

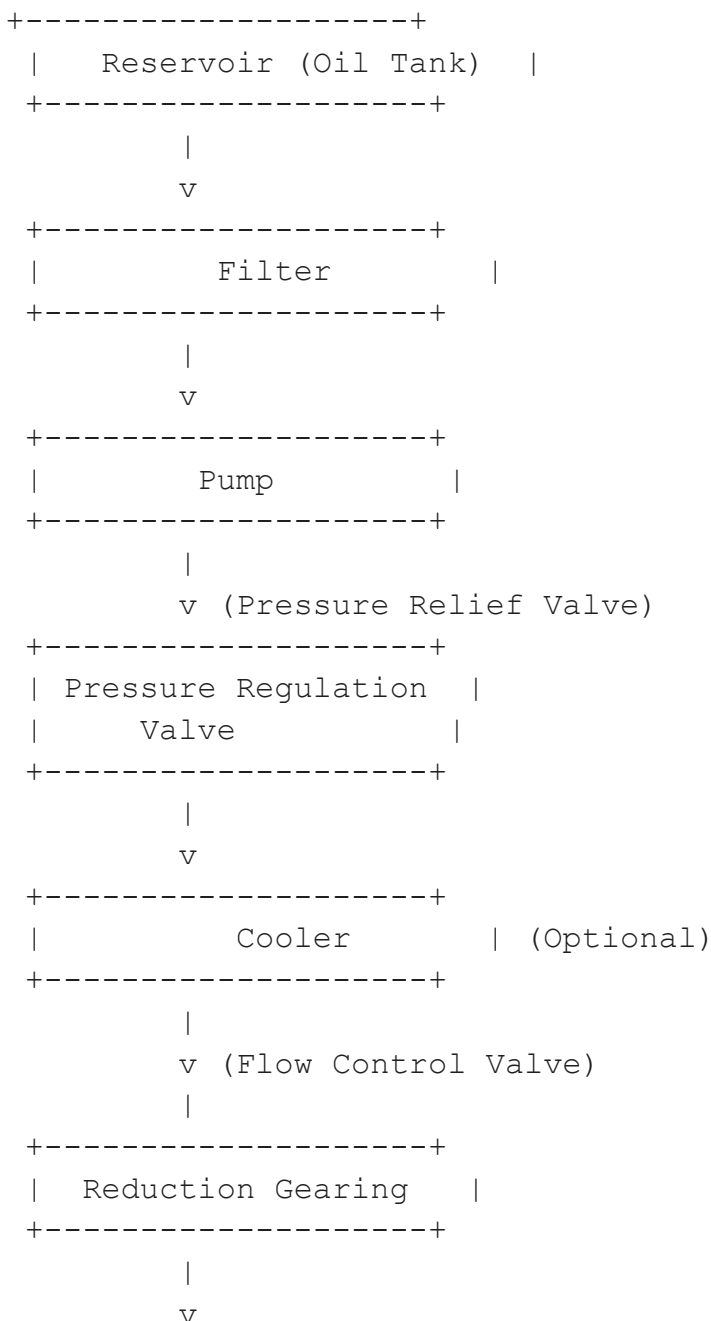
February 2021 MDE

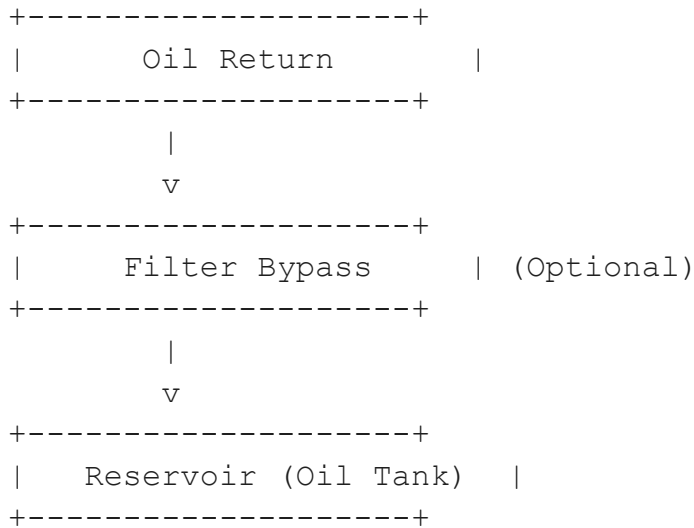
- 10. (a) Sketch a block diagram of a lubricating oil system suitable for use with a reduction gearing, including all the protective devices. (5)
- (b) State the engineering purpose/function of EACH item in the system sketched in part (a). (5)

Lubricating Oil System for Reduction Gearing: Block Diagram and Component Functions

(a) Lubricating Oil System Block Diagram:

Here's a block diagram of a lubricating oil system suitable for a reduction gearing system:





(b) Engineering Purpose/Function of Each Item:

1. **Reservoir (Oil Tank):** This tank stores the lubricating oil for the reduction gearing system. It provides a reserve of oil and allows for thermal expansion of the oil.
2. **Filter:** The filter removes contaminants like dirt, metal particles, and wear debris from the lubricating oil. This helps to protect the gears and bearings from wear and tear.
3. **Pump:** The pump draws oil from the reservoir and pressurizes it to circulate it throughout the system. Proper oil pressure is crucial for lubrication and heat transfer.
4. **Pressure Relief Valve:** This valve protects the system from excessive pressure build-up. If the pressure exceeds a pre-set limit, the valve opens, bypassing the oil back to the reservoir.
5. **Pressure Regulation Valve:** This valve regulates the oil pressure in the system, ensuring it stays within the desired range for optimal lubrication.
6. **Cooler (Optional):** In high-power or high-ambient temperature applications, an oil cooler may be used to remove heat from the oil before it is circulated back to the gears. This helps to maintain proper oil viscosity and prevent overheating.
6. **Flow Control Valve (Optional):** This valve can be used to regulate the flow of oil to specific areas of the reduction gearing, particularly if different components have varying lubrication requirements.
7. **Reduction Gearing:** This is the component being lubricated by the oil system. The oil is directed to critical areas like gear teeth and bearings to minimize friction and wear.
8. **Oil Return:** The used oil from the reduction gearing drains back to the reservoir through a return line.
9. **Filter Bypass (Optional):** This bypass valve allows unfiltered oil to circulate back to the reservoir in case the main filter becomes clogged. However, this is a safety feature to prevent system failure and should not be a normal operating condition.

This block diagram represents a typical oil system for reduction gearing. The specific components and their configurations can vary depending on the size, power rating, and operating conditions of the reduction gear unit.

October 2020 MDE

10. With reference to main reduction gearing:

- (a) explain why lubricating oil should be supplied before the gearing rotates; (4)
- (b) state the condition monitoring techniques that may be employed to assess the condition of the gearing. (6)

Main Reduction Gearing Lubrication and Condition Monitoring:

(a) Importance of Pre-Lubrication:

Supplying lubricating oil to the main reduction gearing before rotation is crucial for several reasons:

- **Minimizing Friction and Wear:** During initial startup, the metal surfaces of gears and bearings are in close contact. Without a lubricating oil film separating these surfaces, significant friction and wear can occur. Pre-lubrication ensures a protective oil film is present from the start, minimizing friction and wear during this critical period.
- **Improved Gear Mesh:** Oil acts as a slight wedge between gear teeth, promoting a more even load distribution and smoother gear mesh. Pre-lubrication ensures this oil film is present, allowing for smoother engagement and reduced gear tooth wear during the initial rotation.
- **Heat Transfer:** Gear operation generates heat due to friction. The lubricating oil plays a vital role in absorbing heat from the gears and bearings and transferring it to other components like the oil cooler (if present). Pre-lubrication ensures the oil is circulating and ready to effectively remove heat from the start, preventing overheating of the gears.
- **Protection from Corrosion:** Lubricating oil can also provide a layer of protection against corrosion on gear and bearing surfaces. Pre-lubrication ensures this protective layer is present before moisture or contaminants can come into contact with the metal surfaces.

In summary, pre-lubrication helps ensure smooth operation, minimizes wear, prevents overheating, and protects against corrosion during critical startup and initial rotation of the main reduction gearing.

(b) Condition Monitoring Techniques for Reduction Gearing:

Several condition monitoring techniques can be employed to assess the health and potential problems within the main reduction gearing:

- **Oil Analysis:** Regular oil analysis involves extracting a sample of lubricating oil and analyzing it for properties like viscosity, presence of wear debris (metal particles), and water contamination. Changes in these properties can indicate potential issues like gear wear, bearing wear, or water ingress into the system.
- **Vibration Analysis:** Monitoring vibrations of the reduction gearing using vibration sensors can reveal imbalances, misalignment, or gear tooth defects. By analyzing the frequency and amplitude of vibrations, potential problems can be identified before they cause major failures.
- **Temperature Monitoring:** Monitoring the operating temperature of the reduction gearing can indicate potential issues like overloading, lubrication problems, or excessive wear.
- **Ultrasonic Inspection:** In some cases, ultrasonic inspection techniques can be used to detect internal cracks or defects in gear teeth or bearings. This non-destructive testing method can help identify potential problems before they escalate.

- **Borescope Inspection:** A borescope, a small camera inserted into the gearbox, can be used to visually inspect gear teeth and bearings for signs of wear, pitting, or damage. This can be helpful in identifying specific problems within the gearing.

By implementing a combination of these condition monitoring techniques, engineers can gain valuable insights into the health of the main reduction gearing. This proactive approach allows for early detection of potential problems, enabling timely maintenance actions to be taken and preventing costly breakdowns.

Oct 2021

October 2021 MDE

10. With reference to reduction gears, state the advantages and disadvantages of EACH of the following:
 - (a) helical teeth compared with spur teeth; (5)
 - (b) double helix compared to single helix. (5)

oct 2023

October 2023 MDE

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 - (a) helical teeth compared with spur teeth; (5)
 - (b) double helix compared to single helix. (5)

Reduction Gears: Helical vs. Spur Teeth & Single vs. Double Helical

(a) Helical Teeth vs. Spur Teeth:

Helical Teeth (Advantages):

- **Smoother Operation:** The angled teeth of helical gears engage gradually, resulting in smoother meshing and quieter operation compared to spur gears with straight teeth.
- **Reduced Load:** The helical teeth transmit force along an oblique path, leading to a more even distribution of load across the tooth width compared to spur gears, which concentrate load at a single point of contact. This reduces stress on individual teeth and bearings.
- **Higher Load Capacity:** Due to the more even load distribution, helical gears can typically handle higher loads than spur gears of similar size.
- **Reduced Axial Thrust:** Helical teeth generate an axial thrust force along the shaft in addition to the rotational force. However, the opposing helix angle on the mating gear cancels out most of this thrust in properly designed helical gear sets.

Helical Teeth (Disadvantages):

- **Higher Manufacturing Cost:** The machining process for helical gears is more complex than for spur gears, making them slightly more expensive to manufacture.
- **Thrust Bearing Requirements:** The axial thrust force generated by helical gears necessitates the use of thrust bearings to accommodate this additional load.

Spur Teeth (Advantages):

- **Lower Manufacturing Cost:** Spur gears are simpler to manufacture compared to helical gears, making them a more cost-effective option.
- **No Axial Thrust:** Spur gears do not generate any axial thrust force, eliminating the need for additional thrust bearings.

Spur Teeth (Disadvantages):

- **Noisier Operation:** The abrupt engagement of straight teeth in spur gears results in higher noise levels compared to helical gears.
- **Higher Stress on Teeth:** The concentrated load at the point of contact in spur gears can lead to higher stress on individual teeth, potentially limiting load capacity.
- **Higher Vibration:** The abrupt engagement of spur teeth can also generate higher vibration levels compared to helical gears.

(b) Single Helical vs. Double Helical Gears:

Single Helical Gears (Advantages):

- **Simpler Design:** Single helical gears are simpler to design and manufacture compared to double helical gears.
- **Lower Cost:** Due to their simpler design, single helical gears are generally less expensive than double helical gears.

Single Helical Gears (Disadvantages):

- **Axial Thrust:** As mentioned earlier, single helical gears generate an axial thrust force that needs to be accommodated by thrust bearings. This can be a disadvantage in applications where space is limited for additional bearings.
- **Shaft Deflection:** The axial thrust force can cause some deflection in the shaft, which can be undesirable in high-precision applications.

Double Helical Gears (Advantages):

- **Balanced Axial Thrust:** Double helical gears have opposing helix angles on each gear, resulting in cancellation of the axial thrust forces within the gear set. This eliminates the need for separate thrust bearings and reduces shaft deflection.
- **Smoother Operation:** Double helical gears offer even smoother operation and quieter noise levels compared to single helical gears due to the balanced opposing forces.

Double Helical Gears (Disadvantages):

- **Higher Complexity:** The design and manufacturing process for double helical gears is more complex compared to single helical gears, leading to higher cost.
- **Increased Weight:** Double helical gears typically require slightly more material due to the additional gear teeth, resulting in increased weight compared to single helical gears.

In conclusion, the choice between helical and spur teeth, and single or double helical gears, depends on the specific application requirements. Helical gears offer smoother operation, higher load capacity, and quieter operation at the expense of higher cost and potential thrust bearing requirements. Double helical gears provide the advantage of balanced axial thrust but are more complex and expensive than single helical gears.

April 2023

April 2023 MDE

10. Explain why main reduction gearing uses oil sprayers for lubrication rather than rely on a wet sump and the gearing picking up oil as it rotates. (10)

Main reduction gearing typically utilizes oil sprayers for lubrication instead of a wet sump for several key reasons:

1. Improved Lubrication and Cooling:

- **Targeted Delivery:** Oil sprayers deliver a precise stream of oil directly onto the critical areas of the gears and bearings. This ensures proper lubrication and cooling where it's needed most, particularly in high-pressure contact zones between gear teeth. A wet sump system relies on the gears rotating through the oil to pick up lubrication, which may not be as efficient or targeted in high-speed applications.
- **Reduced Power Loss:** In a wet sump system, churning of oil by rotating gears can lead to parasitic power losses. Oil sprayers minimize this churning by delivering oil only where necessary.
- **Improved Heat Transfer:** Targeted oil sprayers can improve heat transfer from the gears and bearings by directly washing away hot oil and replacing it with cooler oil. This is crucial for maintaining optimal operating temperatures and preventing overheating.

2. Efficiency at High Speeds:

- **Oil Distribution:** At high rotation speeds, a wet sump system may struggle to distribute oil effectively throughout the gearcase due to centrifugal forces pushing the oil outward. Oil sprayers ensure a consistent and reliable supply of oil even at high speeds.
- **Reduced Windage:** A wet sump with a large oil reservoir can create significant windage losses as the rotating gears churn through the oil. Oil sprayers minimize this windage loss by using a smaller amount of oil delivered directly to the gears.

3. Application Suitability:

- **Space Constraints:** Main reduction gears are often used in applications with limited space. Oil sprayers require less space compared to a wet sump and a large oil reservoir.
- **Environmentally Friendly:** Oil sprayers typically use a smaller volume of oil compared to a wet sump system. This reduces the risk of oil leaks and simplifies oil changes, making it a more environmentally friendly option.

While wet sump lubrication is suitable for some applications, for high-speed, high-power main reduction gears, oil sprayers offer several advantages in terms of efficient lubrication, cooling, power savings, and space optimization.

May 2021 MDE

10. With reference to reduction gearing, explain EACH of the following:

- (a) the purpose of the magnetic filter in the lubricating oil system; (3)
- (b) why the surface finish of the gear teeth is important; (4)
- (c) why EP lubricating oil is preferred. (3)

a) Magnetic Filter:

The magnetic filter in the lubricating oil system of a reduction gear serves the purpose of removing ferrous wear debris from the oil. Here's how it works:

- **Magnetic Attraction:** The filter contains strong magnets that attract ferrous particles (made of iron or steel) suspended in the lubricating oil.
- **Contamination Capture:** As the oil flows through the filter, the ferrous wear debris is drawn towards the magnets and gets trapped on their surface.
- **Cleaner Oil:** By removing these ferrous particles, the magnetic filter helps to keep the lubricating oil cleaner and free from contaminants.

This cleaner oil offers several benefits:

- **Reduced Wear:** Abrasive wear caused by metal particles circulating in the oil is minimized.
- **Improved Gear and Bearing Life:** By reducing wear, the lifespan of gears and bearings is extended.
- **Protection from Scoring:** Large ferrous particles can cause scoring damage on gear teeth and bearing surfaces. The magnetic filter helps prevent this by removing these larger particles.

Magnetic filters are a simple and effective way to remove a specific type of contaminant (ferrous wear debris) from the lubricating oil in reduction gears. They are often used in conjunction with other filtration methods like full-flow filters that remove non-ferrous contaminants and other impurities.

(b) Importance of Gear Teeth Surface Finish:

The surface finish of gear teeth in reduction gearing is crucial for several reasons:

- **Reduced Friction:** A smooth surface finish minimizes friction between gear teeth as they mesh. This reduces power losses and improves overall efficiency.
- **Improved Load Distribution:** A smoother surface allows for more even load distribution across the tooth profile, reducing stress concentrations and minimizing wear.
- **Reduced Noise:** Rough surface finishes can lead to increased noise during gear operation. A smooth finish helps to minimize noise generation.
- **Enhanced Lubrication:** A smooth surface allows for better retention of lubricating oil film between gear teeth, improving lubrication effectiveness.

The specific surface finish requirements depend on factors like gear material, load rating, and operating speed. However, a well-honed or lapped surface finish is generally preferred for optimal performance and longevity of reduction gears.

(c) Preference for EP (Extreme Pressure) Lubricating Oil:

EP (Extreme Pressure) lubricating oils are preferred for reduction gearing due to the demanding operating conditions these components experience. Here's why:

- **High Pressure Contact:** Gear teeth in reduction gearing undergo high contact pressures during operation. EP oils contain special additives that activate under these high pressures.
- **Anti-Seizure Protection:** The EP additives form a thin film on the gear teeth under high pressure, preventing metal-to-metal contact and seizure. This protects the gear teeth from severe wear and potential damage.
- **Reduced Friction:** EP additives can also help to reduce friction between gear teeth under extreme pressure conditions.
- **Improved Load-Carrying Capacity:** EP oils can enhance the load-carrying capacity of the lubricating oil film, enabling the gears to handle higher loads without failure.

While EP oils offer these benefits, it's important to note that they can break down over time due to the activation of the EP additives under pressure. Therefore, regular oil changes are essential to maintain the effectiveness of EP lubrication and protect the reduction gearing.

April 2022

April 2022 MDE

10. With reference to main reduction gearing:

- (a) explain why lubricating oil should be supplied before the gearing rotates; (4)
- (b) state the condition monitoring techniques that may be employed to assess the condition of the gearing. (6)

I'd be glad to address the prompt regarding lubrication and condition monitoring of main reduction gearing:

Importance of Pre-Lubrication:

Supplying lubricating oil to the main reduction gearing before rotation is critical for several reasons:

- **Minimizing Friction and Wear:** During initial startup, metal surfaces of gears and bearings are in close contact. Without a lubricating oil film separating them, significant friction and wear can occur. Pre-lubrication ensures a protective oil film is present from the start, minimizing friction and wear during this critical period.
- **Improved Gear Mesh:** Oil acts as a slight wedge between gear teeth, promoting a more even load distribution and smoother gear mesh. Pre-lubrication ensures this oil film is present, allowing for smoother engagement and reduced gear tooth wear during the initial rotation.
- **Heat Transfer:** Gear operation generates heat due to friction. The lubricating oil plays a vital role in absorbing heat from the gears and bearings and transferring it to other components like the oil cooler (if present). Pre-lubrication ensures the oil is circulating and ready to effectively remove heat from the start, preventing overheating of the gears.
- **Protection from Corrosion:** Lubricating oil can also provide a layer of protection against corrosion on gear and bearing surfaces. Pre-lubrication ensures this protective layer is present before moisture or contaminants can come into contact with the metal surfaces.

Condition Monitoring Techniques:

Several condition monitoring techniques can be employed to assess the health and potential problems within the main reduction gearing:

- **Oil Analysis:** Regular oil analysis involves extracting a sample of lubricating oil and analyzing it for properties like viscosity, presence of wear debris (metal particles), and water contamination. Changes in these properties can indicate potential issues like gear wear, bearing wear, or water ingress into the system.
- **Vibration Analysis:** Monitoring vibrations of the reduction gearing using vibration sensors can reveal imbalances, misalignment, or gear tooth defects. By analyzing the frequency and amplitude of vibrations, potential problems can be identified before they cause major failures.
- **Temperature Monitoring:** Monitoring the operating temperature of the reduction gearing can indicate potential issues like overloading, lubrication problems, or excessive wear.
- **Ultrasonic Inspection:** In some cases, ultrasonic inspection techniques can be used to detect internal cracks or defects in gear teeth or bearings. This non-destructive testing method can help identify potential problems before they escalate.
- **Borescope Inspection:** A borescope, a small camera inserted into the gearbox, can be used to visually inspect gear teeth and bearings for signs of wear, pitting, or damage. This can be helpful in identifying specific problems within the gearing.

By implementing a combination of these condition monitoring techniques, engineers can gain valuable insights into the health of the main reduction gearing. This proactive approach allows for early detection of potential problems, enabling timely maintenance actions to be taken and preventing costly breakdowns

Oct 2022

October 2022 MDE

10. With reference to reduction gearing:

- (a) explain the purpose of the magnetic filter in the lubricating oil system; (3)
- (b) explain why the surface finish of the gear teeth is important; (4)
- (c) state why a flexible coupling is fitted between the engine and gearbox. (3)

Reduction Gearing: Components and Their Importance

(a) Magnetic Filter:

The magnetic filter in a reduction gear's lubricating oil system serves a critical purpose: removing ferrous wear debris from the oil.

- **Magnetic Attraction:** The filter contains strong magnets that attract ferrous particles (made of iron or steel) suspended in the lubricating oil.
- **Contamination Capture:** As the oil flows through the filter, the ferrous wear debris is drawn towards the magnets and gets trapped on their surface.
- **Cleaner Oil:** By removing these ferrous particles, the magnetic filter helps to keep the lubricating oil cleaner and free from contaminants.

This cleaner oil offers several benefits:

- **Reduced Wear:** Abrasive wear caused by metal particles circulating in the oil is minimized.
- **Improved Gear and Bearing Life:** By reducing wear, the lifespan of gears and bearings in the reduction gear is extended.
- **Protection from Scoring:** Large ferrous particles can cause scoring damage on gear teeth and bearing surfaces. The magnetic filter helps prevent this by removing these larger particles.

Magnetic filters are a simple and effective way to remove a specific type of contaminant from the lubricating oil in reduction gears. They are often used in conjunction with other filtration methods like full-flow filters that remove non-ferrous contaminants and other impurities.

(b) Surface Finish of Gear Teeth:

The surface finish of gear teeth in reduction gearing plays a crucial role in its performance and longevity:

- **Reduced Friction:** A smoother surface finish minimizes friction between gear teeth as they mesh. This reduces power losses and improves overall efficiency of the reduction gear.
- **Improved Load Distribution:** A smoother surface allows for more even load distribution across the tooth profile, reducing stress concentrations and minimizing wear.
- **Reduced Noise:** Rough surface finishes can lead to increased noise during gear operation. A smooth finish helps to minimize noise generation by reducing vibrations caused by uneven contact between teeth.
- **Enhanced Lubrication:** A smooth surface allows for better retention of lubricating oil film between gear teeth, improving lubrication effectiveness and reducing friction further.

The specific surface finish requirements depend on several factors, including:

- Gear material
- Load rating
- Operating speed

However, a well-honed or lapped surface finish is generally preferred for optimal performance and lifespan of reduction gears.

(c) Flexible Coupling Between Engine and Gearbox:

A flexible coupling is fitted between the engine and gearbox in a reduction gear system for several important reasons:

- **Misalignment Accommodation:** Engines and gearboxes can experience slight misalignments due to thermal expansion, manufacturing tolerances, or chassis flex. A flexible coupling can accommodate these misalignments without placing undue stress on the engine crankshaft or gearbox shaft. This helps to prevent bearing wear, shaft fatigue, and potential failures.
- **Vibration Damping:** Engines can generate vibrations due to combustion and imbalances. A flexible coupling can help to dampen these vibrations, preventing them from being transmitted to the gearbox and potentially damaging its gears and bearings.
- **Shock Load Protection:** Engines can generate sudden torque spikes during operation, such as during gear changes. A flexible coupling can help to absorb these shock loads, protecting

the more rigid components of the drivetrain (engine crankshaft and gearbox shaft) from damage.

The choice of a specific type of flexible coupling depends on the application and the level of misalignment, vibration, and shock load that needs to be accommodated. Common types of flexible couplings used in reduction gear systems include:

- Gear couplings
- Elastomeric couplings
- Jaw couplings

By incorporating a flexible coupling, the reduction gear system becomes more robust and less susceptible to damage caused by misalignment, vibration, and shock loads.

Jan 2018

January 2018 MDE

10. Describe, with the aid of a sketch, an epicyclic planetary reduction gear. (10)

An epicyclic planetary reduction gear, also known as a planetary gearset, is a compact and efficient means of achieving significant speed reduction and high torque multiplication. It offers several advantages over traditional gear trains. Here's a breakdown of its components and operation:

Components:

- **Sun Gear:** The central gear in the system, typically fixed or driven by the input shaft.
- **Planet Gears:** Smaller gears that rotate around the sun gear and mesh with both the sun gear and the ring gear. These are usually mounted on a carrier.
- **Carrier:** A structure that holds the planet gears and allows them to rotate around the sun gear. The carrier can be fixed, rotating around the sun gear, or both.
- **Ring Gear:** The outer gear that meshes with the planet gears. It can be fixed or be the output shaft.

Operation:

1. **Input:** Rotation is typically applied to the sun gear or the carrier, depending on the desired configuration.
2. **Planetary Motion:** The planet gears rotate around the sun gear, carrying their own rotation as well. This planetary motion is a key characteristic of this gearset.
3. **Output:** The final output rotation and torque depend on which component is fixed and which is rotating:
 - **Fixed Ring Gear:** If the ring gear is fixed, the output is taken from the carrier. The rotation of the carrier is slower than the input (speed reduction) and the torque is multiplied (higher torque output).
 - **Fixed Carrier:** If the carrier is fixed, the output is taken from the ring gear. In this configuration, the ring gear rotates in the opposite direction to the input (reversed output) and the torque is still multiplied.

Advantages of Epicyclic Planetary Gears:

- **High Speed Reduction:** Multiple planet gears meshing with both the sun and ring gear provide a significant reduction in output speed compared to the input.
- **High Torque Multiplication:** The planetary motion and gear ratios contribute to a substantial increase in torque output at the slower speed.
- **Compact Design:** Planetary gearsets can achieve high gear ratios and torque multiplication in a smaller package compared to traditional gear trains.
- **Smooth Operation:** The multiple points of contact between gears distribute the load more evenly, resulting in smoother operation and lower noise levels.
- **Versatility:** By changing which component is fixed and which is rotating, a single planetary gearset can offer multiple gear ratios and output directions.

Applications:

Epicyclic planetary gears are widely used in various applications where high torque and speed reduction are needed in a compact space. Here are some examples:

- **Automatic Transmissions:** Planetary gearsets are the core of automatic transmissions, providing multiple gear ratios and enabling smooth shifting.
- **Hybrid Vehicles:** Planetary gearsets can combine power from an electric motor and an internal combustion engine in hybrid powertrains.
- **Robotic Arms and Industrial Automation:** Planetary gears offer high torque multiplication and smooth motion control in robotic applications.
- **Wind Turbines:** Planetary gearsets are used to increase the rotational speed of the slow-turning wind turbine shaft for efficient electricity generation.

In conclusion, the epicyclic planetary reduction gear is a versatile and efficient solution for applications requiring high torque multiplication and speed reduction in a compact design. Its smooth operation, multiple gear ratio options, and wide range of applications make it a valuable component in various mechanical systems.

Jan 2019

January 2019 MDE

10. With reference to a reduction gearing and pneumatic clutch arrangement of a propulsion system:

- (a) state FIVE protection devices fitted; (5)
- (b) explain the need for EACH device stated in part (a). (5)

Protection Devices in a Reduction Gearing and Pneumatic Clutch Propulsion System:

(a) Five Protection Devices:

1. **Shear Pin:** A sacrificial pin designed to break in case of excessive torque overload in the system.
2. **Pressure Relief Valve:** A valve in the pneumatic clutch system that automatically relieves pressure if it exceeds a safe limit.

3. **Low Oil Pressure Switch:** A sensor that detects a drop in lubricating oil pressure below a safe operating level.
4. **Over-Speed Governor:** A device that shuts down the system if the reduction gearing exceeds a safe rotational speed limit.
5. **Vibration Sensor:** A sensor that monitors vibration levels in the reduction gearing and can trigger an alarm or shutdown if excessive vibration is detected.

(b) Explanation for Each Device:

1. **Shear Pin:** This sacrificial pin protects the reduction gearing from catastrophic failure due to excessive torque overload. In case of a severe jam or blockage, the shear pin breaks, disconnecting the power transmission and preventing damage to gears and shafts. The broken pin requires replacement before restarting the system.
2. **Pressure Relief Valve:** This valve safeguards the pneumatic clutch system from over-pressurization. If the air pressure within the clutch system exceeds a safe limit due to a malfunction, the pressure relief valve opens and releases excess air, preventing damage to the clutch components and potential leaks.
3. **Low Oil Pressure Switch:** This sensor monitors the lubricating oil pressure in the reduction gearing. If the oil pressure falls below a safe operating level due to a leak, pump malfunction, or low oil volume, the switch triggers an alarm or shuts down the system. This protects the gears and bearings from damage caused by insufficient lubrication.
4. **Over-Speed Governor:** This device acts as a safety measure to prevent excessive rotational speeds in the reduction gearing. If the gearing exceeds a safe speed limit due to a malfunction or loss of control, the governor activates a shutdown mechanism, preventing potential damage to gears, shafts, and bearings.
5. **Vibration Sensor:** This sensor continuously monitors the vibration levels within the reduction gearing. Excessive vibration can indicate developing problems like gear wear, misalignment, or bearing issues. The sensor can trigger an alarm or shutdown the system depending on the severity of the vibration, allowing for early detection and prevention of damage.

These five protection devices work together to safeguard the reduction gearing and pneumatic clutch system in a propulsion system. They ensure safe operation by preventing damage due to excessive torque, over-pressure, lubrication issues, overspeeding, and developing mechanical problems.

June 2021

June 2021 MDE

10. With reference to a reduction gearing and pneumatic clutch arrangement of a propulsion system:
- (a) state FIVE protection devices fitted; (5)
 - (b) explain the need for EACH device stated in part (a). (5)

Protection Devices in a Reduction Gearing and Pneumatic Clutch Propulsion System:

(a) Five Protection Devices:

1. **Shear Pin:** This is a sacrificial pin designed to break in case of excessive torque overload in the system.
2. **Pressure Relief Valve:** This valve is located in the pneumatic clutch system and automatically relieves pressure if it exceeds a safe limit.
3. **Low Oil Pressure Switch:** This sensor detects a drop in lubricating oil pressure below a safe operating level in the reduction gearing.
4. **Over-Temperature Switch:** This device monitors the temperature of the reduction gearing and triggers an alarm or shutdown if it exceeds a safe operating limit.
5. **Vibration Sensor:** This sensor continuously monitors vibration levels in the reduction gearing and can trigger an alarm or shutdown if excessive vibration is detected.

(b) Explanation for Each Device:

1. **Shear Pin:** Protects the reduction gearing from catastrophic failure due to excessive torque overload. In case of a severe jam or blockage, the shear pin breaks, disconnecting the power transmission and preventing damage to gears and shafts. The broken pin requires replacement before restarting the system.
2. **Pressure Relief Valve:** Safeguards the pneumatic clutch system from over-pressurization. If air pressure within the clutch system exceeds a safe limit due to a malfunction, the pressure relief valve opens and releases excess air, preventing damage to the clutch components and potential leaks.
3. **Low Oil Pressure Switch:** This sensor monitors the lubricating oil pressure in the reduction gearing. If the oil pressure falls below a safe operating level due to a leak, pump malfunction, or low oil volume, the switch triggers an alarm or shuts down the system. This protects the gears and bearings from damage caused by insufficient lubrication.
4. **Over-Temperature Switch:** Excessive temperatures within the reduction gearing can indicate problems like overloading, insufficient lubrication, or bearing wear. The over-temperature switch detects such conditions and initiates a shutdown or warning signal, allowing for preventive action before serious damage occurs.
5. **Vibration Sensor:** As mentioned earlier, excessive vibration can indicate developing problems like gear wear, misalignment, or bearing issues. The sensor triggers an alarm or shutdown depending on the severity of the vibration, allowing for early detection and prevention of damage.