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CMRIT

Internal Assessment Test 1 -Nov. 2022

Sub:	Turbomachines				Sub Code:	18ME54	Branch:	Mech
Date:	07.11.2022	Duration:	90 min's	Max Marks: 50	Sem/Sec:	V/A		OBE

Answer All the Questions

		MARKS	CO	RBT
1	Define a turbomachine. Explain the different parts of a turbomachine with a neat sketch.	[10]	CO1	L2
2	Differentiate between turbomachine and positive displacement machine under the following aspects : (i) Action. (ii) Operation (iii) Mechanical features (iv) Efficiency of energy conversion and (v) Volumetric efficiency.	[10]	CO1	L2
3	A ¼ scale turbine model is tested under a head of 10 meters. The prototype is required to work under a head of 30 meters and to run at 425 rpm. Estimate the speed of the model if it develops 125 kW and uses 1.1 m^3/s of water at this speed. Also calculate the power output, discharge of prototype and suggest the type of turbine.	[10]	CO1	L3
4	A model of Kaplan turbine one-tenth of the actual size is tested under a head of 5 m, when the actual head of the prototype is 8.5 m. The power developed by the prototype turbine is 8000 kW when running at 120 rpm at an overall efficiency of 85%. Determine (i) Speed, (ii) Discharge. (iii) Power developed, (iv) Specific speed of the model.	[10]	CO1	L3
5	Test on a turbomachine runner of diameter 1.25 m runs at 30 m head and gave the following results: Power developed – 736 kW, Speed of 180 rpm with a discharge of 2.7 cu.m/s. Find the diameter, speed and discharge of a runner to operate at 45 m head and gives 1472 kW at the same efficiency. What is the specific speed of both the turbines.	[10]	CO1	L3

1.

General definition

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

1.5 PARTS OF A TURBOMACHINE

A turbomachine is comprised of the following parts:

(i) Rotor or impeller or runner
(ii) Guide blade or stationary or fixed element or nozzle
(iii) Shaft
(iv) Housing or casing
(v) Diffuser
(vi) Draft tube

Rotor or impeller or runner

Rotor is the rotating element of a turbomachine. It is fixed with blades or vanes and also called the impeller or runner depending upon the particular machine. For example, the rotating member of centrifugal pumps and centrifugal compressors is called the impeller. The rotating member of radial flow hydraulic turbines and pumps is called the runner. In contrast, the rotating member of axial flow gas and steam turbines is called the rotor. Energy transfer occurs between the fluid and the rotating member due to exchange of momentum between the two.

Guide blade or stationary or fixed element or nozzle

The stationary element or guide blade is arranged depending upon the kind of flow required. The stationary element is not a compulsory part of every turbomachine. The ceiling fan is a turbomachine and there is no stationary element.

Shaft

Either input shaft or output shaft or both may be necessary depending upon the type of turbomachines. For example:

(a) Power absorbing turbomachine: only input shaft
(b) Power generating turbomachine: only output shaft
(c) Power transmitting turbomachine: both input and output shaft

Housing or casing

The housing is not a compulsory part of every turbomachine. When the housing is present, it restricts the fluid so that it flows in a given space and does not escape in directions other than those required for energy transfer. A turbomachine having housing is called enclosed machine and the one having no housing is called extended machine.

Turbomachine	*Positive displacement machine*
1. **Action**	
(a) Dynamic	(a) Nearly static
(b) Pressure and momentum of the fluid changes.	(b) Volume of the fluid changes.
2. **Operation**	
(a) Pure rotary motion of the mechanical element.	(a) Usually it is the reciprocating motion of the mechanical element but some rotary positive displacement machines are also built. *Examples:* Gear pump, vane pump.
(b) Steady flow of fluid.	(b) Unsteady flow of fluid.
(c) The fluid state will be the same as that of the surroundings when the machine is stopped.	(c) Entrapped fluid state is different from the surroundings when the machine is stopped and if heat transfers and leakage are avoided.
3. **Mechanical features**	
(a) Rotating masses can be completely balanced and vibrations eliminated. Hence high speeds can be adopted.	(a) Because of the reciprocating masses, vibrations are more. Hence low speeds are adopted.
(b) Light foundations suffice.	(b) Heavy foundations are required.
(c) Design is simple.	(c) Mechanical design is complex because of valves.
(d) Weight per unit output is less.	(d) Weight per unit output is more.
4. **Efficiency of conversion process**	
(a) Efficiency is low because of dynamic energy transfer.	(a) High efficiency because of static energy transfer.
(b) The efficiency of the compression process is low.	(b) The efficiencies of the compression and expansion processes are almost the same.

Turbomachine	*Positive displacement machine*
5. **Volumetric efficiency**	
(a) It is almost 100%.	(a) Much below that of a turbomachine because of valves.
(b) High fluid handling capacity per unit weight of machine.	(b) Low fluid handling capacity per unit weight of machine.

3. D_m/D_p = 1/10
Hm = 10 meters, H_p= 30 m, N_p= 425 m, P_m= 125 kW, Q_m= 1.1 m^3/s

(i) $\left(\frac{gH}{N^2D^2}\right)_p = \left(\frac{gH}{N^2D^2}\right)_m$

N_m^2= $425^2 \times 10/30 \times 4^2$ = 981.49 rpm.

(ii) Power of prototype

$\left(\frac{P}{\rho N^3D^5}\right)_p = \left(\frac{P}{\rho N^3D^5}\right)_m$

P_p= $(425/981.49)^2 \times 4^5 \times 125$ = 10392.48 kW

(iii) Type of turbine

N_{sp}= $\frac{N_p \times \sqrt{P_p}}{H_p^5/4}$ = $\frac{425\times\sqrt{10392.48}}{30^5/4}$ = 617.08 rpm.

4.

$\frac{D_m}{D_p} = \frac{1}{10}$., H_m= 5 m ., H_p = 8.5 m., P_p = 8000 kW., N_p= 120 rpm ., η_o = 0.85

$\left(\frac{gH}{N^2D^2}\right)_p = \left(\frac{gH}{N^2D^2}\right)_m$ => N_m = 920.35 rpm.

$\eta_o = \frac{P_p}{w.Q_p.H_p}$ => Q_p = 0.1128 m^3/sec

$\left(\frac{N\sqrt{P}}{H_m^{5/4}}\right)_p = \left(\frac{N\sqrt{P}}{H_m^{5/4}}\right)_{\text{m}}$ => P_m= 36.093 kW.

5.

Solution: (a) **The speed (N_p):**

$$\left[\frac{H}{(ND)^2}\right]_m = \left[\frac{H}{(ND)^2}\right]_p \qquad \text{(Eq. (1.30))}$$

$$\therefore \qquad N_p = \sqrt{\left[\frac{H_p}{H_m}\right]}\left[\frac{D_m}{D_p}\right] \times N_m = 1500 \times \frac{1}{4} \times \sqrt{\frac{30}{6}} = 838.5 \text{ rpm} \qquad \textbf{Ans.}$$

(b) **Power (P_p):**

$$\left[\frac{P}{\rho D^5 N^3}\right]_m = \left[\frac{P}{\rho D^5 N^3}\right]_p \qquad [\because \rho_p = \rho_m] \qquad \text{(Eq. (1.33))}$$

$$\therefore \qquad P_p = P_m \left[\frac{D_p}{D_m}\right]^5 \left[\frac{N_p}{N_m}\right]^3$$

$$\text{or} \qquad P_p = 5 \times [4]^5 \left[\frac{838.5}{1500}\right]^3 = 894.34 \text{ kW} \qquad \textbf{Ans.}$$

(c) **The ratio of discharge of prototype and model (Q_p/Q_m):**

$$\left[\frac{Q}{ND^3}\right]_m = \left[\frac{Q}{ND^3}\right]_p \qquad \text{(Eq. (1.28))}$$

$$\therefore \qquad \frac{Q_p}{Q_m} = \left[\frac{N_p}{N_m}\right]\left[\frac{D_p}{D_m}\right]^2 = \left[\frac{838.5}{1500}\right] \times [4]^3 = 35.776 \qquad \textbf{Ans.}$$