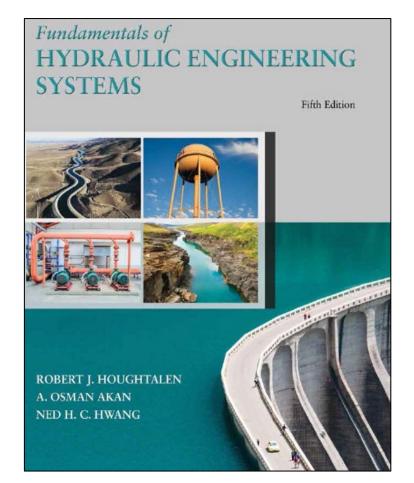
Fundamentals of Hydraulic Engineering Systems

Fifth Edition

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Chapter 5a

Water Pumps



Learning Objectives

5.1 Describe the operational difference between **centrifugal pumps** and other types of pumps.

5.2 Define and use **pump characteristic curves**.

5.3 Describe the operation of **pumps** in **pipelines**, **branching systems**, and **pipe networks**.

5.4 Explain **series** and **parallel pump** configurations.

5.5 Understand the concepts of **cavitation**, **specific speed**, and **pump similarity**.

5.6 Recognize how **pump selection** is accomplished.

5.7 Calculate solutions to various pump analysis and design problems involving these concepts.



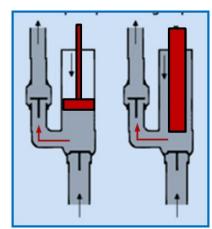
Description of Pumps and Pump Types

Definitions and Visualization

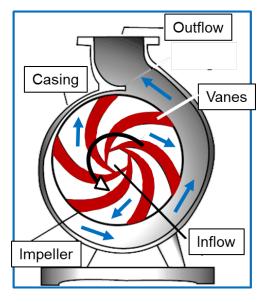
Pump: a device that converts mechanical to hydraulic energy

Turbo-hydraulic: fluid moved by rotating vanes or another moving fluid (e.g., centrifugal, jet, and propeller pumps)

Positive displacement: fluid moved by precise machine displacements (e.g., screw and reciprocal pumps)







Q: Guess these pump types.

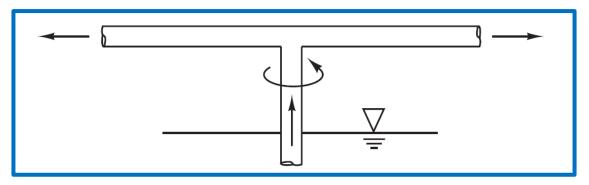


Centrifugal (Radial Flow) Pumps (1 of 7)

Visualization and Flow Principles

- **Q:** Will water be ejected from the pipe T if we spin it?
- **A:** Only if it is filled with water (primed) first.
- **Q:** What principle of physics is being utilized to move water?
- A: Centrifugal Force and Momentum Conservation

Figure 5.1 Demour's centrifugal pump



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Centrifugal (Radial Flow) Pumps (2 of 7)

Visualization and Derivation of Power Input

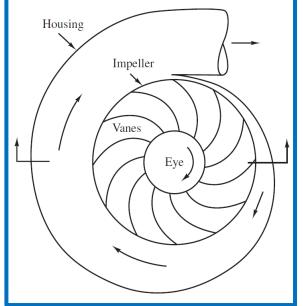
From Newton's 2nd Law, derive the impulse momentum equation:

$$F = ma = m\left(\frac{dV}{dt}\right) = \left(\frac{m}{dt}\right)(dv) = \rho Q(V_o - V_i) \rightarrow \text{from Chap 3}$$

Q: What is the relationship between force and torque (T)?

A: T = force \times perpendicular distance = F \cdot d

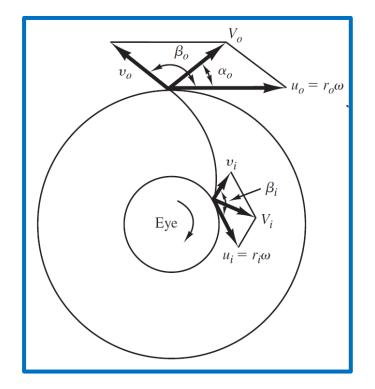
applied to impulse-momentum:





Centrifugal (Radial Flow) Pumps (3 of 7)

 $T = \rho Q (r_o V_o \cos \alpha_o - r_i V_i \cos \alpha_i)$ Also, Power (P) = ωT ; So the **Pump Power Input** is: P_i = $\rho Q \omega (r_o V_o \cos \alpha_o - r_i V_i \cos \alpha_i)$





Centrifugal (Radial Flow) Pumps (6 of 7)

Equations for Power Output & Efficiency

Q: Does energy increase on the output side of the pump? If so, in what form? Does the flow rate increase?

A: The energy increase is in the form of pressure head (see figure below). Flow does not increase (i.e., continuity).

Pump Power Output:

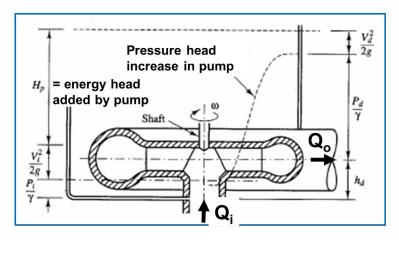
$$P_o = \gamma Q H_p$$

Pump Efficiency:

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

Motor Efficiency: Overall Efficiency:

$$e = e_{p}e_{m} = \frac{P_{o}}{P_{m}}$$



Centrifugal (Radial Flow) Pumps (7 of 7)

Pump and Motor Selection Example Problem

A centrifugal pump is required to lower the stormwater depth in a 12 ft by 10 ft rectangular sump at the rate of 1 foot every minute. The pump must overcome a lift of 20 feet. If the overall efficiency rating of the pump is 75%, select the appropriate pump (flow rate in gpm) and motor (power in kW). Assume pipeline losses are negligible.

Ans.
$$\mathbf{Q} = \left[\frac{(12')(10')(1')}{60 \text{ sec}}\right] \left(\frac{449 \text{ gpm}}{1 \text{ cfs}}\right) \approx 900 \text{ gpm}$$

 $P_o = \gamma QH_P = (62.3 \text{ lb / ft}^3)(2 \text{ ft}^3 / \text{s})(20 \text{ ft}) = 2,490 \text{ ft} - \text{lb/sec}$
 $P_o = (2,490 \text{ ft} - \text{lb / sec}) \left(\frac{1 \text{ hp}}{550 \text{ ft} \cdot \text{lb/sec}}\right) = 4.53 \text{ hp}$
 $P_m = \frac{P_o}{e} = \left[\frac{4.53 \text{ hp}}{(0.75)}\right] \left(\frac{1 \text{ kW}}{1.341 \text{ hp}}\right) = 4.50 \text{ kW}$

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First Drop of Water from a Hand Pump



Everyone is smiling in Jambo, South Sudan.

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