

VTU eNotes On Turbo Machines



Mechanical Engineering

TURBO MACHINES

VTU Syllabus

Subject Code : **06ME55**
 No. of Lecture Hrs./Week : 04
 Total No. of Lecture Hrs. : 52

IA Marks : 25
 Exam Hours : 03
 Exam Marks : 100

PART – A

UNIT – 1

INTRODUCTION: Definition of a Turbomachine; parts of a Turbomachine; Comparison with positive displacement machine; Classification: Application of First and Second Laws to Turbomachines, Efficiencies. Dimensionless parameters and their physical significance; Effect of Reynolds number; Specific speed; Illustrative examples on dimensional analysis and model studies. **6 Hours**

UNIT – 2

ENERGY TRANSFER IN TURBO MACHINE: Euler Turbine equation; Alternate form of Euler turbine equation – components of energy transfer; Degree of reaction; General analysis of a Turbo machine – effect of blade discharge angle on energy transfer and degree of reaction; General analysis of centrifugal pumps and compressors – Effect of blade discharge angle on performance; Theoretical head – capacity relationship **6 Hours**

UNIT – 3

GENERAL ANALYSIS OF TURBO MACHINES: Axial flow compressors and pumps – general expression for degree of reaction; velocity triangles for different values of degree of reaction; General analysis of axial and radial flow turbines – Utilization factor; Vane efficiency; Relation between utilization factor and degree of reaction; condition for maximum utilization factor – optimum blade speed ratio for different types of turbines **7 Hours**

UNIT – 4

THERMODYNAMICS OF FLUID FLOW AND THERMODYNAMIC ANALYSIS OF COMPRESSION AND EXPANSION PROCESSES: Sonic velocity and Mach number; Classification of fluid flow based on Mach number; Stagnation and static properties and their relations; Compression process – Overall isentropic efficiency of compression; Stage efficiency; Comparison and relation between overall efficiency and stage efficiency; Polytrophic efficiency; Preheat factor, Expansion Process – Overall isentropic efficiency for a turbine; Stage efficiency for a turbine; Comparison and relation between stage efficiency and overall efficiency for expansion process, polytrophic efficiency of expansion; Reheat factor for expansion process. **7 Hours**

7 Hours

PART – B

UNIT – 5

CENTRIFUGAL COMPRESSORS: Classification; Expression for overall pressure ratio developed; Blade angles at impeller eye root and eye tip; Slip factor and power input factor; width of the impeller channel; Compressibility effect – need for pre-whirl vanes; Diffuser design: Flow in the vaneless space, determination of diffuser inlet vane angle, width and length of the diffuser passages; Surging of centrifugal compressors;

AXIAL FLOW COMPRESSORS: Classification; Expression for Pressure ratio developed per stage – work done factor, radial equilibrium conditions. **6 Hours**

UNIT – 6

CENTRIFUGAL PUMPS: Definition of terms used in the design of centrifugal pumps like manometric head, suction head, delivery head, pressure rise, manometric efficiency, hydraulic efficiency, volumetric efficiency, overall efficiency, multistage centrifugal pumps, minimum starting speed, slip, priming, cavitation, NPSH.

6 Hours

UNIT – 7

STEAM TURBINES: Classification, Single stage impulse turbine; Condition for maximum blade efficiency, stage efficiency, Compounding – Need for compounding, method of compounding. Impulse Staging – Condition of maximum utilization factor for multi stage turbine with equiangular blades; effect of blades and nozzle losses. Reaction turbine; Parson's reaction turbine, condition for maximum blade efficiency, reaction staging. **7 Hours**

UNIT – 8

HYDRAULIC TURBINES: Classification; Pelton Turbine-velocity triangles, Design parameters, turbine efficiency, volumetric efficiency; Francis turbine – velocity triangles, runner shapes for different blade speeds, Design of Francis turbine; Function of a Draft tube, types of draft tubes; Kaplan and Propeller turbines – Velocity triangles and design parameters. **7 Hours**

TEXT BOOKS:

1. **An Introduction to energy conversion**, Volume III – Turbo machinery, V. Kadambi and Manohar Prasad, New Age International Publishers (P) Ltd.
2. **“Turbines, Compressors & Fans”**, S.M. Yahya, Tata-McGraw Hill Co., 2nd Edition (2002).

REFERENCE BOOKS:

1. **“Principles of Turbo Machinery”**, D.G. Shepherd, The Macmillan Company (1964).
2. **Fundamentals of Turbomachinery:** William W. Perg, John Wiley & Sons, Inc. 2008.
3. **A Text book of Turbo Machines -** M.S.Govindgouda & A.M. Nagaraj-M.M.Publications-IV Edition-2008
4. **“Fluid Machinery”** B.K. Venkanna, PHI.

- ⇒ In these lectures, we will learn different type of turbo machines, their action, as power generating turbo machines or power absorbing turbo machines.
- ⇒ You will be shown schematic diagrams of various turbo machines with flow directions.

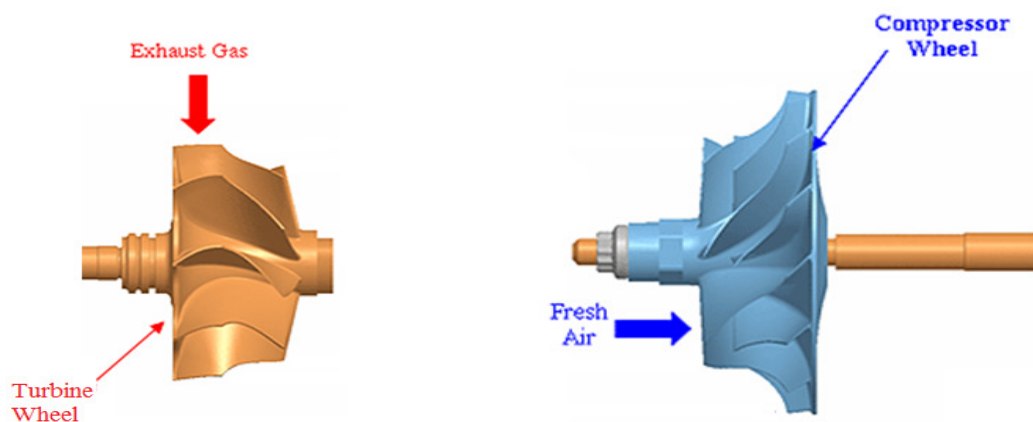
DEFINITION:

A turbo machine is a device in which energy transfer occurs between a flowing fluid and rotating element due to dynamic action. This results in change of pressure and momentum of the fluid.

TYPE:

If the fluid transfers energy for the rotation of the impeller, fixed on the shaft, it is known as **power generating turbo machine**.

If the machine transfers energy in the form of angular momentum fed to the fluid from the rotating impeller, fixed on the shaft, it is known as **power absorbing turbo machine**.



Examples of a turbo machine:

The figures 1 & 2 show a typical turbo charger used in diesel engines to improve its thermal efficiency by increasing the pressure of air pumped into engine combustion chamber.

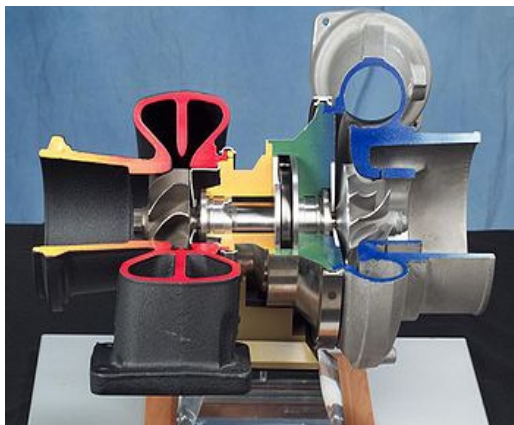


Fig. 1

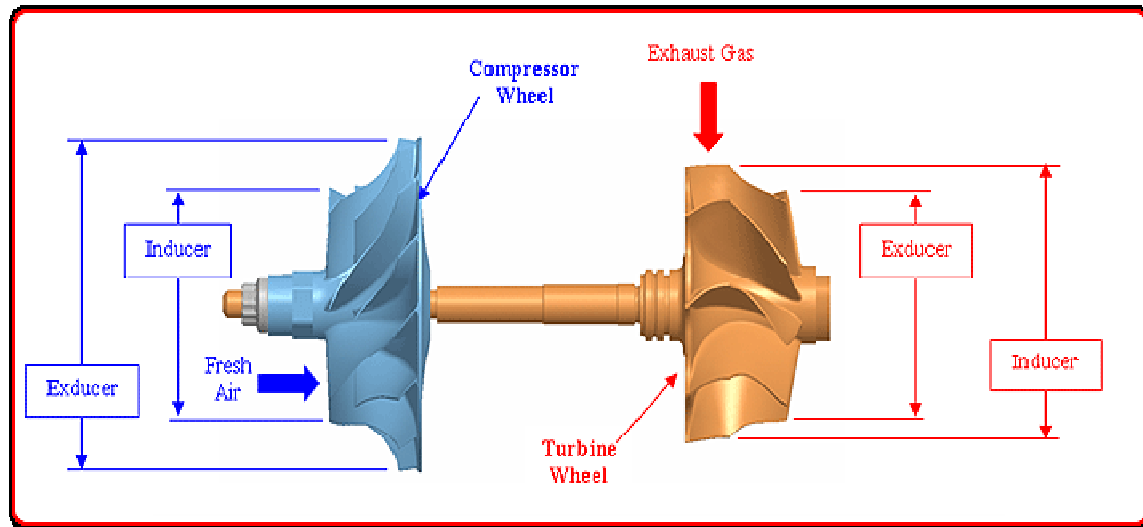


Fig. 2

PARTS OF A TURBO MACHINE

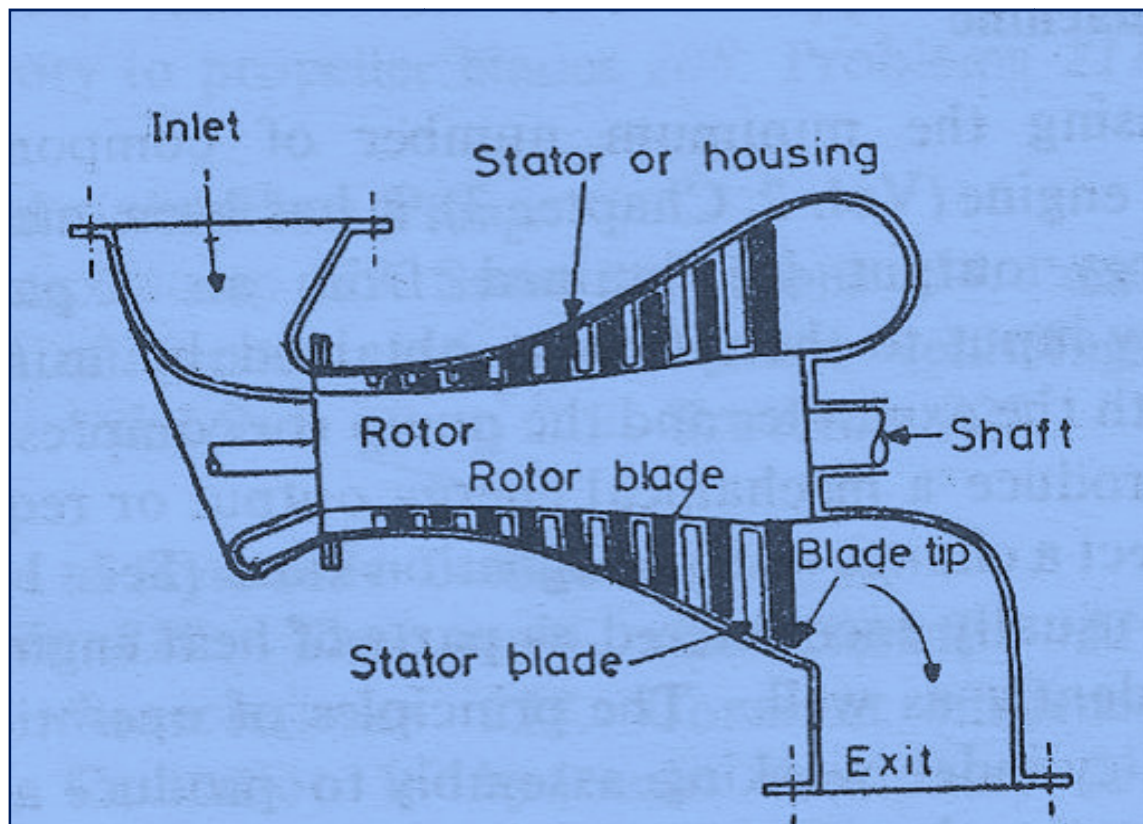


Fig. 3(a) – Schematic diagram showing parts of a steam turbine

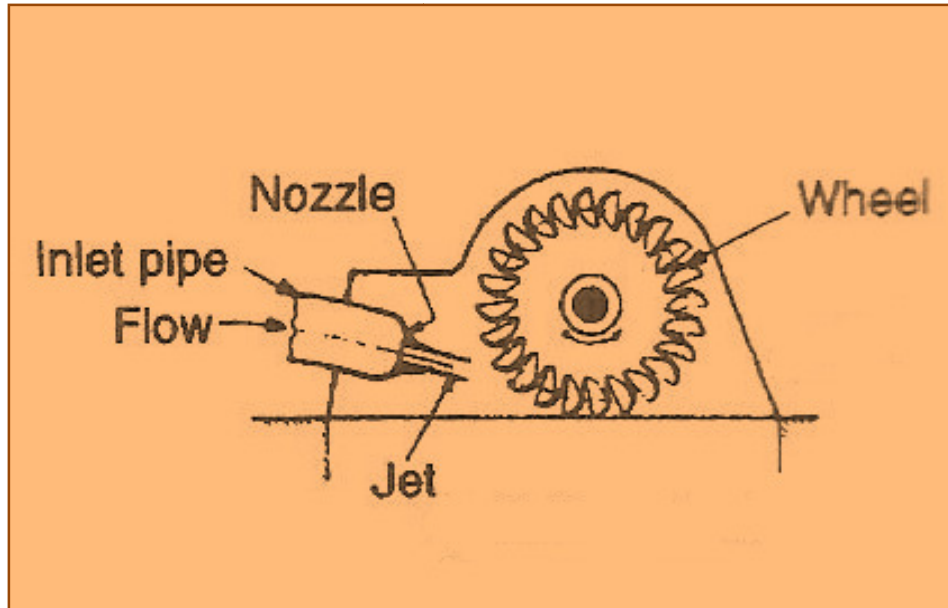


Fig. 3(b) - Schematic diagram of an impulse water turbine (Tangential flow)

PARTS OF A TURBO MACHINE

The principle components of a turbo machine are:

1. **Rotating element** (vane, impeller or blades) – operating in a stream of fluid.
2. **Stationary elements** – which usually guide the fluid in proper direction for efficient energy conversion process.
3. **Shaft** – which either gives input power or takes output power from fluid under dynamic conditions and runs at required speed.
4. **Housing** – to keep various rotating, stationary and other passages safely under dynamic conditions of the flowing fluid.

E.g. Steam turbine parts and Pelton turbine parts.

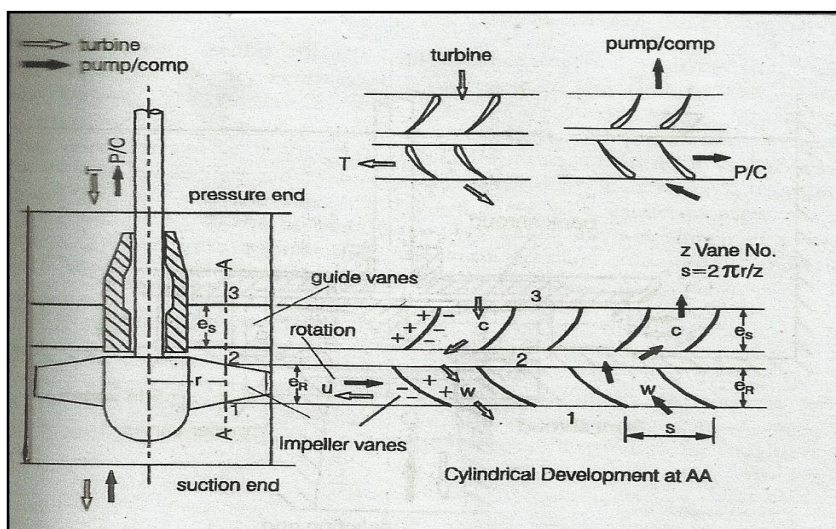


Fig. 3(c) Axial flow turbo machine

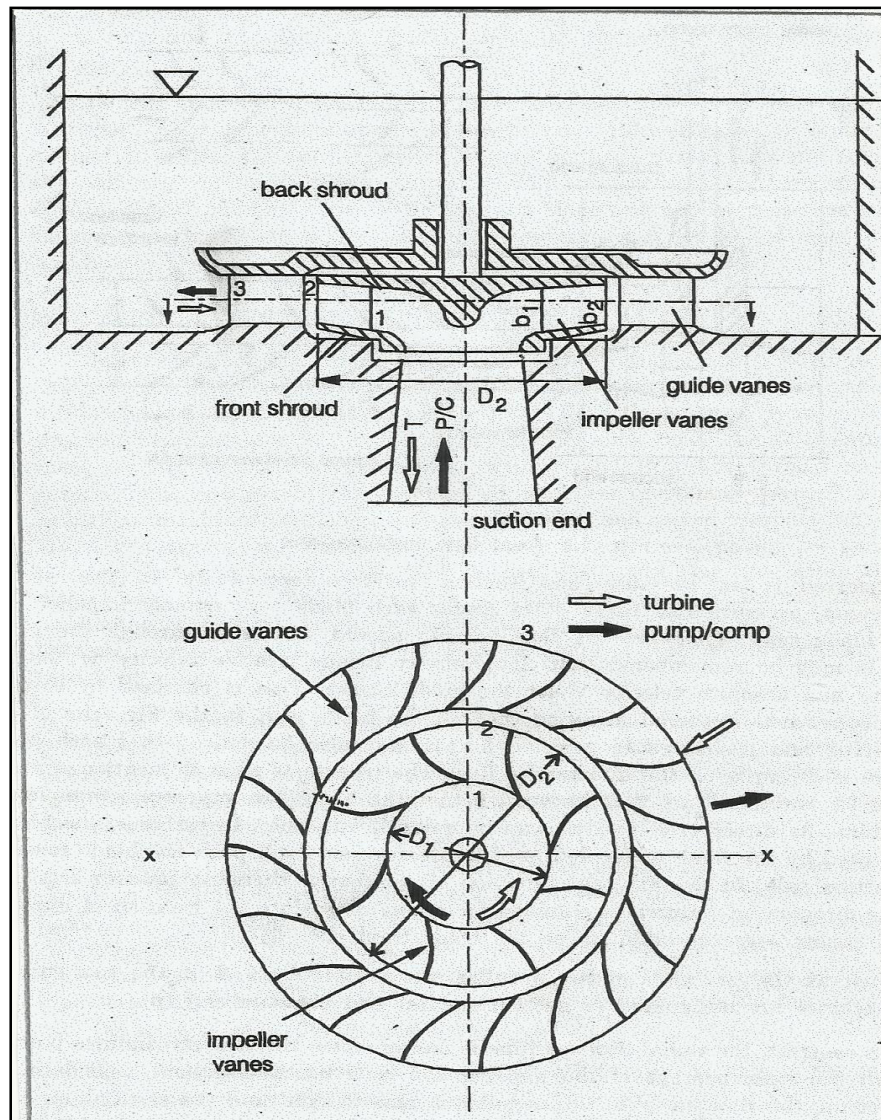


Fig. 3(d) Radial flow turbo machine

CLASSIFICATION OF TURBO MACHINES

1. Based on energy transfer

- a) Energy is given by fluid to the rotor - Power generating turbo machine E.g. Turbines
- b) Energy given by the rotor to the fluid - Power absorbing turbo machine
- c) E.g. Pumps, blowers and compressors

2. Based on fluid flowing in turbo machine

- a) Water
- b) Air
- c) Steam
- d) Hot gases
- e) Liquids like petrol etc.

3. Based on direction of flow through the impeller or vanes or blades, with reference to the axis of shaft rotation

- a) Axial flow – Axial pump, compressor or turbine
- b) Mixed flow – Mixed flow pump, Francis turbine
- c) Radial flow – Centrifugal pump or compressor
- d) Tangential flow – Pelton water turbine

4. Based on condition of fluid in turbo machine

- a) Impulse type (constant pressure) E.g Pelton water turbine
- b) Reaction type (variable pressure) E.g. Francis reaction turbine

5. Based on position of rotating shaft

- a) Horizontal shaft – Steam turbines
- b) Vertical shaft – Kaplan water turbines
- c) Inclined shaft – Modern bulb micro-hydel turbines

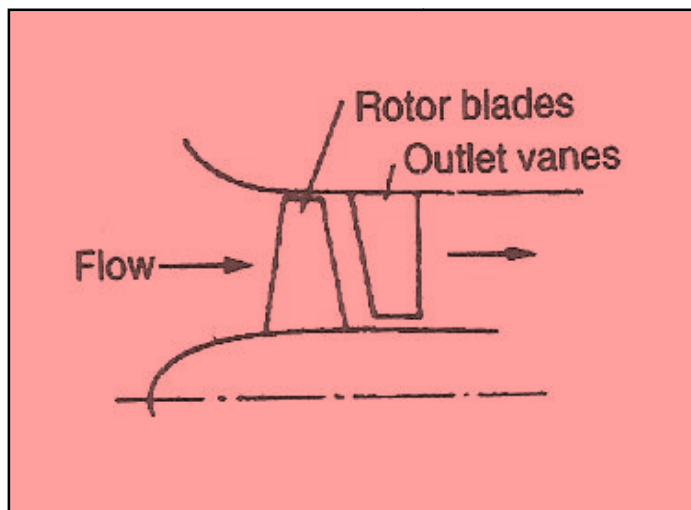


Fig. 4 (a) – Single stage axial flow pump or compressor

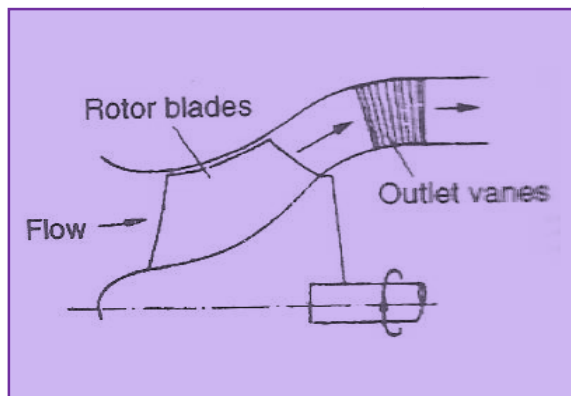


Fig. 4(b) – Kaplan turbine (axial flow)

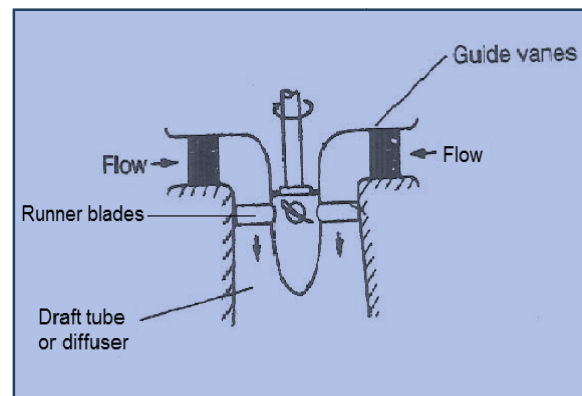


Fig. 4(c) – Mixed flow pump

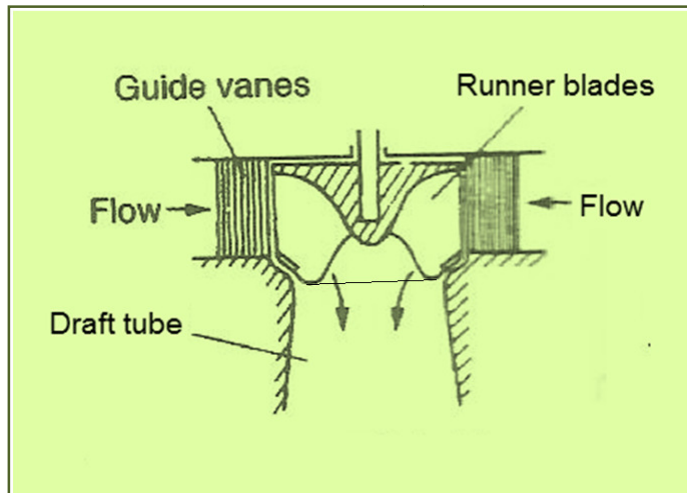


Fig. 4 (d) – Modern Francis turbine (mixed flow type)

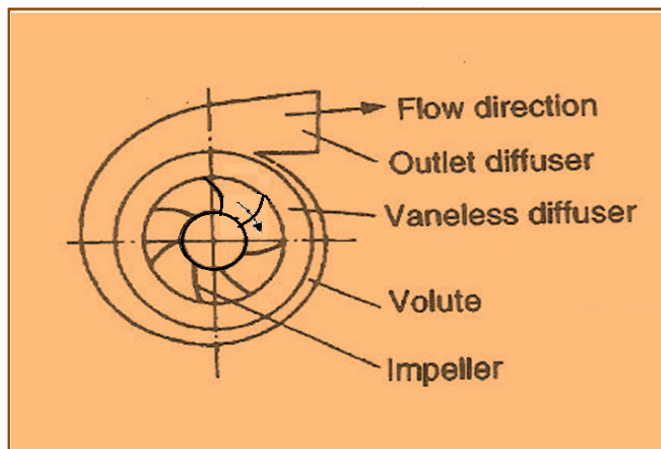


Fig. 4(e) – Centrifugal compressor or pump

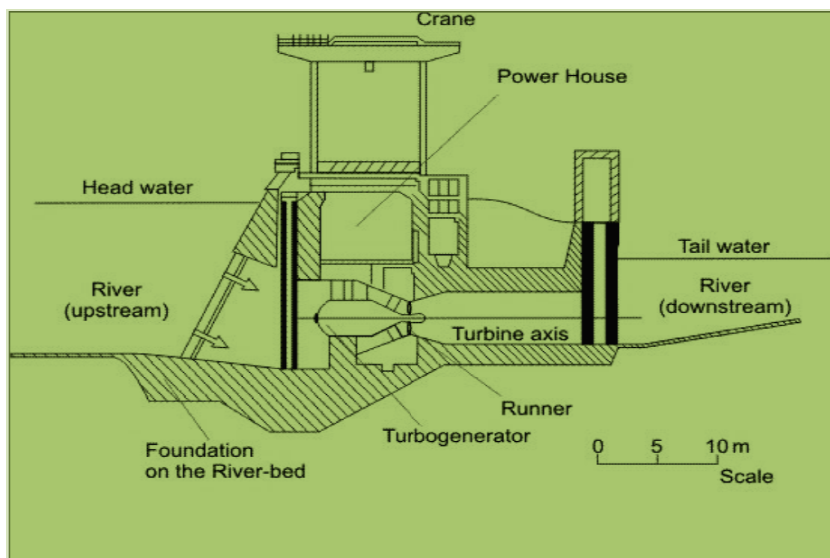


Fig. 4 (f) – Bulb turbine (inclined shaft)

APPLICATION OF FIRST AND SECOND LAWS TO TURBO MACHINES

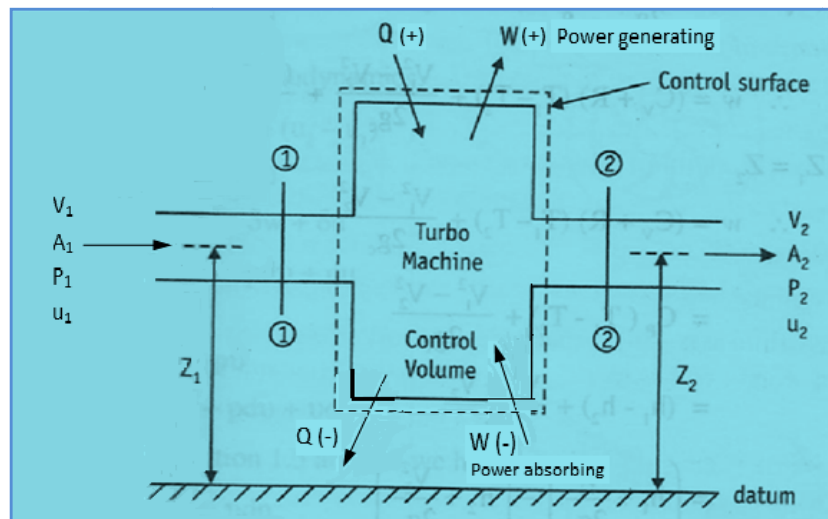


Fig. 5 – Steady flow energy process in turbo machine

STEADY FLOW ENERGY EQUATION – I Law of Thermodynamics

Taking unit mass flow rate entering the turbo machine (1 Kg) at section 1-1 and leaving at section 2-2 through control volume as shown in figure.

$$\Rightarrow u_1 + p_1 u_1 + V_1^2/2 + gZ_1 + q = w + u_2 + p_2 u_2 + V_2^2/2 + gZ_2 \quad \dots\dots (1)$$

Where,

- u = Internal Energy (J/Kg)
- p = Pressure Intensity (N/m²)
- v = Specific Volume (m³/Kg)
- V = Velocity of the fluid (m/sec)
- Z = Potential head from datum (m)
- g = Acceleration due to gravity (m/sec²)
- q = Heat transfer through control volume (J/Kg)
- w = Work done (Nm/Kg)

In a Turbo machine, during the flow process, it is assumed to be adiabatic, i.e. no heat enters or leaves the system, hence heat transfer can be neglected i.e., $q = 0$.

Taking $pv = RT$ and $u = C_v T$, the equation (1) becomes

$$\Rightarrow (C_v T_1 + RT_1) + V_1^2/2 + gZ_1 = w + (C_v T_2 + RT_2) + V_2^2/2 + gZ_2 \quad \dots\dots (2)$$

or

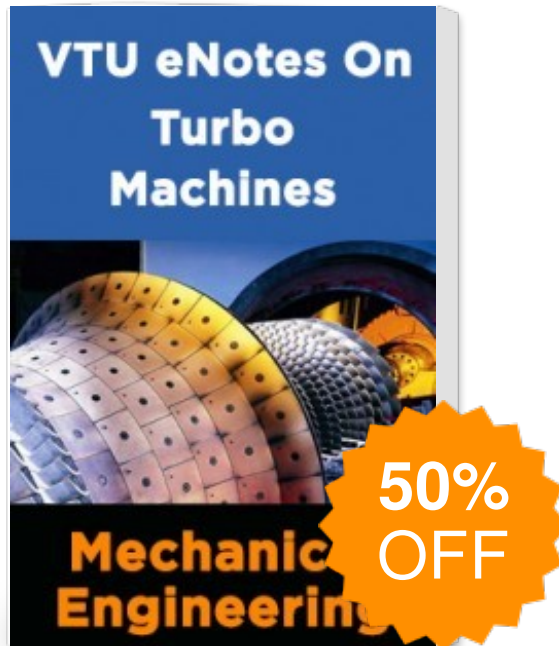
$$T_1 (C_v + R) + V_1^2/2 + gZ_1 = w + T_2 (C_v + R) + V_2^2/2 + gZ_2 \quad \dots\dots (3)$$

If the flow through the turbo machine is horizontal as shown in figure and aligned, $Z_1 = Z_2$

Hence, rearranging equation (3) it becomes

$$\Rightarrow w = (C_v + R) (T_1 - T_2) + (V_1^2 - V_2^2)/2 \quad \dots\dots (4)$$

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