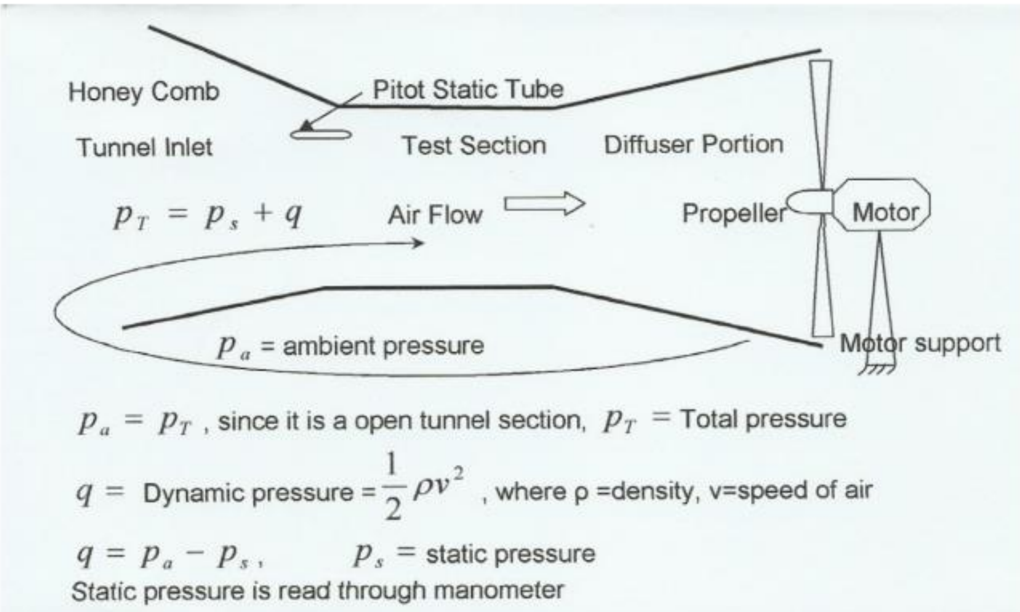


Fig. Tunnel static pressure concept

TABULATION:

Sl. No.	Speed (RPM)	Actual Velocity V_a in m/s	Manometer Differential height, Δh (mm)	Flow Velocity $V_c = 129.7\sqrt{\Delta h}$ m/sec	Frequency Hz	Percentage Error
1						
2						
3						
4						
5						
6						

GRAPH:

1. Speed v/s Velocity

RESULT:

Thus, the wind tunnel is calibrated using the pitot-static probe by measuring the total and static pressure.

EXP NO : 5 DATE :	**ESTIMATION OF PRESSURE DISTRIBUTION OF CIRCULAR CYLINDER.**

AIM:

To Measure the pressure distribution on a two-dimensional circular cylinder and to estimate the drag of the cylinder.

APPARATUS REQUIRED:

Low speed wind tunnel, Multi tube manometer, Cylinder model with pressure tapings and with support mount, Pitot - static tube.

DIAGRAM:

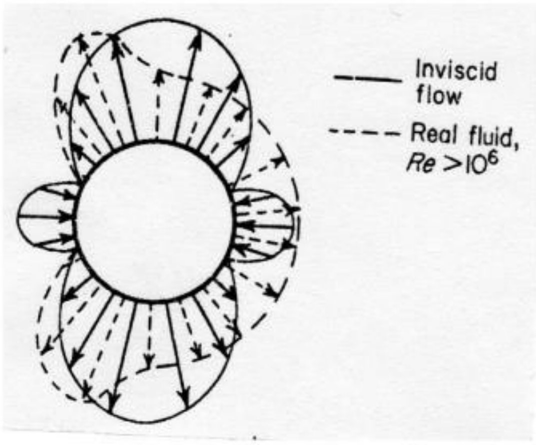


Fig: Ideal flow and Actual static pressure distribution over a circular cylinder

THEORY:

There are various methods by which the drag of the bluff body can be measured. One such method is estimating the drag of the body by measuring the pressure distribution over the body. Here the pressure distribution over the cylinder is measured which comes from the pressure force created by the free stream flow over the cylinder. Then in turn by suitable formula the drag generated by the cylinder is calculated.

PROCEDURE:

1. Assemble the cylinder with pressure tapings in the test section with the help of support. Connect the pressure tapping to manometer.
2. Rotate the cylinder such that the static holes form the upper or lower surface of the cylinder.
3. Ensure the tunnel for any loose components and start the tunnel.
4. Run the tunnel at various desired speeds and note down the manometer reading which measures the surface pressure distribution of the cylinder.
5. Also note down the Pitot-Static tubes manometer reading.
6. Since the cylinder is axially symmetric the pressure distribution is measured for half the surface and the same trend follows for another half portion.
7. Gradually shut down the tunnel.

DATA REDUCTION:

1. Dynamic Pressure,q:

$$q = p_T - p_S = \frac{1}{2}\rho V_\infty^{\ 2}$$

p_s = tunnel static pressure

2. Pressure Coefficient:

$$C_p = \frac{p_i - p_s}{q_\infty} = \frac{\Delta h_i}{q_\infty}$$

where, p_i= Static pressure values measured around cylinder
p_s= Tunnel static pressure
Δh_i = manometer differential column height wrt tunnel static

3. Pressure Coefficient (theoretical value):

$$C_p = 1 - 4Sin^2\theta$$

where ,θ= Angular location of static ports around the cylinder

4. Drag Coefficient :

$$C_D \approx \int_0^\pi C_p \cos\theta \, d\theta$$

$$C_D = C_{p\ exp} \ Cos\ \theta\ d\theta$$

We do not have continuous pressure distribution; therefore we evaluate this with a numerical summation.

TABULAR COLUMN:

$$\frac{2(P_T - P_S)}{\rho} = V^2 \Rightarrow V = 129.7\sqrt{\Delta h}$$

$$q = \frac{1}{2}\rho V_\infty^{\ 2}$$

Experimental Pressure Drag, $C_D = C_{pexp} \times \cos\theta . d\theta$

Speed: **Velocity:**

Static Pressure, Ps (reading on 34th port):

Pressure Tappings	Pi	Cp Experimental $C_p = \frac{\Delta h_i}{q}$	Cp Theoretical $C_p = 1 - 4Sin^2\theta$	θ (rad)	Interval between ports dθ	Experimental Pressure drag
1						
2						
3						
					$C_D = \sum C_p \cos\theta \, d\theta$	

GRAPH:

Cp Vs θ theoretical and compare with experimental values.

RESULTS:

1. Thus the pressure distribution around the cylinder is measured and the drag of the cylinder is estimated.
2. The coefficient of drag of cylinder, C_D =

EXP NO : 6 DATE :	ESTIMATION OF PRESSURE DISTRIBUTION OF SYMMETRIC AIRFOIL.

AIM:

To Measure the pressure distribution on a two-dimensional symmetric airfoil at low speeds at different angle of attacks.

APPARATUS REQUIRED:

Low speed wind tunnel, Multi tube manometer, wing model with pressure tapings and with support mount, Pitot - static tube

THEORY:

A symmetric airfoil is one which has same shape on both sides of the chord line i.e. the chord line and camber line for the symmetric airfoil coincides. The pressure distribution and shear stress distribution over the airfoil generates the aerodynamic forces. For a symmetric airfoil no lift is produced for zero angle of attack.

PROCEDURE:

1. Assemble the wing model with pressure tapings in the test section with the help of support.
2. Rotate the wing model such that the chord line is horizontal, thereby keeping the wing at zero angle of incidence.
3. Ensure the tunnel for any loose components and start the tunnel.
4. Run the tunnel at a desired speed and note down the manometer reading which measures the surface pressure distribution.
5. Also note down the Pitot-Static tubes manometer reading.
6. Gradually shut down the tunnel.
7. Again repeat the experiment for various angles of attack and tabulate the readings.

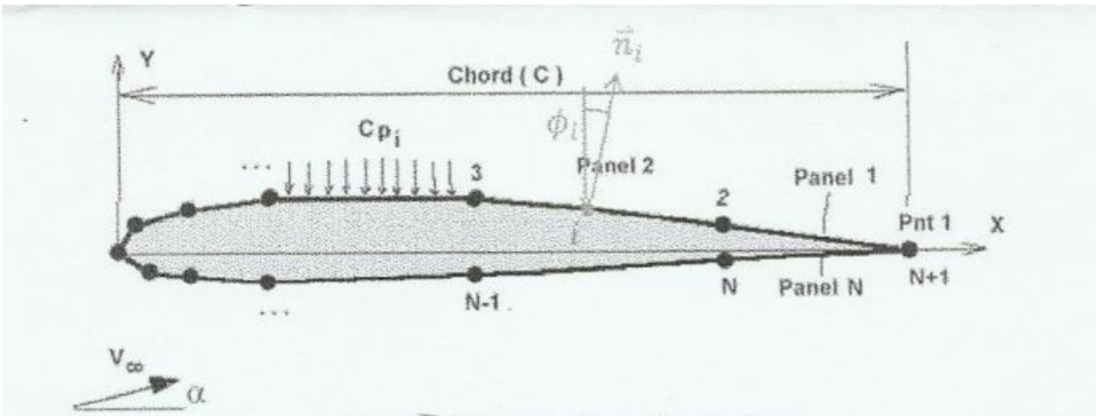


Figure Wing planform illustration

Fig. Shows the port points and nomenclatures

$$C_{p_i} = \frac{p_i - p_s}{q} = \frac{\Delta h_i}{q}$$

where,

p_i= Static pressure values measured around cylinder(note it is also the stagnation pressure at the leading edge and is equal to tunnel total)

p_s= Tunnel static pressure

Δh_i = manometer differential column height w.r.t tunnel total

TABULATION:

Angle of attack: Speed: Velocity:

Static Pressure, Ps (reading on 34th port):

Port. No	Pi	Pressure Coefficient $C_p = \frac{\Delta h_i}{q}$
1		
2		
3		
4		
5		

GRAPH:

Cp vs X/C

RESULT:

Thus the pressure distribution around the airfoil is measured.