Module 6: Pumps

**Terms and Definitions**

- **Aeration** is air in the fluid.
- **Cavitation** is the formation of air or gas bubbles at the inlet of the pump because the pump does not completely fill with fluid and is also used to denote the collapse of air and gas bubbles in the pump, creating a distinctive noise and causing damage to the pump.
- **Displacement** is the volume of fluid that is moved by the pump in one complete revolution.

**Types of Pumps**

- Pumps produce flow, not pressure.
  - Pressure in system results from resistance to flow produced by the pump.
  - Resistance primarily due to load system must move and some types of valves.
- Nonpositive displacement pump.
  - Designed so buildup of pressure at outlet causes fluid to recirculate or leak back inside pump housing.

**Types of Positive Displacement Pumps**

- Gear-type of positive displacement pump.
- Vane-type of positive displacement pump.
- Piston-type of positive displacement pump.
Calculating Hydraulic Pump Displacement

READY FOR REVIEW

- Formula for calculating hydraulic pump displacement.
  \[ d = 231 \times \frac{Q}{N} \]
- \( d \) is displacement in cubic inches per revolution (in\(^3\)/rev), \( Q \) is pump flow rate in gallons per minute (gpm), and \( N \) is pump speed in revolutions per minute (rpm).

Calculating Theoretical Hydraulic Pump Flow Rate

READY FOR REVIEW

- Formula for calculating theoretic hydraulic pump flow rate.
  \[ Q = \frac{N \times d}{231} \]

  Note: This is the theoretical flow rate of the pump. The actual flow rate can be determined only by using a flow meter to measure it.

Calculating Volumetric Efficiency

READY FOR REVIEW

- Formula for calculating volumetric efficiency.
- Volumetric efficiency is the actual flow rate of the pump divided by the theoretical flow rate, or
  \[ \text{Volumetric efficiency} = \frac{\text{Actual flow rate}}{\text{Theoretical flow rate}} \]

Calculating Hydraulic Pump Power

READY FOR REVIEW

- Formula for calculating hydraulic pump power.
  \[ P = p \times Q \]
- To calculate pump output horsepower (HP), use
  \[ HP = \frac{p \times Q}{1,714} \]
  where \( p \) is pressure in pounds per square inch (psi), \( Q \) is flow rate in gallons per minute (gpm), and 1,714 is a constant conversion factor.

Operation of a Gear Pump

READY FOR REVIEW

- All pumps operate basically the same way, even with very different mechanisms.
- Through the rotation of the interior mechanism, the pump volume is increased at the pump inlet.
- This creates a low pressure area at the inlet and allows fluid to be pushed into the pump by atmospheric pressure, a fluid head, or both.
- Fluid is then carried to the outlet port where the action of the mechanism decreases the volume in the pump, forcing the fluid out through the outlet port.

  Spear gear pumps consist of housing, a drive gear (driven by the shaft), a driven gear, and other mechanisms, such as pressure plates, etc.

  As the gears rotate, the gears separate at the pump inlet, allowing fluid to be forced into the pump.

  The fluid is carried in the spaces between the gear teeth and the pump housing to the outlet port.

  The meshing of the teeth forces the fluid out through the outlet port and into the system.

  Gear pumps are typically limited to operating pressures of 2,500 psi.
Operation of a Vane Pump

- Vane pump consists of a rotor containing sliding vanes in slots, and the rotor is offset from the centerline of the housing.
- As the mechanism rotates, the volume in the pumping chambers created between the vanes increases at the inlet port, creating the low pressure area that allows fluid to be pushed into the pump.
- Fluid is carried around the pump in the pumping chambers between the vanes and the pump housing.
- As the volume decreases at the outlet port, the fluid is forced out of the pump and into the system.
- Some vane pumps have a variable displacement capability.
- Vane pumps are typically limited to operating pressures of around 2,000 psi.

Types of Piston Pumps

- Inline axial piston pumps’ pistons operate parallel to the axis (drive shaft) of the pump.
- Bent axis axial piston pumps’ pistons operate at an angle to the axis of the pump.
- Radial piston pumps’ pistons operate perpendicular to the axis of the pump.

Operation of Axial Piston Pumps

- Axial piston pumps.
  - Angled swash plate controls piston position.
  - As piston barrel rotates, some pistons pull away from inlet port, allowing fluid to be pushed into pump.
  - As barrel rotates, some pistons push in towards outlet post, forcing fluid out of pump and into system.
  - Typically operate at pressures of 5,000 psi or higher.
- Bent axis pumps.
  - Operates the same as axial piston.
  - Difference is the piston barrel is set at a fixed angle to the swash plate instead of the swash plate set at fixed angle to the pistons.

Operation of Radial Piston Pumps

- Works on same principle as a radial piston engine.
- Piston block rotates around a fixed pintle (crankshaft), allowing pistons to reciprocate, alternately filling with fluid, and then pushing it out into the system.

Operation of Variable Displacement Pumps

- There are two types of variable displacement pumps: vane and piston.
- Vane pump.
  - The variable displacement vane pump has a moveable pressure ring inside the pump, and a screw adjustment is used to position the pressure ring.
- Piston pump.
  - The variable displacement piston pump has a swash plate that is part of a moveable yoke.
  - Yoke (swash plate) angle varies piston stroke, increasing or decreasing pump displacement.
  - An external screw mechanism is used to adjust the swash plate angle.
Pressure compensator is a device that senses pressure and makes automatic adjustment as a result of that pressure. Compensator is set to the maximum required system pressure. Mechanism includes variable yoke (swash plate), which is similar to that for the variable displacement pump.

Pressure-compensated pump still needs a pressure-relief valve in the system.

Operation of a Servo-Controlled Variable Displacement Pump

Pump mechanism is similar to that of a pressure-compensated pump. Servo sensors sense either pump flow or system pressure as desired.

The electromechanical mechanism mounted on the pump adjusts the swash plate angle to adjust the pump output flow as required.

Causes of Pump Cavitation

Results from restriction in pump suction line. Allows high vacuum in line. Vapor bubbles form in fluid. Air bubbles evolve from fluid and are caused by:
- Clogged suction filter.
- Items stuck in suction line.
- Kinked suction line.
- Collapsed hose liner.
- Suction line too small or too long, etc.
- Clogged reservoir breather.

Fluid aeration or excessive air in fluid is caused by:
- Low fluid level.
- Leaking fittings in suction line.
- Leaking seals somewhere in system allowing air to enter.
- Installing new components without filling them with fluid.
- Foaming in tank, etc.

Effects of Pump Cavitation

Excessive pump noise. Excessive pump wear due to bubbles and cavities imploding and damaging pump components.

System contamination due to debris from pump component damage.

Common Causes of Pump Failure


Shearing shafts, when excessive system pressure causes the pump mechanism to stall. Clogged or kinked case drain lines. Abuse and incorrect operating procedures. An example is excessive pressures or speeds.
**Pump Symbols**

**READY FOR REVIEW**

- Fixed displacement.
- Variable displacement.
- Bidirectional fixed.
- Bidirectional variable.
- Pressure compensated.

**Types of Pump Systems**

**READY FOR REVIEW**

- Open loop systems.
  - Fluid picked up from reservoir by pump.
  - Circulates through system.
  - Returns to reservoir.
  - Most common type of system.

- Closed loop system.
  - Fluid circulates from pump, through system, and returns directly to pump.
  - System may contain small makeup reservoir.
  - Typical of a hydrostatic system.

- Variable displacement pump or hydraulic motor.

**Testing Hydraulic Pumps**

**READY FOR REVIEW**

- No-load flow rate.
  - Run pump at full rpm with no resistance in test system.
  - Use flow meter to measure pump output.
  - Compare actual output to manufacturer's data.

- Flow/pressure profile.
  - Install load valve (flow control valve) and pressure gauge in test system.

- Closed loop system.
  - Fluid circulates from pump, through system, and returns directly to pump.
  - System may contain small makeup reservoir.
  - Typical of a hydrostatic system.

- Variable displacement pump or hydraulic motor.