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

U20ASCJ03 – Low and High-speed Aerodynamics

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 endeavor 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)

CO 1	**Apply** the concept of lift generation and the factors for efficient wing design. (**Apply**)
CO 2	**Show** that subsonic nozzle is convergent and supersonic nozzle is divergent, with variation in pressure and temperature. (**Apply**)
CO 3	**Calculate** the properties of flow through shock and expansion waves. (**Apply**)
CO 4	**Outline** a supersonic convergent divergent nozzle **(Analyze)**
CO5	**Determine** the skin friction drag over surfaces. (**Apply**)
CO6	**Carry out** flow analysis over various aerodynamic models. (**Imitation**)
CO7	**Demonstrate** the qualitative analysis of the shock pattern by using shadowgraph technique (**Manipulation**)
CO8	**Carry out** the experiments of jet flows. (**Imitation**)

Mapping/Alignment of Cos with PO & PSO

	PO1	PO2	PO 3	PO 4	PO5	PO6	PO7	PO8	PO9	PO1 0	PO 11	PO12	PSO1	PSO2
CO1	H	L										H	H	
CO2	H	L										H	H	
CO3	H	H								M		H	H	
CO4	H	L								M		H	H	
CO5	H	H										H	H	
CO6	H	H		H					H	H		H	H	
CO7	H	H		H					H	H		H	H	
CO8	H	H		H					H	H		H	H	

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

LIST OF EXPERIMENTS:

S.No	Name of Experiment	Course Outcome
1.	Pressure distribution over symmetrical and unsymmetrical airfoil at various angle of attack	CO6,CO7,CO8
2.	Velocity profiles of free and wall jets.	CO6,CO7,CO8
3.	Study on supersonic wind tunnel	CO6,CO7,CO8
4.	Wall pressure measurements of subsonic diffusers	CO6,CO7,CO8
5.	Velocity and pressure measurements of high-speed jets.	CO6,CO7,CO8
6.	Qualitative analysis of circular jet using shadowgraph	CO6,CO7,CO8

EXP NO : 1.a DATE :	**PRESSURE DISTRIBUTION OVER AN SYMMETRICAL AIRFOIL MODEL**

AIM

To determine the pressure distribution on a symmetrical airfoil.

APPARATUS REQUIRED

- Low speed wind tunnel
- Multi-tube manometer
- Unsymmetric aerofoil model

Procedure:

1. Prepare the low speed wind tunnel and check for all the electrical installations for correct insulation.
2. Ensure no dust particle on the multi-tube manometer inlets.
3. Fix the aerofoil in the test section.
4. Set the required angle of attack using angle setter.
5. Connect the pressure tube bundle coming from multi-tube manometer to the steel tube extension of the aerofoil model.
6. Now set the required velocity of airflow using DC motor controller knobs and observe the displacement of the manometer liquid in all tubes, standing at different levels and note them down.
7. Repeat steps 4 to 6 for different angle of attack and locate the stalling angle of attack beyond which the distribution falls..
8. The negative angle of attack is given to the model and the pressure distribution gets reversed in the other direction, which is an interesting phenomenon to note.

Formula:

$$V = \sqrt{\frac{2\rho_w g \Delta h}{\rho_a}}$$

Here

V = Free stream velocity inside the test section

ρ_w = Density of water

g = Gravity

Δh = manometer difference

ρ_a = Density of air

Coefficient of pressure calculation

$$C_p = \frac{p - p_\infty}{0.5\rho V^2} \qquad C_p = \frac{\rho_w g \Delta h}{0.5 V^2 \rho_a}$$

Here

C_p = coefficient of pressure

p_∞ = Free stream pressure

p = local pressure

Lift calculation

$$C_y = \int_0^1 \left(C_{p_l} - C_{p_l}\right) d\left(\frac{x}{c}\right) \qquad C_L = C_y \cos\alpha - C_x \sin\alpha \qquad C_D = C_y \sin\alpha - C_x \cos\alpha$$

Approximate Equation at low angle of attack

$$C_L = \int_0^1 \left(C_{p_l} - C_{p_l}\right) d\left(\frac{x}{c}\right)$$

Here

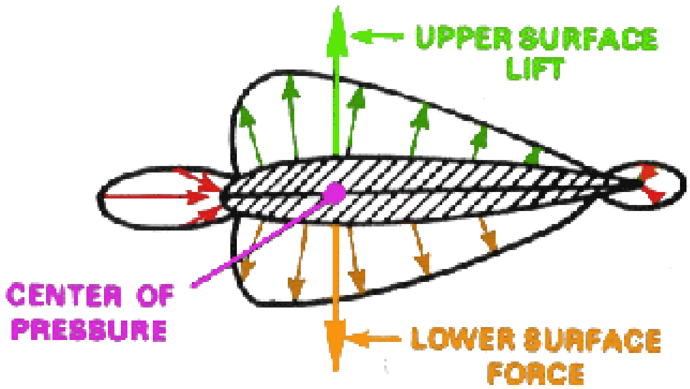
C_L = coefficient of Lift

C_D = coefficient of drag

C_y = Normal force coefficient

C_x = Axial force coefficient

α = Angle of Attack



SYMMETRICAL AIRFOIL AT ZERO LIFT

Table of Content

Velocity =

Density of air =

S.no	Port location	h_1	h_2	$\Delta h = h_2 - h_1$	$C_p = \dfrac{\rho_w g \Delta h}{0.5 V^2 \rho_a}$

RESULT

Thus, the pressure distribution over the symmetrical aero foil at various angles of attack are plotted and studied successfully.

EXP NO : 1.b DATE :	PRESSURE DISTRIBUTION OVER AN UNSYMMETRICAL AIRFOIL MODEL

AIM

To determine the pressure distribution on a unsymmetrical airfoil.

APPARATUS REQUIRED

- Low speed wind tunnel
- Multi-tube manometer
- Unsymmetric aerofoil model

Procedure:

1. Prepare the low speed wind tunnel and check for all the electrical installations for correct insulation.
2. Ensure no dust particle on the multi-tube manometer inlets.
3. Fix the aerofoil in the test section.
4. Set the required angle of attack using angle setter.
5. Connect the pressure tube bundle coming from multi-tube manometer to the steel tube extension of the aerofoil model.
6. Now set the required velocity of airflow using DC motor controller knobs and observe the displacement of the manometer liquid in all tubes, standing at different levels and note them down.
7. Repeat steps 4 to 6 for different angle of attack and locate the stalling angle of attack beyond which the distribution falls..
8. The negative angle of attack is given to the model and the pressure distribution gets reversed in the other direction, which is an interesting phenomenon to note.

Formula:

$$V = \sqrt{\frac{2\rho_w g \Delta h}{\rho_a}}$$

Here

V = Free stream velocity inside the test section

ρ_w = Density of water

g = Gravity

Δh = manometer difference

ρ_a = Density of air

Coefficient of pressure calculation

$$C_p = \frac{p - p_\infty}{0.5\rho V^2} \qquad C_p = \frac{\rho_w g \Delta h}{0.5 V^2 \rho_a}$$

Here

C_p = coefficient of pressure

p_∞ = Free stream pressure

p = local pressure

Lift calculation

$$C_y = \int_0^1 \left(C_{p_l} - C_{p_l}\right) d\left(\frac{x}{c}\right) \qquad C_L = C_y \cos\alpha - C_x \sin\alpha \qquad C_D = C_y \sin\alpha - C_x \cos\alpha$$

Approximate Equation at low angle of attack

$$C_L = \int_0^1 \left(C_{p_l} - C_{p_l}\right) d\left(\frac{x}{c}\right)$$

Here

C_L = coefficient of Lift

C_D = coefficient of drag

C_y = Normal force coefficient

C_x = Axial force coefficient

α = Angle of Attack

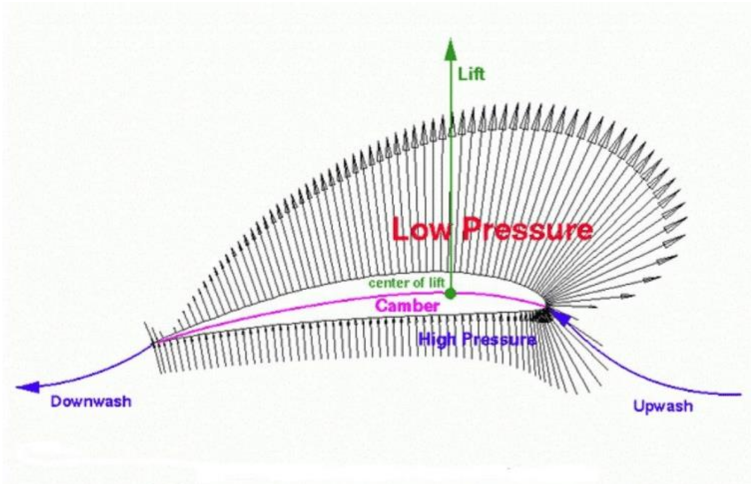


Table of Content

Velocity =

Density of air =

S.no	**Port location**	h_1	h_2	$\Delta h = h_2 - h_1$	$C_p = \dfrac{\rho_w g \Delta h}{0.5 V^2 \rho_a}$

RESULT

Thus, the pressure distribution over the cambered aero foil at various angles of attack are plotted and studied successfully.

EXP NO : 2.a DATE :	VELOCITY PROFILES OF FREE JETS.

AIM

To determine the free jet velocity profile and plot the variation of velocity profile along the central axis of jet.

APPARATUS REQUIRED

- Blower
- Free jet setup facility
- Multitube Manometer

THEORY

We still study a free air of jet issuing from a tube into the air in a nominally quiescent room and measure dynamic pressure at various locations in the flow using a pitot tube and manometer. From the dynamic pressure, kinetic energy per unit volume and hence local speed will be determined. As the fluid exists the nozzle, its slows down due to shear as the fluid exits the nozzle, its slows down due to shear interaction with the surrounding fluid, which is ultimately dissipated as heat. Calculations will show that jet entrains surrounding fluid and mass flow rate of jet increases.

In the second part, you will measure the axial speed at different radial positions to obtain its radial Profile at four stream wise location with the others being downstream of the core measure the speed at radial positions is strong, wait until the reading has settled at each point. The measured dynamic pressure must first be converted to speed using equations. Then use of numerical integration will be helpful. Since the profile is assured to be ax symmetric, the area integral reduces to a single radial quadrate, with an approximate radial weighting. Mass flow rate is obtained by integration.

FORMULA:

$$V = \sqrt{\frac{2\rho_w g \Delta h}{\rho_a}}$$

Here

V = Free stream velocity inside the test section

ρ_w = Density of water

g = Gravity

Δh = manometer difference

ρ_a = Density of air

PROCEDURE

• Fix the free jet and check the props.

• Switch on the blower.

• Adjust velocity using blower controller.

• Find the pressure difference for corresponding pressure port using multi-tubemanometer.

• Switch off the blower.

• Calculate the velocity form pressure difference using given formula.

• Plot the graph (probe location (x axis) to velocity (y axis))

TABLE OF CONTENT

Velocity =

Density of air =

S.no	**Port location**	h_1	h_2	$\Delta h = h_2 - h_1$	$V = \sqrt{\frac{2\rho_w g \Delta h}{\rho_a}}$

CALCULATION:

GRAPH

Probe location vs velocity.

RESULT

Thus, the wall jet characteristic has been studied successfully.

EXP NO : 2.b DATE :	VELOCITY PROFILES OF WALL JETS.

AIM

To determine the wall jet velocity profile and plot the variation of velocity profile along the central axis of jet.

APPARATUS REQUIRED

- Blower
- Wall jet setup facility
- Multitube Manometer

THEORY

A wall jet exits a wall in front of nozzle of a moving fluid. We still study a free air of jet issuing from a tube into the air in a nominally quiescent room and measure dynamic pressure at various locations in the flow using a pitot tube and manometer. From the dynamic pressure, kinetic energy per unit volume and hence local speed will be determined. As the fluid exists the nozzle, its slows down due to shear as the fluid exits the nozzle, its slows down due to shear interaction with the surrounding fluid, which is ultimately dissipated as heat. Calculations will show that jet entrains surrounding fluid and mass flow rate of jet increases.

In the second part, you will measure the axial speed at different radial positions to obtain its radial Profile at four stream wise location with the others being downstream of the core measure the speed at radial positions is strong, wait until the reading has settled at each point. The measured dynamic pressure must first be converted to speed using equations. Then use of numerical integration will be helpful. Since the profile is assured to be ax symmetric, the area integral reduces to a single radial quadrate, with an approximate radial weighting. Mass flow rate is obtained by integration.

FORMULA:

$$V = \sqrt{\frac{2\rho_w g \Delta h}{\rho_a}}$$

Here

V = Free stream velocity inside the test section

ρ_w = Density of water

g = Gravity

Δh = manometer difference

ρ_a = Density of air

PROCEDURE

• Fix the wall jet and check the props.

• Switch on the blower.

• Adjust velocity using blower controller.

• Find the pressure difference for corresponding pressure port using multi-tube manometer.

• Switch off the blower.

• Calculate the velocity form pressure difference using given formula.

• Plot the graph (probe location (x axis) to velocity (y axis))

TABLE OF CONTENT

Velocity =

Density of air =

S.no	**Port location**	h_1	h_2	$\Delta h = h_2 - h_1$	$V = \sqrt{\frac{2\rho_w g \Delta h}{\rho_a}}$

Calculation:

Graph

Probe location vs velocity.

Result

Thus, the wall jet characteristic has been studied successfully.

EXP NO : 3 DATE :	**STUDY ON SUPERSONIC WIND TUNNEL**

AIM

To study the supersonic wind tunnel and its classifications

THEORY

Wind Tunnels Wind tunnels are devices that provide air streams flowing under controlled conditions so that models of interest can be tested using them. From an operational point of view, wind tunnels are generally classified as low-speed, high-speed, and special purpose tunnels. Low-speed tunnels are those with a test-section speed of less than 650 kmph. Depending upon the test-section size, they are referred to as small-size or full-scale tunnels. They are further classified into the following categories: open-circuit tunnels, having no guided return of air, and closed-circuit or return-flow tunnels, having a continuous path for the air. In low-speed tunnels, the predominant factors influencing the tunnel performance are inertia and viscosity. The effect of compressibility is negligible for these tunnels. Thus, if the Reynolds number of the experimental model and full-scale prototype are equal, any difference in viscosity becomes unimportant.

High-Speed Wind Tunnels:

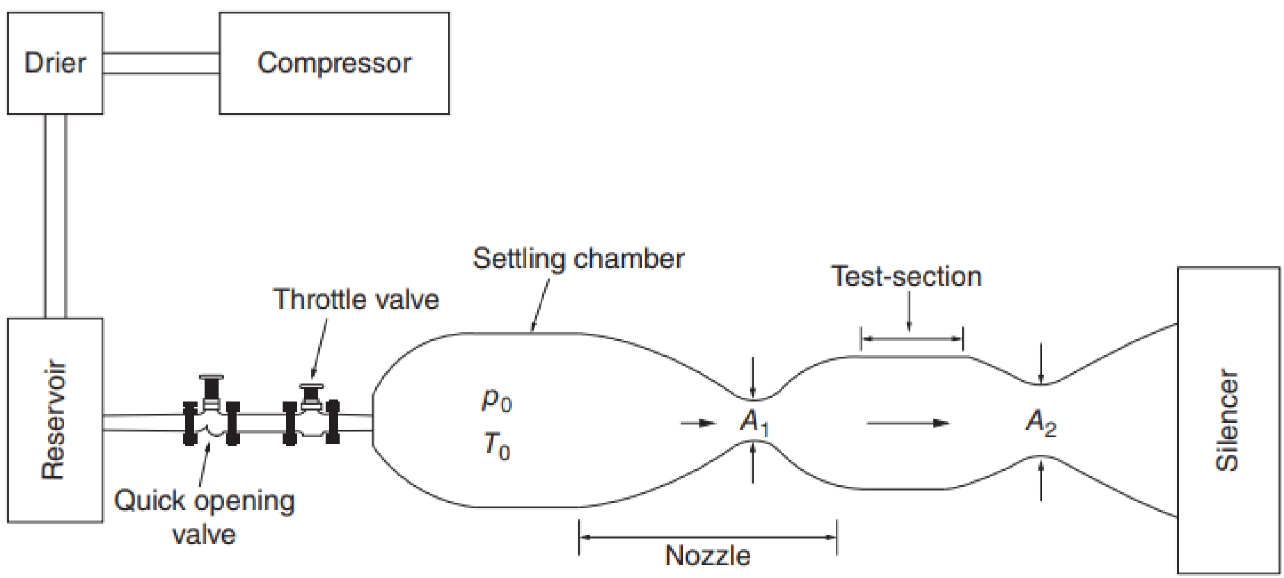
Tunnels with a test-section speed of more than 650 kmph are called high-speed tunnels. The predominant aspect in a high-speed tunnel operation is that the influence of compressibility is significant. This means that in high-speed flows it is essential to consider the Mach number as a more appropriate parameter than velocity. A lower limit of high-speed might be considered the flow with a Mach number of approximately 0.5 (about 650 kmph) at standard sea level conditions. Based on the test-section Mach number M range, the high-speed tunnels are classified as follows.

- $0.8 < M < 1.2$ Transonic Tunnel
- $1.2 < M < 5$ Supersonic tunnel
- $M > 5$ Hypersonic tunnel

Like low-speed tunnels, high-speed tunnels are also classified as intermittent or open-circuit tunnels and continuous-return-circuit tunnels, based on the type of operation. The power to drive a low-speed wind tunnel varies as the cube of the test-section velocity. Although this rule does not hold in the high-speed regime, the implication of rapidly increasing power requirements with increasing test-section speed holds for high-speed tunnels also. Because of the power requirements, high-speed wind tunnels are often of the intermittent type, in which energy is stored in the form of pressure or vacuum, or both, and is allowed to drive the tunnel only a few seconds out of each pumping hour. The intermittent blowdown and induction tunnels are normally used for Mach numbers from 0.5 to about 5.0, and the intermittent pressure–vacuum tunnels are normally used for higher Mach numbers. The continuous tunnel is used throughout the speed range. Both intermittent and continuous tunnels have their own advantages and disadvantages.

Blowdown Type Wind Tunnels

Essential features of the intermittent blowdown wind tunnel are schematically shown in



Schematic layout of intermittent blowdown tunnel

Advantages

The main advantages of blowdown type wind tunnels are the following.

• They are the simplest among the high-speed tunnel types and most economical to build.

• Large-size test-sections and high Mach numbers (up to M = 4) can be obtained.

• Constant blowing pressure can be maintained and a running time of considerable duration can be achieved.

These are the primary advantages of intermittent blowdown tunnels. In addition to these, there are many additional advantages for this type of tunnel. For example, a single drive may easily run several tunnels of different capabilities, failure of a model usually will not result in tunnel damage, extra power is available to start the tunnel, and so on.

Disadvantages

The major disadvantages of blowdown tunnels are the following.

• The ratio of charging time to running time will be very high for large tunnels.

• Stagnation temperature in the reservoir drops during tunnel run, thus changing the Reynolds number of the flow in the test-section.

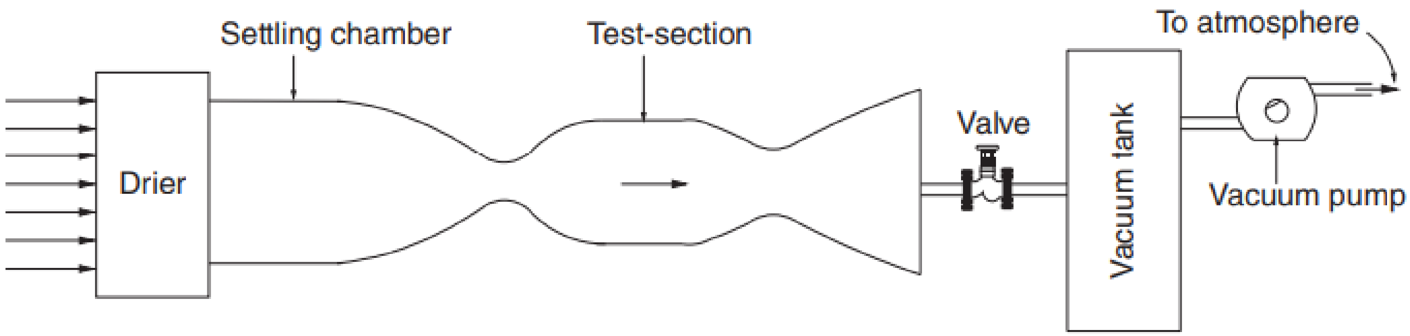
• An adjustable (automatic) throttling valve between the reservoir and settling chamber is necessary for constant stagnation pressure (temperature varying) operation. • Starting load is high (no control possible).

• Reynolds number of flow is low, owing to low static pressure in the test-section.

The commonly employed reservoir pressure range is from 600 kPa to 2 MPa for blowdown tunnel operations. As large as 15 MPa is also used where space limitations require it.

Induction Type Tunnels

In this type of tunnel, a vacuum created at the downstream end of the tunnel is used to establish the flow in the test-section. A typical induction tunnel circuit is shown schematically in



Advantages

The advantages of induction tunnels are the following. • Stagnation pressure and stagnation temperature are constant. • No oil contamination in air, since the pump is at the downstream end. • Starting and shutdown operations are simple.

Disadvantages

The disadvantages of induction type supersonic tunnels are the following.

• Size of the air drier required is very large, since it has to handle a large mass flow in a short duration.

• Vacuum tank size required is also very large.

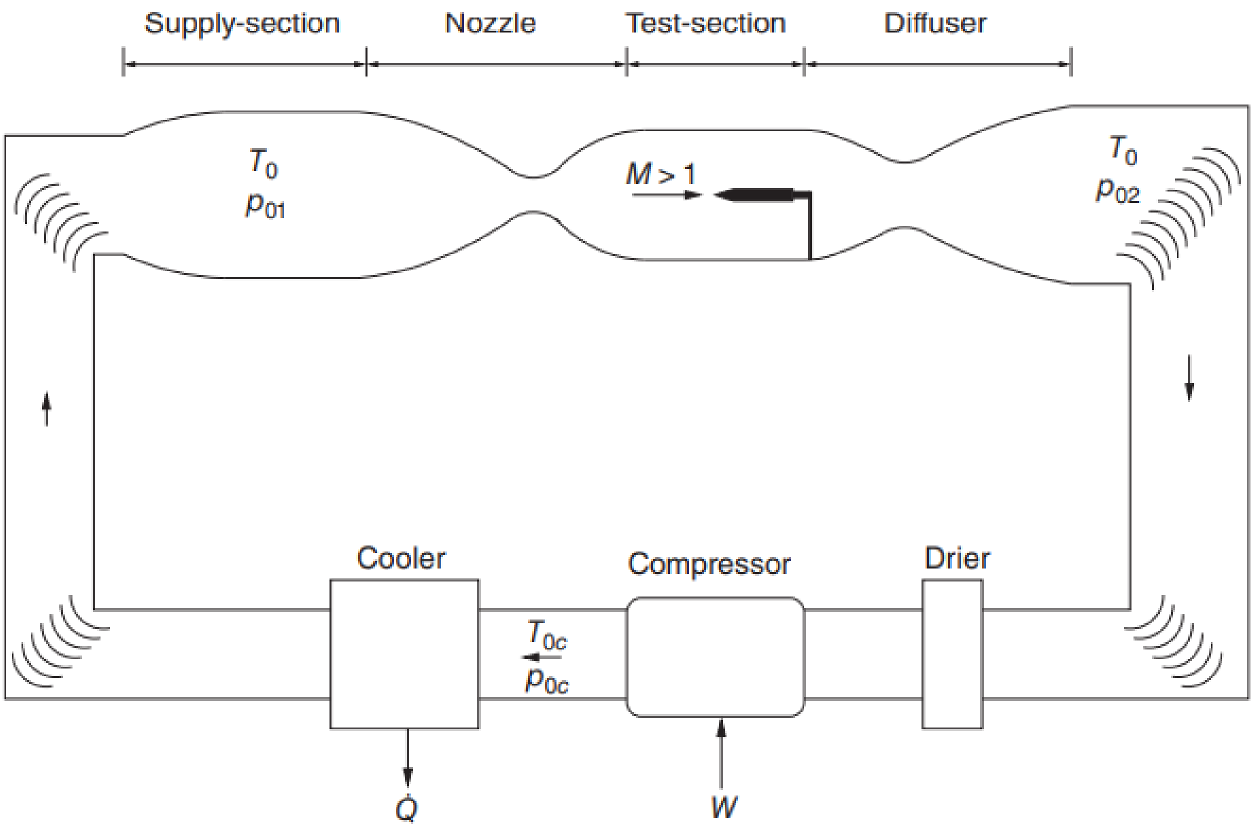
• High Mach numbers (M > 2) are not possible because of large suction requirements for such Mach numbers.

• The Reynolds number is very low, since the stagnation pressure is atmospheric.

The blowdown and induction principles can also be employed together for supersonic tunnel operation to derive the benefits of both types.

Continuous Supersonic Wind Tunnels

The essential features of a continuous-flow supersonic wind tunnel are shown in below figure.



Advantages:

The main advantages of continuous supersonic wind tunnels are the following.

• Better control over the Reynolds number is possible, since the shell is pressurized.

• Only a small capacity drier is required.

• Testing conditions can be held the same over a long period of time.

• The test-section can be designed for high Mach numbers (M > 4) and large models.

• Starting load can be reduced by starting at low pressure in the tunnel shell.

Disadvantages:

The major disadvantages of continuous supersonic tunnels are the following.

• Power required is very high.

• Temperature stabilization requires a large cooler.

• A compressor drive has to be designed to match the tunnel's characteristics.

• Tunnel design and operation are more complicated.

It can be seen from the foregoing discussions that both intermittent and continuous tunnels have certain specific advantages and disadvantages. Before going into the specific details about supersonic tunnel operation, it will be useful to note the following details about supersonic tunnels.

• Axial flow compressor is better suited for large pressure ratio and mass flow.

• Diffuser design is critical since increasing diffuser efficiency will lower the power requirement considerably. The supersonic diffuser portion (geometry) must be carefully designed to decrease the Mach number of the flow as much as possible, before shock formation. The subsonic portion of the diffuser must have an optimum angle, to minimize the frictional and separation losses.

• Proper nozzle geometry is very important to obtain a good distribution of Mach number and freedom from flow angularity in the test-section. Theoretical calculation of a high accuracy and boundary layer compensation, and so on, have to be carefully worked out for large test-sections. Using fixed nozzle blocks for different Mach numbers is simple but very expensive and it is quite laborious for changeover in the case of large test-sections. A flexible wall-type nozzle is complicated and expensive from a design point of view and the Mach number range is limited (usually $1.5 < M < 3.0$).

• Model size is determined from the shock-rhombus.

The model must be accommodated inside the rhombus formed by the incident and reflected shocks, for proper measurements.

RESULT:

Thus the study of supersonic wind tunnel has been done successfully.

EXP NO : 4 DATE :	**WALL PRESSURE MEASUREMENTS OF SUBSONIC DIFFUSERS**

AIM

To determine the static pressure at wall of the subsonic diffuser and plot the variation of velocity profile along the length of the diffuser.

APPARATUS REQUIRED

- Static prope
- Diffuser
- Multitube Manometer

THEORY

The conical diffusers offer potential performance improvements in centrifugal compressors. At the present time, there is very little experimental or analytical data on the performance of conical diffusers for the high speed flow conditions characteristic of centrifugal compressor diffusers. The flow in a diffuser has been analyzed by assuming that the diffuser flow can be approximated by a thin boundary layer adjacent to the wall and an inviscid ' core in the center of the passage. This type of flow is characteristic of the un-stalled flow regime. If the boundary layer separates from the wall, a region of transitory stall exists in which the separated region varies in position, size, and intensity with time. A jet flow regime is encountered when a steady-state separated region extends around the complete circumference of the diffuser and constricts the core flow to a jet in the center of the passage. Experimental data of conical diffusers, was used to predict diffuser performance.

FORMULA:

$$V = \sqrt{\frac{2\rho_w g \Delta h}{\rho_a}}$$

Here

V = Free stream velocity inside the test section

ρ_w = Density of water

g = Gravity

Δh = manometer difference

ρ_a = Density of air

PROCEDURE

- Fix the diffuser on jet setup and check the props.
- Switch on the blower.
- Adjust velocity using blower controller.
- Find the pressure difference for corresponding pressure port using multi-tube manometer.
- Switch off the blower.
- Calculate the velocity form pressure difference using given formula.
- Plot the graph (probe location (x axis) to velocity (y axis))

Table of Content

Velocity =

Density of air =

S.no	Port location	h_1	h_2	$\Delta h = h_2 - h_1$	$V = \sqrt{\frac{2\rho_w g \Delta h}{\rho_a}}$

Calculation:

Graph

Probe location vs velocity.

Result

Thus, the wall jet characteristic has been studied successfully.

EXP NO : 5 DATE :	**VELOCITY AND PRESSURE MEASUREMENTS OF HIGH-SPEED JETS.**

AIM

To calculate the velocity and pressure of high speed jets by using pitot static tube

APPARATUS REQUIRED

- Pitiot static tube
- Nozzle
- Pressure Transducer

THEORY

The three pressures of primary interest in fluid dynamics are the total or pitot, static, and dynamic pressures. We saw that the total pressure is that which results when a flow is decelerated to rest isentropically. From this we can infer that, at a position in a flow where the flow velocity is zero, the total pressure and the undisturbed static pressure are identical. The static pressure is that pressure which acts equally in all directions. The third pressure, namely the dynamic pressure, can be associated with the flow conditions at a point (say the Mach number) by taking the difference between the stagnation pressure and undisturbed static pressure. In modern terminology yet another term namely, velocity pressure, is used. It is simply half of the product of fluid density and square of the speed; also termed kinetic pressure. In incompressible flow it is simply the difference between total and static pressures. Pitot static port used to calculate these pressure both incompressible and compressible flow application.

t at supersonic speeds there will be a detached shock formed and positioned in front of the pitot probe nose. It implies that the tube does not measure the actual stagnation pressure but it only measures the stagnation pressure behind a normal shock. This new value is called pitot pressure and in modern terminology it refers to a supersonic stream.

FORMULA:

For high subsonic speed

$$p_0 - p = q\left(1 + \frac{M^2}{4} + \frac{M^4}{40}\right) \qquad q = \frac{p_0 - p}{K}$$

For supersonic speed

$$\frac{p_1}{p_{02}} = \left[\frac{\left(\frac{2\gamma}{\gamma+1}M_1^2 - \frac{\gamma-1}{\gamma+1}\right)^{\frac{1}{\gamma-1}}}{\left(\frac{\gamma+1}{2}M_1^2\right)^{\frac{\gamma}{\gamma-1}}}\right]$$

Here

p_0 = total pressure

p = Static pressure

q = dynamic pressure

p_{02} = Total pressure after bow shock

M=Mach number

K = Compressibility correction factor

PROCEDURE

- Fix the Nozzle on jet setup and check pitot static the props..
- Run the Jet facility based on require NPR
- Find the pressure difference for corresponding pressure Transducer.
- Calculate the velocity form pressure difference using given formula.
- Plot the graph (probe location (x axis) to velocity (y axis))

TABLE OF CONTENT

S.no	Location	Total pressure	Static pressure	$p_0 - p$	$q = \frac{p_0 - p}{K}$

Calculation:

Graph

Probe location vs velocity, location vs Pressure

Results:

Thus the velocity and pressure measured by using pitot static tube

EXP NO : 6 DATE :	QUALITATIVE ANALYSIS OF CIRCULAR JET USING SHADOWGRAPH.

Aim

To analyze the pattern of circular jets by using shadow graph techniques

APPARATUS REQUIRED

- High speed jet facility
- Nozzle
- Shadow grpah arrangments

THEORY

For visualizing compressible flows, optical flow visualization techniques are commonly used. Interferometer, schlieren, and shadowgraph are the three popularly employed optical flow visualization techniques for visualizing shocks and expansion waves in supersonic flows. They are based upon the variation of the refractive index, which is related to the fluid density by the Gladstone–Dale formula and consequently to the pressure and velocity of the flow. For making these variations visible, three different classes of methods mentioned above are generally used. With respect to a reference ray, that is, a ray which has passed through a homogeneous field with refractive index n, the

• Interferometer makes visible the optical phase changes resulting from the relative retardation of the disturbed rays.

• Schlieren system gives the deflection angles of the incident rays.

• Shadowgraph visualizes the displacement experienced by an incident ray which has crossed the high-speed flowing gas.

These optical visualization techniques have the advantage of being nonintrusive and thereby in the supersonic regime of flow, avoiding the formation of unwanted shock or expansion waves. They also avoid problems associated with the introduction of foreign particles which may not exactly follow the fluid motion at high-speeds, because of inertia effects. However, none of these techniques gives information directly on the velocity field. The optical patterns given by interferometer, schlieren, and shadowgraph, respectively, are sensitive to the flow density, its first derivative, and its second derivative. For quantitative evaluation, interferometer is generally chosen because this evaluation is based upon the precise measurement of fringe pattern distortion instead of the not so precise measurement of change in photographic contrast, as in schlieren and shadowgraph

PROCEDURE

• Fix the Nozzle on jet setup

• Fix the Shadow graph based on focal length

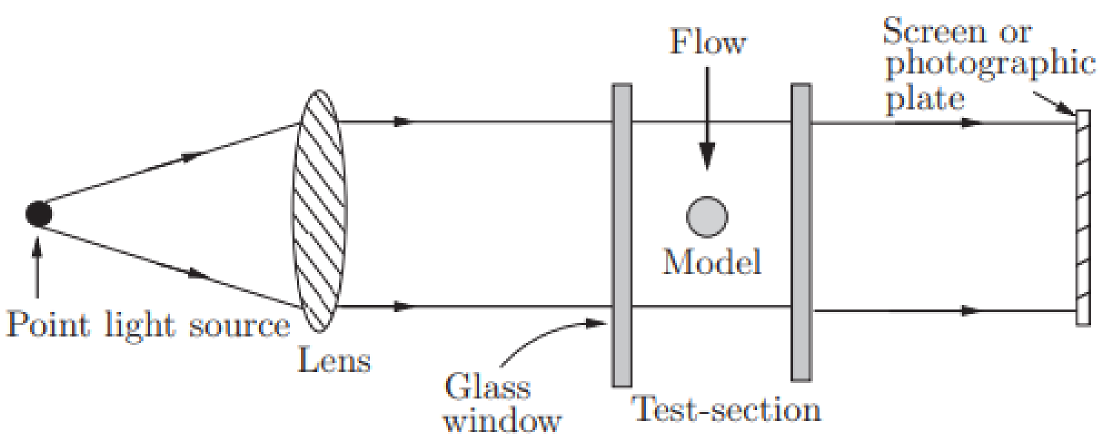
• Run the high speed jet facility

• Fix the camera at proper location and set the frame.

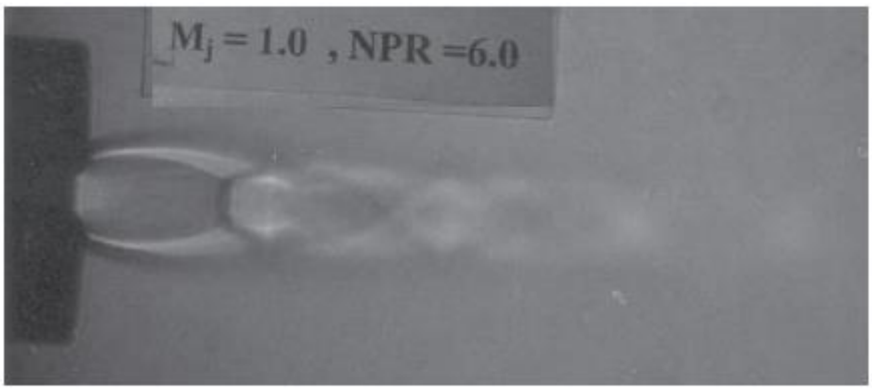
•Analyze the jet pattern based picture and to the image processing

Shadowgraph

A shadowgraph consists of a light source, a collimating lens, and viewing screen. Let us assume that the test-section has stagnant air in it and that the illumination on the screen is of uniform intensity. When flow takes place through the test-section the light beam will be refracted wherever there is a density gradient. However, if the density gradient everywhere in the test-section is constant, all light rays would deflect by the same amount, and there would be no change in the illumination of the picture on the screen. Only when there is a gradient in density gradient will there be tendency for light rays to converge or diverge. In other words, the variations in illumination of the picture on the screen are proportional to the second derivative of the density.



A typical shadowgraph of a highly under expanded circular sonic jet is shown in given below figure. Since the jet is under expanded, the waves present in the field would be strong enough to result in a large density gradient across them. One such wave termed Mach disk, normal to the jet axis, is seen in the field. The Mach disk is essentially a normal shock and hence, the shock has positive and negative rate of change of density gradient across it. Therefore, the shock is made up of a dark line followed by a bright line in the shadow picture, in accordance with the shadow effect.



Shadowgraph of an under expanded sonic jet

Results:

Thus the jet pattern of circular jets captured with help of shadow graph techniques