Hydraulics & Pneumatics

Chapter 1: Hydraulics (Hydraulic Pump)

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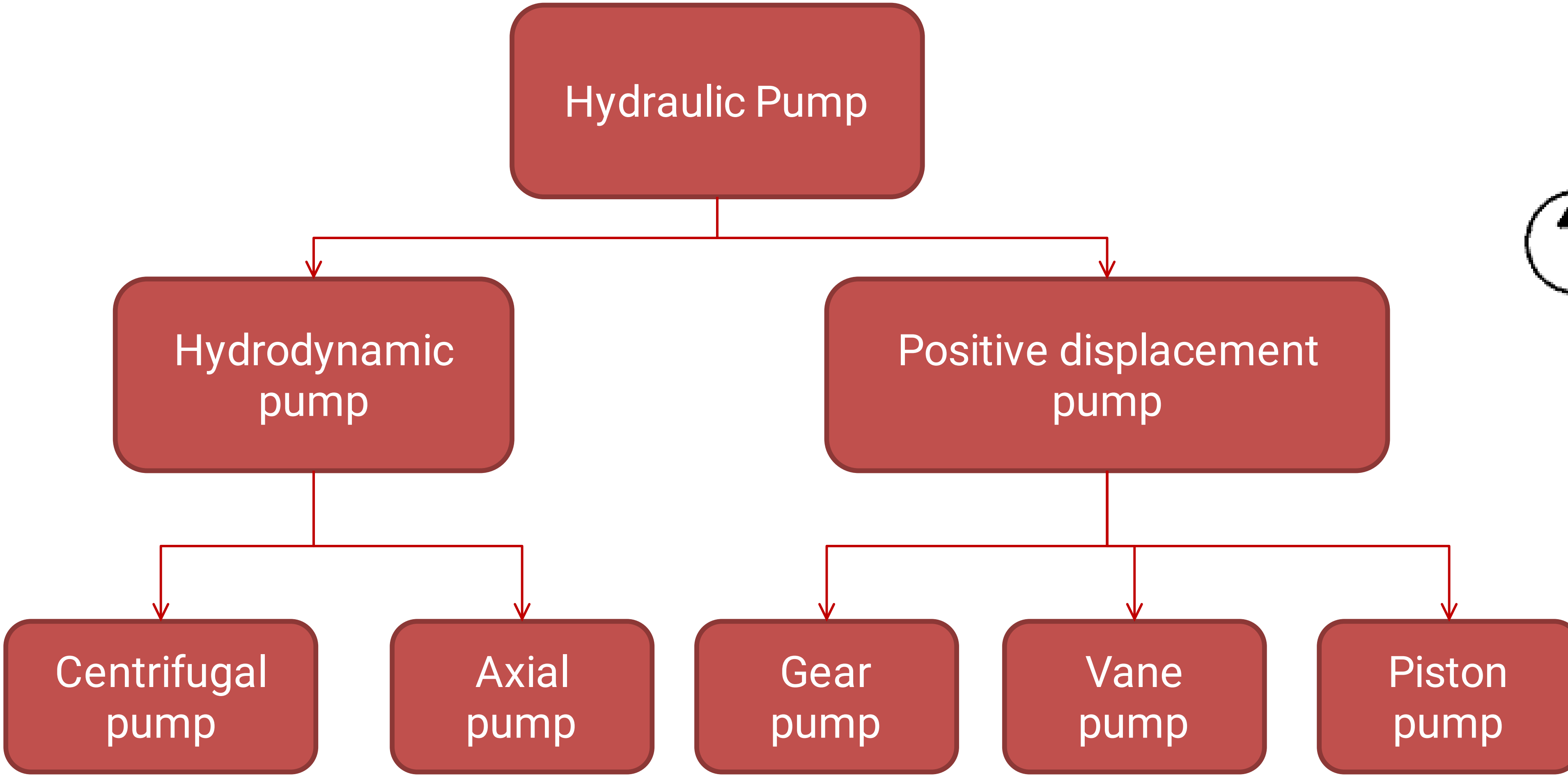
Lesson Outcome

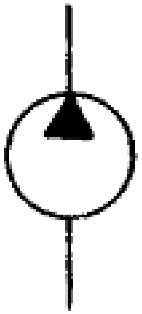
- By the end of this lesson, student should be able to explain type of hydraulic pump, ideal and real pump analysis, pump characteristics and efficiency (mechanical, volumetric and total)

Content

- Hydrodynamics pump
- Gear pump
- Vane pump
- Piston pump
- Ideal pump analysis
- Real pump analysis

Types of Pump

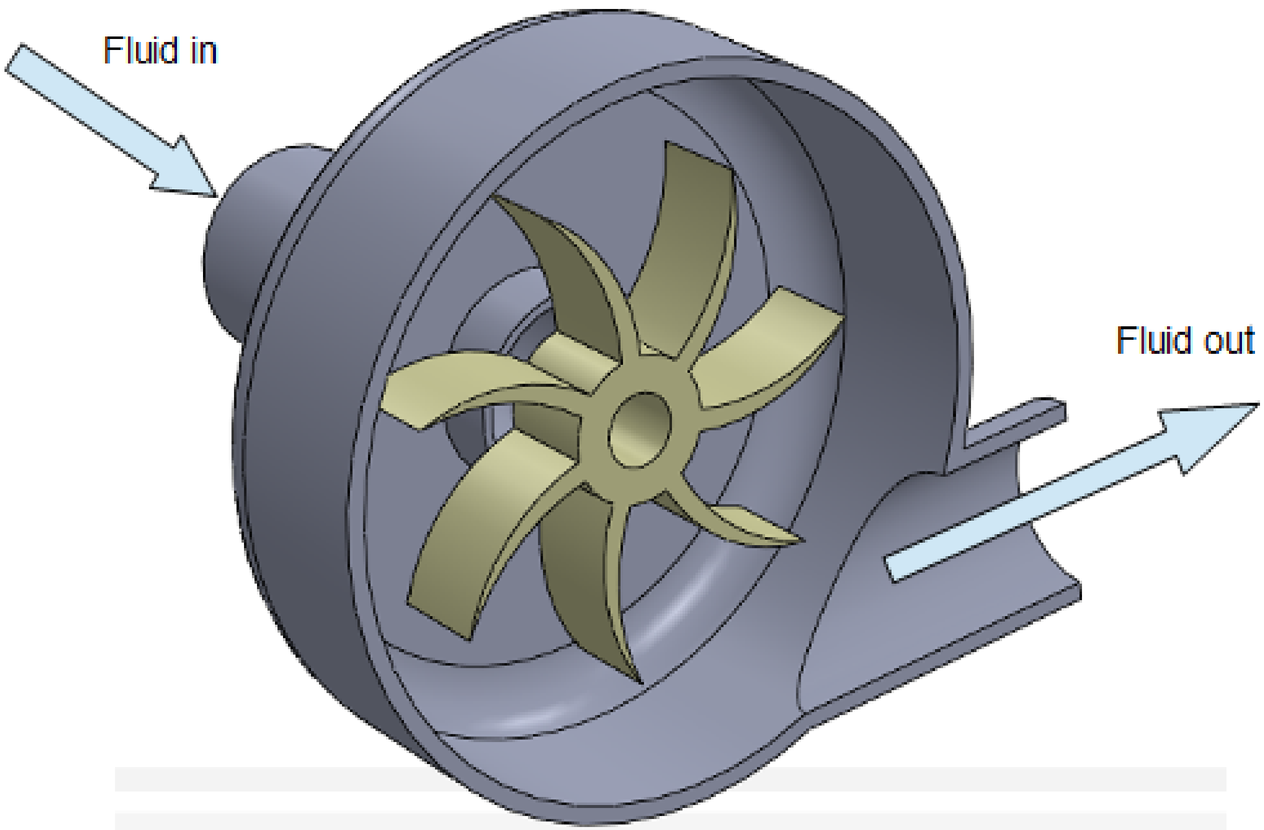




Hydrodynamic pump

- Used in situation that required for high volume and low pressure flow applications.
- This type of pump incapable to withstand high pressure fluids.
- Normally the maximum pressure capacity is limited to 250-300 psi.
- Normally used to transport the fluids from one point to different points.
- E.g. – Centrifugal pump
  - Axial pump

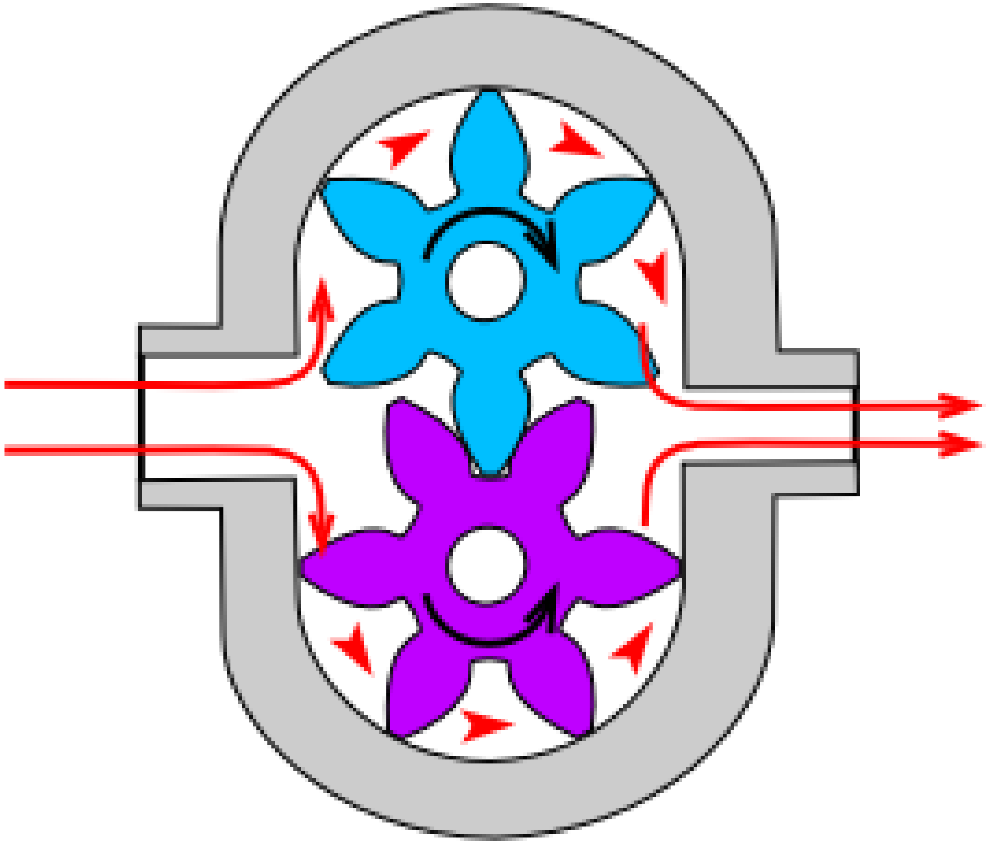
Centrifugal and Axial Pump



Positive Displacement Pump

- Expel a fixed fluid volume to the system for each of revolution.
- Capable of overcoming the pressure from mechanical loads and friction.
- Advantages:
  - Can be used for high pressure application up to 12000 psi.
  - Compact and small size
  - The volumetric efficiency is high
  - Flexible pressure and speed, depend on the requirements.

Gear pump



Source: Wikimedia

Gear pump

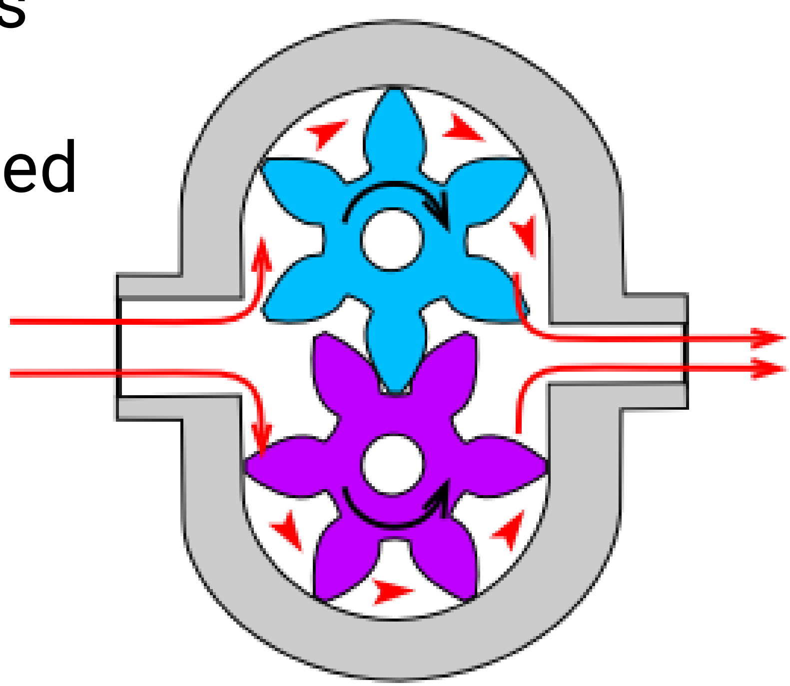
Gear pump always produce fixed volume displacement. For this pump, the volumetric displacement can be calculated by:

$$V_D = \frac{\pi}{4}(D_o^2 - D_i^2)L$$

D_o: outside diameter,

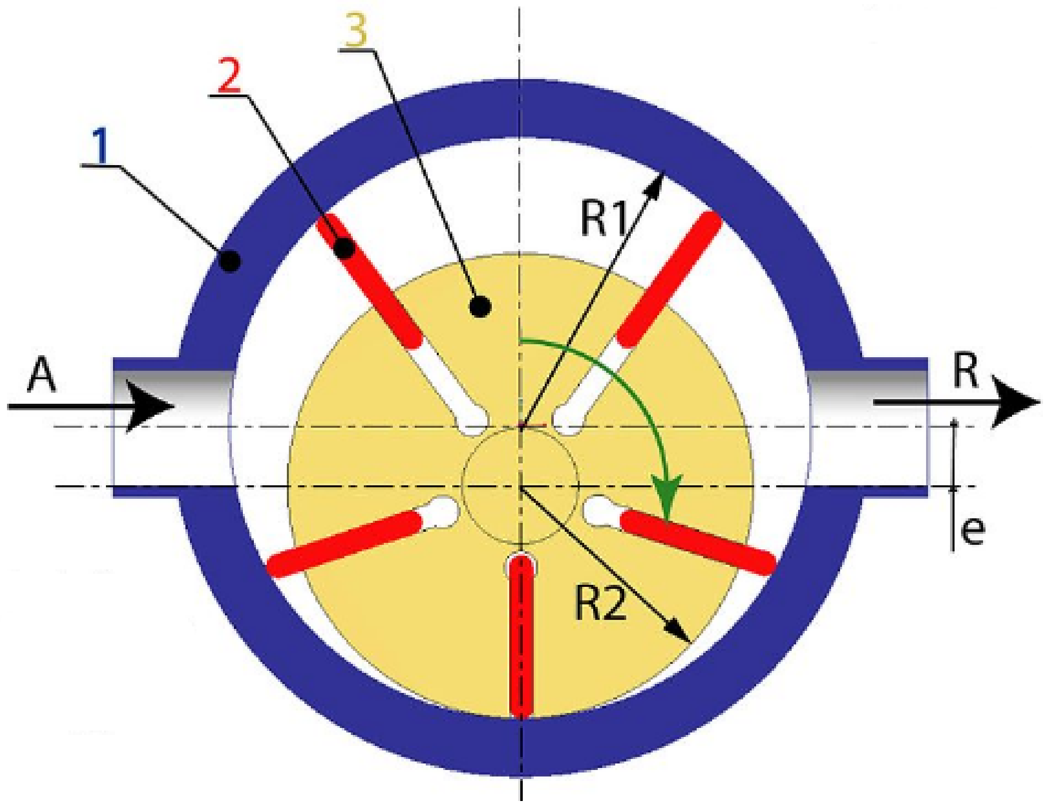
D_i: inside diameter and

L: width of the gear teeth



Source: Wikimedia

Vane pump



1. Housing
2. Vane blade attached to spring
3. Cam

Source: [Wikimedia]

Ideal Pump Analysis

- Assuming an ideal pump, without internal leakage, friction and also pressure losses. The pump flow rate can be calculated as follow:

$$Q_t = V_g n$$

where Q_t = Pump theoretical flow rate, m^3/s
n = Pump speed, rev/s

- the input mechanical power is equal to the increase in the fluid power

Power, N = $2\pi n T_t = Q_t(P - P_i) = V_g n \Delta p$

$$T_t = \frac{V_g}{2\pi}\Delta P$$

where T_t = Pump theoretical driving torque, Nm
ΔP = Pressure increase due to pump action, Pa

Real Pump Analysis

- The effect of leakage is expressed by the volumetric efficiency, η_v, defined as follows

$$\eta_v = \frac{Q}{Q_t}$$

  - Q - actual pump flow rate
  - Qt - theoretical flow rate
- η_v indicates amount of leakage that takes place in the pump

Real Pump Analysis

- Mechanical efficiency (η_m): Energy losses because of other factors than leakage.

$$\eta_m = pQ_t/\omega T_A \qquad \omega = 2\pi N / 60$$

where p : pump output pressure [Pa]

Q_t: pump theoretical flowrate [m^3/s]

T_A : actual torque [Nm]

ω : radial pump speed [rad/s]

Pump Efficiency (Mechanical)

- Or

$\eta_m = T_T/T_A$

where

T_T [Nm] = (V [m^3] × P [Pa])/2π

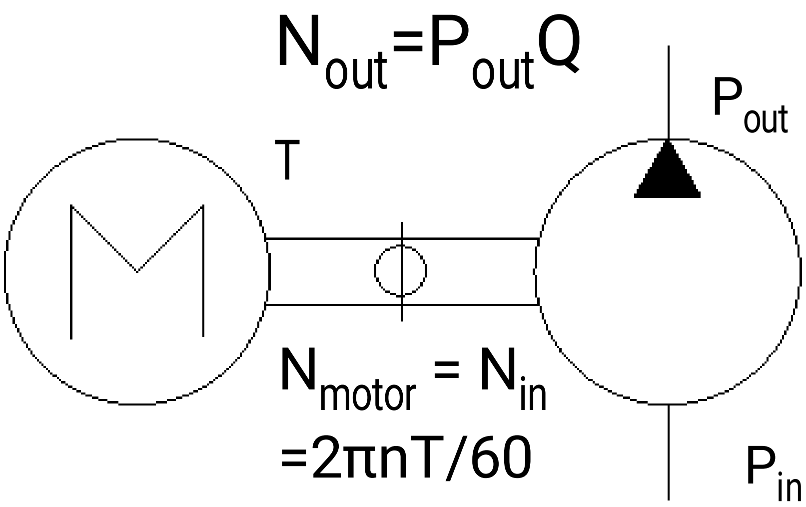
T_A = (actual power delivered to pump [W])/(2πN/60 [rpm])

- $\eta_m \leq 1.0$, *therefore* $T_T \leq T_A$
- YES!!! Theoretical torque is smaller than actual torque.
- Why?
  - Theoretical torque is based from calculation. Did not consider the resistance force
  - Actual torque = Theoretical torque + Resistance force during rotation

Total/overall efficiency

Total efficiency = volumetric efficiency x mechanical efficiency

$$\eta_{tot} = \eta_{vol} \times \eta_{m}$$



Q_T: Fixed based on calculation

Q_A: Fixed based on actual

Torque

- Pump torque is calculated as force (F) time the distance from the force to the pivoted point (d).

$$T = F \times d$$

- Pump torque can also be calculated as the relation of pressure and pump delivery.

$$T = \frac{P}{2\pi N} = \frac{p \times Q}{2\pi N} = \frac{p \times V}{2\pi}$$

Lesson Summary

- In this lesson, we have learned about the type of hydraulic pump, ideal and real pump analysis, pump characteristics and efficiency

References

- Parr, A. (2002). Hydraulics and Pneumatic: A Technician's and Engineer Guide. 2ed. Butterworth Heinemann.