Subject: FLUID MECHANICS -II

Topic: Hydraulic Machines
Module 1 (Pumps)
Part - I

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Branch: Civil Engineering
Class & Sem: B.Tech (H), 4th Sem.
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• Fluid machine is a device either for converting the energy held by a fluid into mechanical energy or vice versa.
• Fluid machines deal with conversion of power from fluid power to shaft power or from shaft power to fluid power.
• Fluid machines such as turbines, centrifugal pumps, compressors, fans, hydraulic couplings and torque converters fall under the category of rotodynamic machines.
• The rotodynamic machines are also called turbomachines and have a rotating element which plays an important role in causing the energy transfer between the fluid and the rotating element.
Centrifugal Pumps

- The hydraulic machines which convert Mechanical Energy to Hydraulic Energy are called pumps.
- Centrifugal pump is a hydraulic machine used to rise the liquid from a lower to higher level by creating a required pressure by means of centrifugal action.
- Centrifugal pump works on the principal of forced vortex flow, which means that when a certain mass of liquid is rotated by an external torque, the rise in pressure head of the rotating liquid takes place.
- Convert Mechanical energy (M.E) of shaft into Kinetic Energy (K.E) and Pressure Energy (P.E) of liquid which may be used to rise the level of the fluid. (Convert ME to KE to PE)
- The rise in pressure head at any point of rotating liquid is proportional to the square of tangential velocity of the liquid at that point (i.e., rise in pressure head = \( \frac{V^2}{2g} \)). Thus at the outlet of the impeller, the rise in pressure head is more and liquid will be discharged with high pressure.
Classification of pumps

A) On the basis of transfer of mechanical energy

1) Rotodynamic/centrifugal pump
   • Radial flow pumps
   • Axial flow pumps
   • Mixed flow pumps

2) Positive displacement pumps
   • Single acting
   • Double acting

Classification of centrifugal pumps based on:

I. Working head
II. Type of casing
III. Specific speed
IV. Number of entrances to the impeller
V. Directions of flow
VI. Number of stages
VII. Disposition of shaft
1) Working head
   a) Low head: They work against heads up to 15mts
   b) Medium head: Used to build up heads as high as 15-40mts.
   c) High head: Heads above 40mts.

2) Types of casing
   a) Volute casing pump
   b) Vortex chamber or whirlpool pump
   c) Diffuser pump or turbine pump

3) Specific speed pump

<table>
<thead>
<tr>
<th>Pump</th>
<th>Speed</th>
<th>Specific speed</th>
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<tbody>
<tr>
<td>Radial flow</td>
<td>Slow</td>
<td>10-30</td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td>30-35</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>50-80</td>
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<tr>
<td>Mixed flow</td>
<td></td>
<td>80-160</td>
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<tr>
<td>Axial flow</td>
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<td>100-450</td>
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4) Number of entrances to the impeller
   a) Single suction pump
   b) Double suction pump
5) Direction of flow of water
   a) Radial flow (High head and low discharge)
   b) Mixed flow (Medium discharge, medium head, axial and radial flows)
   c) Axial flow (Not of centrifugal pump, Kaplan pump High discharge, low head)

6) Number of stages
   a) Single stage
   b) Multi stage

7) Disposition of shaft
   a) Horizontal shaft disposition (Centrifugal pumps)
   b) Vertical shaft disposition
      (May be used where the space limitation such as in deep wells and mines etc.,)
Advantages of centrifugal pump over displacement pump:

The centrifugal pump claims the following advantages with reference to a positive displacement (reciprocating) pump.

- The cost of a centrifugal pump is less as it has fewer parts.
- Installation and maintenance are easier and cheaper.
- Its discharging capacity is much greater than that of a reciprocating pump.
- It is compact and has smaller size and weight for the same capacity and energy transfer.
- Its performance characteristics are superior.
- It can be employed for lifting highly viscous liquid such as paper pulp, muddy and sewage water, oil, sugar molasses etc.
- It can be operated at very high speeds without any danger of separation and cavitation.
- It can be directly coupled to an electric motor or an oil engine.
- The torque on the power source is uniform, the output from the pump is also uniform.
Principal components

1) Impeller
2) Casing
3) Suction pump
4) Delivery pump
Impeller:
It is a wheel or rotor with a series of backward curved vanes or blades. It is mounted on a shaft which is usually coupled to an electric motor

1) Shrouded or closed impeller:
   - Whose vanes are provided with metal cover blades or shrouds on both sides
   - Provides better guidance for the liquid and is more efficient
   - Must suited when the liquid is free from debris

2) Semi open impeller:
   - Vanes have only the base plate and no crown plate, then the impeller is known as semi open type impeller suitable even if the liquids are charged with some debris.

3) Open impeller:
   - Vanes have neither crown plate nor base plate
   - Useful in the pumping of liquids containing suspended solid matter such as paper pulp, sewage and grit.

Casing:
- Air tight chamber which surrounds the impeller
- Similar to the casing of reaction turbine

Suction pump:
- Pipe which is connected at its upper end to the inlet of the pump or to the centre of impeller, which is commonly known as eye
- Lower end dips into liquid in a suction tank or sump
- Lower end pipe filled with foot valve or strainer (one way type or non return)

Delivery pipe:
- A pipe connected at its lower end to the outlet of the pump
- Delivers the liquid to the required height
- A delivery valve is coupled
Energy transfer per unit weight is referred to as Euler head, $H_e$

Work done per second per unit weight of liquid (or) $He$

$$H_e = \frac{V_2^2 - V_1^2}{2g} + \frac{u_2^2 - u_1^2}{2g} + \frac{V_{r1}^2 - V_{r2}^2}{2g}$$

The term $\frac{V_2^2 - V_1^2}{2g}$ represents the increase in KE or dynamic head

The term $\frac{u_2^2 - u_1^2}{2g}$ represents an increase in static pressure

The term $\frac{V_{r1}^2 - V_{r2}^2}{2g}$ represents the change in KE