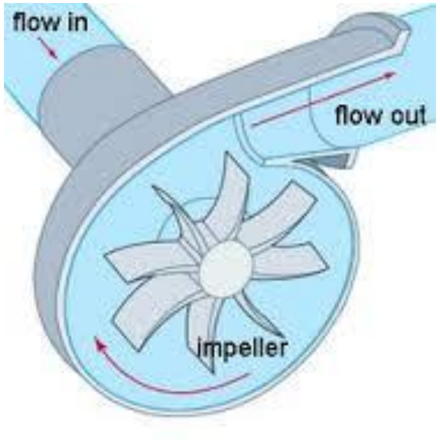
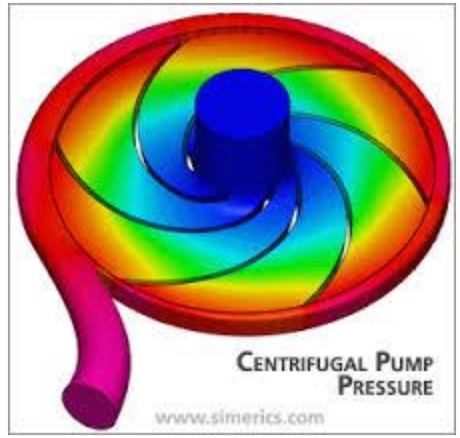
TURBOMACHINES





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TURBOMACHINES:

Prerequisite: ME302

Course Objectives:

To provide the knowledge of basic principles, governing equations and applications of turbomachine

Course Outcomes (COs):

{with mapping shown against the Program Outcomes (POs))

Upon completion of the course, students shall be able to:

1	identify and differentiate positive displacement machines and turbo machines	1, 5
2	analyze energy transfer through graphical and analytical methods in turbo machines	1, 5
3	design different kinds of turbomachines	1, 3, 9

COURSE CONTENTS:

PART – A

Unit – 1 Introduction:

Definition of a turbo machine, parts of turbo machine, Comparison with positive displacement machine, Classification, Applications of first and second law of thermodynamics to turbo machines, efficiencies, dimensional analysis dimensionless numbers related to turbo machines and their physical significance, Effect of Reynolds number; Specific speed, model studies.

07 Hrs.

Unit – 2

Energy Transfer in Turbo Machines: Euler's Turbine equation, Alternate form of Euler's turbine equation – components of energy transfer; Degree of reaction, Utilization factor, Vane efficiency, Relation between utilization factor and Degree of reaction ,Axial flow steam turbines - Velocity diagram for different values of degree of reaction. Maximum utilization factor, optimum blade speed ratio for different types of turbines. (Impulse and 50%Reaction), comparison of Energy transfer. 07 Hrs.

PART – B

Unit – 3 Energy Transfer in Turbo Machines (Continued)

Radial inward and outward flow machines; Francis turbine, Degree of reaction, General analysis of centrifugal pumps and compressors, Head–capacity curve for Radial out ward flow devices. Velocity triangles for Axial flow compressors 06 Hrs.

Unit – 4 Hydraulic Turbines:

Classification, Unit Quantities, Specific Speed, Pelton Wheel- velocity triangles, bucket dimensions, efficiency; Francis turbine-velocity triangles, runner shapes for different blade speeds, Design of Francis turbine, Draft tube-functions, types of draft tubes, Kaplan turbine and velocity triangles and design.

07 Hrs.

PART - C

Unit – 5 Centrifugal Pumps:

Definition of terms used in the design of centrifugal pumps like Manometric head, suction head, delivery head, overall efficiency, etc., Multistage centrifugal pumps design procedure.

06 Hrs.

Unit - 6 Steam Turbines:

Impulse staging and need for compounding, Methods of compounding: Velocity and pressure Compounding, Pressure and velocity compounding, Difference between Impulse and Reaction turbines, condition for maximum utilization factor with equiangular blades for impulse turbine.

07 Hrs

PART - D

Unit – 7 Steam Turbines(Continued)

Multi stage Impulse turbine(Curtis Turbine),Advantages and disadvantages of velocity compounding , Reaction staging(Parson's Turbine), Reheat factor in turbine. steam turbine losses.

06 Hrs

Unit -8 Introduction to Centrifugal and Axial flow compressors

Centrifugal Compressors: Expression for overall pressure ratio developed: Blade angles at impeller eye tip: Slip factor and power input factor: Compressibility effects-need for pre-whirl vanes, Surging of centrifugal compressors.

(Elementary Numericals)

Axial Flow Compressors: Classification: Expression for pressure ratio developed per stage-work done factor, radial equilibrium conditions. (Elementary Numericals)

06 Hrs

Text Books:

1. V.Kadambi and Manohar Prasad, *An introduction to energy conversion - Volume III-Turbo machinery*,Wiley Basten Ltd. (1977).
2. D.G.Shepherd, *Principles of Turbo Machinery*, The Macmillan Company (1964). ISBN-81-7319-563-3

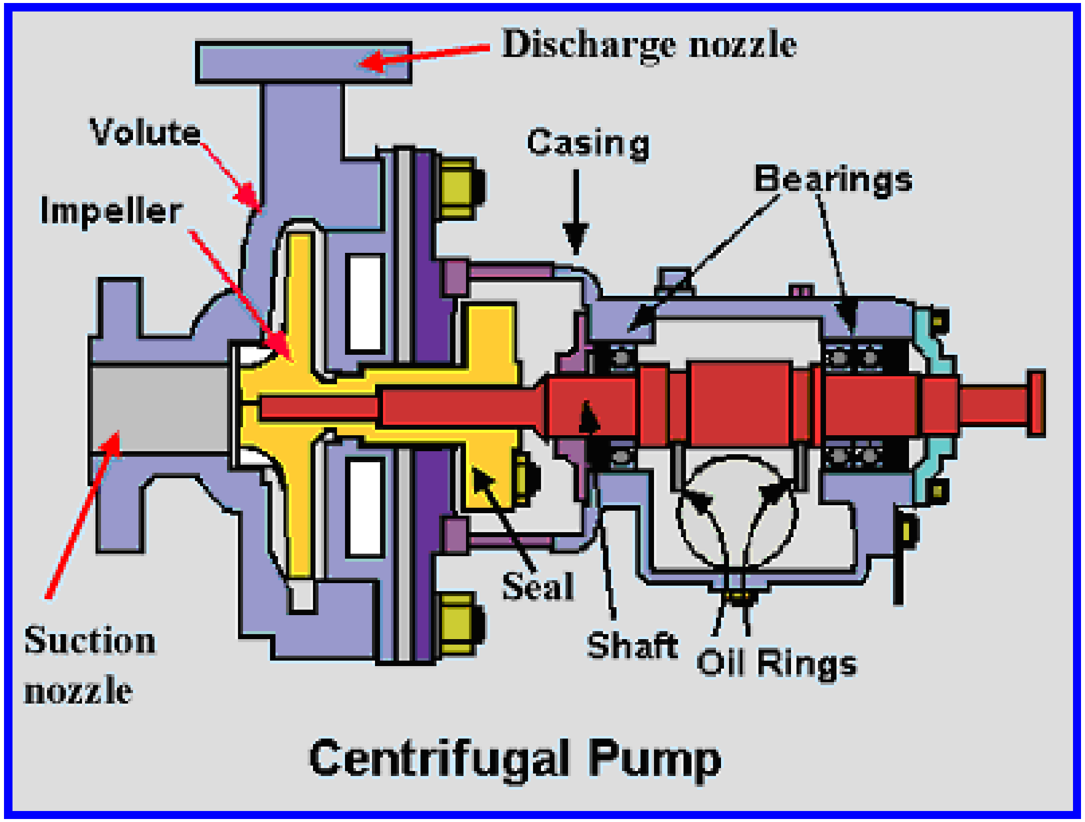
Reference Books:

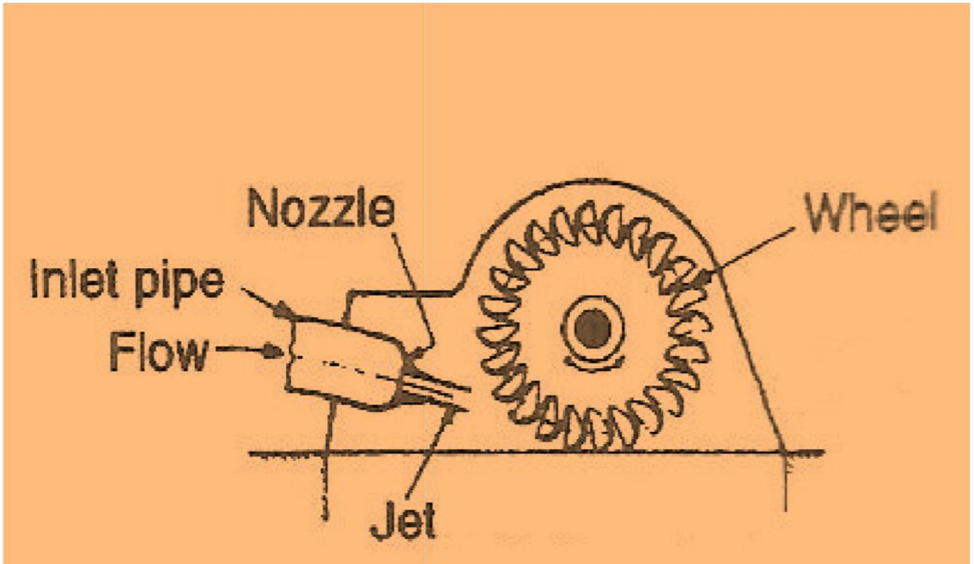
1. S.M.Yahya *Turbines*, *Compressors & fans*, TMH 2nd edition (2002). ISBN 10:0074519913 ISBN-13:978007451219912
2. H.Cohen, GFC Rogers , & HIH Saravanamuttoo, *Gas turbine theory*, Thomson press India Ltd.,4th Edition (1998). ISBN: 81-297-0486-2
3. G Gopalakrishna & D Prithviraj, *A treatise on Turbomachines*, Scitech Publications Pvt. Ltd, 2002

TURBOMACHINES

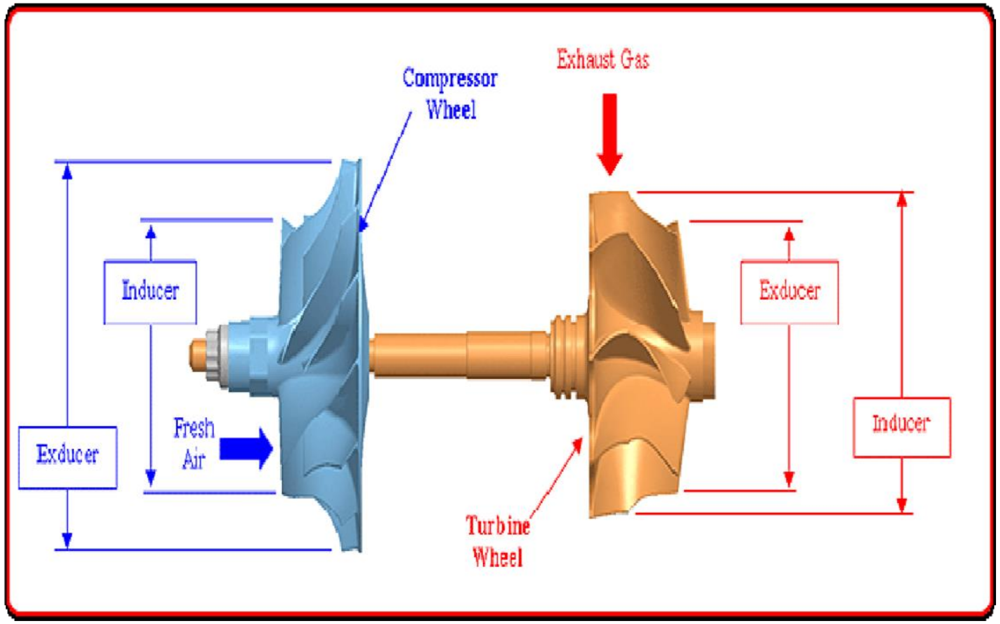
- Fluid machines
  1. Turbomachines
  2. Positive Displacement Machines
- Classification of turbomachines
- Velocity triangle concepts

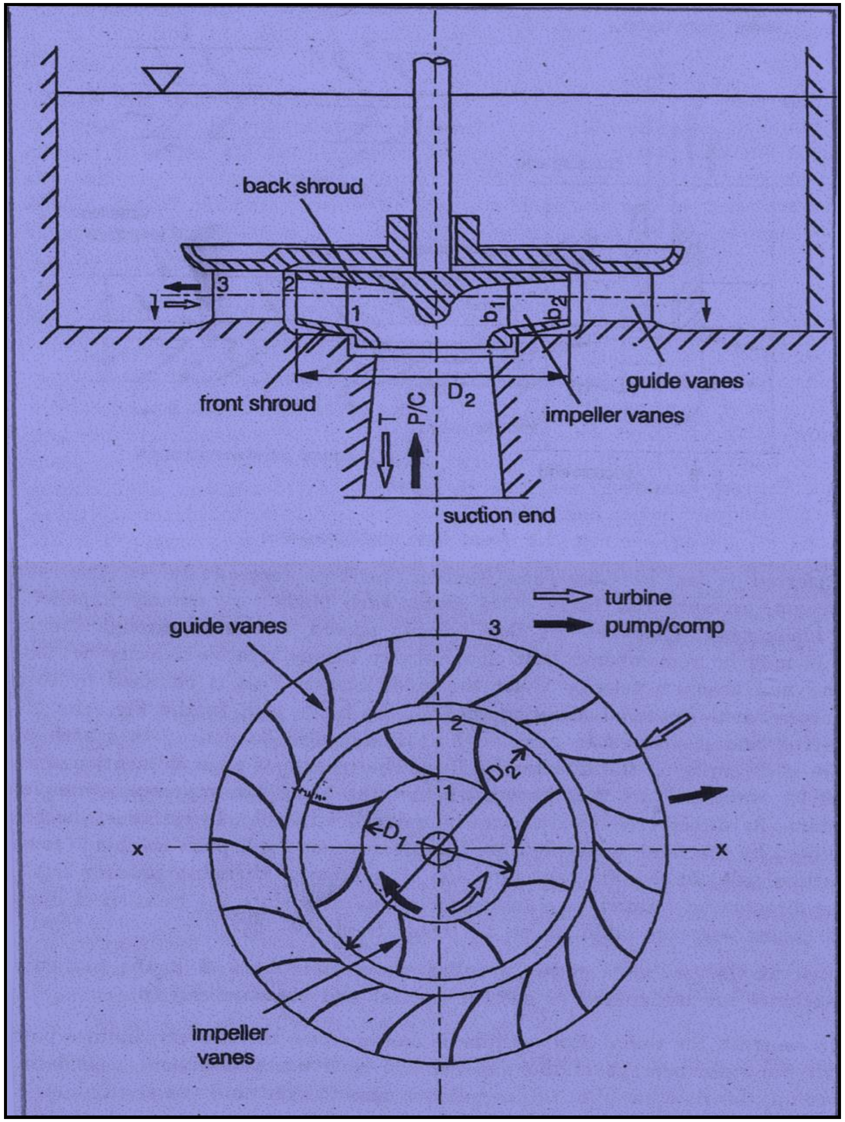
TURBOMACHINES





Pelton Turbine





Radial Flow Turbomachine

Twice as big as an Airbus A380 turbine, the steam-turbine rotor being manufactured in Siemens' Mülheim an der Ruhr factory is the biggest and heaviest in the world

What is a Turbomachine?

Turbo or turbinis is of Latin origin and it implies that which spins or whirls around.

- A turbomachine is a rotary machine

- Which always involves an energy transfer between a continuously flowing fluid and a rotor

- It is a power or head generating machine

- It uses the dynamic action of the rotor or impeller or runner which changes the energy level of the continuously flowing fluid through the rotor.

In a turbomachine

- **the energy transfer occurs either from rotor to the flowing fluid or from working fluid to the rotor depending upon the type of machine.**
- **the dynamic action of the rotating blade rows sets up forces between the blade row and the fluid , while the components of these forces in the direction of blade motion give rise to the energy transfer between the blades and fluid.**

Examples: Wind mills, water wheels, ship propeller, hydraulic, steam and gas turbines, centrifugal and axial pumps, turbo compressors etc.

Types of turbomachines

- **Turbomachines are classified into two main groups, depending on whether the work is done by fluid on the rotating element or work is done on fluid by the rotor.**

Sl. No.	Work is done by fluid POWER GENERATING	Work is done on fluid POWER ABSORBING
1	Axial flow hydraulic turbine	Centrifugal pump
2	Radial flow hydraulic turbine	Axial flow pump
3	Mixed flow hydraulic turbine	Centrifugal compressor
4	Axial flow gas turbine	Axial flow compressor
5	Pelton wheel hydraulic turbine	Radial flow fan

Detailed classification:

I	1. Those that absorb power to increase the fluid pressure or head called power absorbing type turbomachines. In these type machines the energy transfer occurs from rotor to the fluid. These machines possess input shaft. e.g. Ducted fans, compressors and pumps etc.
	2.Those that produce power by expanding the fluid to a lower pressure or head called power generating type turbomachines. In these type machines the energy transfer occurs from the continuously flowing fluid to the rotor. These machines possess output shaft. e.g. Hydraulic turbines, Steam turbines, gas turbines.
	3.Those machines that transfer mechanical energy from one shaft to another, resulting in a change of speed and change of torque called power transmitting turbomachines. These machines possess both input and output shafts. e.g. Fluid couplings and torque converters used for power transmission in automobiles, trucks etc.

	Nature of the flow path through the passage of the rotor
II	1. Axial flow turbomachines: Path of the through flow is wholly or mainly parallel to the axis of rotation. e.g. Axial flow pumps, Axial flow compressors, Axial flow fans and turbines.
	2. Radial flow turbomachines: Path of the through flow is wholly or mainly in a plane perpendicular to the axis of rotation. e.g. Centrifugal pumps, Centrifugal compressors, etc
	3. Mixed flow turbomachines: In these type of machines the flow at rotor exit has both radial and axial components in significant amounts. e.g. Mixed flow pumps, Francis turbine.

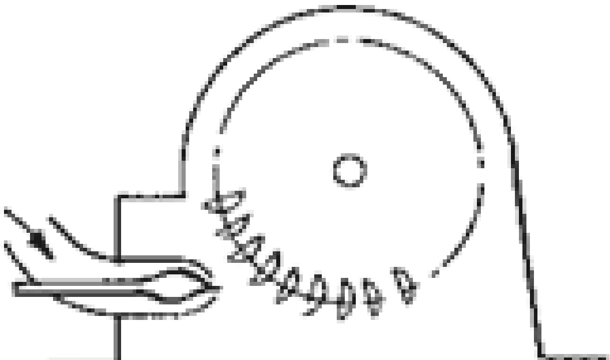
III	1. Whether the pressure changes are absent or present respectively in the flow through the rotor the turbomachiones are classified as impulse or reaction type. e.g. Impulse turbine (Pelton Wheel) Reaction turbine (Francis turbine)

IV	**Enclosed and extended turbomachines** When a housing is present, it is used to contain and restrict a fluid so that the fluid flows in a given space and does not escape in a direction other than those required for energy transfer. The turbomachine that has housing is said to be enclosed while that which has no housing is said to be extended type turbomachine.

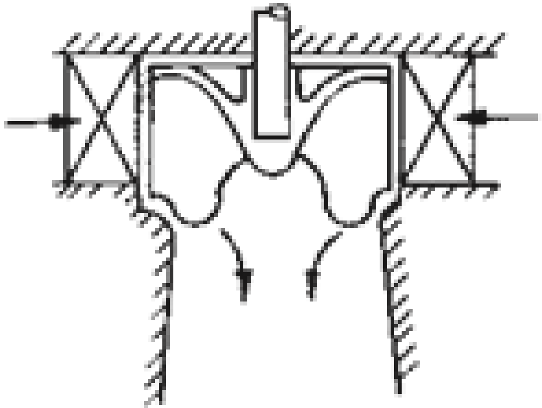
Principle components of a turbomachine:

1. A vane carrying rotating element called rotor or impeller or runner.
2. A stationery element or elements.
3. An input or/and output shaft.
4. A housing

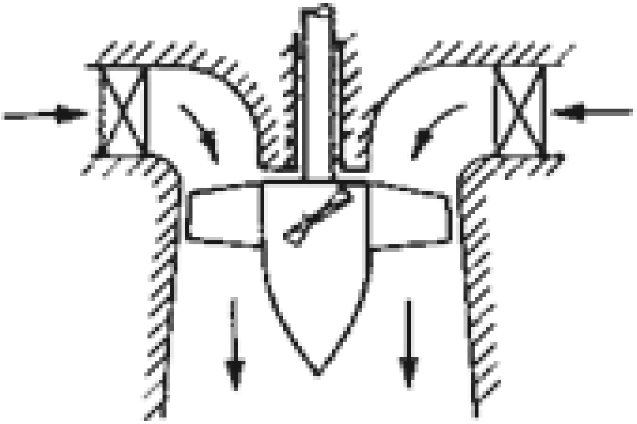
Examples of turbomachines:



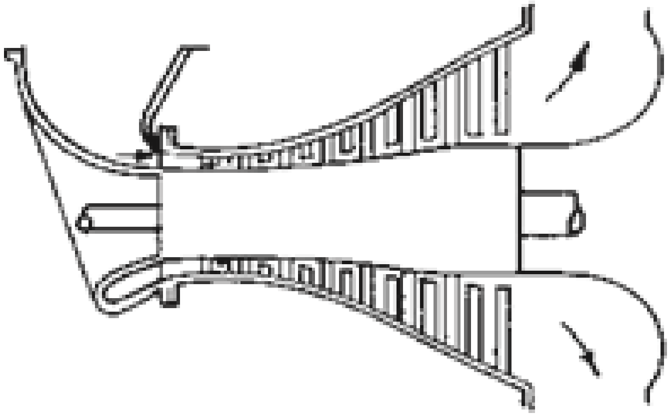
Pelton wheel



Francis turbine

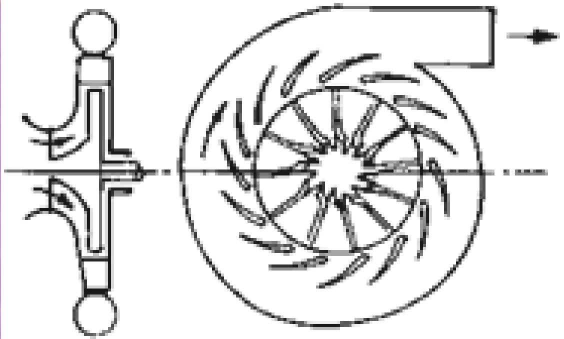


Kaplan turbine

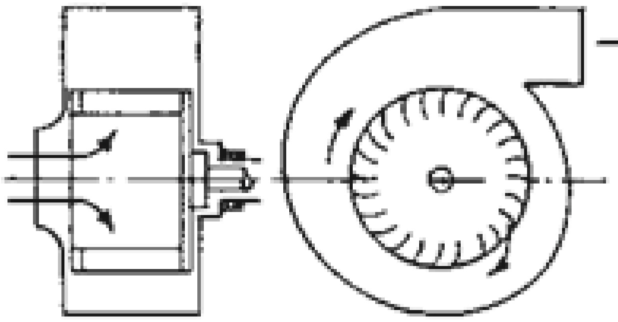


Steam turbine

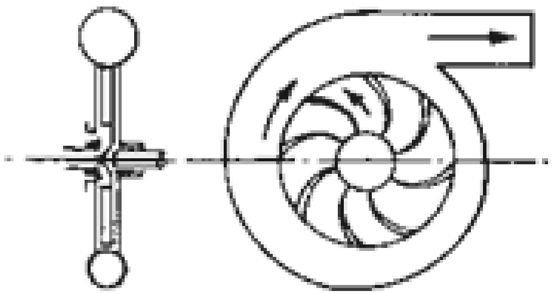
POWER GENERATING TURBOMACHINES



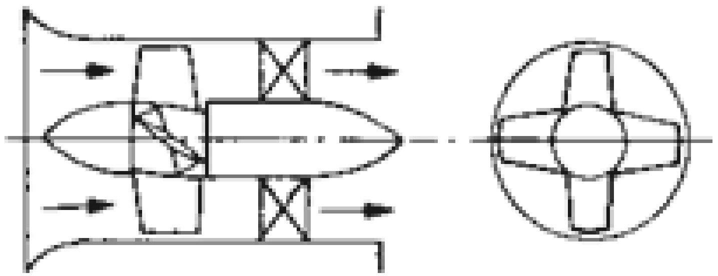
Centrifugal compressor



Radial flow fan

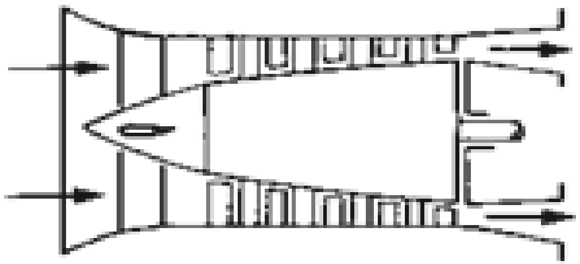


Centrifugal pump



Axial flow pump

POWER ABSORBING TURBOMACHINES



Axial flow compressor

Positive displacement machines:

Characteristics of a positive displacement machine

1. **The moving part of the machine involves a change of volume.**
2. **Expansion or compression occurs without an appreciable displacement of the mass centre of gravity of the contained fluid.**
3. **Action is nearly static.**
4. **Commonly involves a reciprocating motion and unsteady flow of fluid.**
5. **Slow speed machines and complex in mechanical design, heavy/ unit output and employs valves, heavy foundations required.**

e.g. Reciprocating compressors, pumps etc.

Comparison between turbomachines and positive displacement machines

Comparison is based on the following

1. Action
2. Operation
3. Mechanical features
4. Efficiency of energy conversion
5. Volumetric efficiency
6. Fluid phase change and surging

Sl. No.	Aspects	Positive displacement machines	Turbomachines
1	Action	Involves thermodynamic and mechanical action between nearly static fluid and slow moving surface, volume change causes pressure change	Involves thermodynamic and dynamic action between a continuously flowing fluid and a rotating element. The pressure change occurs primarily by means of dynamic action of a rotating element.
2	Operation	Involves reciprocating motion, unsteady flow of fluid, fixed amount of fluid being positively contained during its passage through the machine, stopping of the machine during operation traps a certain amount of fluid whose state is different from that of the surroundings	Involves rotary motion with nearly steady flow. Stopping of the machine will let the fluid state change rapidly and become same as that of the surroundings.

3	Mechanical features	Employs low speed, complex in mechanical design, heavy per unit output, valves are present, vibration problems, heavy foundations required.	High speed machines, simple in design, light weight, no valves, vibration not severe, light foundation required.
4	Efficiency of energy conversion	Efficiency of energy conversion during both expansion and compression is high.	Low.
5	Volumetric efficiency	Low	High, Nearly 100%.
6	Fluid phase change and surging	Relatively minor importance in these machines.	Cavitation, surging cause serious difficulties to smooth operation.