# UNIT M2- DIESEL ENGINE COMPONENTS

## OBJECTIVE

The objective of this block is to make you understand about the major components of the Diesel Engine as per the following details:

- Construction
- Manufacturing process
- Salient features and required dimensional accuracy in the key areas
- Assembling technique and their inspection procedure.
- Failure analysis of components

### STRUCTURE

Self-assessment

## INTRODUCTION

This unit contains, in brief, the essential details in respect of design, construction, working principle and maintenance procedure of the Diesel Engine components. The discussion has been kept confined to standard locomotives of Indian Railways that is WDM2.

The Diesel engines consists of following major components & assemblies: -

| | | | |
|---|---|---|---|
| 1.Engine base | 2.Engine block | 3.Crank shaft | 4.Cam shaft |
| 5.Cylinder head and Valves | 6. Liner | 7. Piston, **P**iston rings and Connecting rods**.** | |

## ENGINE BASE: -

When diesel engines were of low speed and low horsepower the engine base and blocks were made of heavy cast iron casting. In older types engines one of the main functions of the base was to take the crank shaft. In the modern engines the crank Shaft is under hung from the engine block.

With the development in diesel engines and with the change in design, fabricated engine blocks and bases are finding favour though in some small horse power engines cast iron blocks are still in use. The engine base of ALCO Locos WDM2, WDM4 are made from weld able quality steel to specification IS-2062 with 0.2% of carbon.

The engine bases of ALCO Locos have following functions.
It has to -

a) Support the engine block
b) Serve as oil sump
c) Accommodate lube oil main header
d) Take lube oil pump and water pump at the free end
e) Allow openings for crank case inspection
f) Take fitment of crank case explosion cover
g) Foundation pads are provided for transmitting load to the chassis and also to take lower blots of the main generator magnet frame.

A perforated screen is fitted to the base to prevent foreign matter like pieces of metal etc. getting access to the sump. The top face of the base which takes the engine block is machined smooth and a sealing compound is applied before fitting the block to make the crank case air tight so that crank case vacuum can be maintained.

Except for the size and sump capacity the engine base of YDM4 Locos is same as that of WDM2 in respect of material and manufacturing technique.

In case of WDS4B Engines there is no separate base. The function of oil sump is performed by fabricated steel sheet fitted at the bottom of the block with gasket in between.

## ENGINE BLOCK

The engine block is the most important and very highly stressed structure on which are fitted a number of important fittings like crank shaft, cam shaft, cylinder heads**,** cylinder liners, pistons**, C**on. Rods, fuel injection pumps and cross-head, turbo support, governor etc to form a complete Power pack.

Manufacturing Process

This structure is fabricated from low carbon steel to specification IS-2062. The saddle, however, is a forging out of steel to specification IS-1875. The fabrication is done in a definite sequence to minimize distortion and build up of stresses. In order to ensure that best quality of fabrication is done in all cases down hand welding is resorted to. For this purpose extensive use of positioners are made. Wherever possible, continuous welding is done in the process of automatic submerged arc welding. To make sure that there is no defect in the welding, X-ray testing of welding is done liberally.

After fabrication by welding, stress relieving and shot blasting is done and then hydraulic test of water chamber is done so that no water leakage can take place. Finally the block is taken to the marking table for marking and then machining. After marking, the engine blocks are placed on the planning machine for machining the sides and the top faces, all the faces being machined at a time. While setting up for machining, it is ensured that the side faces are at right angle to the end face. The bottom face and the saddle faces are also machined in the same machine.

The blocks are then taken for serration milling of saddle faces. In continuation with serration of saddle faces the serration milling of bearings caps are done. This is to avoid error caused due to wear and tear to the milling cutter. Each bearing cap is marked for the location so that the bearing cap cannot be pooled about or wrongly fitted. After the milling operation the depth of serration, and distance between two consecutive pitches are measured with the help of special dial gauges.

After the inspection the bearing caps are assembled and they are tightened to the specified torque value. Subsequent to fitting of the caps to the block the engine block is placed on the horizontal boring cum milling machine. On this machine, end face milling is done and boring of main bearing housing and camshaft bearing is done in one setting with the help of a fixture. This is done to ensure that the distance between crankshaft to camshaft is exactly equal throughout and the central line is perfectly parallel to each other. The maximum possible misalignment permitted in main bearing housing bore are as follows: -

Horizontal misalignment:

1. Between adjacent bores. 0.002"

2. Between any to any bore. 0.004"

Vertical misalignment:

1. Between adjacent bore 0.0015"

2. Between any to any bore. 0.003"

This sort of misalignment can be checked with the help of mandrel and feeler gauge. But this is considered to be rather crude method. It is advisable to make such checks with the help of optical instruments like collimators to give accurate results.

After the boring of crank and camshaft bearing housing, the work of machining top & middle decks of cylinder liners is taken up. The two bores, the chamfers and facing of the top face are all done simultaneously with the help of machine with two boring bars fixed at an angle of $45^{O}$.

The engine blocks have been found to show signs of distortion after a life of 12 to 15 years or as an after effect of crankshaft seizure or major accident. In order to cope with such defects, capacity has been created in DLW for reclamation of blocks.

The method of construction, manufacture, inspection and maintenance of YDM4/WDS6 engines base and block is almost the same as WDM2 block except for dimensional difference and except for the fact that WDM2 are 16 cylinder "VEE" blocks and YDM4 are with 6 cylinder in line engine blocks.

## *Maintenance & Inspection*

Schedule: POH & Major

Details of Inspection:

- Visual Inspection: To check about the physical damages in the block and take decision about its reuse or reclamation.
- Examination of threads and renewals of threads, if essential.
- Measurement of top and bottom deck to select liner as well as to change liner sleeve, if necessary.

- Measure cam bearing dimension and change bearing, if necessary.

- Main Bearing housing Inspection:
  1. Check serration of saddle and M/ Bearing cap by serration gauge.
  2. Fit main bearing cap and elongate properly upto .040" as per laid down procedure.
  3. Measure each bore at two different planes ½" away from both sides and in each plane at 3 different locations, vertical and at 45°angular position at both sides of it.

     Difference in readings at a particular plane gives the value of ovality (limit 0.003")

     Difference in vertical readings gives the value of vertical taper (limit 0.001"}.

     *Difference in angular readings gives value of angular taper (limit 0.003")

     Concentricity of Main Bearing bore should be maintained within the following limit:

     Horizontal misalignment: 1) between adjacent bores: 0.002"

     2) Between any to any: 0.004"

     Vertical misalignment: 1)Adjacent 0.0015"

     2)Between any to any 0.003"

     Misalignment is checked with the help of Mandrel and filler gauge.

- While assembling, block and base should be perfectly aligned within the limit (Gen end: 0.000", side ways: 0,002" max).
- Hydraulic test: Hydraulic test conducted at 2.5 kg/cm² at normal temperature to check whether any leakage exists between block and liner. If so, liner O-rings are changed or other corrective measures are taken accordingly. This is done after assembling liners during assembly stage.

## CRANKSHAFT

The engine crankshaft is probably the singular costliest item in the diesel engine. It is the medium of transforming reciprocating motion to rotary motion. Output of the engine is collected from crankshaft. WDM2 locomotive is having electrical transmission system hence to convert Mech power of engine into electrical power a Generator is fitted at the traction output end of the engine. The Rotor of the Traction Generator is mounted directly on the crankshaft through flange joint. The crankshaft may be assembled type or two pieces bolted type or may be single piece forging. Counter weights are provided for dynamic balancing of the crankshaft; they are either bolted up or welded. The standard Locomotives of Indian Railways are provided with single-piece crankshaft with welded counter weights. In case of CLW/MAK engines the counter weights are bolted. The portions of crank shaft which form the axis of rotation are called main journals where it is housed in the engine block through main bearings and the eccentric portions where piston is connected through connecting rod are called crankpins. In case of WDM2 type engine there are 9 main journals and 8 crankpins to accommodate 16 pistons in a V shaped engine. Through internal drill holes of crank shaft lube oil is supplied for lubrication of main bearing and con rod bearing portion and the same oil is further circulated for piston cooling through internal drill hole of con rod.

The ALCO crankshafts are manufactured from chrome-molybdenum steel equivalent to SAE 4140. The process of forging is such that continuous grain is maintained. In manufacture of crankshaft, following sequence of operation is generally followed**: -**

a) Forging and forming operation

b) Rough machining

c) Drill of oil holes.

d) Ultrasonic & Mechanical testing

e) Welding of counter weights & their X-ray test.

f) Stress relieving & shot blasting

g) Final machining & for giving fillet radius at crank journal corners and making oil holes.

h) Nitriding

i) Grinding Lapping

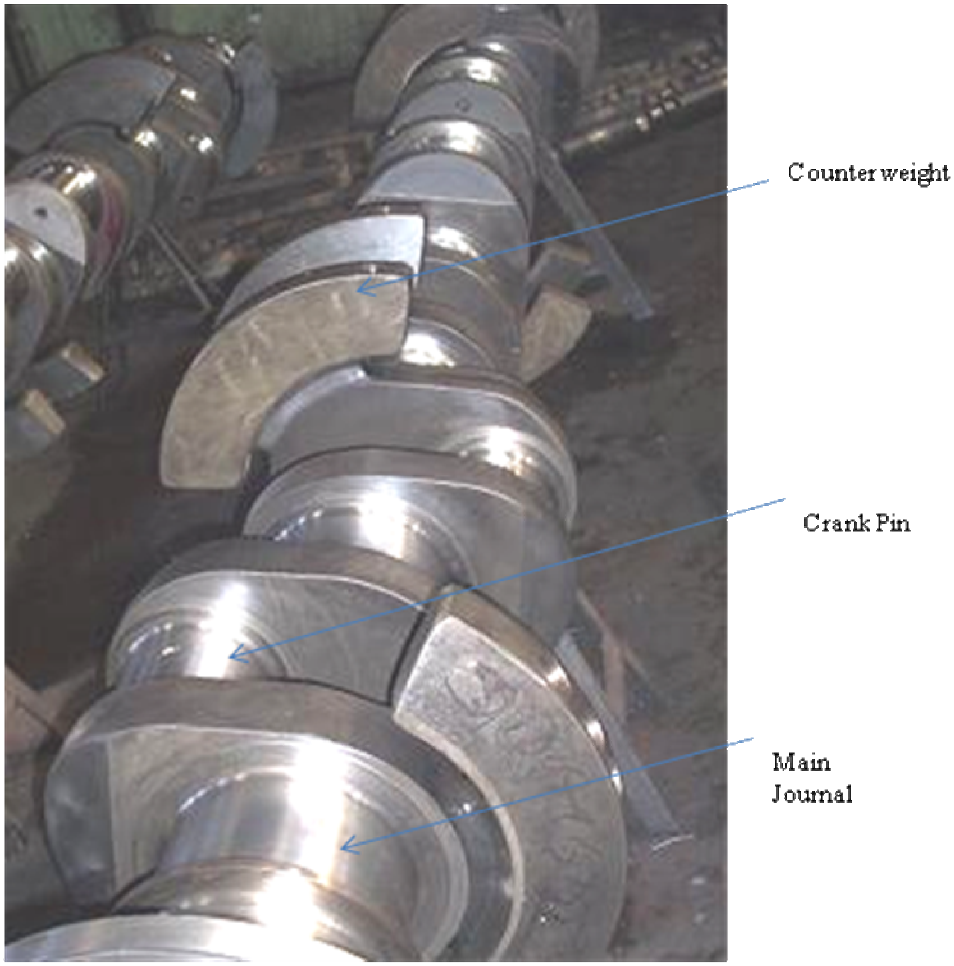
j) Static & dynamic balancing

k) Final inspection

There are two processes of surface hardening with details given below:-

| Method of hardening | Hardness | Depth of hardness |
|---|---|---|
| Induction hardening | C-40 | 0.124" |
| Nitriding | C-60 | 0.012 to 0.015" |

Generally for low HP engines the first process is preferred, as depth of case is more and the crank journals and man bearing journals can be ground down to next step size. In case of high HP and high-speed engines, the preference is for the second process as it gives long life, the rate of wear being negligible.




## *Maintenance & Inspection*

*Schedule*: POH

*Procedure:* After cleaning thoroughly, Dye penetration / Magnaflux test is conducted to detect surface crack. The following dimensional checks are to be carried out:

*Crank pin:* Positioning it vertically check dimension at two locations just beside two oil holes (at two right angular planes in each location) to check ovality and taperness.

Nominal Dia: 6", Limit upto 5.996"

Ovality: .002"(max) Taperness: .001"(max)

*Main journal:* Position the crankshaft, keeping No 1 crankpin in vertical location, measure the dimension as that of crank pin.

Nominal Dia: 8.5", Limit upto 8.496"

Ovality: 0. 002" (max) Taperness: 0.001" (max)

*Fillet Radius:* Checked through a special gadget. (0.0005" filler gauge should not pass between the gadget and the fillet)

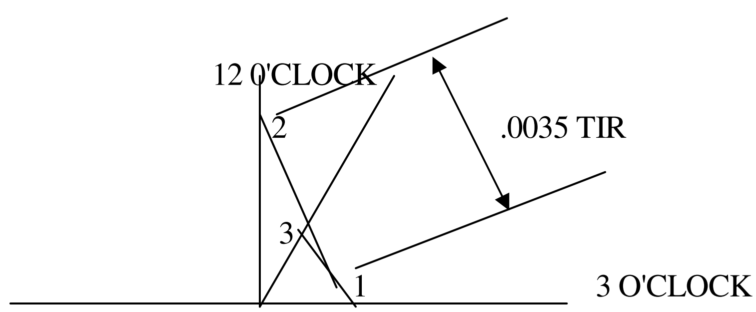
*Eccentricity checking:* Eccentricity is checked between any three consecutive main journals (1,2,3) is given by the distance between the center points of journal 2 and the mid point of the line joining the center points of journals 1 & 3. The limit of eccentricity is .001". Eccentricity is checked by the following way:

- Place the crankshaft horizontally on a "V" block supported at No3 and No 7 Main Journals, keeping No 1 crank pin in vertical position.
- Mark Dial of a clock at the free end flange in this position, to understand angular location of the maximum deviated zone.
- Record the readings of maximum deviation of every main journal along with their angular location.
- An example of calculating the eccentricity (For No 1,2,3 Main Journals) is given below:
    - Highest total indicator reading (TIR) for:

      No 1 M.J.0.0015" at 3 o'clock location.

      No 2 M.J. 0.004" at twelve o'clock

      No 3 M.J. 0.0015 at 1-30 o'clock
    - Plot the graph according to deflection and o'clock location, with suitable scale.
    - Connect TIR position of No1 and No3 with a straight line.
    - Mark the midpoint of the above straight line and connect it with the TIR of No 2. This is the relative runout of No 1,2,and 3 main journals.
    - Divide the runout by 2. This is the eccentricity and must not exceed .001". (This case it is .00175" and not acceptable.)
    - Repeat the above case for each group of three consecutive main journals



*Crank web deflection:* Checking of crank web deflection is one of the major works while assembling engine.

Main generator rotor is coupled at one end of the crankshaft, whose other end is supported on a bearing housed at the magnet frame. As such, for any dislocation of magnet frame, if axis of armature does not completely align with the axis of the crankshaft, the unbalanced mass of armature will cause uneven loading on crank web at different angular positions during rotation. This causes **deflection on crank web**, which will be changing at various positions of crankshaft during rotation. Such kind of continuous cyclic variation of load leads to main bearing seizure and breakage of crankshaft.

The crank web deflection is measured by fitting a deflection gauge at the located punch mark on the $8^{th}$ crank web (web nearer to TG) and manually rotating the crankshaft in both the directions

The permissible limit of deflection on each side is ±0. 0008", TIR ±. 0.0016".

If the deflection is beyond the permissible limit, correction is made by adding or subtracting shims at the mountings of magnet frame with engine block. The magnet frame is mounted at two locations with the engine block and at two locations at the base. Adjustable shims are provided at the mountings of the magnet frame with the block. The shims of the magnet frame with the base are fixed and normally not disturbed during crankshaft deflection.

## CAM SHAFT

In diesel engine the cam shaft performs the vital role of opening and closing inlet and exhaust valves and operates Fuel Injection Pump for timely injection of fuel inside the cylinder. Usual practice is to provide 3 cams for each cylinder the two outer cams being for exhaust and inlet valves and the central cam being for fuel injection.

ALCO engines have cams integral with camshaft. Each camshaft section takes care of two cylinders. After profile milling of the cam lobes the cams are given for induction hardening. Subsequent to this the cams are put on profile grinding machine. The individual camshafts are joined together by bolting. The location of dowel hole is of importance as it determines the relative angular position of one camshaft section with respect to the adjacent one.

In order to avoid wrong assembly respective catalogue Nos. of camshaft sections are punched onto the shaft. Care has to be taken to see that the correct section is fitted in correct location. The rifle hole is made in the center of the shaft for lubrication of cam bearings. Lubrication to cam lobes is provided by oil coming from valve lever mechanism via the push rod.

*Material composition:* The ALCO camshafts are made from AISI specification 1050 with following metallurgical composition.

Carbon 0.48 to 0.53%

Manganese 0.60 to 0.90%

Chromium 0.15 to 0.30% Max.

Phosphorus 0.025% Max.

Sulphur 0.025% max.

## *Assembly & Inspection*

Schedule: POH & Major

Inspection: Check cam profile through profile gauge. (If damaged or worn out the cam segment is changed.)

Setting of Cam shaft & Valve/ FIP timing: Proper assembling and setting of camshaft is essential to ensure correct valve and FIP timing.

(a) Timing Mark & Pointer

- Timing Marks are provided on Timing Disc (Main Generator fan) fitted with Main Generator armature, mounted on crankshaft. (Relation between crank shaft, armature and armature fan are maintained through dowels, provided)
- TDC, INJ Pointer is mounted on the block to read the relative position of cylinder corresponding to pointer and timing disc. (Pointer needs to be calibrated during engine overhauling by finding TDC with the help of dial indicator or trammel gauge.)

(b) Setting of cam shaft

- Assemble the cam segments as per correct sequence and order (Part Number indicates the sequence and dowels fix their angular relation). Thus left and right side camshafts are formed.
- Position the crankshaft to 1R TDC. Match both side cam gears with crankshaft gear in such way that cut marks (line mark) on cam gear should perfectly match with block edges.
- Now fit both camshafts matching with the key holes of cam gears.
- Secure the camshafts finally on cam gear by tightening it properly through locknut.

(c) Valve Timing

- Rotate the crankshaft and bring the corresponding cylinder to compression stroke (ensure compression stroke by feeling free rotation of push rods.)

- Check the gap between the valve stem and yoke. It should be 0.034". If not adjust it through valve lever adjustment nut and yoke adjustment nut.

(d) FIP Timing

- Rotate the engine to bring the injection point against the corresponding cylinder.
- Match the body cut mark of FIP at inspection window with the given line mark on guide cup .If not, adjust it through timing allenscrew provided at the bottom of the FP lifter.

## CYLINDER HEAD

The cylinder head is held on to the cylinder liner by seven hold down studs or bolts provided on the cylinder block. It is subjected to high shock stress and combustion temperature at the lower face, which forms a part of combustion chamber. It is a complicated casting where cooling passages are cored for holding water for cooling the cylinder head. In addition to this, provision is made for providing passage of inlet air and exhaust gas. Further, space has been provided for holding fuel injection nozzles, through Nozzle Sleeve fitted in the cylinder head. Valve guides and valve seat inserts also fitted in the cylinder head casted body.

In cylinder heads valve seat inserts with lock rings are used as replaceable wearing part. The inserts are made of stellite or weltite. To provide interference fit, inserts are frozen in ice and cylinder head is heated to bring about a temperature differential of 250°F and the insert is pushed into recess in cylinder head. The valve seat inserts are ground to an angle of 44.5° whereas the valve is ground to 45° to ensure line contact. (In the latest engines the inlet valves are ground at 30° and seats are ground at 29.5°). Each cylinder has 2 exhaust and 2 inlet valves of 2.85" in dia. The valves have stem of alloy steel and valve head of austenitic stainless steel, butt-welded together into a composite unit. The valve head material being austenitic steel has high level of stretch resistance and is capable of hardening above Rockwell –34 to resist deformation due to continuous pounding action.

The valve guides are interference fit to the cylinder head with an interference of 0.0008" to 0.0018". After attention to the cylinder heads the same is hydraulically tested at 70 psi and 190°F. The fitment of cylinder heads is done in ALCO engines with a torque value of 550 Ft.lbs. The cylinder head is a metal-to-metal joint on to cylinder.

The cylinder head castings are made from special alloy cast iron as per specification given below**: -**

## *Material composition:*

Total carbon 3.00 to 3.40%

Silicon 1.80 to 2.20%.

Sulphur 0.12% to 0.8%.

Phosphorous 0.15 Max..

Manganese 0.65% to 90%

Chromium 0.20% to 0.40%

Nickel 1% Min.

Molybdenum 0.35% to 0.45%

ALCO 251+ cylinder heads are the latest generation cylinder heads, used in uprated engines, with the following feature:

-Fire deck thickness reduced for better heat transmission.

-Middle deck modified by increasing number of ribs (supports) to increase its mechanical strength. The flying buttress fashion of middle deck improves the flow pattern of water eliminating water stagnation at the corners inside cylinder head.

-Water holding capacity increased by increasing number of cores (14 instead of 11)

-Use of frost core plugs instead of threaded plugs, arrest tendency of leakage.

-Made lighter by 8 kgs (Al spacer is used to make good the gap between rubber grommet and cylinder head.)

-Retaining rings of valve seat inserts eliminated.

Benefits:-

-Better heat dissipation

-Failure reduced by reducing crack and eliminating sagging effect of fire deck area.

## *Maintenance and Inspection*

Schedule: Yearly

- Cleaning: By dipping in a tank containing caustic solution or ORION-355 solution with water (1:5) supported by air agitation and heating.
- Crack Inspection: Check face cracks and insert cracks by dye penetration test.
- Hydraulic Test: Conduct hyd. test (at 70 psi, 200°F) for checking water leakage with the special attention at nozzle sleeve, ferrule, core plugs and

combustion face.

- Dimensional checks:
  - (a) Face seat thickness: within 0.005" to 0.020"
  - (b) Interference:
    - I. Valve seat insert to housing: 0.0015" to 0.0035" (Stellite)
      0.003" to 0.005" (Weltite)
    - II. Valve Guide: 0.0008" to 0.0018"
    - III. Yoke Guide: 0.0015"
  - (c) Projected Height:
    - I. Valve Guide: 2.25"
    - II. Yoke Guide: 3.210" to 3.272"
  - (d) Clearance between valve and guide: 0.004" to 0.007"
  - (e) Thickness of valve disc & Insert: 5/32" (new) 3/32" (min)
  - (f) Straightness of valve stem: Runout should not exceed 0.0005"
  - (g) Free & Compressed height (at 118 lbs.) of springs: 3 13/16" & 4 13/16"
- Checks during overhauling:
  - (a) Ground the valve seat insert to 44.5°/ 29.5°, maintain run out of insert within 0.002" with respect to valve guide while grinding.
  - (b) Grind the valves to 45°/ 30° and ensure continuous hair line contact with valve guide by checking colour match.
  - (c) Ensure no crack has developed to inserts after grinding, checked by dye penetration test.
  - (d) Make pairing of springs and check proper draw on valve locks and proper condition of groove and locks while assembling of valves.
  - (e) Lap the face joint to ensure leak proof joint with liner.
  - (f) Blow by test:
    - I. On bench *blow by* test is conducted to ensure the sealing effect of cylinder head.
    - II. Blow by test is also conducted to check the sealing efficiency of the combustion chamber on a working engine, as per the following procedure:

a) Run the engine to attain normal operating temperature (65°C)

b) Stop running after attaining normal operating temperature.

c) Bring the piston of the corresponding cylinder at TDC in compression stroke.

d) Fit blow-by gadget (Consists of compressed air line with the provision of a pressure gauge and stopcock) removing decompression plug.

e) Charge the combustion chamber with compressed air.

f) Cut off air supply at 70 psi. through stop cock and record the time when it comes down to zero.

g) 7 to 10 secs is OK., if less check the leakage.

h) To check leakage, charge continuously at 70 psi

-Leakage through TSC indicates head defective.

-Leakage through Sump indicates defect in Piston or Liner.

(g) Tale-tell hole checks: Tale tell hole in cylinder head tells about the condition of cylinder heads in running condition as per the following:

I. No leakage: OK

II. Fuel droplets: Upto 2 drops/min OK.

If more, Nozzle leak off rate is high.

III. Fuel Mist: Nozzle seat defective.

IV. Water leakage: Nozzle Sleeve cracked.

V. L/Oil leakage: Rubber ring on Nozzle perished.

LINERS

Liner forms the wall of the combustion chamber as well as it also guides the movement of piston inside it. Liners are mainly of two types i.e. (a) Dry liner (b) Wet liner.

(a) Dry liners are those, which does not come in direct contact with coolant but fits in as a sleeve inside an already complete cylinder. The temperature of the inside surface of dry liner is higher than corresponding wet liner. Dry liners are in use in only very small engines.

(b) Wet liners are those, which not only form the cylinder wall**,** but also form a part of the water jacket. ALCO Locomotives are fitted with wet liners, which have slight interference fit on upper and lower decks. In addition to this, synthetic rubber seals of suitable qualities are to be used, one on the upper deck groove (Si Rubber) and two on middle deck (Viton rubber). Lack of interference or defect in gaskets may result in water leakage causing water contamination of crank case oil. The liner bore has chrome-plated surface and is honey combed by electrolytic process. ALCO liners have no step size in the bore. It has got only one standard size permitting a wear of 0.009 inch.

The General Motor cylinder liners are fabricated type embodying the water jacket. In General Motor Locomotives, instead of liner bore being chrome plated the piston rings are chrome plated.

The ALCO cylinder liners are made of high strength close-grained alloy cast iron heat-treated to relieve stresses. The liner metal composition of a typical ALCO engine is given below**: -**

COMPOSITION

(Unalloyed cast iron grade 17)

Carbon 3.00 -0 3.50%

Silicon 1.70 to 2.30%

Sulphur 0.12% Max (mandatory)

Phosphorus 0.15% Max (mandatory)

Manganese 0.60 to 0.90%

Chromium 0.25 to 0.60 %

Molybdenum 0.35 to 0.70% (mandatory)

***Maintenance & Inspection*****:** Yearly inspection, 3 yearly & POH renewal

The cylinder liners suffer from the following major defects:

(a) Wear in the bore (Nominal bore 9".Max allowed 9.009")

Max ovality: .003"(max) Max taperness: .002"(max)

(b) Loss of interference in the top & bottom decks.

In the bottom deck portion, in between Liner and block a sleeve is used, made of spheroidal gray cast iron. Hence in case of losing interference or any other defect the sleeve is renewed.

Interference between block to sleeve: .004" to .008"

Int. between sleeve to liner: .0005"to .0015"

As the liners form water jacket with the engine block, hence for proper sealing one rubber ring of Si- rubber and two rubber rings of Viton rubber are used at the top and bottom deck respectively. It is essential to change the rubber rings while renewing or removing liners.

(c)Cavitation erosion of outside circumference particularly near the location of fuel injection pump side and also opposite to fuel injection pump side.

- The cylinder liners can be reclaimed by re-chrome-plating in case of wear in the bore up to a certain limit. In case of cavitation and erosion, if the cavity is more than 1/8" deep then the liner needs to be replaced.

## PISTONS, PISTON RINGS AND CONNECTING ROD

PISTON

The piston is the most important component in the diesel engine as it forms a part of the combustion chamber and also takes direct part in transmission of power. It is, therefore, necessary that the designers and users must know the essential details about the piston. The combustion of fuel results in large amount of heat being developed. Out of this about 18% of the heat is absorbed by piston only.

The functions of the piston are: -

(a) It compresses the air to required pressure & temperature.

(b) It receives the thrust of expanding gases and transmits the force through connecting rod (for rotating crankshaft).

(c) It forms the crosshead through which side thrust due to angularity of connecting rod is transmitted to the cylinder wall.

(d) With the help of piston rings it prevents leakage of gas from combustion chamber to crank case.

Guiding factors for dimensions are as follows**: -**

(a) The top portion of the piston is in contact with direct heat of combustion. Inspite of cooling arrangement, it takes up more expansion and as such the need for more clearance at this location.

(b) Relief has to be provided at the piston pin located area to prevent seizure of piston due to bulging of material at this location in course of working.

*Ring Grove Insert*

The top most ring bears the maximum burnt of high pressure hot gases. This result in heavy wears in the upper ring groove. In order to over come this problem, Ni-resist ring insert is fitted in the uppermost ring groove. Ni-resist rings apart from being dove tailed in Aluminium casting/forging, are molecularly bounded to the Aluminium body by AI-FIN-process.

## *Piston material:*

In many ways cast iron is best-suited material for manufacture of piston. The reasons are as follows**: -**

(a) Co-efficient of expansion matches with cylinder liner whereas Aluminium has got twice the co-efficient of cast iron.

(b) Heat conductivity is 3 times better than Aluminium.

(c) Compressive strength is much more than Aluminium at high temperature.

(d) Wear is less than Aluminium.

But the two main disadvantages with cast iron piston are**: -**

(a) Weight of Aluminium is 0.097 1bs. per cubic inch whereas in place of cast iron it is 0.284 1bs. per cubic inch. Thus cast iron pistons are about 3 times heavier than Aluminium piston in weight.

(b) Possibilities of cylinder liner being scored are more in case of cast iron piston.

The factor of weight has become more over riding in view of the high speed of the modern diesel engines and hence Aluminium alloy pistons are favoured. ALCO 251 engines pistons are of Aluminium alloy with composition given below-

COMPOSITION

Copper 5.8 to 6.8%

Zinc 0.10% max.

Manganese 0.20 to 0.40

Titanium 0.02 to 0.10

Vanadium 0.05 to 0.15 %

Zirconium 0.10 to 0.25 %

Silicon 0.20% Max.

Iron 0.30% Max.

Magnesium 0.02% Max.

Other 0.15% TOTAL

Aluminium - remainder

These pistons are in two parts i.e. the piston body (or skirt) and the ring carrier having interference fit. The joint between the ring carrier and piston is welded at the crown by inert gas welding.

Mahle has developed single cast Al alloy piston, reducing the chances of dislodging of ring carrier during working.

Steel cap pistons are used in Fuel efficient and upgraded engines.

## PISTON RINGS

The main functions of piston rings are: **-**

a) Sealing of combustion chamber and thus prevents blow by of air and high temperature combustion gasses from getting access to crank case.

b) Scraps down excess lube oil from walls of cylinder liner and thus prevents reaching lube oil into combustion chamber.

Piston rings are made of malleable grey cast iron with open graphite structure and a hard pearlitic matrix. The piston ring operates during a part of its life under conditions of marginal lubrication hence material composition has important role in this regard.

Piston rings are used in combination to perform the above functions. They are either 5 ring combination or 6 ring combinations. Now a days 5 ring combinations are in use.

| | | |
|---|---|---|
| Compression Rings: | 1. Square Face | 1. Square Face |
| | 2.Taper Face | 2. Taper Face |
| | 3. Taper Face | 3. Taper Face |
| Oil scrapper Rings: | 4.DoubleTaper face | 4.DoubleTaper Face |
| | 5. Conformable | 5.Double Taper face |
| | | 6.Conformable |

In the latest fuel efficient engines barrel faced piston rings are used in place of square faced compression rings and both the oil scrapper rings are conformable rings.

## CONNECTING ROD

Connecting rod is a member connecting piston and crankshaft and is a medium for converting the reciprocating motion to rotary motion. In four stroke engines during the compression and power stroke the connecting rod is subject to high compressive load. In suction stroke it undergoes high tensile stresses. In case of two-stroke engine the connecting rod is only subject to compressive load. Connecting rod length is usually about 4 to 5 times of the crank radius. They are I beam sections of fine-grained, fully killed alloy steel forging. Connecting rods are having a fine-drilled hole from the big end to the small end for transporting oil for lubrication at small end bearing and piston pin and for cooling of piston.

The connecting rod assembly consists of**: -**

(i) Connecting rod, (ii) Connecting rod cap (iii) Piston pin bushing (iv) Bearing Shell upper (v) Bearing Shell lower (vi) Connecting rod bolts and nuts.

During assembly the bolts are to be tightened with specified torque value and elongation upto .015” to .018”. Connecting rods are mostly made of carbon steel or alloy steel forging. The metallurgical composition of connecting rod is given below in percentage.

COMPOSITION

Carbon 0.43

Manganese 0.75%

Phosphorous 0.025% Max.

Sulphur 0.025% Max.

Silicon 0.20 %

Nickel 0.40 %

Chromium 0.40 - 0.60%

Molybdenum 0.15 - 0.25%

Boron 0.5% Min.

## *Maintenance & Inspection:*

Schedule: Yearly

Cleaning: Solution of ORION 516 in HSD Oil is used for Piston cleaning

Checks: Zyglo test for checking surface cracks.

Visual checks for checking damages in piston crown, Ring grooves, circlip groove and Ni- resist insert

## Dimension checks:

a) Piston crown, skirt and bottom
b) Piston pin hole dia: ( Tolerance : +0.001”, Ovality : 0.0005”)
c) Con rod to Piston side clearance: 0.013”to 0.024”
d) Piston to pin Dia clearance: 0.0005 to 0.0025”( max 0.0035”)
e) Bushing to pin dia. clearance 0.0025 to 0.004” (max 0.006”)

## Piston ring checks during assembly:

a) Proper sequencing
b) Maintaining proper side ( top and bottom)
c) Ring Gap check:

   Compression Ring: 0.045 to 0.055” (max 0.200”)

   Oil Scrapper Ring: 0.030 to 0.040” ( max 0.125”)
d) Side clearance

   Compression Ring: 0.006 to 0.0085”(max 0.012”)

Oil Scrapper Ring: 0.002 to 0.0045” (max 0.006”)

e) Maintain 180° interval between two consecutive ring gaps.

## Con Rod checks:

a) Measure big end bore dia, ovality (max 0.003”)

b) Twist: 0.002”, bend 0.001”(max)

c) Length of Con Rod bolt 11±.005”

**FAILURE ANALYSIS OF COMPONENTS & FAILURE INVESTIGATION**

A part or assembly is said to have failed under one of the three conditions-

When it becomes completely inoperable-occurs when the component breaks into two or more pieces.

When it is still inoperable but is no longer able to perform its intended function satisfactorily- due to wearing and minor damages.

When serious deterioration has made it unreliable or unsafe for continuous use, thus necessitating its complete removal from service for repair or replacement-due to presence of cracks such as thermal cracks, fatigue crack, hydrogen flaking.

## GENERAL PRACTICE OF FAILURE INVESTIGATION

The objective of failure investigation, and subsequent analysis is to determine the primary cause of failure, and based on this determination, decide on corrective measures, which should be initiated to prevent similar failures. The principal stages of investigation are-

Collection of background data and collection of sample-

All available information regarding the manufacturing, processing, and service history should be collected. Particulars and condition of other affected components should also be noted. Details about operating conditions must also be noted meticulously. Selection of the sample should be done prior to starting the examination.

2. Visual examination of failed components-

After the receipt of the broken and affected components in a metallurgical lab, each sample is registered against a particular sample number. The fracture face is cleaned with K oil. And soft metallic brush. Location of the fracture must be done in relation to some fixed corner or side depending upon the specimen. Examine the fracture face with a magnifying glass to determine the type of fracture. Nature of stress raiser can also be determined. Examination can be done for the presence of welding or reclamation marks, wearing etc., and if possible, photographs may be taken.

To determine the nature of fracture and stress raiser-

On the basis of visual examination, fractures may be classified as:

*Ductile fractures*: it involves a reduction in area and neck formation at the location of the fracture. Overloading is the main reason of this type of fracture. Generally found in tough materials

*Brittle fractures:* the entire fracture face is crystalline without any origin. Sudden shock or loading is the main cause of this type of fracture. There is no reduction in area of cross section at the point of fracture. Generally occurs in fragile materials. However, sometimes a part made of tough material, can sometime fracture in a brittle manner if that part contains a large enough flaw or if there is sufficient elastic or plastic constraint.

*Fatigue fractures.* They result from the application of repeated or cyclic stresses, each of them may be substantially below the normal yield strength of the material. Fatigue fracture face has two distinct zones. It is comparatively smooth and huge concentric circles or marks originating from a single nucleus are present. They generally show slight roughness as the crack grows. The remaining portion is crystalline in nature due to the sudden fracture**.**

3. *Non-destructive testing:-* These tests include magnetic particle inspection, ultrasonic testing, liquid penetrant inspection, and radiography. These tests are done to find out surface and sub-surface defects. The magnetic particle inspection is done on Ferro-magnetic components, while penetrant tests, ultrasonic tests, and radiography tests can be done on all the components.

*Mechanical testing:-* Mechanical tests include hardness tests, UTS, elongation, bend tests, izod-charpy tests etc. They help ascertain whether the component conforms to the physical properties mentioned in the drawing. Nick break test is done on non-ferrous materials to see segregation and oxidation.

*Chemical testing:-* Drillings of the component are taken to determine its chemical composition.

*Macro examination:-* Two types of macro examination are done:

Deep etch test to determine the grain flow and to decide whether the component is forged, rolled, or cast. It gives indication of inclusion, segregation, rolling seam etc.

Sulphur print: this test gives the indication of Sulphur segregation, and is done by pressing Silver Bromide paper dipped in 5% sulphuric acid on the polished surface of transverse cut section.

Micro-examination:- This determines the microstructure, inclusion, and mode of heat treatment given to the component. This also tells about the presence of micro-cracks, welding, structural changes due to working etc. a small piece of fractured material is cut, including the region of fracture, and is polished. The final polishing of longitudinal section is done on the polishing disc. Unetched micro-examination is done on the polished surface after etching the micro-piece with suitable chemicals under bench microscope, at magnification from 100 to 1000.

Analysis of all the evidence, formulation of conclusion on the basis of all the previous steps.

Recommendations are made on the basis of findings, and remedial measures are suggested to minimize such failures.

## SUMMARY

This unit mainly deals about the Diesel Engine of WDM2 type Locomotive, the standard Diesel Locomotive**,** in use**,** in Indian Railways. Diesel Engine is the power unit of the Locomotive, hence it is also called power pack assembly. It is a V shaped 16 cylinder Engine. Engine Block, made of fabricated steel, forms the structure of the Engine. Various components are housed in it to form the complete Engine assembly. Cylinder Liner, Cyl Head and Piston form the combustion chamber of the engine. Cylinder head forms the lid of the combustion chamber. It houses inlet and exhaust valves to provide passage for incoming air and outgoing gas. It also accommodates Nozzle for supply of fuel in atomized form into the combustion chamber. Cylinder Liner is made of cast iron with honey combed chromeplated bore. They are basically wet type liner. Piston, made of Al alloy, in combination with special malleable grey cast iron Piston Rings seals the combustion chamber. Con Rod, made of forged steel, connects the movement of piston with Crankshaft. Crankshaft, made of forged steel with hardened surface, converts the reciprocating motion of Piston into rotating motion as the output power. It also gives drive to camshaft, water pump, lube oil pump, Expressor, Radiator Fan, main generator and many other auxiliaries of the engine. Camshaft operates inlet & exhaust valves and Fuel Injection pump of different cylinders as per their firing order. Each piece of camshaft takes care of two Nos. of cylinder, hence, there are total 8 Nos. of cam pieces to form left and right bank camshaft. Cam shaft is made of forged steel and surface hardened to reduce wear and tear. Camshaft and Crankshaft are supported with bi-metal and tri-metal bearings at their housing to reduce wear and tear, which are further assisted by lubrication system to do so. Different methods of failure investigation and their analysis help to detect the failures and to decide corrective measure to save the components from premature failure in service.

## KEY WORDS

Saddle: The portion of the engine block, which houses the crankshaft.

Mandrel: Gauge (straight iron bar) for checking alignment of main bearing bore.

## SELF ASSESSMENT

1. What are the main components housed in the Engine Block to form the complete Diesel Engine.

2. What is crank web deflection? How it is adjusted?

3. What are the duties of a Camshaft? Each section of camshaft serves how many cylinders? Describe briefly the procedure of installation of camshaft in the Engine block.

4. What are the common defects noticed in the liners in course of service?

5. What are the guiding factors for selecting the dimensions of the piston?

6. What checks and measures should be done during fitment of piston rings?

7. What checks and measurements are required to be done during overhauling of Cylinder heads?

8. What are the various types of fracture? How do you detect them?