Sept 2020

2. A centrifugal bilge pump has not been operating satisfactorily, the air pump was tested and found to be operating correctly.

List FIVE faults that could have caused the problem, stating why EACH fault causes poor operation. (10)

Question 2. All give reasons for pump performance deteriorating but many do not explain why the fault causes reduction in performance.

Here are five faults that could cause a centrifugal bilge pump to malfunction, assuming the air ejector (if present) and air line are functioning properly:

1. **Blocked Impeller:**
   - **Reason:** Debris or foreign objects can become lodged within the impeller, preventing it from spinning freely and reducing the pump's ability to move water.
2. **Worn Out Impeller:**
   - **Reason:** Over time, the impeller vanes can wear or become damaged, reducing their efficiency in pushing water. This can lead to a decrease in the pump's flow rate.
3. **Leaking Valve or Piping:**
   - **Reason:** Leaks on the suction or discharge side of the pump can significantly reduce its pumping capacity. Air entering the system through leaks can also hinder the pump's ability to move water efficiently.
4. **Faulty Electrical Supply:**
   - **Reason:** Insufficient voltage or amperage reaching the motor can cause it to run slowly or not at all, preventing the pump from operating effectively.
5. **Seized Pump Shaft:**
   - **Reason:** Corrosion, wear, or foreign objects can cause the pump shaft to seize or become stiff, preventing the impeller from rotating. This will completely halt the pump's operation.

In addition to these faults, a malfunctioning pressure switch or float switch could also prevent the pump from automatically turning on when the bilge water level rises. However, since the scenario specifies the pump not operating satisfactorily, these control components are less likely to be the root cause.

Feb 2021

Feb 2021

2. Describe, with the aid of a sketch, the operation of a gear pump. (10)

A gear pump utilizes meshing gears to transfer fluids in a positive displacement manner. Here's a breakdown of its operation:

Components:

- **Housing:** The main body of the pump that encloses all the internal components.
- **Gears:** Two interlocking gears, typically spur gears with identical profiles.
- **Inlet Port:** The opening where the fluid enters the pump chamber.

- **Outlet Port:** The opening where the pressurized fluid exits the pump.

Operation:

1. **Rotation:** The gears rotate in opposite directions, driven by a shaft or motor.
2. **Suction Creation:** As the gears rotate, the spaces between their teeth on the suction side increase in volume. This creates a low-pressure zone at the inlet port, drawing fluid into the pump chamber.
3. **Trapping Fluid:** The meshing of the gears at the center of the pump traps the fluid within the spaces between their teeth.
4. **Displacement and Pressure Build-Up:** Continued rotation forces the trapped fluid around the outside of the gears and towards the discharge port. The decreasing volume between the meshing teeth and the housing progressively increases the pressure of the trapped fluid.
5. **Discharge:** The high-pressure fluid is expelled from the pump through the discharge port.

Key Points:

- **Positive Displacement:** The fixed volume between the gears ensures a constant amount of fluid is delivered with each rotation, regardless of the discharge pressure.
- **Low Pressure Drop:** The design allows for smooth fluid flow within the pump chamber, minimizing internal pressure losses.
- **High Viscosity Fluids:** Gear pumps are well-suited for pumping viscous fluids due to their positive displacement nature and relatively low shear forces applied to the fluid.
- **Tight Clearances:** The clearances between the gears and the housing are minimal to ensure efficient pumping and prevent internal leakage.

Additional Notes:

- Depending on the design, some gear pumps may have crescent-shaped seals between the gears and the housing to further improve sealing and efficiency.
- Gear pumps can be bi-directional, meaning they can pump fluid in either direction depending on the direction of rotation of the gears.

I hope this explanation clarifies the operation of a gear pump!

May 2024

2. (a) Explain how cavitation damage occurs within a pump. 5 (6)

(b) State, with reasons, TWO operational causes of increased cavitation within a pump. 4 (4)

Nov 2021

Nov 2021

2. (a) Explain how cavitation damage occurs within a pump. (6)

(b) State, with reasons, TWO operational causes of increased cavitation within a pump. (4)

Question 2. Many still mentioning air bubbles, some even saying that boiling causes air bubbles to form. Hardly any make any reference to NPSH or vapour pressure.

Cavitation Damage in Pumps

(a) How Cavitation Damage Occurs:

Cavitation damage within a pump is a destructive process caused by the formation, growth, and collapse of vapor bubbles in the liquid being pumped. Here's a breakdown of the phenomenon:

1. **Pressure Drop:** As liquid flows through the pump, pressure decreases in specific areas, particularly at the inlet of the impeller or around the leading edges of the impeller vanes.
2. **Bubble Formation:** When the pressure drops below the liquid's vapor pressure at a specific temperature, dissolved gases and vapor pockets within the liquid begin to form small vapor bubbles.
3. **Bubble Growth:** As the low-pressure zone persists, the vapor bubbles expand in size.
4. **Bubble Collapse:** When the liquid flows to a higher pressure zone within the pump (e.g., discharge side of the impeller), the pressure on the bubbles rapidly increases. This causes the vapor bubbles to implode violently.
5. **Shockwaves and Erosion:** The rapid collapse of the bubbles generates intense shockwaves that travel through the liquid. These shockwaves can damage the pump components, particularly the impeller vanes and housing, by causing erosion, pitting, and material fatigue.

Over time, continuous cavitation can lead to significant wear and tear on the pump, reducing its efficiency, increasing noise and vibration, and potentially causing complete pump failure.

(b) Operational Causes of Increased Cavitation:

(i) Low Suction Pressure:

- **Reason:** If the pressure at the pump inlet (suction side) drops too low, it creates a larger pressure differential within the pump, promoting more extensive bubble formation and collapse. This can occur due to:
  - **Clogged inlet filter or piping:** Restrictions on the suction side increase resistance to flow, leading to a lower pressure at the pump inlet.
  - **Pumping from a deep sump:** The higher the suction lift (vertical distance between the pump and the liquid source), the lower the pressure at the pump inlet.
  - **Insufficient available NPSH (Net Positive Suction Head):** NPSH is a parameter that considers the available pressure head at the pump inlet and the vapor pressure of the liquid. If the available NPSH is lower than the pump's required NPSH, cavitation is more likely to occur.

(ii) High Operating Speed:

- **Reason:** Increasing the pump speed (RPM) can also exacerbate cavitation. At higher speeds, the pressure drop across the impeller vanes becomes more significant, creating conditions more favorable for bubble formation and collapse. This can happen due to:
  - **Operating the pump above its design speed:** Running the pump faster than recommended can lead to cavitation issues.
  - **Increased system demand requiring higher flow rates:** If the system demands a higher flow rate than the pump's design capacity, the pump might need to operate at a higher speed to compensate. This can increase the risk of cavitation.

Oct 2020

1. (a) Sketch a cross-section of a relief valve suitable for use with a fuel supply pump. (6)

(b) Describe the operation of the valve sketched in part (a). (4)

Relief Valve for Fuel Supply Pump: Cross-Section and Operation

(a) Cross-Section of a Relief Valve:

A relief valve suitable for a fuel supply pump is typically a **pilot-operated pressure relief valve**. Here's a breakdown of its key components in a cross-section:

- **Valve Body:** The main housing, typically made of brass or stainless steel for strength and corrosion resistance.
- **Main Valve:** A disc or poppet-shaped element that controls the flow path between the pump outlet and the bypass line. The main valve is spring-loaded to remain closed under normal operating pressure.
- **Spring Chamber:** The chamber containing the compression spring that holds the main valve shut.
- **Pilot Valve:** A smaller valve within the body that controls the pressure acting on the top side of the main valve piston.
- **Sensing Port:** A connection point on the body that allows fuel pressure from the pump discharge to reach the pilot valve chamber.
- **Bypass Port:** The connection point on the body that diverts excess fuel back to the pump inlet or fuel tank when the relief valve opens.
- **Adjustment Mechanism (optional):** An external screw or knob that allows for adjusting the spring compression in the spring chamber, thereby setting the cracking pressure (pressure at which the valve opens).

(b) Operation of the Relief Valve:

1. **Normal Operation:** During normal operation, the pump discharge pressure acts on the sensing port, pushing down on the pilot valve. The spring in the pilot valve chamber applies an opposing upward force. As long as the pump discharge pressure remains below the cracking pressure setting, the pilot valve remains closed. The main valve spring holds the main valve shut, keeping the flow path between the pump outlet and the system open.
2. **Pressure Increase:** If the pressure in the fuel system exceeds the cracking pressure setting due to a blocked filter, pump malfunction, or other factors, the force exerted by the discharge pressure on the pilot valve overcomes the spring force in the pilot valve chamber.
3. **Pilot Valve Opens:** The pilot valve opens, allowing fuel pressure to enter the top chamber above the main valve piston.
4. **Main Valve Opens:** The pressure acting on the top of the main valve piston overcomes the spring force holding it shut. The main valve lifts from its seat, opening a bypass flow path.
5. **Pressure Relief:** Excess fuel is diverted through the bypass port back to the pump inlet or fuel tank, preventing further pressure rise in the system.

6. **Pressure Drop and Reset:** When the pressure in the system drops below the cracking pressure, the pilot valve closes due to the spring force. The pressure above the main valve piston bleeds off, and the main valve spring again forces the main valve shut, stopping the bypass flow and re-establishing the normal flow path.

This pilot-operated design provides a more sensitive and controlled pressure relief mechanism compared to a simple spring-loaded relief valve.

Nov 2018 9th

Nov 2018 9th

2. (a) Sketch a vane type pump, labelling ALL components. (6)

(b) Explain the operation of the pump sketched in part (a). (4)

sept 2021

Sept 2021

2. (a) Sketch a vane type pump, labelling ALL components. (6)

(b) Explain the operation of the pump sketched in part (a). (4)

feb 2024

2. (a) Sketch a vane type pump, labelling ALL components. (6)

(b) Explain the operation of the pump sketched in part (a). (4)

Vane Pump: Components and Operation

(a) Components of a Vane Pump:

A vane pump is a positive displacement pump that utilizes sliding vanes within a rotor to move fluid. Here's a breakdown of its key components:

- **Housing:** The main body of the pump, typically made of cast iron or aluminum for strength and weight considerations.
- **Rotor:** A cylindrical or elliptical shaped rotor with slots machined along its circumference. The rotor is positioned eccentrically within the housing, meaning its center is not aligned with the center of the housing.
- **Vanes:** Flat, rectangular-shaped plates inserted into the slots of the rotor. The vanes are made from a wear-resistant material like spring steel or composite materials, and they slide freely within the slots. Spring mechanisms, centrifugal force, or a combination of both can be used to keep the vanes in contact with the housing wall.
- **Cam Ring (Optional):** In some vane pump designs, a circular inner lining within the housing surrounds the rotor. This cam ring provides a smooth surface for the vanes to slide against and can improve sealing efficiency.

- **Inlet Port:** The opening on the housing wall where fluid enters the pump chamber.
- **Outlet Port:** The opening on the housing wall where pressurized fluid exits the pump.

(b) Operation of a Vane Pump:

1. **Rotation:** The rotor is driven by a shaft or motor, causing it to rotate eccentrically within the housing.
2. **Vane Movement:** As the rotor rotates, the centrifugal force and/or spring mechanisms push the vanes outward, making them slide against the inner wall of the housing (or the cam ring, if present).
3. **Suction Creation:** The eccentric positioning of the rotor creates increasing volume spaces between adjacent vanes on the inlet side of the pump. This decrease in volume generates a low-pressure zone at the inlet port, drawing fluid into the pump chamber.
4. **Trapping Fluid:** The sliding vanes act as seals, trapping the fluid within the expanding chambers between them.
5. **Displacement and Pressure Build-Up:** Continued rotation forces the trapped fluid around the outside of the rotor and towards the outlet port. The decreasing volume between the vanes and the housing progressively increases the pressure of the trapped fluid.
6. **Discharge:** The high-pressure fluid is expelled from the pump through the outlet port.

Key Points:

- **Positive Displacement:** The fixed volume between the vanes and the housing ensures a constant amount of fluid is delivered with each rotation, regardless of the discharge pressure.
- **Self-Priming:** Vane pumps can be self-priming to a certain extent due to their ability to evacuate air from the inlet chamber.
- **Variable Flow:** Some vane pump designs allow for adjusting the angle of the vanes, enabling flow rate control.

This explanation provides a general overview of vane pump components and operation. Specific designs and functionalities may vary depending on the manufacturer and application.

Oct 2020

Oct 2020

2. Describe, with the aid of sketch, a system for priming a centrifugal pump using a priming pump driven from the centrifugal pump. (10)

Centrifugal Pump Priming System using a Self-Priming Driven Pump

Here's a description of a system for priming a centrifugal pump using a priming pump driven from the centrifugal pump itself:

Components:

- **Centrifugal Pump:** The main pump that needs to be primed.

- **Self-Priming Driven Pump:** A smaller pump, often a vane pump, designed to be self-priming. This pump will be driven by the shaft of the centrifugal pump.
- **Drive Mechanism:** A pulley or gear arrangement that connects the shaft of the centrifugal pump to the shaft of the driven pump. This ensures the driven pump operates whenever the main pump is running.
- **Check Valve (Optional):** A one-way valve installed on the discharge line of the driven pump.
- **Common Discharge Manifold:** A pipe connecting the discharge of the driven pump to the inlet of the centrifugal pump.
- **Vent Valve:** A valve installed on the highest point of the centrifugal pump casing to allow air to escape during priming.

Operation:

1. **Initial State:** The centrifugal pump is filled with air, and the vent valve is open.
2. **Start-Up:** The centrifugal pump is started. This simultaneously starts the driven pump due to the drive mechanism.
3. **Self-Priming of Driven Pump:** The self-priming driven pump utilizes its own design features (e.g., vanes, internal geometry) to evacuate air from its inlet and itself.
4. **Fluid Transfer:** The driven pump draws liquid from the suction source (e.g., reservoir, tank) and discharges it through the common discharge manifold.
5. **Centrifugal Pump Filling:** The liquid from the driven pump fills the casing of the centrifugal pump, displacing air through the open vent valve.
6. **Vent Valve Closure:** Once the centrifugal pump casing is filled with liquid and air is expelled, the vent valve is closed.
7. **Priming Complete:** With the centrifugal pump filled with liquid and the vent valve closed, the system is now primed, and the centrifugal pump can operate efficiently.

Optional Check Valve:

- A check valve installed on the discharge line of the driven pump can prevent backflow from the centrifugal pump into the driven pump when the centrifugal pump is not operating.

Benefits:

- **Simple and Reliable:** This system utilizes readily available components and is relatively simple to implement.
- **Automatic Operation:** The priming process is automatic as long as the centrifugal pump is running.
- **Reduced Manual Intervention:** Eliminates the need for a separate priming procedure or external source for priming.

Limitations:

- **Head Limitations:** The driven pump needs to have sufficient suction lift capability to draw liquid from the source and overcome any elevation difference.
- **Power Consumption:** Running the driven pump adds a small load to the centrifugal pump motor, increasing overall power consumption during priming.

Note: This is a general description, and specific implementations may vary depending on the pump sizes, system requirements, and safety considerations. Always refer to manufacturer's recommendations and safety protocols when working with pump systems.

Nov 2020

Nov 2020

2. (a) Describe, with the aid of sketches, the operating principles of a centrifugal pump. (7)

(b) State why centrifugal pumps are not self-priming. (3)

Question 2. Poor. Most mention kinetic energy but very few seem to know where the fluid gets the KE from. Nearly all state what priming is but fail to explain why a centrifugal pump is not self-priming, just stating that it can't displace air.

Centrifugal Pump Operation and Priming

(a) Operating Principles of a Centrifugal Pump:

Centrifugal pumps utilize the principle of rotary motion to convert mechanical energy into energy of fluid flow. Here's a breakdown of the key aspects:

1. **Components:**
    - **Impeller:** A rotating disc with curved vanes housed within a volute casing.
    - **Volute Casing:** A spiral-shaped chamber that surrounds the impeller and collects the pressurized fluid.
    - **Inlet Port:** The opening where fluid enters the pump casing.
    - **Outlet Port:** The opening where pressurized fluid exits the volute casing.
2. **Rotation:** The impeller is driven by a shaft connected to a motor or engine. As the impeller rotates, it spins the fluid within the casing.
3. **Centrifugal Force:** The rotation of the impeller imparts centrifugal force on the fluid particles. This force pushes the fluid outwards from the center of the impeller towards the periphery of the casing.
4. **Pressure Increase:** The volute casing design progressively converts the kinetic energy of the high-velocity fluid exiting the impeller vanes into pressure energy. The decreasing volume of the volute as it spirals outwards further contributes to the pressure rise.
5. **Discharge:** The high-pressure fluid is channeled through the volute casing and exits the pump through the outlet port.
6. **Continuous Flow:** As fluid is continuously discharged from the pump, a low-pressure zone is created at the inlet port. This pressure difference draws more fluid into the pump casing from the suction source, maintaining a continuous flow.

(b) Why Centrifugal Pumps are Not Self-Priming:

Centrifugal pumps are not self-priming for two main reasons:

1. **Air Pockets and Cavitation:** Centrifugal pumps rely on the presence of liquid within the casing to function effectively. Air pockets within the pump can hinder the transfer of centrifugal force to the fluid. Additionally, air pockets can cause cavitation, a phenomenon where the

pressure drops below the vapor pressure of the liquid, leading to the formation and collapse of vapor bubbles that can damage the pump impeller.

2. **Need for Initial Pressure Difference:** For the centrifugal force principle to work, there needs to be a pressure difference between the inlet and outlet of the pump. A centrifugal pump cannot create a vacuum to draw in liquid on its own. Therefore, the pump casing and suction line must be initially filled with liquid to establish this pressure difference and enable the pump to operate efficiently.

Nov 2023

2. With reference to positive displacement pumps:

   (a) explain the need for a relief valve, stating where it would be fitted; (5)

   (b) explain when a pulsation damper may be fitted to the delivery line, stating how it works. (5)

May 2021

May 2021

2. With reference to positive displacement pumps:

   (a) explain the need for a relief valve, stating where it would be fitted; (5)

   (b) explain when a pulsation damper may be fitted to the delivery line, stating how it works. (5)

Question 2. The question asks to explain why a relief valve is needed, it does not ask what a relief valve does or how it works. Just stating that a positive displacement pump can deliver high pressure is not an explanation. Just stating that the relief valve is on the delivery side of the pump is not specific enough.

Positive Displacement Pumps and Ancillary Equipment

(a) Relief Valve:

Need for a Relief Valve:

Positive displacement pumps deliver a constant volume of fluid with each rotation regardless of the discharge pressure. If the discharge pressure in the system exceeds the pump's design pressure due to a blocked outlet, closed valve, or other restriction, it can cause several problems:

- **Overload on Pump Components:** Excessive pressure can put undue stress on the pump's internal components like bearings, gears, or vanes, leading to premature wear and potential failure.
- **Pipe Rupture:** The high pressure can exceed the pressure rating of the piping system, leading to pipe bursts and potential safety hazards.
- **Pump Damage:** In extreme cases, very high pressure can cause permanent damage to the pump housing or internal components.

Placement of Relief Valve:

To prevent these issues, a **relief valve** is installed on the discharge line of a positive displacement pump. This valve acts as a safety mechanism by:

- **Sensing Pressure:** The relief valve continuously monitors the pressure in the discharge line.
- **Pressure Relief:** When the pressure exceeds a pre-set level (cracking pressure), the relief valve opens, bypassing a portion of the flow back to the pump inlet (internal bypass) or to a reservoir (external bypass).
- **Pressure Regulation:** By diverting excess flow, the relief valve helps to maintain the pressure within the system at a safe operating level.

Typical Location:

The relief valve is typically installed as close to the pump discharge port as possible to minimize the volume of the system exposed to excessive pressure in case of a pressure surge.

(b) Pulsation Damper:

Pulsation Damper Function:

Positive displacement pumps, due to their operating principle, can generate pulsating flow. This means the flow rate is not constant but varies with each rotation of the pump's internal element (gear, vane, piston, etc.). These pulsations can cause several problems in the piping system:

- **Vibration and Noise:** The pulsating flow can induce vibration in pipes and connected equipment, leading to increased noise levels and potential fatigue failure in components.
- **Pressure Spikes and Drops:** The rapid changes in flow rate can translate to pressure spikes and drops within the system, stressing components and potentially affecting the performance of pressure-sensitive equipment.

Pulsation Damper Operation:

A **pulsation damper** is a device installed on the discharge line of a positive displacement pump to mitigate these pulsations. It functions similarly to a shock absorber in a car:

- **Bladder or Diaphragm:** The pulsation damper typically contains a flexible bladder or diaphragm that separates two chambers - a gas chamber pre-charged with an inert gas (e.g., nitrogen) and a fluid chamber connected to the discharge line.
- **Energy Absorption:** During the high-flow phase of the pump cycle, the pulsating pressure in the fluid chamber compresses the gas in the gas chamber. The gas acts as a spring, absorbing the excess energy of the pulsating flow.
- **Energy Release:** During the low-flow phase of the pump cycle, the compressed gas in the gas chamber expands, pushing fluid back into the discharge line and smoothing out the pulsations in the flow rate.

Overall Effect: By absorbing and releasing the pulsating pressure, the pulsation damper helps to create a more steady and consistent flow of fluid within the system. This reduces vibration, noise, and pressure fluctuations, protecting components and improving overall system performance.

Note: The selection and sizing of a relief valve and pulsation damper depend on the specific pump characteristics, system pressure rating, and desired performance outcomes.

Nov 2018 2nd

Nov 2018 2nd

2. (a) Sketch a vane type pump, labelling ALL components. (6)

(b) Explain the operation of the pump sketched in part (a). (4)

Vane Pump: Components and Operation

(a) Components of a Vane Pump:

A vane pump is a positive displacement pump that utilizes sliding vanes within a rotor to move fluid. Here's a breakdown of its key components:

- **Housing:** The main body of the pump, typically made of cast iron or aluminum for strength and weight considerations.
- **Rotor:** A cylindrical or elliptical shaped rotor with slots machined along its circumference. The rotor is positioned eccentrically within the housing, meaning its center is not aligned with the center of the housing.
- **Vanes:** Flat, rectangular-shaped plates inserted into the slots of the rotor. The vanes are made from a wear-resistant material like spring steel or composite materials, and they slide freely within the slots. Spring mechanisms, centrifugal force, or a combination of both can be used to keep the vanes in contact with the housing wall.
- **Cam Ring (Optional):** In some vane pump designs, a circular inner lining within the housing surrounds the rotor. This cam ring provides a smooth surface for the vanes to slide against and can improve sealing efficiency.
- **Inlet Port:** The opening on the housing wall where fluid enters the pump chamber.
- **Outlet Port:** The opening on the housing wall where pressurized fluid exits the pump.

(b) Operation of a Vane Pump:

1. **Rotation:** The rotor is driven by a shaft or motor, causing it to rotate eccentrically within the housing.
2. **Vane Movement:** As the rotor rotates, the centrifugal force and/or spring mechanisms push the vanes outward, making them slide against the inner wall of the housing (or the cam ring, if present).
3. **Suction Creation:** The eccentric positioning of the rotor creates increasing volume spaces between adjacent vanes on the inlet side of the pump. This decrease in volume generates a low-pressure zone at the inlet port, drawing fluid into the pump chamber.
4. **Trapping Fluid:** The sliding vanes act as seals, trapping the fluid within the expanding chambers between them.
5. **Displacement and Pressure Build-Up:** Continued rotation forces the trapped fluid around the outside of the rotor and towards the outlet port. The decreasing volume between the vanes and the housing progressively increases the pressure of the trapped fluid.
6. **Discharge:** The high-pressure fluid is expelled from the pump through the outlet port.

Key Points:

- **Positive Displacement:** The fixed volume between the vanes and the housing ensures a constant amount of fluid is delivered with each rotation, regardless of the discharge pressure.
- **Self-Priming (to an extent):** Vane pumps can be self-priming to a certain extent due to their ability to evacuate air from the inlet chamber.
- **Variable Flow (in some designs):** Some vane pump designs allow for adjusting the angle of the vanes, enabling flow rate control.

Note: This explanation provides a general overview of vane pump components and operation. Specific designs and functionalities may vary depending on the manufacturer and application.

Sept 18th 2020

Sept (18th) 2020

2. With reference to positive displacement pumps:

(a) describe, with the aid of a sketch, the operation of a pulsation damper; (6)

(b) explain why some positive displacement pump types do not require pulsation dampers. (4)

Positive Displacement Pumps and Pulsation Dampers

(a) Pulsation Damper Operation:

Positive displacement pumps, due to their internal mechanics, can generate a pulsating flow. This means the flow rate is not constant but varies with each cycle of the pump's internal element (gear, vane, piston, etc.). A pulsation damper, installed on the discharge line, helps mitigate these pulsations. Here's how it works:

1. **Components:** A pulsation damper typically consists of a housing containing two chambers separated by a flexible bladder or diaphragm. One chamber is pre-charged with an inert gas (like nitrogen) and connected to the gas side of the bladder. The other chamber connects to the pump's discharge line and fills with fluid.
2. **Energy Absorption During High Flow:** During the high-flow phase of the pump cycle, the pulsating pressure in the fluid chamber pushes against the bladder, compressing the gas in the gas chamber. The compressed gas acts like a spring, absorbing the excess pressure and energy from the pulsating flow.
3. **Energy Release During Low Flow:** During the low-flow phase of the pump cycle, the compressed gas in the gas chamber expands. This pushes the bladder back, forcing fluid back into the discharge line and smoothing out the pulsations in the flow rate.

(b) Why Some Positive Displacement Pumps Don't Need Pulsation Dampers:

Not all positive displacement pumps require pulsation dampers. Here's why some types can operate without them:

- **Internal Design:** Certain pump designs inherently produce minimal flow pulsations. For example, some **multi-vane pumps** with a high number of vanes or **screw pumps** with overlapping helical rotors create a more continuous flow compared to pumps with fewer vanes or pistons.

- **Operating Speed:** Lower operating speeds generally result in less pronounced flow pulsations. If a pump operates at a relatively slow speed and the system pressure fluctuations are tolerable, a pulsation damper might not be necessary.
- **System Characteristics:** The overall system characteristics can influence the need for a pulsation damper. If the piping system has a large volume or includes components like accumulators that help dampen pressure fluctuations, the pulsations might be sufficiently mitigated without a dedicated damper.

However, factors like:

- **High Operating Speed:** Increased pump speed often leads to more significant flow pulsations.
- **Low System Volume:** Systems with limited volume have less capacity to absorb pressure variations.
- **Sensitive Equipment:** If the system includes pressure-sensitive equipment susceptible to pulsations, a damper might be necessary.

In conclusion: The decision to use a pulsation damper depends on the specific pump type, operating speed, system characteristics, and desired performance outcomes. When pulsations are a concern, consulting with a pump expert to determine the appropriate solution is recommended.

Aug 2023

2. Describe, with the aid of a sketch, the operation of a double acting, piston type positive displacement pump. (10)

April 2021

April 2021

2. Describe, with the aid of a sketch, the operation of a double acting, piston type positive displacement pump. (10)

Double-Acting Piston Pump Operation

A double-acting piston pump utilizes a reciprocating piston within a cylinder to create a positive displacement flow of fluid. Here's a breakdown of its operation:

Components:

- **Housing:** The main body of the pump, typically made of cast iron or steel for strength.
- **Cylinder:** A cylindrical chamber within the housing where the piston reciprocates.
- **Piston:** A tightly fitting cylindrical plunger that moves back and forth within the cylinder.
- **Piston Rod:** A rod connected to the piston, extending out of the cylinder to connect to the driving mechanism.
- **Inlet Valves:** One-way check valves located at each end of the cylinder, allowing fluid to enter but not flow back. These valves are typically located on the cylinder head and crankcase.

- **Outlet Valves:** One-way check valves located at each end of the cylinder, allowing fluid to exit but not flow back. These valves are typically located on the discharge manifold.
- **Discharge Manifold:** A chamber that collects the pressurized fluid from both sides of the piston and directs it out of the pump.
- **Driving Mechanism:** A crankshaft, connecting rod, or other mechanism that converts rotary motion into reciprocating motion for the piston rod.

Operation:

1. **Inlet Stroke:**
    - **Piston Movement:** The driving mechanism pushes the piston rod forward, causing the piston to move towards the opposite end of the cylinder.
    - **Inlet Valve Operation:** The inlet valve on the forward end of the cylinder (crankcase side) opens, allowing fluid to enter the chamber in front of the piston. The inlet valve on the opposite end (cylinder head side) remains closed due to the pressure of the existing fluid in that chamber.
    - **Suction Creation:** The movement of the piston creates a decreasing volume in the front chamber, generating a low-pressure zone. This low pressure draws fluid into the cylinder through the open inlet valve.
2. **Outlet Stroke:**
    - **Piston Movement:** The driving mechanism changes direction, pulling the piston rod back, causing the piston to move towards its original position.
    - **Outlet Valve Operation:** The inlet valve on the forward end of the cylinder closes as the pressure in that chamber increases. The outlet valve on the opposite end (cylinder head side) opens due to the pressure of the trapped fluid behind the piston exceeding the discharge pressure.
    - **Displacement and Discharge:** The movement of the piston back towards its original position reduces the volume in the chamber behind the piston. This pressurizes the trapped fluid, forcing it to flow through the open outlet valve on the cylinder head side and into the discharge manifold.
3. **Continuous Flow:** The continuous back-and-forth motion of the piston creates a continuous flow of fluid into one side of the cylinder while simultaneously discharging pressurized fluid from the other side. The inlet and outlet valves ensure unidirectional flow during each stroke.

Key Points:

- **Double Acting:** The pump utilizes both the forward (inlet) and return (outlet) strokes of the piston to move fluid, resulting in a higher flow rate compared to single-acting piston pumps.
- **Positive Displacement:** The fixed volume between the piston and the cylinder ensures a constant amount of fluid is delivered with each cycle, regardless of the discharge pressure.
- **High-Pressure Capability:** Double-acting piston pumps can achieve high discharge pressures due to the balanced forces acting on the piston.

Note: This explanation provides a general overview of double-acting piston pump operation. Specific designs and functionalities may vary depending on the manufacturer and application. Some pumps might utilize different valve configurations or additional components for specific purposes.

Feb 19th 2021

2. With reference to a centrifugal pump/motor set:

(a) state FIVE indications that a fault has occurred; (5)

(b) state a possible cause of EACH fault stated in part (a). (5)

Centrifugal Pump/Motor Set Faults: Indications and Causes

(a) Five Indications of a Fault:

1. **Reduced Flow Rate:** The pump delivers a noticeably lower flow rate than expected at the system's operating pressure.
2. **Increased Vibration:** The pump and/or motor vibrate excessively during operation.
3. **Unusual Noises:** Abnormal noises like grinding, rattling, or cavitation sounds are heard from the pump or motor.
4. **Loss of Prime:** The pump loses its prime and fails to deliver any fluid, even after attempting to reprime.
5. **Overheating:** The pump motor or bearings experience excessive temperature rise during operation.

(b) Possible Causes for Each Fault:

1. **Reduced Flow Rate:**
   - Cause: Clogged impeller, worn-out wear ring or casing, blocked suction or discharge line, incorrect pump selection for the application (insufficient capacity).
2. **Increased Vibration:**
   - Cause: Bent shaft, worn bearings, loose coupling between pump and motor, cavitation due to insufficient NPSH (Net Positive Suction Head) available, foreign object lodged within the pump.
3. **Unusual Noises:**
   - Cause: Cavitation, worn bearings, damaged gears (if gear-driven pump), loose components within the pump, air leak in the suction line.
4. **Loss of Prime:**
   - Cause: Air leak in the suction line, faulty check valve on the suction side not holding pressure, insufficient liquid level in the suction reservoir.
5. **Overheating:**
   - Cause: Running the pump dry (no liquid to cool it), excessive load on the motor due to high system pressure or blocked discharge, malfunctioning bearings causing friction, failing motor windings.

Note: These are just some possible causes, and the actual cause of a fault can vary depending on the specific pump/motor set and operating conditions. Consulting a qualified pump technician is recommended for proper diagnosis and repair of any faults.

July 2021

2. (a) State FOUR types of pumps suitable for use in a hydraulic system. (4)

(b) Explain why the pumps stated in part (a) are suitable for hydraulic systems. (6)

Pumps for Hydraulic Systems: Types and Suitability

(a) Four Types of Pumps Suitable for Hydraulic Systems:

1. **Gear Pump:**
   - This positive displacement pump utilizes meshing gears to trap and move fluid.
   - **Suitability:** Gear pumps offer high efficiency, simple design, and good reliability at moderate pressures. They are a popular choice for hydraulic systems due to their affordability and robustness.
2. **Piston Pump:**
   - This positive displacement pump uses a reciprocating piston within a cylinder to create high-pressure fluid flow.
   - **Suitability:** Piston pumps can achieve very high pressures, making them suitable for demanding hydraulic applications requiring precise control. They offer good efficiency and can be single or double-acting for higher flow rates.
3. **Vane Pump:**
   - This positive displacement pump utilizes sliding vanes within a rotor to move fluid.
   - **Suitability:** Vane pumps offer a good balance between pressure and flow capabilities, along with a relatively simple design. They are compact, efficient, and can be self-priming to a certain extent, making them suitable for various hydraulic applications.
4. **Axial Piston Pump:**
   - This positive displacement pump uses pistons arranged around a swashplate to create high-pressure fluid flow. The angle of the swashplate determines the pump displacement and flow rate.
   - **Suitability:** Axial piston pumps offer excellent flow control and high efficiency. Their ability to vary flow rate makes them suitable for hydraulic systems requiring precise control and variable power demands.

(b) Why These Pumps are Suitable for Hydraulic Systems:

Hydraulic systems require pumps that can deliver a **controlled flow of fluid** at a **specific pressure**. The pumps listed above share key characteristics that make them well-suited for this purpose:

- **Positive Displacement:** These pumps deliver a constant volume of fluid with each cycle, regardless of the discharge pressure. This ensures consistent performance and predictable flow within the hydraulic system.
- **Pressure Capability:** All these pumps can generate sufficient pressure to operate hydraulic actuators and overcome system resistance. Gear pumps are suitable for moderate pressures, while piston pumps excel at very high pressures.
- **Efficiency:** These pumps convert a significant portion of the input mechanical power into hydraulic power, minimizing energy losses.

- **Controllability:** Some pumps, like axial piston pumps with variable swashplate designs, offer good control over flow rate, which is crucial for precise positioning of hydraulic actuators.
- **Durability:** Hydraulic pumps are designed to withstand the demanding operating conditions of hydraulic systems, including high pressures and constant use.

The specific choice of pump for a hydraulic system depends on factors like required pressure, flow rate, desired controllability, system size, and budget.

March 19th 2021

March 19th 2021

2. With reference to centrifugal pumps:

(a) explain why it is common practice to start with the discharge valve closed or throttled; (4)

(b) explain why the delivery valve must not be left closed after starting; (3)

(c) state why it is not always necessary to fit a relief valve. (3)

Centrifugal Pump Operation and Valve Considerations

(a) Starting with Closed or Throttled Discharge Valve:

It's common practice to start a centrifugal pump with the discharge valve closed or throttled for several reasons:

- **Reduced Starting Load:** When the discharge valve is closed, the pump initially operates against minimal resistance. This reduces the starting torque required by the motor, minimizing strain on the motor and electrical system.
- **Reduced Risk of Cavitation:** A closed discharge valve reduces the flow rate through the pump during startup. This can help prevent cavitation, a phenomenon where bubbles form and collapse due to low pressure at the pump inlet, potentially damaging the impeller.
- **Safer System Startup:** A closed discharge valve allows for a controlled system startup. The pump can be brought up to speed gradually, allowing for any trapped air to purge from the system before full pressure is established.

(b) Not Leaving Discharge Valve Closed After Starting:

Leaving the discharge valve closed after starting the pump can have detrimental effects:

- **Overheating:** With no flow through the pump, the liquid inside the casing cannot circulate and absorb heat generated by the motor and bearings. This can lead to overheating and potential damage to the pump components.
- **Excessive Pressure Build-Up:** If the discharge valve remains closed for an extended period, the pump continues to deliver fluid, leading to a rapid pressure build-up within the system. This can exceed the pressure rating of the pipes or equipment, potentially causing leaks or ruptures.
- **Pump Damage:** In extreme cases, excessive pressure due to a closed discharge valve can lead to mechanical damage to the pump housing or internal components.

(c) Why Relief Valve Might Not Be Necessary:

While relief valves are crucial for positive displacement pumps, they might not always be necessary for centrifugal pumps. Here's why:

- **Self-Limiting Flow:** Centrifugal pumps are not positive displacement pumps. Their flow rate is not constant but increases with increasing discharge pressure. As the discharge pressure rises due to a closed valve, the flow rate through the pump naturally decreases.
- **System Relief Measures:** Some systems might already have pressure relief valves or safety devices installed elsewhere in the piping system. These can act as a safeguard against excessive pressure build-up in case of a closed discharge valve.
- **Application Considerations:** For applications with low-pressure requirements and limited risk of system overpressure, a relief valve might be deemed unnecessary.

However, there are situations where a relief valve is still recommended for centrifugal pumps:

- **High-Pressure Systems:** In systems with high operating pressures, a relief valve provides an extra layer of safety by protecting the pump and piping from exceeding their pressure limitations.
- **Dead-End Systems:** If the discharge line terminates in a dead-end with no pressure relief path, a relief valve on the pump itself is essential to prevent excessive pressure build-up.
- **Variable Speed Pumps:** For pumps with variable speed drives, a relief valve is important to safeguard against unexpected pressure surges in case of control system malfunctions.

Ultimately, the decision to include a relief valve in a centrifugal pump system depends on a risk assessment considering factors like system pressure, potential for closed discharge scenarios, and the presence of other safety measures.

March 26th 2021

March 26th 2021

2. With reference to centrifugal pumps used for bilge/ballast purposes:

   (a) explain the specific problems which may arise using the pumps for these purposes; (4)

   (b) explain TWO methods used to improve pump performance when used for these purposes. (6)

Centrifugal Pumps for Bilge and Ballast Duties: Challenges and Solutions

(a) Specific Problems Using Centrifugal Pumps for Bilge/Ballast:

While centrifugal pumps are widely used for bilge and ballast purposes, they encounter specific challenges in these applications:

- **Debris Handling:** Bilge water can contain debris like rags, plastic, or other objects. Centrifugal pumps with enclosed impellers can clog easily when encountering such debris, hindering their ability to pump effectively.

- **Air Entrapment:** During bilge pumping, air can become entrapped in the volute casing or around the impeller. This air can hinder pump performance by reducing the amount of liquid being moved (air pockets occupy space meant for water) and can also lead to cavitation.
- **Self-Priming:** Centrifugal pumps typically require priming (filling the casing with liquid) before they can operate efficiently. This can be inconvenient or impractical in bilge applications where the water level might be low initially.

(b) Two Methods to Improve Pump Performance:

Here are two methods used to address these challenges and improve the performance of centrifugal pumps for bilge and ballast duties:

1. **Vortex Impeller Pumps:**
- **Design:** These pumps utilize a specifically designed impeller with a large open passage. This open design allows for better passage of solids and debris compared to enclosed impellers, reducing the risk of clogging.
- **Bilge Applications:** Vortex impellers are well-suited for bilge pumping due to their ability to handle debris. They can also help evacuate air trapped within the bilge water.
2. **Submersible Bilge Pumps:**
- **Placement:** These pumps are designed to be completely submerged within the bilge well. This allows them to operate even with low water levels, eliminating the need for priming.
- **Automatic Operation:** Submersible bilge pumps often incorporate automatic float switches that activate the pump when the water level rises above a certain point and turn it off when the level falls below a set point. This automatic operation simplifies bilge pumping and ensures continuous operation until the bilge is dry.

Additional Considerations:

- **Material Selection:** Bilge pumps are often constructed with corrosion-resistant materials like stainless steel or composite materials to withstand the harsh environment within the bilge well.
- **Pump Sizing:** Selecting the appropriate pump size for the bilge volume and desired pumping rate is crucial for effective bilge dewatering.

By implementing these solutions, centrifugal pumps can be adapted for bilge and ballast purposes, providing reliable and efficient operation for critical onboard operations.

May 28th 2021

May 28th 2021

2. (a) Explain how cavitation damage occurs within a pump. (6)

(b) State, with reasons, TWO operational causes of increased cavitation within a pump. (4)

Cavitation Damage in Centrifugal Pumps

(a) How Cavitation Damage Occurs:

Cavitation damage in a centrifugal pump occurs due to the formation, growth, and violent collapse of vapor bubbles within the liquid flowing through the pump. Here's the breakdown of the process:

1. **Pressure Drop:** As liquid flows through the pump, the pressure decreases in specific areas, particularly around the low-pressure region near the impeller inlet.
2. **Bubble Formation:** If the pressure drops below the liquid's vapor pressure at a given temperature, dissolved gases and vapor pockets within the liquid begin to form vapor bubbles.
3. **Bubble Growth:** As the liquid continues to flow into the low-pressure region, the existing vapor bubbles expand in size.
4. **Bubble Collapse:** When the bubbles move to a region of higher pressure (typically near the discharge side of the impeller vanes), the surrounding pressure rapidly increases. This sudden pressure rise causes the vapor bubbles to violently collapse.
5. **Shockwave Generation:** The rapid collapse of the bubbles generates intense shockwaves within the liquid. These shockwaves are highly destructive and can cause significant damage to the pump components.

(b) Two Operational Causes of Increased Cavitation:

1. **Low Net Positive Suction Head (NPSH):**
    - **Reason:** NPSH is a critical parameter that represents the available energy (pressure head) at the pump inlet above the vapor pressure of the liquid. A low NPSH indicates insufficient pressure head at the pump inlet, making it easier for cavitation to occur.
    - **Increased Cavitation:** Operating the pump with a NPSH below the pump's Minimum Required NPSH (NPSHr) creates ideal conditions for bubble formation and collapse, leading to increased cavitation damage.
2. **High Flow Rate:**
    - **Reason:** Increased flow rate through the pump can lead to a pressure drop at the pump inlet due to frictional losses within the suction line. This decrease in pressure can bring the local pressure closer to the vapor pressure, promoting bubble formation.
    - **Increased Cavitation:** Operating the pump at flow rates exceeding its design capacity can contribute to cavitation, especially if the NPSH available is already marginal.

Additional Factors:

- **High Liquid Temperature:** Higher temperatures elevate the vapor pressure of the liquid, making it easier for cavitation to occur at a given pressure head.
- **Impeller Design:** The specific design of the impeller can influence cavitation susceptibility. Impellers with sharp corners or sudden changes in flow direction can create localized pressure drops that promote bubble formation.