Module 2: Disassembly Procedures and Analysis

**Terms and Definitions**

- **Beach marks** are radial stress lines spreading outward from a fatigue crack.
- **Carbon deposits** (black) are byproducts of combustion deposited on piston domes, rings, ring grooves, cylinder head(s), valves, and injector tips.
- **Cavitation** is the formation of bubbles in a fluid that occurs when the fluid is subjected to low pressures.
- **Cavitation erosion** is the gradual erosion and pitting of parts exposed to bursting cavitation bubbles.
- **Clearance distance** by which an object clears another or the clear space between them.
- **Contaminate** is to make unfit for use by contact with foreign material.
- **Corrode** is to weaken or destroy gradually by chemical means.
- **Defect** is an imperfection that impairs value or usability.
- **Failure** is the inability to perform the desired function; usually occurs prematurely or unexpectedly.
- **Fatigue** is the tendency of a material to break under repeated stress.
- **Foreign material** is any extraneous material not intended to be present. Examples include particles of steel, dirt, rust, carbon, acid, and condensation (water).
- **Indicator** is a symptom that helps identify the product, operation, or maintenance problem.
- **Pitted** refers to the indentations or holes in the surface of an object.
- **Polished** means to make a surface smooth and shiny by friction.
- **Ratchet marks** are the tiny fractures developing between individual cracks.
- **Root cause** is the specific condition that started the problem.
- **Scored** means marked with lines or scratches.
- **Scuffed** means surface wear caused by friction between parts.
- **Seize** is to bond to a moving part through excessive pressure, temperature, or friction.
- **Viscosity** is a measure of a fluid's resistance to flow.
- **Wear** is the undesirable removal of material from the surface of a part.

**Special Engine Tools and Their Functions**

- A camshaft bushing remover/installer removes and replaces camshaft bushings in all gas and diesel engines.
- An engine pre-oiler pressurizes the lubricating system prior to start-up to ensure positive lubrication to all friction surfaces.
- An engine stand supports the engine's weight, allowing safe access to all engine components.
- A fuel sight gauge attaches to the inlet side of the fuel pump to visually identify air leaks in the suction side of the fuel delivery system.
- A gear puller uses torque or hydraulic pressure to remove gears in place.
- A harmonic balancer puller removes the harmonic balancer without damaging the inertia ring.
- Injector remover tools remove threaded, pencil-type, and “Top Stop” injectors.
- Lift T-handles replace rocker arms and provide lifting points for cylinder head removal.
- A liner installer presses the cylinder liner/cylinder pack into the cylinder block.
- A liner puller removes the cylinder liner from the block.
- A ring compressor aids installation of the piston and ring assembly into the cylinder liner/cylinder bore.
- A ring expander removes and installs piston rings without breakage.
- Rod bolt protectors guide the connecting rod bolts over the crankshaft rod journal while protecting the machined surface of the journal.
A valve spring compressor compresses the valve spring, allowing removal or installation of valve spring keepers.

A valve spring tester indicates valve spring operating tension.

**Precision Instruments and Their Functions**

READY FOR REVIEW

- A ball and hole gauge measures small bore diameters, such as valve guides.
- A depth gauge measures the distance between two surfaces.
- A dial bore gauge measures the cylinder diameter to determine wear, out-of-round, and taper.
- A dial test indicator measures back-and-forth movement of a component.
- A diesel compression gauge measures the maximum cylinder pressure and gives an indication of ring and valve seat wear.
- A direct contact pyrometer measures the surface temperature at a point of contact.
- The feeler gauge measures the clearance between two mating parts.
- An infrared pyrometer measures the surface temperature of an object when pointed at that object and does not require physical contact to give an accurate reading.
- An inside micrometer measures the inner diameter of a cylinder, tube, or journal.
- A magnahelic gauge is a highly accurate gauge that measures small changes in vacuum or pressure.

A magnetic gauge base mounts and positions dial test indicators to flat or round metal surfaces.

A manometer measures the pressure of gases and vapors.

**Note:** Mercury manometers are typically used in high heat applications such as exhaust manifolds. Water manometers may be used in less extreme conditions.

A micrometer measures outer diameter and thickness, and the measurement is read on a graduated scale.

Outside calipers measure outer diameter and thickness, and the measurement is read on either a ruler-like scale or a gauge.

A precision straight-edge provides an accurate reference for measuring warpage of machined surfaces.

A protrusion gauge (cylinder liner height) measures cylinder liner lip protrusion above the cylinder block surface.

A radius gauge set measures radii machined into the crankshaft journals.

**Disassembly Procedures and Analysis**

READY FOR REVIEW

- Always follow all shop safety rules, and remember that “safety always comes first.” Eyes and fingers are hard to replace!
- Use guide studs/dowels to help center parts.
- Always keep hands and fingers away from mating parts.
- Wear all personal protective equipment as required, including safety glasses and gloves.
- Use a hoist or chain for lifting any components over 45 pounds (100 kilograms).
- Keep attaching hardware with their components, using plastic bags labeled or wire-tied to the part, or coffee cans labeled with their contents.
- Keep the workbench surface clean: free of dirt and grease, clear of paper towels and other trash, and clear of open containers of solvent and lubricants.
- Store parts in groups as subassemblies: grouping parts as assemblies, marking parts with paint sticks or tags, or marking engine brackets as they are removed.
- Retain old parts to compare with new ones.
- Put away tools and equipment when they are not in use.
Disconnecting Accessory Components

These are the accessory components and lines that must be pulled (disconnected) before the engine is removed.
- Intake air duct to turbocharger inlet
- Air-conditioning compressor
- Air lines
- Fuel supply lines
- Radiator hose
- Heater hoses
- Fan/fan clutch
- Starting fluid injection lines
- Wiring to sensors
- Alternator leads

Methods for Cleaning Engine Components

Methods for cleaning engine components:
- High pressure hot water for initial grease/grime removal from engine, transmission, and frame; avoid spraying electrical components/harnesses.
- Solvent and bristle brushes for larger parts are easily cleaned and are safe for all metals.
- Bead blasting/crushed media blasting for cleaning individual hand-held components; it’s nondestructive, ideal for cleaning aluminum, and the surface must be grease-free.
- A wire wheel used for rapid removal of “baked-on” grime has an injury hazard from flying wire bristles and is not suitable for aluminum or soft metal.
- An abrasive disc quickly removes gasket material, but the type of disc determines the suitability for different metals.

Measurement and Analysis of Engine Components

- A cylinder head measures and analyzes fire deck flatness, valve stem diameter, valve guide wear, valve condition, and seat condition.
- A crankshaft measures and analyzes end play, main journal diameter, rod journal diameter, fillet, and journal surface color.
- A cylinder block measures and analyzes liner protrusion/height, liner counter bore, camshaft bearing inside diameter, crankshaft main bearing bore alignment, and block-to-head mating face flatness.
- A piston/liner measures and analyzes liner/bore inside diameter, piston-to-bore clearance, liner surface, piston crown, and piston thrust face.
- A connecting rod measures and analyzes wrist pin bushing inside diameter and big-end bore inside diameter.
- Camshaft/lifters measure and analyze lobe condition, journal outside diameter, and lifter condition.
- A flywheel measures and analyzes clutch surface condition, surface runout, and starter ring gear wear.

Materials Used on Engine Components

- Ferrous metals (contain iron)
  - Cast iron is used on cylinder blocks, cylinder heads, rocker housings, and some gears.
  - Steel is used on crankshafts, camshafts, connecting rods, valves, and gears.
- Nonferrous metals and synthetics
  - Aluminum alloys are used on pistons and many new parts to reduce engine weight without sacrificing strength.
  - Synthetic materials, including ceramics and plastics, are used on many replaceable parts, such as lines, fittings, seals, and electronic components.
Types of Analysis for Engine Failure

**Failure analysis**
- Determines the conditions leading to the root cause of unexpected component failure
- The primary concern is prevention of future component failure.
- Parts are inspected to determine what conditions led to the component failure.
- The end result involves a future change in either the manufacturing, service, or operation of the engine.

**Wear analysis**
- Determines the conditions leading to the root cause of component wear
- The primary concern is reconditioning the engine for further service.
- Parts are inspected to determine which reconditioning procedures are necessary.

Steps of Failure Analysis

**State the problem clearly and concisely.**
- Write it down.
- Describe the result accurately.

**Organize your fact gathering.**
- Focus on the most probable areas first.
- Check the maintenance/operating records for the past 3–4 months.

**Observe and record the facts.**
- Obtain application information.
- Obtain, identify, and protect failed parts.
- Use pen and paper, photographs, and video.

**Think logically with the facts.**
- Determine whether damage to a specific part is the root cause or the result.
- Determine the problem pattern.
  - Continuous, always present
  - Periodic, present under specific conditions
  - Sporadic, presence is erratic and unexplained
- Determine the problem trend.
  - Stable, severity remains the same
  - Increasing
  - Decreasing

**Identify the most probable root cause.**
- List all the possible root causes.
- Compare each suggested root cause with the problem statement and the facts.
- Identify which root cause fits all the facts.
- Double check your findings.
- Use the root cause to identify the responsible party.
  - Manufacturer
  - Dealer/technician
  - Customer

**Communicate your findings with the responsible party.**
**Make repairs as directed.**
**Follow-up with the customer.**

Normal Engine Wear

**Normal wear is the expected wear with engine operation as parts push, slide, and work against each other.**
- Cylinder liners
- Piston rings

**A turbocharger bearing has seals that can wear as well if they are equipped on this component.**
- Valves and valve guides
- Main and rod bearings
Abnormal Engine Wear

Abnormal wear is unexpected wear that can lead to premature engine failure.

- Generally, abnormal wear results from incorrect maintenance or improper operating techniques, such as:
  - Wrong lubricant
  - Too long between oil changes
  - Lack of coolant additives
  - Inadequate engine warm-up

Parts that can undergo abnormal wear:
- Cylinder heads
- Cylinder blocks
- Crankshafts
- Camshafts
- Pistons and connecting rods

Mechanical Wear and Characteristics

Abnormal Engine Wear

- Abrasive wear
  - Occurs when hard particles such as dirt or debris get trapped in the lubricating film between moving parts
  - Heat build-up occurs, weakening the parts.
  - Soft metal parts are damaged first.
  - Accounts for the majority of wear failures (over 50%)
- Adhesive wear
  - Consists of localized bonding between contacting surfaces, which leads to material transfer from one surface to the other or loss of material from either surface
  - Is frequently referred to as scoring, scuffing, seizing, or galling
  - Contact between the moving surfaces produces intense heat.
  - Metal surfaces begin a cycle of welding/shearing until one part is destroyed.
  - Caused by inadequate lubrication between moving surfaces
- Corrosive wear
  - Occurs when metal surfaces are exposed to an electrolyte, dissimilar metals (for example, aluminum in contact with steel), or high temperatures.

- It is typically a reaction between ferrous and nonferrous metals.
- Metal is removed by electrochemical action.
- Erosive wear (erosion)
  - Occurs when small hard particles, carried by fast-moving fluids, strike metal surfaces at high speeds
  - Metal parts suffer damage from impact and abrasive wear.
  - Erosion is greatly accelerated when worn parts begin to break up.
- Cavitation erosion
  - Occurs when vapor bubbles in a fluid strike a metal surface
  - As the bubbles burst, they send a fluid “jet” against the metal surface at supersonic speeds.
  - Pits form as small metal particles are blown away.
- Fretting wear
  - Occurs when tight fitting (shift or press fit) parts are allowed to move slightly against each other such as by vibration
  - Flash welding creates small pits.
  - The particles interfere with running clearances, affecting lubrication.
Root Causes of System Failures

Fuel system failures
- Wrong fuel, either incorrect grade or incorrect sulfur level
- Contaminated fuel (biological, dirt, or water)
- Incorrect installation of components or lines
- Incorrect timing of fuel injectors

Cooling system failures
Note: Over 40% of engine failures result from cooling system problems. The cooling system is most critical to engine life.
- Supplemental coolant additive (SCA) problems: either too little or too much, the incorrect or incompatible type, or deteriorated or low quality
- Coolant problems: either an incorrect mix of water, antifreeze, and additives, or contaminated coolant (metal, dirt, oil)
- Faulty cooling system components (thermostat, fan, pump) that cause the engine to run too hot or too cool

Lubrication system failures
- Wrong lubricant: either the incorrect viscosity (too thick or too thin) or the incorrect weight or grade
- Too little (or marginal) lubricant
- Contaminated lubricant (metals, dirt, coolant)
  Note: Contaminated oil is the single largest cause of engine crankshaft bearing failures.
- Clogged oil filters
  Note: Metal in the filter indicates internal engine wear.

Air induction and exhaust system failures
- Air or exhaust restrictions: either plugged air filters or malfunctioning turbochargers or other components
- Dirty air