Nov 2021

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   (b) state where they would be fitted; (2)

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Nov 2021

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

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Nov 2021

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Nov 2021

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Nov 2021

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Nov 2021

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   (a) describe, with the aid of a sketch, the tightening procedure; (7)

   (b) state how it is determined that the push fit is complete. (3)

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   (a) state THREE necessary parameters that must be checked before connecting to the vessel's distribution system; (3)

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Question 1. Mainly well answered. Candidates loose marks by not how the valve closes after it has been tripped.

Tank Quick Closing Valves: Remote Actuation and Purpose

(a) Remote Actuation Methods:

1. **Hydraulic or Pneumatic Activation:** This method utilizes pressurized fluid (hydraulic) or compressed air (pneumatic) for remote closure. An activation signal triggers the release of pressurized air/fluid, pushing a piston within the valve to shut it rapidly.
2. **Solenoid Actuation:** An electrical signal energizes a solenoid, which in turn operates a mechanism to close the valve quickly. This method is often used in conjunction with a control panel for remote activation.

(b) Where They Are Fitted:

Quick closing valves are strategically placed on the **outlet lines** of tanks containing flammable or hazardous liquids, typically in:

- **Fuel oil tanks** within engine rooms, boiler rooms, or near emergency generators.
- Tanks storing other flammable liquids in industrial settings.

(c) Why They Are Fitted:

These valves are crucial safety features for several reasons:

- **Emergency Shut-Off:** In critical situations like fire, the valve can be shut remotely to stop the flow of flammable liquids, potentially preventing the fire from spreading or intensifying.
- **Leak Isolation:** If a leak or tank rupture occurs, the valve can be quickly closed to isolate the issue and minimize the amount of liquid released.
- **Remote Operation:** Emergencies can render the tank area inaccessible. Remote operation allows for safe closure of the flow from a safe location away from the hazard.

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Nov 2021

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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.

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3. (a) Sketch a starting air reservoir, labelling ALL mountings. (8)

(b) State TWO coatings that can be used to protect the interior surface of a large air reservoir against corrosion. (2)

Question 3. Well answered

Starting Air Reservoir and Corrosion Protection

(a) Starting Air Reservoir Mountings:

A starting air reservoir is a pressure vessel used to store compressed air for engine starting purposes. Here's a description of the typical mountings used for a starting air reservoir:

- **Saddle Supports:** These are the most common type of mounting. The reservoir rests on two or more cradles (saddles) welded or bolted to a solid foundation. The saddles distribute the weight of the reservoir evenly and provide stability.
- **Trunnion Mounts:** For larger or horizontal reservoirs, trunnion mounts might be used. Trunnions are cylindrical shafts welded to the ends of the reservoir that fit into bearing blocks on the support structure. This allows the reservoir to pivot slightly, accommodating thermal expansion and contraction.
- **Bracket Mounts:** In some cases, particularly for smaller reservoirs, brackets welded or bolted to the reservoir shell can be used to secure it directly to a wall or support structure.

Additional Considerations:

- **Anchor Bolts:** Regardless of the mounting type, the reservoir will likely be secured to the foundation using anchor bolts to prevent excessive movement or tipping due to forces exerted during pressurization or engine starting.
- **Vibration Isolation:** In some applications, vibration isolation pads or mounts might be placed between the reservoir and its supports to dampen vibrations transmitted to the surrounding structure.

(b) Coatings for Interior Corrosion Protection:

The interior surface of a large air reservoir is susceptible to corrosion due to moisture present in the compressed air. Here are two common coatings used for protection:

1. **Zinc Rich Epoxy:**
   - **Composition:** This coating consists of a zinc-rich primer with an epoxy resin topcoat. The zinc particles in the primer act as sacrificial anodes, corroding preferentially to protect the steel substrate. The epoxy topcoat provides additional protection against moisture and chemical attack.
   - **Benefits:** Zinc rich epoxy offers good adhesion, flexibility, and cathodic protection. It's a widely used and cost-effective solution for protecting air receiver interiors.
2. **Polyurethane:**
   - **Properties:** Polyurethane coatings are known for their excellent chemical resistance, abrasion resistance, and flexibility. They form a tough, impermeable barrier against moisture and corrosive elements.
   - **Applications:** Polyurethane coatings are a good choice for air receivers operating in harsh environments or where there might be exposure to contaminants in the compressed air.

Additional Considerations:

- **Surface Preparation:** The success of any coating system relies heavily on proper surface preparation. The interior surface of the air receiver needs to be thoroughly cleaned and blasted to remove rust, mill scale, and other contaminants before coating application.
- **Coating Selection:** The choice of the most suitable coating depends on factors like operating pressure, temperature, budget, and potential exposure to contaminants within the compressed air system. Consulting with a qualified coatings specialist is recommended for selecting the optimal coating solution.

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(b) explain why it is desirable to remove moisture from the air; (2)

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Question 4. Well answered by most

Air Compressors vs. Hydraulic Systems and Maintaining Clean Air

(a) Advantage and Disadvantage of Compressed Air vs. Hydraulic Systems:

- **Advantage: Clean and Environmentally Friendly:** Compressed air systems are generally cleaner and more environmentally friendly. Leaks pose less risk of environmental contamination compared to hydraulic fluid leaks.
- **Disadvantage: Lower Power Density:** For the same size actuator, compressed air systems can transmit less force compared to hydraulic systems due to the compressibility of air. Hydraulic systems are better suited for high-power applications.

(b) Importance of Removing Moisture from Compressed Air:

Moisture (water) in compressed air is undesirable for several reasons:

- **Corrosion:** Water can cause corrosion of metal components within the system, including pipes, valves, cylinders, and actuators. This can lead to sticking valves, reduced performance, and premature component failure.
- **Freezing:** In cold environments, moisture can freeze within the system, causing blockages and potentially damaging components due to pressure surges.
- **Reduced Efficiency:** Moisture can interfere with the lubrication properties of compressed air, leading to increased friction within moving parts. This reduces the overall efficiency of the system and shortens the lifespan of components.
- **Reduced Service Life of Components:** Water can erode seals and damage internal components of valves and actuators, leading to premature wear and tear.

Therefore, removing moisture from compressed air is crucial for reliable operation, efficient performance, and extended lifespan of the pneumatic control system.

(c) Importance of Limiting Oil Carry Over:

While some control systems utilize oil, limiting oil carry over in most pneumatic applications is desirable for these reasons:

- **Gumming:** Oil can build up on internal surfaces of valves, solenoids, and other components over time. This can cause them to stick or malfunction, hindering proper operation of the control system.
- **Contamination of Downstream Equipment:** Oil can contaminate downstream processes or products that are sensitive to oil contact. This can lead to product defects or safety hazards.
- **Compatibility Issues:** Certain materials used in control components might not be compatible with oil, leading to degradation or damage.

Therefore, minimizing oil carry over helps ensure smooth operation, prevent contamination of downstream equipment, and avoid compatibility issues with components.

(d) Methods for Maintaining Clean Air:

(i) Removing Moisture from Air:

Several methods can be employed to remove moisture from compressed air:

- **Refrigerated Air Dryers:** These dryers use refrigeration to cool the compressed air, causing moisture to condense and separate from the air stream. The condensate is then drained automatically.

- **Desiccant Air Dryers:** These dryers utilize desiccant materials that absorb moisture from the compressed air as it passes through. The desiccant is then regenerated by heat or purging with dry air.
- **Membrane Dryers:** These dryers use semi-permeable membranes that allow water vapor to pass through but not air. This separates the moisture from the compressed air stream.

(ii) Limiting Oil Carry Over:

Several methods can be used to limit oil carry over from lubricated compressors into the air stream:

- **Aftercoolers:** These heat exchangers cool the compressed air after leaving the compressor. This helps condense and separate oil vapors from the air stream.
- **Oil Separators:** These separators utilize baffles, filters, or centrifugal force to remove oil droplets from the compressed air stream.
- **Coalescing Filters:** These filters contain fine fibers that allow air to pass through but trap oil droplets due to surface tension. This helps coalesce the oil droplets into larger drops that can be drained from the filter.

By implementing these methods, compressed air systems can be equipped to deliver clean, dry, and oil-free air for optimal performance and longevity of pneumatic control systems.

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Nov 2021

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(a) sketch an arrangement of rams and tiller, including fittings; (6)

(b) explain why spherical bearings are required on the ram ends. (4)

Question 5. Most, not all, make a reasonable sketch but few can then relate the sketch, or use it, to show the need for spherical bearings.

Two-Ram Steering Gear with Spherical Bearings

(a) Arrangement of Rams and Tiller, Including Fittings:

A two-ram steering gear utilizes two hydraulic cylinders (rams) to control the movement of the rudder. Here's a breakdown of a typical arrangement, including fittings:

- **Rams:** The two rams are typically positioned symmetrically on either side of the vessel's centerline, often mounted on the hull structure. They consist of a cylinder body, piston rod, and end fittings.
- **Tiller:** The tiller is a lever arm attached to the rudder stock. It acts as the point where the rams apply their force to turn the rudder. The tiller can be a forged or fabricated steel structure designed to handle the forces exerted by the rams.

- **Ram End Fittings:** The piston rods of the rams connect to the tiller using suitable fittings. These fittings can vary depending on the design but typically involve:
    - **Clevises:** U-shaped yokes with a pin connecting them to the tiller. The clevis allows some angular movement at the connection point.
    - **Fork Heads:** A forked end on the piston rod that connects directly to a pin on the tiller.
    - **Trunnion Mounts:** In some cases, trunnion mounts might be used, where the piston rod is supported on a fixed pin on the tiller, allowing for some rotational movement.
- **Tie Bar (Optional):** In some configurations, a tie bar may connect the two piston rods at their ends to ensure they move in unison and distribute the load evenly across the rudder stock.

(b) Why Spherical Bearings are Required on Ram Ends:

Spherical bearings are essential on the ram ends connecting to the tiller for several reasons:

- **Angular Misalignment:** Ships experience flexing and torsional movements due to wave action and hull stresses. Spherical bearings allow for a small degree of angular misalignment between the ram and the tiller, accommodating these movements without binding or placing undue stress on the rams or tiller.
- **Self-Alignment:** Spherical bearings can automatically adjust to slight variations in alignment between the ram and the tiller, ensuring smooth and efficient force transfer.
- **Reduced Friction:** These bearings have a low coefficient of friction, minimizing friction losses at the connection point and maximizing the effectiveness of the hydraulic force.
- **Increased Load Capacity:** Spherical bearings can handle high radial and axial loads, making them suitable for the forces exerted by the rams.
- **Reduced Maintenance:** Compared to plain bearings, spherical bearings require minimal maintenance due to their enclosed design and self-lubricating properties (in some types).

Overall, spherical bearings provide flexibility, reduce friction, and handle high loads, making them crucial components for a reliable and efficient two-ram steering gear system.

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Nov 2021

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Maintaining Maneuverability and Actions in Case of Control System/Hydraulic Failure (Single CPP)

(a) Maintaining Maneuvering with Control System Failure:

Maintaining some level of maneuverability even with a control system failure in a single electro/hydraulic controllable pitch propeller (CPP) system depends on the available backup features:

- **Emergency Pitch Control System (Optional):**
  - Some CPP systems might have a secondary, non-hydraulic control system (electric, mechanical) for limited blade pitch adjustment. This allows the operator to potentially feather the blades (set them to a negative pitch angle) for minimal drag or even adjust them to a low forward thrust setting for basic maneuvering.
- **Manual Pitch Locking Mechanism (Optional):**
  - In some designs, a manual locking mechanism might be available. This allows the crew to secure the blades in a specific pitch position (usually feathered) using tools, even if the control system fails. This would eliminate drag and allow for some steering control with the rudder.
- **Rudder Control:**
  - The rudder remains functional even with control system failure. By skillfully using the rudder, the crew can maintain some degree of directional control, especially at lower speeds.

However, it's important to note that these are limited options, and maneuvering capability will be significantly reduced compared to normal operation.

(b) Action if Hydraulic System Fails and Blades Assume Zero Pitch:

If the hydraulic system fails completely and the blades go to zero pitch while underway, the following actions should be taken:

- **Stop Engine:** Immediately stop the main engine to prevent unnecessary wear and tear on the propeller and drivetrain components due to zero thrust generation.
- **Assess Situation:** Evaluate the vessel's position, surrounding traffic, and weather conditions. This helps determine the most appropriate course of action.
- **Alert Crew and Authorities:** Inform the crew of the situation and activate emergency procedures. Broadcast a distress signal (if necessary) to alert nearby vessels and coastal authorities of the situation and potential need for assistance.
- **Anchor Deployment (Optional):** If conditions allow and the water depth is suitable, consider deploying the anchor to help stabilize the vessel's position and prevent drifting.
- **Activate Backup Systems (if Available):** If the vessel has auxiliary propulsion systems like bow thrusters or stern thrusters, attempt to use them for limited maneuvering capabilities.
- **Prepare for Assistance:** Prepare to receive assistance from tugboats or other vessels if necessary.

Remember: The priority in this situation is to ensure the safety of the crew and vessel. By taking prompt action, maintaining communication, and utilizing available resources, the impact of the failure can be minimized while awaiting assistance.

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Nov 2021

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(a) describe, with the aid of a sketch, the tightening procedure; (7)

(b) state how it is determined that the push fit is complete. (3)

Question 7. Some sketches are very poor and show little understanding of the mode of operation of the coupling, this is then reflected in the answer. Many think that the separation oil is only for lubrication.

Main Propulsion Shaft Hydraulic Sleeve Type Couplings: Tightening and Push Fit

(a) Tightening Procedure:

Tightening a main propulsion shaft hydraulic sleeve coupling requires careful attention to ensure proper engagement and a secure fit. Here's a general outline of the procedure:

Preparation:

1. **Cleanliness:** Ensure the coupling components (shaft taper, inner sleeve bore) are clean and free of any debris or contaminants that could affect the fit.
2. **Lubrication (Optional):** Some designs might specify the use of a specific lubricant on the tapered surfaces to aid assembly and prevent fretting corrosion. Follow manufacturer's instructions for lubricant type and application.
3. **Positioning:** Carefully position the inner sleeve onto the shaft taper, ensuring proper alignment.

Tightening:

1. **Hydraulic Pressure Application (Primary Method):** Hydraulic sleeve couplings typically utilize hydraulic pressure to achieve the necessary force for a tight fit. This is achieved through a dedicated hydraulic system integrated into the coupling design.
   - The specific procedure will involve connecting the hydraulic system to the coupling and carefully applying controlled pressure according to the manufacturer's instructions.
   - Pressure gauges and predetermined pressure values are used to ensure the correct force is applied for proper engagement.
2. **Mechanical Tightening (Optional - Some Designs):** In some coupling designs, there might be additional mechanical fasteners (bolts, nuts) that require tightening after hydraulic pressure application. These fasteners further secure the coupling halves together. Tightening torque values and sequence should strictly follow manufacturer's specifications.

Important Notes:

- The specific tightening procedure will vary depending on the coupling design and manufacturer's instructions. Consulting the relevant manuals for detailed steps and safety precautions is crucial.
- It's essential to ensure the hydraulic system is functioning properly and free of leaks before applying pressure.
- During the tightening process, proper safety protocols should be followed to prevent injury from unexpected movement or high-pressure systems.

(b) Determining Push Fit Completion:

Verifying a complete push fit after tightening a hydraulic sleeve coupling is critical for ensuring a secure connection. Here are methods used to determine proper engagement:

1. Pressure Gauge Reading:

- In hydraulically actuated couplings, the pressure gauge used during tightening will typically provide a direct indication of successful engagement. Reaching the designated pressure value specified by the manufacturer indicates the proper force has been achieved for a secure fit.

2. Measurement and Tolerance Checks:

- After tightening, consult the coupling manufacturer's specifications for the required final dimensions of the assembled coupling (e.g., overall length, specific gap measurements).
- Use precision measuring tools (calipers, micrometers) to verify that the achieved dimensions fall within the specified tolerance range. This confirms proper engagement and interference between the shaft and the inner sleeve.

3. Factory-provided Tools (Optional):

- Some coupling manufacturers might provide specialized tools or gauges for verifying the push fit. These tools may measure displacement during the tightening process or utilize other parameters to indicate proper engagement.

4. Visual Inspection:

- While not the sole method, a thorough visual inspection can reveal any obvious gaps or misalignments between the coupling halves after tightening.

Overall:

A combination of these methods is typically used to ensure a complete and secure push fit after tightening a hydraulic sleeve coupling. Following manufacturer's instructions, monitoring pressure readings, and utilizing appropriate measurement tools are crucial for verifying successful assembly.

Nov 2021

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(b) State THREE checks which should be made before using the pump after the motor has been aligned. (3)

Question 8. Many do not explain how the alignment is checked – simply stating use dial indicator with a sketch of it in position is not enough. Some, not many, mention shims but none actually explain which shims would be adjusted to change the alignment or that angular misalignment can be in more than one plane.

(a) Aligning a New Motor with an Existing Pump

Aligning a new motor with an existing pump ensures the shafts of both machines are in proper alignment to minimize vibration, wear, and improve overall efficiency. Here's a breakdown of the process:

Preparation:

1. **Lockout and Tagout:** Implement proper lockout/tagout procedures to ensure safety and prevent accidental energization.
2. **Mounting:** Securely mount the new motor on the foundation or frame, following the manufacturer's instructions.
3. **Shaft Cleaning:** Clean the motor and pump shafts to remove any dirt or debris that could affect the alignment process.

Alignment Procedure (There are multiple methods, here's a common one):

1. **Dial Indicators:** Attach dial indicators to brackets on the pump and motor shafts. These indicators will measure any runout (wobble) or misalignment between the shafts.
2. **Shimming:** Loosen the motor mounting bolts slightly. Use shims (thin wedges of metal) placed strategically between the motor feet and the foundation to adjust the motor's position.
3. **Dial Gauge Readings:** By turning the shafts and observing the dial indicator readings, the technician can adjust the shims to minimize both horizontal and vertical misalignment between the shafts.
4. **Alignment Tolerances:** Tighten the motor mounting bolts to the specified torque values. Re-check the dial indicator readings to ensure they fall within the acceptable alignment tolerances specified by the pump and motor manufacturers.

Additional Techniques:

- **Laser Alignment:** In some cases, laser alignment tools might be used for a more precise alignment process. These systems project laser beams onto targets on the shafts and provide real-time data on misalignment.

Important Notes:

- The specific alignment procedure will vary depending on the type of pump, motor, and the chosen alignment method.
- Always follow the manufacturer's instructions for both the pump and motor regarding alignment procedures and acceptable tolerances.
- The process requires proper training and experience to ensure accurate alignment.

(b) Checks Before Using the Pump After Alignment

Before operating the pump after motor alignment, it's crucial to perform some final checks to ensure everything is in order:

1. **Recheck Alignment:** While unlikely, it's good practice to perform a final verification of the alignment after tightening the motor mounting bolts. This ensures any slight movement during tightening hasn't affected the alignment.
2. **Lubrication:** Verify that the pump is properly lubricated according to the manufacturer's recommendations. This includes checking oil levels (if applicable) and ensuring grease points are lubricated.
3. **Coupling Inspection:** Visually inspect the coupling between the motor and pump shaft for any signs of damage or wear. Ensure all coupling bolts are tightened to the specified torque values.
4. **Pipework:** Double-check that all piping connections to the pump are secure and free of leaks. Ensure proper venting of any air pockets within the piping system.
5. **Electrical Connections:** Verify that all electrical connections to the motor are secure and meet the required specifications.

By performing these checks before starting the pump, you can help ensure safe and reliable operation.

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Nov 2021

9. With reference to shore supplies:

(a) state THREE necessary parameters that must be checked before connecting to the vessel's distribution system; (3)

(b) explain the possible consequences of connecting an incorrect shore supply. (7)

Question 9. Several mention the parameters and then totally ignore them in part b. Many state what will occur but not the consequences – eg high current but not explaining that this will cause overheating and damage.

Shore Supply Connection: Safety Checks

(a) Three Necessary Parameters to Check:

Before connecting a shore supply to a vessel's electrical distribution system, it's crucial to verify the following three parameters to ensure compatibility and prevent potential damage:

1. **Voltage:** The shore supply voltage must match the rated voltage of the vessel's electrical system. Supplying a higher voltage can damage electrical equipment on board. Conversely, a lower voltage might not provide sufficient power for operation.
2. **Frequency:** The frequency of the shore supply (typically 50 Hz or 60 Hz) needs to be compatible with the frequency rating of the vessel's electrical system. Mismatched frequencies can cause malfunctioning of equipment and overheating.
3. **Phase Sequence:** For three-phase systems, the phase sequence (order in which the AC voltage peaks occur on each phase) of the shore supply must match the phase sequence of the vessel's system. An incorrect phase sequence can lead to serious damage to motors, generators, and other equipment.

Additional Checks (Recommended):

While not always mandatory, some additional checks can enhance safety and prevent issues:

- **Earthing Arrangement:** Verify that the earthing arrangements of the shore supply and the vessel are compatible. This ensures proper grounding and minimizes the risk of electrical shock.
- **Amperage Rating:** Check the shore supply's amperage rating and ensure it can provide sufficient current for the vessel's needs without overloading the shore supply or the vessel's internal distribution system.

(b) Consequences of Incorrect Shore Supply Connection:

Connecting an incorrect shore supply can have several negative consequences, ranging from minor inconveniences to severe damage:

- **Equipment Damage:** Supplying incorrect voltage or frequency can damage electrical equipment on board, leading to costly repairs or replacements.
- **Overheating:** Incorrect voltage or overloading can cause excessive heat generation in transformers, motors, and other components, potentially leading to fires or equipment failure.
- **Malfunction:** Mismatched frequency or phase sequence can cause electrical equipment to malfunction or operate erratically, compromising functionality and potentially posing safety risks.
- **Electrical Shock:** Improper earthing arrangements could increase the risk of electrical shock for personnel working on board the vessel.
- **System Shutdown:** In some cases, safety features might trigger a system shutdown to prevent damage if the shore supply parameters are out of range.

By carefully verifying the shore supply parameters and performing the necessary checks before connection, you can minimize the risk of these problems and ensure a safe and reliable electrical supply for the vessel.

Nov 2021

10. Describe the construction of a three phase induction motor of the caged rotor type. (10)

Question 10. The question is just asking for the features of the rotor and stator, many struggle with this, unable to even say that the rotor is supported in bearings in the covers. Many explain how a motor works rather than describe its construction.

A three-phase induction motor with a caged rotor, also known as a squirrel cage rotor, is a robust and widely used AC electric motor. Here's a breakdown of its construction:

Main Components:

- **Stator:** The stationary outer part of the motor that houses the magnetic field generating components.
- **Rotor:** The rotating inner part of the motor that converts electrical energy into mechanical energy.

Stator Construction:

1. **Stator Frame:** A rigid steel frame that supports and protects the stator core and windings.
2. **Stator Core:** Made of laminated electrical steel to minimize eddy current losses. The laminations are typically slotted to accommodate the stator windings.
3. **Stator Windings:** Three sets of insulated copper wires distributed around the stator core. These windings are connected to create a rotating magnetic field when supplied with three-phase AC power. The number of poles created by the windings depends on the winding configuration and the desired motor speed.

Rotor Construction (Squirrel Cage Rotor):

1. **Rotor Core:** Similar to the stator core, it's made of laminated electrical steel to minimize eddy current losses. The rotor core also has slots on its periphery.
2. **Rotor Bars:** Heavy copper or aluminum bars inserted into the rotor core slots. These bars are usually brazed or welded to end rings at both ends of the rotor. The end rings are also made of copper or aluminum and short-circuit all the rotor bars together.

Operating Principle:

1. When three-phase AC power is supplied to the stator windings, a rotating magnetic field is generated.
2. The rotating magnetic field induces an electric current in the rotor bars due to the principle of electromagnetic induction.
3. The induced current in the rotor bars interacts with the rotating magnetic field, creating a force that tries to rotate the rotor in the same direction as the magnetic field.
4. As the rotor starts to rotate, due to Lenz's Law, the induced current in the rotor bars tries to oppose the change in magnetic field. This creates a torque that keeps the rotor speed slightly less than the speed of the rotating magnetic field, a condition known as slip.

Advantages of Squirrel Cage Rotor:

- **Simple and robust construction:** The caged rotor design is very reliable and requires minimal maintenance.
- **Low cost:** Due to its simple design, squirrel cage rotors are generally less expensive to manufacture compared to wound rotor motors.
- **High starting torque:** The robust rotor construction allows for good starting torque capabilities.

Disadvantages of Squirrel Cage Rotor:

- **Limited speed control:** Squirrel cage motors typically have limited speed control options compared to wound rotor motors. Their speed is primarily determined by the supply frequency and the number of poles in the stator windings.
- **Lower efficiency at lower loads:** Squirrel cage motors might have lower efficiency when operating at partial loads.

This description provides a basic overview of the construction and operation of a three-phase induction motor with a caged rotor. The specific design details and materials used might vary depending on the motor's application and power rating.