Hydraulic Machinary

Introduction

Hydraulic machines are the machines that transfer energy between its operating parts and a fluid.

Examples:

- Pumps
- Turbines
- Blowers
- Compressors

Classification

Based on energy transfer direction

Machine to Fluid

Examples:

- Pumps (for liquids)
- Blowers, Compressors (for gases)

Fluid to Machine

Examples:

- Turbines
- Fluid motors

Energy transfer using fluid

Examples:

- Hydraulic Jack

Based on principle of operation

Positive displacement

Fluid taken into an enclosed space and forced out by repeated mechanical action.

Examples:

- Piston pump
- Rotary pump

> ⓘ **Note**
>
> In piston pump (slider-crank mechanism), the movement of the piston is called as "reciprocating action".

Rotodynamic

Main component is a rotating element. It rotates inside a fluid. Rotating element's kinetic energy is transferred to fluid when the fluid flows through it.

Machine	Main rotating element
Pumps	Impeller
Turbines	Runner
Fans/Blowers	Rotor

Summary

	Machine to Fluid	Fluid to Machine	Fluid as a energy transfer medium
Positive Displacement	Piston pump, Rotary pump	Motors	Hydraulic Ram, Jack Press
Rotodynamic	Pumps, Compressors	Turbines	Hydraulic coupling, Torque converter

> ⓘ **Note**
>
> In s1, only rotodynamic pumps and rotodynamic turbines are studied.

Pumps

Vane

A curved blade used in a pump.

Impeller

Set of vanes attached to a disc or a cyllinder. Main rotating element in a pump.

In a pump, impeller is mounted on a shaft. The shaft is driven by an electric motor or IC engine.

Direction of the fluid flow

Axial flow

Fluid enters and exits the impeller axially.

Radial flow

Fluid enters the impeller axially. Leaves radially.

Mixed flow

Fluid enters the impeller axially. Leaves in both axial and radial directions. Aka. centrifugal pumps.

> **Note**
>
> For s1, only centrifugal pumps are studied.

Parameters

Head provided

The head provided by a pump depends on the flow rate.

$$H = f(Q)$$

Here:

- H - provided head
- Q - flow rate

For a given pump running at a given speed, there is a unique variation of H and Q.

Power input

Denoted by P_i. Varies with Q.

Efficiency

Denoted by μ. Varies with Q.

$$\mu = \frac{P_o}{P_i}$$

> **Note**
>
> $$\text{Energy per unit volume} = \frac{P_{i_A}}{Q}$$

All these parameters, plotted vs Q, is known as **performance characteristic** of the pump. Will be given by the manufacturer. Can be found by laboratory testing.

In a pipeline system

$$H = H_0 + KQ^2$$

H is the head required (or received) to create the flow rate Q in the pipeline system. The above equation is known as **system characteristic** or **system load curve**.

Here K is the loss coefficient and is given by:

$$K = \frac{8}{\pi^2 g D^4}\left(K_L + \frac{\lambda L}{D}\right)$$

> ⓘ **Note**
>
> Working state of a pipeline system is given by the intersection of system characteristic and performance characteristic (of the pump) curves.

Resultant pumps

In serial

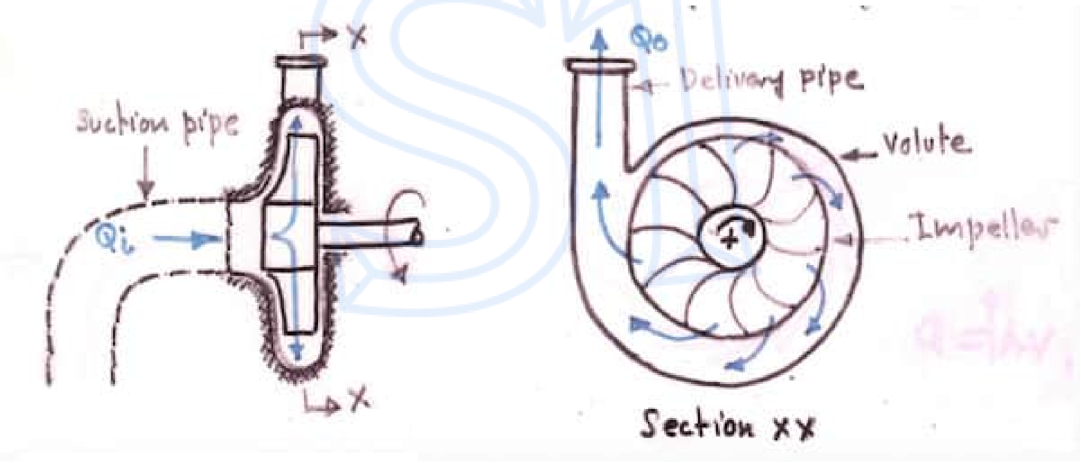
When 2 pumps are operating in a series, their head inputs are added.

In parallel

When 2 pumps are operating in a parallel, their flow rates are added.

Centrifugal Pumps

Most used pumps in engineering because they support wide range of heights and flow rates. Mixed flow, rotodynamic pump.



Volute

Casing of the impeller. A passage with increasing area, to reduce velocity (to reduce losses).

> ⓘ **Note**
>
> Energy loss in a fluid flow is directly proportional to v^2.

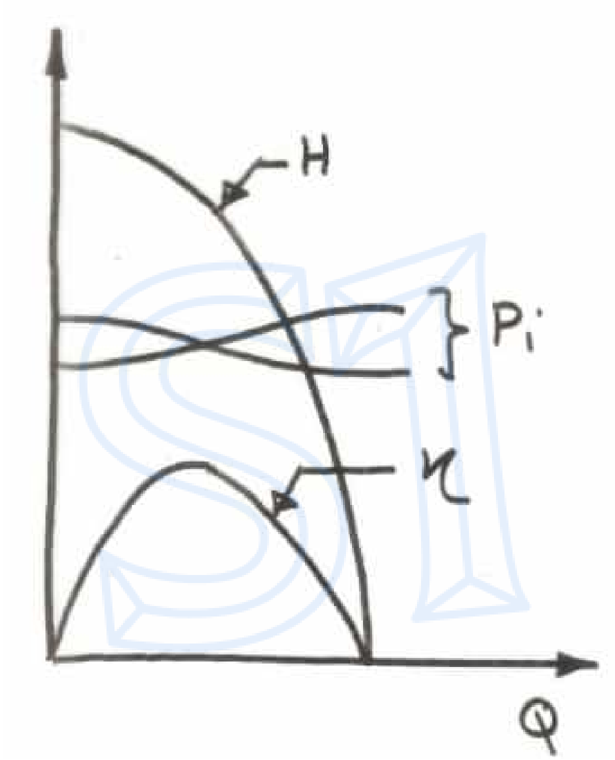
Diffuser

A fixed set of vanes added to the impeller. To direct the flow into the volute, to minimize impact losses. Optional.

Operation

- Volute must be filled with fluid to start pumping
- Fluid enters through the *eye* of the impeller
- v and P are increased when the fluid flows through the impeller

Performance characteristic



Turbines

Used to generate electricity.

Runner

A wheel with buckets attached. Mounted on a shaft.

Types of turbines

Reaction turbines

Aka. pressure turbines. Similar to pumps; but operating in reverse direction (direction of fluid flow and energy transfer). Guide vanes are placed to guide fluid flow onto the runner.

3 types of reaction turbines based on the direction of fluid flow.

Axial flow

Aka. Kaplan turbine. Commonly used to get a head output of 3 to 70m.

Radial flow

Aka. Francis turbine. Commonly used to get a head output of 30 to 500m.

Mixed flow

A combination of radial flow and axial flow.

Impulse turbines

Aka. velocity turbines. Used for high heads. Highly efficient. High velocity jet is focused on the buckets of the runner.

Efficiency of an impulse turbine is given by:

$$\mu = \frac{1}{v_1^2}(2u)(v_1 - u)(1 + k\cos\beta)$$

Here:

- v_1 - velocity of the jet of fluid
- u - velocity of the bucket
- k - loss coefficient (a little less than 1)
- β - angle of deflection of fluid inside the bucket

μ can be considered as a function of u. And from that, the turbine works at maximum efficiency when $2u = v_1$.