Module 7: Energy conservation

Lecture 25: Centrifugal pump: characterisitcs, efficiency, NPSH

- Centrifugal pump
- Efficiency of pump
- Net positive-suction head (NPSH)
- Performance characterstics of a pump

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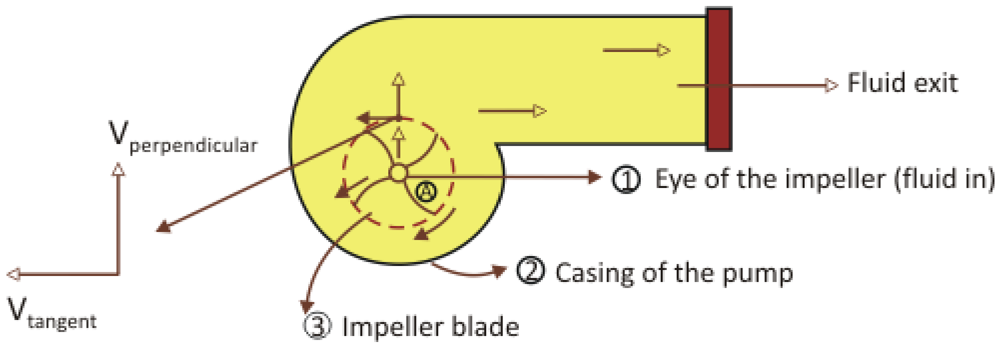
Centrifugal pump

The fluid turbo machinery essentially consists of an impeller rotating in a casing. Fluid enters the eye of the impeller (the center of the impellers) and exits though the space between the impeller blades to the space between the impeller and casing walls. The velocity of fluid elements is in both tangential and radial directions, as the impeller rotates. The velocity as well as the pressure, both increase, as the fluid flows through the impeller



(Fig. 25a)

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Efficiency of pump

Difference between heads at location (A) and (B) may be calculated as

$$\Delta H = \left(\frac{P}{\rho g} + \frac{V^2}{2g} + Z\right)_B - \left(\frac{P}{\rho g} + \frac{V^2}{2g} + Z\right)_A$$

where the terms in each parenthesis consist of pressure, kinetic energy and potential energy.

The increase or difference between the kinetic and potential heads is usually negligible. Therefore,

$$\Delta H \sim \frac{\Delta p}{\rho g}$$

The efficiency of the pump η is defined as $\frac{(\rho g\ \Delta H)\theta}{BHP}$, where the term in the numerator represents power delivered by the pump because of the pressure-developed. BHP is the brake–horse power; required to drive the pump. BHP depends upon the speed of the pump, vane angle (design of the impeller) and the flow rate of the fluid.

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Net positive – suction head (NPSH)

Defined as the net head developed at the suction port of the pump, in excess of the head due to the vapor pressure of the liquid at the temperature in the pump. NPSH must be positive for preventing the liquid from boiling. Boiling or cavitations may damage the pump.

$$\boxed{\mathrm{NPSH} = \left(\frac{P}{\rho g} + \frac{V^2}{2g} + Z\right)_{\text{suction}} - \left(\frac{P_v}{\rho g}\right)}$$

where, P_v is the vapor–pressure of the liquid. If the pump is placed at a height $'z'$ above the free surface of a liquid where the atmosphere pressure is Pa, the NPSH may be evaluated by writing the Bernoulli's equation between the free surface and the suction port of the pump as

$$\boxed{\mathrm{NPSH} = \left(\frac{P_a}{\rho g} - Z\right) - h_{fl} - \left(\frac{P_v}{\rho g}\right)}$$

where $h_{fl} =$ frictional loss in the suction pipe between the liquid–surface and the pump.

Therefore, it is obvious that for NPSH to be positive or maximum, Z and h_{fl} should be minimum.

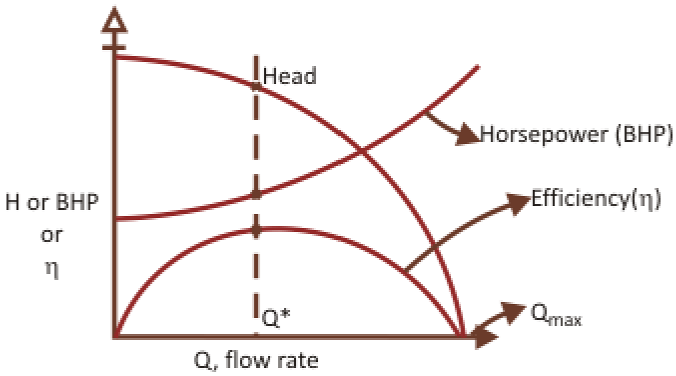
Most ideally, for maximum NPSH, $Z = h_{fl} = 0$ and $\boxed{\mathrm{NPSH} = \left(\frac{P_a - P_v}{\rho g}\right)}$

Performance characteristics of a pump

There are there performance characteristics of pump:

1. Head developed by the pump (H)
2. Brake horse power (BHP)
3. Efficiency of the pump (η)

-all plotted against the flow rate.



(Fig. 25b)

As seen from the graph, head decreases with increasing flow rate till the pump cannot deliver the fluid at $Q = Q_{max}$. Horsepower increases with flow rate. Efficiency of the pump initially increases with increasing flow rate, reaches a maximum, and then decreases to zero at $Q = Q_{max}$. Pump is operated at $Q = Q*$.

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