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1. With reference to four stroke diesel engine exhaust valves:

(a) explain the effects of EACH of the following:

(i) too large a tappet clearance; (4)

(ii) too small a tappet clearance; (4)

(b) explain why double (nested) valve springs may be fitted. (2)

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2. With reference to air coolers, explain the purpose of EACH of the following:

(a) zinc anodes; (3)

(b) vent cocks; (3)

(c) tube fins. (4)

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3. Describe a procedure for manually testing the set points on diesel generator HT cooling water, high temperature alarm and shut down. (10)

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4. With reference to Bosch or jerk type fuel injection pumps:

(a) describe how the delivered quantity of fuel oil may be controlled; (6)

(b) explain the purpose of the delivery valve. (4)

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5. (a) Describe TWO methods of cylinder liner lubrication in medium speed diesel engines. (6)

   (b) Describe the possible effects of EACH of the following:

   (i) insufficient lubrication; (2)

   (ii) excessive lubrication. (2)

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6. (a) Describe, with the aid of a sketch, the construction of a plate type heat exchanger. (7)

   (b) State THREE advantages of the plate types, compared with the tube type heat exchanger. (3)

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7. (a) List FOUR safety interlocks that may be fitted to a direct air start medium speed diesel engine to prevent inadvertent starting during maintenance. (4)

   (b) Explain, with the aid of a diagram, the opening period of an air start valve on a four stroke diesel engine in relation to the crank angle, inlet and exhaust valves. (6)

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8. (a) Describe the inspection of a cylinder liner and piston assembly, when the piston has been removed from the engine. (6)

   (b) State possible faults which may be found. (4)

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9. With reference to an engine connected to a gearbox via a friction clutch, explain EACH of the following:

   (a) why vibration from the engine should be damped; (7)

   (b) how vibration damping is achieved. (3)

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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)

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1. With reference to four stroke diesel engine exhaust valves:

   (a) explain the effects of EACH of the following:

   (i) too large a tappet clearance; (4)

   (ii) too small a tappet clearance; (4)

   (b) explain why double (nested) valve springs may be fitted. (2)

Four-Stroke Diesel Engine Exhaust Valves and Tappet Clearance (a):

Tappet clearance refers to the gap between the valve stem and the rocker arm (or other valve actuation mechanism) when the cam lobe is not pushing on the valve. Here's how incorrect tappet clearance affects exhaust valves in a four-stroke diesel engine:

(i) Too Large Tappet Clearance:

- **Delayed Valve Opening:** With excessive clearance, the rocker arm takes longer to contact the valve stem and push it open. This leads to a delayed opening of the exhaust valve, causing hot exhaust gases to remain in the cylinder for a longer duration. This can result in:
  - **Increased Cylinder Temperatures:** Excessive heat can damage pistons, valves, and other engine components.
  - **Reduced Power Output:** Incomplete exhaust gas evacuation can reduce the efficiency of the next intake stroke, leading to lower power output.
  - **Increased Fuel Consumption:** Incomplete combustion due to higher cylinder temperatures and inefficient gas exchange can lead to increased fuel consumption.
- **Increased Valve Train Noise:** The extra space allows for more play between the valve stem and rocker arm, creating knocking or clattering sounds during engine operation.

(ii) Too Small Tappet Clearance:

- **Premature Valve Opening:** With minimal clearance, the valve might remain slightly open even when the cam lobe is not pushing on it. This can lead to:
  - **Loss of Compression:** Premature opening allows some compressed air to escape the cylinder during the compression stroke, reducing engine efficiency and power output.
  - **Burned Exhaust Valve:** Hot exhaust gases can leak past a slightly open valve, burning the valve seat and damaging the valve itself.
  - **Valve Sticking:** In extreme cases, tight clearance can cause the valve to stick open due to heat expansion, leading to severe engine damage.

Double (Nested) Valve Springs (b):

Double or nested valve springs are commonly used in diesel engines for several reasons:

- **High Exhaust Gas Pressure:** Diesel engines experience significantly higher exhaust gas pressures compared to gasoline engines. Double springs provide the necessary force to overcome these high pressures and ensure proper valve closure against the valve seat.
- **Control Valve Dynamics:** The dual springs allow for a more precise control of valve opening and closing. The spring rates and characteristics can be designed to achieve the desired valve opening profile, optimizing engine performance and reducing valve train noise.
- **Safety and Reliability:** In case one spring breaks or weakens, the other spring can still provide some level of valve control, preventing catastrophic engine failure due to a completely open exhaust valve.

By utilizing a combination of high spring force and controlled valve dynamics, double valve springs help ensure proper exhaust valve operation under the demanding conditions of a diesel engine.

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2. With reference to air coolers, explain the purpose of EACH of the following:

(a) zinc anodes; (3)

(b) vent cocks; (3)

(c) tube fins. (4)

Air Cooler Components and Functions:

Air coolers utilize the principle of evaporative cooling to provide a cool and refreshing airflow. Here's a breakdown of the purpose of each component you mentioned:

(a) Zinc Anodes:

- **Function:** Zinc anodes are sacrificial elements typically installed within the water tank of an air cooler. They are made of zinc, a metal more susceptible to corrosion than the materials used in the water tank.
- **Purpose:** Zinc anodes act as a cathodic protection system. By corroding preferentially, they attract the corrosive elements present in the water, protecting the water tank from corrosion. As the zinc anode corrodes and wears away, it needs to be replaced periodically during maintenance to ensure continued protection for the water tank.

(b) Vent Cocks:

- **Function:** Vent cocks are small valves typically located on the water tank of an air cooler, often at a high point.
- **Purpose:** Vent cocks serve two main purposes:
    1. **Air Venting:** During the initial filling of the water tank or after maintenance procedures, the vent cock allows trapped air within the tank to be purged. Air pockets in the tank can

hinder the water circulation within the system and reduce the effectiveness of the evaporative cooling process.

2. **Overflow Prevention:** In some designs, the vent cock might also act as a simple overflow mechanism. If the water tank is overfilled, excess water can escape through the vent cock, preventing overflow and potential water damage to the surrounding area.

(c) Tube Fins:

- **Function:** Air cooler heat exchangers consist of a series of thin metal tubes through which water circulates. These tubes are not smooth; they have extended surfaces in the form of fins. The fins can be flat, louvered, or have other shapes depending on the design.
- **Purpose:** Tube fins significantly increase the heat transfer surface area between the circulating water and the surrounding air. This allows the water to absorb more heat from the air passing through the fins as it evaporates. The larger the surface area, the more efficient the heat transfer and the cooler the air exiting the air cooler. The specific fin design can also influence airflow characteristics and overall cooling performance.

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3. Describe a procedure for manually testing the set points on diesel generator HT cooling water, high temperature alarm and shut down. (10)

Manually Testing Diesel Generator HT Cooling Water Set Points: Alarm and Shutdown

Here's a procedure for manually testing the set points on a diesel generator's high temperature (HT) cooling water system, including the alarm and shutdown functions:

Important Notes:

- **Safety First:** Ensure all safety precautions are followed before performing this procedure. Refer to the manufacturer's manual for specific safety instructions related to your generator model.
- **Qualified Personnel:** This procedure should ideally be performed by a qualified technician familiar with the generator and its control system.
- **Alternatives:** Consult the manufacturer's manual to see if there are alternative methods for testing the set points, such as using diagnostic software or built-in testing functions.

Procedure:

1. **Preparation:**
    - Ensure the generator is off and disconnected from any electrical load.
    - Familiarize yourself with the location and function of the HT cooling water temperature sensor, alarm indicator, and shutdown mechanism (usually a relay or contactor). Refer to the generator's manual or electrical schematics for guidance.
    - Gather necessary tools, which might include a reliable thermometer, a heat source (optional), and safety equipment like gloves and safety glasses.
2. **Temperature Monitoring:**
    - Start the engine and allow it to run for a short period to reach normal operating temperature. Monitor the coolant temperature using the engine's built-in gauge or a separate thermometer at the designated point (refer to the manual).
3. **Alarm Test:**
    - **Gradual Increase (Preferred Method):** If feasible, gradually increase the coolant temperature using a controlled heat source (e.g., heat lamp) directed towards the cooling system. This allows for observing the alarm activation at the designated set point.
    - **Manual Intervention (Alternative):** If a controlled heat source isn't available, you might carefully simulate a temperature rise by briefly disconnecting the sensor or simulating a high resistance with a resistor (consult a qualified electrician for safe implementation).
    - Monitor the instrument panel or alarm indicator. Once the coolant temperature reaches the alarm set point as specified in the manual, the high-temperature alarm should activate (usually a visual or audible signal).
4. **Shutdown Test (Use Caution):**
    - **Important:** Proceed with caution as this test involves stopping the engine. Ensure no critical loads depend on the generator's operation during this test.
    - **Gradual Increase (Preferred Method):** If using a controlled heat source, continue raising the coolant temperature slightly above the alarm set point. Observe if the engine shuts down automatically as programmed.
    - **Manual Intervention (Alternative):** If using manual intervention, keep the sensor disconnected or resistance simulated for a very brief period (seconds) just beyond the alarm set point. The engine control system should trigger a shutdown.
5. **Reset and Verification:**
    - Once the alarm and shutdown functions have been tested, allow the engine to cool down naturally.
    - Reconnect the sensor (if disconnected) or restore normal operation if a resistor was used.
    - Verify that the engine starts and runs normally after the cooling system temperature has returned to a safe range.

Documentation:

- Record the observed alarm and shutdown set points during the test and compare them to the manufacturer's specifications.
- Document any discrepancies or malfunctions for further investigation or repairs.

Remember:

- Exercise caution during the test, especially during the shutdown simulation.
- Consider alternative testing methods recommended by the manufacturer if available.

- If unsure about any step, consult a qualified technician for safe and proper execution of the procedure.

021

October 2021 MDE

4. With reference to Bosch or jerk type fuel injection pumps:

(a) describe how the delivered quantity of fuel oil may be controlled; (6)

(b) explain the purpose of the delivery valve. (4)

Bosch (Jerk Type) Fuel Injection Pump: Fuel Delivery Control and Delivery Valve

(a) Controlling Fuel Delivery Quantity:

In Bosch or jerk-type fuel injection pumps, the delivered quantity of fuel oil is controlled by the interplay of three main components:

1. **Plunger and Helical Groove:**
- The pump has a plunger that moves reciprocally within a barrel.
- The key element for fuel metering is a helical groove machined on the plunger's surface.
2. **Spill Port and Control Rack:**
- The barrel has a spill port that allows pressurized fuel to return to the suction side of the pump when uncovered.
- A control rack, connected to the engine governor or electronic control unit, positions a sleeve around the plunger.
3. **Operating Principle:**
- During the upward stroke of the plunger, fuel gets drawn into the pump chamber through an inlet port.
- As the plunger continues to move up, the helical groove on its surface progressively covers the spill port.
- The duration for which the spill port remains covered determines the amount of fuel trapped in the pump chamber for injection.
- The control rack position influences the orientation of the plunger and the helical groove relative to the spill port.
    - By moving the rack, the governor or ECU can adjust the position of the helical groove, thereby controlling how long the spill port remains covered during the plunger's stroke.
    - A shorter coverage time (less fuel trapped) corresponds to a lower fuel delivery. Conversely, a longer coverage time results in a higher fuel delivery.

(b) Purpose of the Delivery Valve:

The delivery valve, also known as the discharge valve or pressure relief valve, plays a critical role in ensuring proper fuel injection pressure and preventing internal damage:

- **Location:** The delivery valve is typically located at the outlet of the pump chamber, directly connected to the high-pressure fuel line leading to the injectors.
- **Function:** The valve remains closed by a spring until the pressure within the pump chamber exceeds a predetermined level.
- **Operation:** As the plunger moves upwards and the spill port closes, the fuel pressure within the chamber builds up.
- **Opening and Injection:** Once the pressure reaches the set limit, the delivery valve opens, allowing the high-pressure fuel to flow through the line and reach the injectors for fuel injection.
- **Safety Function:** The delivery valve acts as a safety mechanism by preventing excessive pressure buildup within the pump and fuel lines that could lead to component damage.
- **Closing and Cycle Repeat:** After fuel injection occurs and the pressure drops, the delivery valve closes again, and the cycle repeats for the next injection event.

The delivery valve ensures that the fuel injection pump operates within the designated pressure range, delivering pressurized fuel to the injectors for efficient engine operation while safeguarding the system from excessive pressure.

October 2021 MDE

5. (a) Describe TWO methods of cylinder liner lubrication in medium speed diesel engines. (6)

(b) Describe the possible effects of EACH of the following:

(i) insufficient lubrication; (2)

(ii) excessive lubrication. (2)

Cylinder Liner Lubrication in Medium Speed Diesel Engines:

(a) Methods of Cylinder Liner Lubrication:

There are two primary methods for lubricating cylinder liners in medium speed diesel engines:

(i) Forced Lubrication:

- **Description:** This method utilizes an external pump and dedicated lubrication system to deliver a measured amount of lubricating oil directly to the cylinder liner walls. The oil is typically injected through quills (nozzles) positioned strategically on the cylinder liner.
- **Mechanism:** The pressurized oil forms a thin film between the piston rings and the cylinder liner, reducing friction and wear during piston movement. Excess oil drains back to the engine sump through designated channels.
- **Benefits:**
  - Precise control over oil delivery allows for optimizing lubrication based on engine load and operating conditions.
  - Ensures a consistent oil film for effective wear reduction.

(ii) Splash Lubrication (Dipping System):

- **Description:** This is a simpler method where the crankcase oil bath serves as the primary source of lubrication. The rotating components like the connecting rods churn the oil in the sump, splashing it onto the cylinder walls.
- **Mechanism:** As the crankshaft rotates, the connecting rods dip into the oil bath and splash oil upwards, lubricating the cylinder liners and pistons. The excess oil drains back into the sump through gravity.
- **Benefits:**
  - Simpler design with fewer moving parts, resulting in lower maintenance requirements.
  - Suitable for engines with less demanding lubrication requirements.

(b) Effects of Lubrication Issues:

(i) Insufficient Lubrication:

Insufficient lubrication due to factors like low oil level, clogged oil passages, or incorrect oil viscosity can lead to several negative consequences:

- **Increased Friction and Wear:** Without a proper oil film, metal-to-metal contact between the piston rings and liner increases friction, leading to accelerated wear and potential scuffing or scoring of the cylinder liner surface.
- **Increased Heat Generation:** Friction creates heat, and insufficient lubrication can lead to excessive heat buildup within the cylinder. This can damage pistons, rings, and other engine components.
- **Piston Ring Sticking:** High temperatures can cause piston rings to stick in their grooves, reducing their sealing effectiveness and leading to compression loss and increased blow-by of combustion gases.
- **Potential for Seizures:** In extreme cases of insufficient lubrication, complete seizure can occur, where the piston becomes welded to the cylinder liner due to excessive heat and friction, causing catastrophic engine failure.

(ii) Excessive Lubrication:

While insufficient lubrication is a major concern, excessive lubrication can also have detrimental effects:

- **Increased Oil Consumption:** Excessive oil being delivered to the cylinders can lead to higher oil consumption as more oil is burned in the combustion process.
- **Spark Plug Fouling:** Excess oil can reach the combustion chamber and foul the spark plugs, hindering proper ignition and engine performance.
- **Increased Emissions:** Burning excess oil contributes to increased emissions of hydrocarbons and pollutants.
- **Degraded Power Output:** Oil film buildup on cylinder walls can increase friction and slightly reduce engine power output.
- **Environmental Impact:** Excessive oil consumption leads to increased oil disposal needs, requiring proper handling and potentially creating environmental concerns.

Maintaining proper lubrication through regular oil changes, using the correct oil viscosity, and monitoring oil levels is crucial for optimal engine performance, longevity, and reduced emissions.021
2021

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6. (a) Describe, with the aid of a sketch, the construction of a plate type heat exchanger. (7)

(b) State THREE advantages of the plate types, compared with the tube type heat exchanger. (3)

(a) Plate Heat Exchanger Construction:

A plate heat exchanger (PHE) offers a compact and efficient design for transferring heat between two fluids. Here's a breakdown of its construction:

Main Components:

- **Frame:** A sturdy housing, typically made of cast iron or stainless steel, that encloses and supports the entire assembly.
- **Pressure Plates:** Thick metal plates positioned at each end of the assembly. These plates seal the plate pack and have connections for fluid inlets and outlets.
- **Tie Rods:** Threaded rods that pass through the frame and tighten with nuts, applying pressure to compress the plate pack.
- **Gaskets:** Seals positioned around the periphery of each plate to prevent leakage between the fluid channels formed between adjacent plates. Gasket material selection depends on the specific fluids being handled.
- **Plate Pack:** The heart of the PHE, consisting of numerous thin, corrugated metal plates stacked alternately. The corrugations create a wavy pattern on the plates.

Flow Path:

- Two separate fluids flow through dedicated channels formed between adjacent corrugated plates. The corrugations create a tortuous path, forcing the fluids into turbulent flow which maximizes heat transfer across the large plate surface area.
- The flow direction of each fluid can be arranged in a counter-current (most efficient) or co-current (simpler design for specific applications) configuration.

(b) Advantages of Plate Heat Exchangers over Shell and Tube Heat Exchangers:

1. **Compact Size and Lighter Weight:** PHEs are significantly smaller and lighter than shell and tube exchangers for achieving the same heat transfer duty. This makes them ideal for applications with space constraints, such as building HVAC systems or marine applications where weight reduction is crucial.
2. **Superior Heat Transfer Efficiency:** The large plate surface area and the turbulent flow within the channels lead to significantly better heat transfer efficiency compared to shell and tube exchangers. This translates to a smaller PHE size required for achieving the desired heat transfer rate, saving space and material.

3. **Lower Pressure Drop:** The design of plate heat exchangers allows for lower pressure drop on both the hot and cold fluid sides compared to shell and tube exchangers. This translates to lower pumping costs and reduced energy consumption for operating the system.
4. **Easier Maintenance:** The plate pack in a PHE is accessible for cleaning or replacement. By loosening the tie rods and separating the pressure plates, the plates can be individually accessed for maintenance. This is simpler compared to shell and tube exchangers, which might require more disassembly effort or even removal of piping connections.
5. **Versatility:** Plate heat exchangers can handle a wider range of fluid viscosities and pressures compared to shell and tube exchangers. This makes them suitable for various applications, including handling viscous fluids or those with high-pressure differentials.

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7. (a) List FOUR safety interlocks that may be fitted to a direct air start medium speed diesel engine to prevent inadvertent starting during maintenance. (4)

(b) Explain, with the aid of a diagram, the opening period of an air start valve on a four stroke diesel engine in relation to the crank angle, inlet and exhaust valves. (6)

Safety Interlocks for Direct Air Start Medium Speed Diesel Engines (a)

Here are FOUR safety interlocks commonly fitted to a direct air start medium speed diesel engine to prevent inadvertent starting during maintenance:

1. **Starting Air Isolation Valve:** This is a manually operated valve that isolates the entire air start system from the receivers. When closed, no compressed air can flow to the engine's air start valves, preventing accidental starting.
2. **Neutral Gear Interlock:** This interlock prevents the engine from starting unless the transmission is in neutral. This avoids sudden jerks and potential damage to the drivetrain if the engine were to start unexpectedly in gear.
3. **Engine Stop Switch:** A physical switch that cuts off fuel supply or electrical power to the engine, immediately stopping it or preventing it from starting. This allows for quick shutdown in case of emergencies during maintenance.
4. **Crankshaft Position Sensor Interlock:** This electronic interlock uses a sensor to detect the crankshaft position. In some systems, the engine may not start unless the crankshaft is positioned at a specific top dead center (TDC) for a particular cylinder, ensuring the engine is in a safe starting position.

Air Start Valve Opening Period on a Four-Stroke Diesel Engine (b)

In a four-stroke diesel engine, the opening period of the air start valve is precisely controlled in relation to the crank angle, inlet, and exhaust valves to ensure efficient starting:

- **Crank Angle:** The air start valve typically opens slightly **before** the piston reaches Top Dead Center (TDC) of the compression stroke. This timing ensures sufficient compressed air is present in the cylinder when the piston begins its downward power stroke.

- **Inlet Valve:** The inlet valve on a four-stroke engine remains closed during the compression and combustion strokes. Therefore, the air start valve operates during a period when the inlet valve is closed.
- **Exhaust Valve:** The exhaust valve typically closes just before TDC of the compression stroke. The air start valve opens shortly after the exhaust valve closes, ensuring no remaining exhaust gases are pushed back out and the cylinder receives a full charge of clean air for starting.

Overall, the precise timing of the air start valve opening maximizes the compressed air available for initiating combustion during the power stroke, leading to efficient engine starting.

October 2021 MDE

8. (a) Describe the inspection of a cylinder liner and piston assembly, when the piston has been removed from the engine. (6)

(b) State possible faults which may be found. (4)

Here's a breakdown of the inspection process for a cylinder liner and piston assembly once the piston has been removed from the engine:

Cleaning:

1. **Initial Cleaning:** Before inspection, thoroughly clean the liner and piston with a suitable solvent to remove any dirt, carbon deposits, or oil residue. This allows for a clear visual inspection of the surfaces.

Liner Inspection:

2. **Visual Inspection:**
   - Look for any cracks, scoring, pitting, or signs of excessive wear on the cylinder liner wall.
   - Check the liner surface for signs of corrosion or erosion.
   - Inspect the liner sealing surfaces for any damage or distortion.
3. **Measurements:**
   - Using a micrometer or bore gauge, measure the liner diameter at various points (top, middle, bottom) to check for ovality or taper.
   - Consult the engine manual for the specified liner diameter and allowable wear limits.

Piston Inspection:

4. **Crown Inspection:**
   - Visually inspect the piston crown for cracks, signs of overheating, or excessive wear.
   - Check the piston ring grooves for wear and ensure they are not excessively wide or damaged.
5. **Ring Gap Inspection:**
   - Using a feeler gauge, measure the gap between each piston ring and its groove.
   - Compare the measured gaps to the manufacturer's specifications to identify excessive wear or improper ring fit.

6. **Piston Skirt Inspection:**
    - Inspect the piston skirt for scoring, scuffing, or signs of excessive wear.
    - Check for signs of piston slap (looseness) by carefully measuring the piston skirt diameter and comparing it to the liner diameter.

Additional Checks:

7. **Piston Ring Condition:**
    - Inspect the piston rings themselves for wear, cracks, or breaks.
    - Ensure the ring ends have proper side clearance within the ring grooves.
8. **Piston Pin and Bushings:**
    - Check the piston pin and connecting rod bushing for excessive wear or damage.

Documentation:

- Record all inspection findings, including measurements and observations, for further analysis and potential replacement decisions.

(b) Possible Faults:

The inspection can reveal various faults in the cylinder liner and piston assembly:

Liner Faults:

- **Cracks:** Cracks in the liner can compromise engine block integrity and require immediate replacement.
- **Scoring or Wear:** Excessive wear on the liner wall can reduce compression and lead to oil blow-by. Depending on the severity, the liner might require honing or replacement.
- **Corrosion or Erosion:** Corrosion or erosion can damage the liner surface and affect sealing. Repairs or replacement might be necessary.
- **Improper Sealing Surfaces:** Damaged or distorted sealing surfaces can cause oil leaks and require resurfacing or liner replacement.
- **Out-of-round Liner:** Excessive ovality or taper in the liner diameter can affect piston ring sealing and require replacement.

Piston Faults:

- **Cracked Piston Crown:** Cracks compromise piston integrity and require immediate replacement.
- **Overheating Damage:** Signs of overheating, like melted aluminum or warping, indicate a potential engine cooling system issue and require piston replacement.
- **Excessive Piston Ring Groove Wear:** Worn grooves can hinder proper ring seal and necessitate piston replacement.
- **Improper Piston Ring Gaps:** Excessive gaps reduce compression and oil control, requiring new rings or piston replacement depending on the severity.
- **Scuffed or Worn Piston Skirt:** Scoring or wear on the skirt can increase friction and lead to piston slap. Depending on the severity, the piston might need honing or replacement.
- **Worn Piston Pin or Bushings:** Excessive wear in these components can increase noise and potential for piston movement issues. Repairs or replacements might be necessary.

By performing a thorough inspection and identifying faults, you can determine if repairs or replacements are necessary for the cylinder liner and piston assembly to ensure optimal engine performance and longevity.

021

October 2021 MDE

9. With reference to an engine connected to a gearbox via a friction clutch, explain EACH of the following:

(a) why vibration from the engine should be damped; (7)

(b) how vibration damping is achieved. (3)

Vibration Damping in Engine-Gearbox Connection (Friction Clutch):

(a) Why Engine Vibration Needs Damping:

Uncontrolled vibration from the engine can have several detrimental effects on the engine, gearbox, and overall driving experience:

- **Increased Wear and Tear:** Vibrations can cause excessive wear on engine and gearbox components due to the rapid back-and-forth movements. This can lead to premature failure of bearings, gears, and other parts.
- **Noise Harshness:** Engine vibrations can transmit through the drivetrain and chassis, creating unwanted noise and a harsh driving experience for occupants.
- **Gear Shift Difficulty:** Vibrations can make gear changes rough and difficult, especially when the engine RPM doesn't synchronize well with the gearbox speed.
- **Damage to Connected Components:** In severe cases, excessive vibration can damage other parts connected to the engine, such as engine mounts, driveshafts, and radiator components.

(b) How Vibration Damping is Achieved:

There are two main ways to dampen vibration between the engine and gearbox using a friction clutch:

1. Engine Mounts:

- Engine mounts are strategically placed rubber or hydraulic mounts that connect the engine to the chassis.
- The rubber or hydraulic fluid in these mounts absorbs and dampens engine vibrations before they can be transmitted to the drivetrain and chassis.
- Different engine mounts are positioned at various points to address vibrations in different directions (vertical, horizontal, and torsional).

2. Friction Clutch Disc Design:

- The design of the friction clutch disc itself can also play a role in vibration damping.
- Some clutch discs incorporate features like:
    - **Damping Springs:** These springs are embedded within the clutch disc and help to absorb and dissipate torsional vibrations from the engine crankshaft.
    - **Friction Material Properties:** The specific material composition of the friction lining on the clutch disc can influence its ability to absorb some level of vibration.

By using a combination of effective engine mounts and a well-designed clutch disc, the overall vibration transmission between the engine and gearbox can be significantly reduced. This leads to smoother operation, increased component lifespan, and a more comfortable driving experience

021

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

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.