Department of Mechanical Engineering

Indian Institute of Technology New Delhi

II Semester -- 2018 – 2019

MCL 241 Energy systems and Technologies

Turbo-machinery Laboratory

List of Experiments:

1. Study of flow through blade cascades.

2. Performance analysis of centrifugal blowers.

3. Performance analysis of micro-axial flow fans used in cooling of Electronics.

4. Performance analysis of pumps.

5. Study of Turbo-prop Engine.

Brief Description of experiments:

Experiment 1: Study of flow through blade cascades.

Objectives : Measurement of:-
- Velocity profile in cascades.
- Pressure distribution on a airfoil.

**Minute details about the practical Setup :-(or the theoretical brief background)**

For the Cascade:-

A row blades representing the blade ring of an actual turbo machine is called cascade.

The blades can be arranged in a straight line or along an annulus. Before studying a particular turbine, compressor or fan stage, it will be useful to study the behavior of flow through blade rows of such machines.

The boundary layer growth on the suction and pressure sides of the blades in a real flow leads to the formation of low energy regions in the exit flow field. There are distinct separate lanes of

chaotic flow with considerably low fluid velocities and the presence of vortices. These lanes are referred to as blade wakes. The fluid velocity rises from the wake regions to a maximum in the free stream.
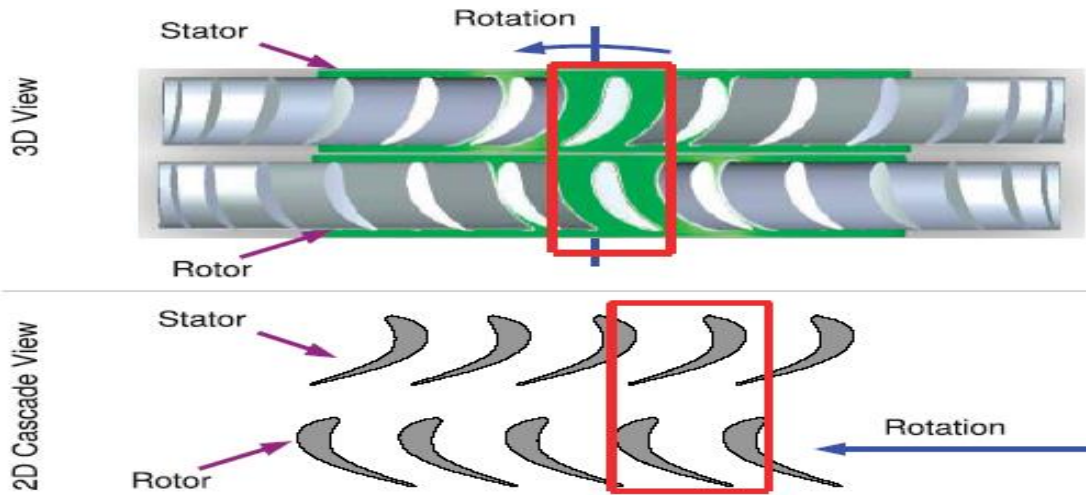

Flow through cascade

Construction of a cascade:

A cascade is constructed by assembling a number of blades of a given shape and size at the required pitch and the stagger angle. The assembly is then fixed on the test section of the wind tunnel. Air at slight pressure and near ambient temperature is blown over the cascade of blades to simulate the flow over an actual blade row in a turbo machine.

Upstream and downstream traversing:

Though it is expected that the flow parameters are uniform in the test section of the upstream of the cascade , it is preferable to check the variations of these quantities at the mid section of the blades over at least one blade pitch(s) in the central region.

The stagnation pressure (Po_1) is measured through wall tappings in the settling chamber is a good reference. The losses from the settling chamber to the test section in the free stream are negligible. Therefore stagnation   pressure measured by a pitot tube in the test section is almost equal to (Po_1). The measurement of static pressure , temperature, velocity and direction is also important. Similarly the flow parameters are checked at the downstream.
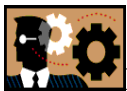
Experimental Procedure/what you should aim at: -

For Cascade:

- Draw a neat sketch with all the major dimensions of the test rig and details of all the instruments available on the test rig.

- Measurement of velocity profile at the upstream of the cascade.

- Measure the static pressure distribution on the central aerofoil.

- Measurement of velocity at the downstream of the cascade.

- Repeat the same for another cascade arrangement.

For the impeller:

- Draw a neat skecth with all the major dimensions of the impleler.

What next (Things you can ponder over):-

1. Why did I do this whole experiment? (What is the technical applicability in real world?)
2. What difference does a single airfoil have in comparison to a cascade of blades?
3. What effect did the pitch have on the flow?
4. What are the different manufacturing companies involved in making turbo machinery blades and impellers?
5. What are the varieties of applications for which impeller blades are designed?

Experiment 2: **Performance analysis of centrifugal blowers.**

Objective: - Performance analysis of centrifugal blowers.

- To verify the laws of centrifugal blower.
- To plot characteristic curve for centrifugal blower.

Prerequisites: -

1. Basics of fan Vs blowers.
2. Concept of centrifugal blowers.
3. Self Reading before Coming to The Laboratory:

- What are Fan Laws?
- How to organize the experiments to verify Fan Laws?
- Prepare Brief Planning and show to the instructor, before start the experiments.

![lightbulb icon]**Minute details about the practical Setup :-(or the theoretical brief background)**

Blowers *are turbo machines which deliver air at a desired high velocity (and accordingly at a high mass flow rate) but at a relatively low static pressure.*

The rise in static pressure across a blower is relatively higher and is more than 1000 mm of water gauge that is required to overcome the pressure losses of the gas during its flow through various passages. A blower may be constructed in multi stages for still higher discharge pressure.

A large number of blowers for relatively high pressure applications are of centrifugal type. The main components of a centrifugal blower are shown in Fig. A blower consists of an impeller which has blades fixed between the inner and outer diameters. The impeller can be mounted either directly on the shaft extension of the prime mover or separately on a shaft supported between two additional bearings. Air or gas enters the impeller axially through the inlet nozzle which provides slight acceleration to the air before its entry to the impeller. The action of the impeller swings the gas from a smaller to a larger radius and delivers the gas at a high pressure and velocity to the casing. The flow from the impeller blades is collected by a spiral-shaped casing known as *volute casing* or *spiral casing* . The casing can further increase the static pressure of the air and it finally delivers the air to the exit of the blower.
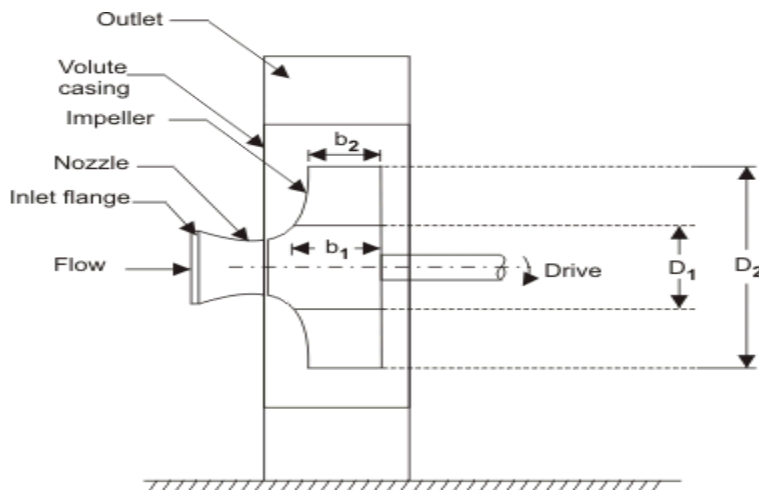
Main components of a centrifugal blower

Fan laws:

1.   Volume flow:

$$q_{v2} = q_{v1} \times \left(\frac{n_2}{n_1}\right)^1 \times \left(\frac{d_2}{d_1}\right)^3$$

2. Pressure:

$$p_2 = p_1 \times \left(\frac{n_2}{n_1}\right)^2 \times \left(\frac{d_2}{d_1}\right)^2 \times \left(\frac{\rho_2}{\rho_1}\right)^1$$

3. Absorbed power:

$$P_{R2} = P_{R1} \times \left(\frac{n_2}{n_1}\right)^3 \times \left(\frac{d_2}{d_1}\right)^5 \times \left(\frac{\rho_2}{\rho_1}\right)^1$$

4. Efficiency %:

$$\frac{q_v \times p_1 F}{10\, P_R}$$

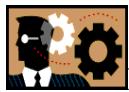Nomenclature for symbols used in this page:-

q_v = volume flow of air, m^3/sec
n = rotational speed of fan
d = diameter of fan
p = pressure developed by the fan
p = density of air, kg/m^3
P_R = power absorbed by the fan, kW

Experimental Procedure/what you should aim at: -

- Draw a neat skecth with all the major dimensions of the test rig and details of all the insturments available on the test rig.

- Measurement of speed and power consumed by the blower.

- Measurement of static pressure at inlet and exit of the blower for various flow rates.

- Carryout all the measurements to verify blower laws.

What next (Things you can ponder over):-

1. Why did I do this whole experiment?
2. What are the different manufacturing companies involved in making Blowers?
3. How does a blower score over fans and where do fans have upper hand?
4. Can I find the historical lineage of how blowers of the day came into being?
5. What are the different large and small blower applications?

Experiment 3: Performance analysis of micro-axial flow fans used in cooling of Electronics.

Objective: - Performance analysis of micro-axial flow fans used in cooling of Electronics.

Prerequisites: -

1. A brief Knowledge about axial fans.

2. Self Reading before Coming to The Laboratory:
   - What are Fan Laws?
   - How to organize the experiments to verify Fan Laws?
   - Prepare Brief Planning and show to the instructor, before start the experiments.

Minute details about the practical Setup :-(or the theoretical brief background)

In essence, an axial fan is simply a single stage compressor of low pressure (and temperature) rise.

Fans are used to move a large mass of gas or vapor without appreciable change in pressure. Micro axial fans are used for cooling. The dimensions of these fans are measured in millimeters; common sizes include 60 mm, 80 mm, 92 mm and 120 mm. Fans with a round frame are also available; these are usually designed so that one may use a larger fan than the mounting holes would otherwise allow (i.e., a 120 mm fan with 90 mm holes). The amount of airflow which fans generate is typically measured in cubic feet per minute (CFM), and the speed of rotation is measured in revolutions per minute (RPM). Often, computer enthusiasts choose fans which have a higher CFM rating, but produce less noise (measured in decibels, or dB), and some fans come with an adjustable RPM rating to produce less noise when the computer does not require additional airflow. Fan speeds may be controlled manually (a simple potentiometer control, for example), thermally, or by the computer hardware or by software. It is also possible to run many 12V fans from the 5 V supply, at the expense of airflow, but with reduced noise levels.

These fans are used for cooling purpose in the cabinet of personal computers. They draw air in to the case from outside, expel warm air from inside, or move air across a heat sink to cool a particular component (like the processor of mother board). These fans are used for active cooling.

Fan laws:

5.   Volume flow:

$$q_{v2} = q_{v1} \times \left(\frac{n_2}{n_1}\right)^1 \times \left(\frac{d_2}{d_1}\right)^3$$

6.   Pressure:

$$p_2 = p_1 \times \left(\frac{n_2}{n_1}\right)^2 \times \left(\frac{d_2}{d_1}\right)^2 \times \left(\frac{\rho_2}{\rho_1}\right)^1$$

7.   Absorbed power:

$$P_{R2} = P_{R1} \times \left(\frac{n_2}{n_1}\right)^3 \times \left(\frac{d_2}{d_1}\right)^5 \times \left(\frac{\rho_2}{\rho_1}\right)^1$$

8.   Efficiency %:

$$\frac{q_v \times p_i F}{10\, P_R}$$

Nomenclature for symbols used in this page:-
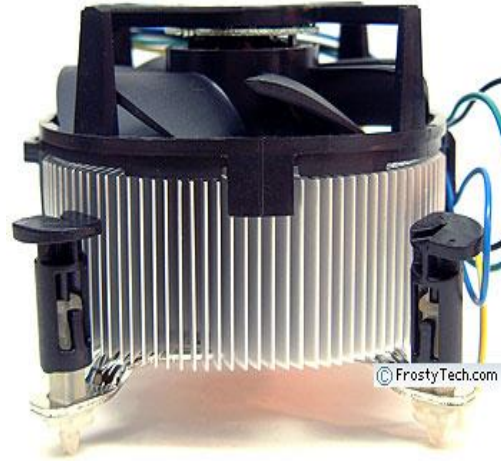
q_v = volume flow of air, m^3/sec
n = rotational speed of fan
d = diameter of fan
p = pressure developed by the fan

p = density of air, kg/m^3

PR = power absorbed by the fan, kW

The specifications of some of the fans are specified here:-

Manufacturer: Glacialtech
Model No: Igloo 5062 Cu Light
Materials: Extruded aluminum, Cu inserts.
Fan Mfg: Power Logic PLA08025S12H
Fan Specifications: 2000RPM, 12V, 0.17A
Fan Dimensions: 25x80x80mm.
Heat Sink & Fan Dimensions: 78x90x90.
Weight: 341 grams.
Includes: Pre-applied thermal compound.

Manufacturer: Coolmaster
Fan Specifications: 3300±10%RPM, 12VDc
Fan Dimensions: 70x70x25
Heat Sink & Fan Dimensions: 85.4x68.3x41.5
Noise: 19 dBA(min)

Manufacturer: Galaxy Cooler
Fan Specifications: 2200±10%RPM, 12VDc
Fan Dimensions: Ø92x25mm
Heat Sink : Ø95x38mm
Noise: 23.8dBA(min)

Manufacturer: Galaxy Cooler
Fan Specifications: 12VDc
Fan Dimensions: 60x60x15mm
Heat Sink : 60x58x24mm
Noise: 31dBA(min)
Wind: 18CFM
Fan Laws:-

Experimental Procedure/what you should aim at: -

- Draw a neat sketch with all the major dimensions of the test rig and details of all the instruments available on the test rig.

- Study the fan characteristics at various speed.

    ✓ Draw the fan performance curve i.e. Static Pressure Vs air volume for various regulated speeds.
    ✓ Draw the pressure Drop curves.
    ✓ Draw the Air flow Vs temperature rise for various power transfer levels.
    ✓ Repeat the whole process with different sets of enclosures.
- Study the various fans to understand the geometry of the fan blades.
- Compare the AC and DC fans performance Curves.

What next (Things you can ponder over):-

1. Why did I do this experiment?
2. What is the need to draw a performance curve at all?
3. Will the performance curve show any difference when the shape of sink is changed?
4. What effect does the performance experience when we placed in different enclosures?
5. What are the various others means besides the forced convection cooling of

Experiment 4. Performance analysis of pumps.

Prerequisites: -

1. A brief introduction to centrifugal pumps and axial pumps.
2. What is a stage in turbomachinery?

Minute details about the practical Setup :-(or the theoretical brief background):-

*A **centrifugal pump** is a rotodynamic pump that uses a rotating impeller to increase the pressure of a fluid.*

A centrifugal pump consists essentially of a rotating impeller followed by a diffuser. Fluid is drawn through the inlet casing into the eye of the impeller. The function is to increase the energy of the fluid by whirling it out-wards thereby increasing the angular momentum of the fluid.

Centrifugal pumps are commonly used to move liquids through a piping system. The fluid enters the pump impeller along or near to the rotating axis and is accelerated by the impeller, flowing radially outward into a diffuser or volute chamber (casing), from where it exits into the downstream piping system. Centrifugal pumps are used for large discharge through smaller heads.
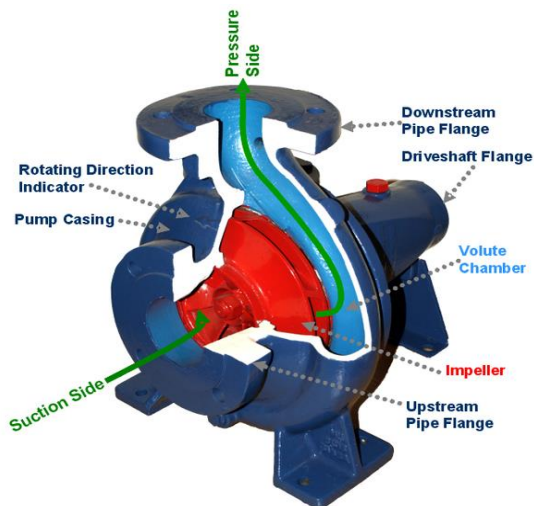
Centrifugal Pump   Axial Flow Pump

An axial flow pump, or AFP, is a common type of pump for water that essentially consists of a propeller in a pipe. The propeller can be driven directly by a sealed motor in the pipe or mounted to the pipe from the outside or by a right-angle drive shaft that pierces the pipe.

The main advantage of an AFP is that it can easily be adjusted to run at peak efficiency at low-flow/high-pressure and high-flow/low-pressure by changing the pitch on the propeller (some models only).

Experimental Procedure/what you should aim at: -

1. Draw the experimental rig with details of each measuring instruments used.
2. Draw the performance characteristic curves based on measured data.
3. Draw the efficiency curves of the pumps.
4. Study the geometry of pump impeller?

What next (Things you can ponder over):-

Why did I do this experiment?
What are the different types of pumps used?
Do the blade angles of impeller in a pump have any effect on the flow characteristics?
What are they?
Where was pump first used?
What was the first pump used by man (or the most primitive one)?

Experiment 5: Study of Turbo-prop Engine

Collect information about the structure of Turbo-prop engine. Use the same for study of the engine available in the laboratory.

Submission of Report:

- A single report per person.
- All are equally responsible for the preparation of the report.
- Should answer the question on your report.
- Each Report will be evaluated for 10 points

References:-

1. Heat Transfer A Practical Approach 2nd Edition Yunus CEngel.
2. Fluid Mechanics and thermodynamics of turbo machinery by S.L. Dixon.
3. Turbines, compressors and Fans by S. M. Yahya.