UNIT M 3- PLAIN BEARINGS

OBJECTIVE

The objective of this unit is to make you understand about the following:

- Roll of Plain bearing in general and their application in diesel locomotive
- Classification of bearings
- To study desired properties of bearings in connection to material selection and manufacturing.
- Good workmanship practices
- Failure mechanism and their remedies

STRUCTURE

1. Introduction
2. Use of plain bearings in locomotives
3. Classification of plain bearings and their desired properties
4. Failure trend
5. Workmanship improvement
6. Failure mechanism and suggested remedies
7. Summary
8. Self assessment exercise
1. INTRODUCTION

Plain bearing plays a vital role in the Diesel Engine. This is being the weakest part of the diesel engine, for any abnormality in the operation of diesel engine and fitment lapses of bearings, they become the easiest prey. Hence knowledge on bearing is essential for the reliable and failurefree service of the Diesel Locomotive.

The function of a bearing is to reduce friction and wear of the load-bearing shaft of a machine having rotational / sliding motion. But its function remains incomplete without the assistance of Lubrication. Optimum condition of bearing lubrication exists when the sliding surfaces are separated by a film of lubricant thick enough to prevent metal-to-metal contact of the shaft with the bearing, depending upon surface roughness and load characteristics. Favourable surface configuration, adequate oil viscosity and a high bearing characteristic number are essential to produce hydrodynamic film lubrication. A pure hydrodynamic Lubrication perfects the work of plain bearings, so they are also called hydrodynamic bearings. High loads, improper speeds, extreme temperatures or insufficient lubricant promotes the most undesirable condition of lubrication. In limiting condition hydrodynamic Lubrication transforms to boundary layer lubrication and dry bearings and during this transition phase the bearing metallurgy needs to meet the tribological requirement. Hence, selection of bearing material is very important to meet the boundary conditions specially during starting and stopping of engine while temporary loss of lubrication takes place.

2. USE OF PLAIN BEARINGS IN LOCOMOTIVES

The important areas of Diesel Locomotive where plain bearings used are: - Main bearing (at crankshaft main journal), Con Rod bearings (Big and small end), TSC Bearings, Valve lever bushes, Cam bushes, T/Motor suspension bearings etc.
In recent trend, Roller bearings are replacing the plain bearings in many areas, as in the case of suspension bearings of diesel locomotives. But there are some areas like crankshaft bearings and Con Rod bearings; plain bearings have no substitute because of their fitment constraint and superiority of performance at shock/impact loading. In Turbo supercharger also use of plain bearing is continued because of its superiority over roller bearing at higher speed range.

3. CLASSIFICATION OF PLAIN BEARINGS & THEIR DESIRED PROPERTIES.

Plain bearings are mainly designed to bear load in radial direction. They are either bush type or split type depending upon fitment requirement. Crankshaft bearings (Main bearings and con rod big end bearings) are split type and in other areas they are bush types. In 9th main bearing collared bearing is used to bear load both in radial and axial direction, they are called thrust bearings.

Plain bearings are further classified as Bi-metal or Tri-metal bearings depending upon number of layer used to form bearing. In Bimetal bearing two layers are used having one babbit layer and the steel back. In Trimetal bearing two babbit layers are there with the steel back.
The manufacturing process, material composition and thickness of the babbit layers are decided to meet the following desired properties of the bearing i.e. Load Capacity (Ability to withstand max pressure with low friction and moderate wear), Mechanical strength, Fatigue strength, Compatibility (Anti seizure & Anti scoring property), Bond strength, Conformability (Ability to compensate slight misalignment and variation in shape of shaft and bearing surface), embeddability and corrosion resistance.

COMPATIBILITY: This is the measure of anti scoring & anti welding property of bearings, to meet boundary conditions during starting and stopping.
CONFORMABILITY: Ability to compensate slight misalignment and to conform to variation in the shape of shaft and housing. (Materials with low Modulus of elasticity and good Plasticity have better conformability)
EMBEDDABILITY: Ability to embed dirt and foreign particles. (Embeddability and conformity are the parallel properties of metal)
LOAD CAPACITY: Is the measure of Max Pressure that the bearing material can withstand with low friction and moderate wear. This depends upon Viscosity of Lubricant, Surface finish of Shaft, Operating temperature and composition of Bearing Materials.
STRENGTH: Compressive and Shear Strength are important. Tensile and Yield Strength are the easy measure of Mechanical Strength. (In general low strength materials provides more deflection under load and better conformability.)
A material with low Shear Strength can sustain shearing of small particles with little heat generation and welding
FATIGUE STRENGTH: Ability to sustain load of reversible nature, such as in IC Engines. Sufficiently high Fatigue Strength is necessary to enable bearing to operate within Elastic limit without developing cracks and surface pits.
A thin layer of soft materials with strong Steel backing gives the desirable combination of Fatigue Strength and Compressive Strength.
CORROSION RESISTANCE: Acidic behaviour of lubricant (due to oxidation, mixing of exhaust gases etc) causes such corrosion. Pb is more prone to corrosion where as Sn and Al are not usually affected.
HARDNESS: Softer the material, the better its antiscoring, conformability and embeddability properties. Higher hardness provides better load capacity and greater wear resistance.

Typical configurations of ALCO Bi-metal and Tri-metal bearings are sketched below for better understanding of the above aspects.
Used in: Cam shaft bearing bushes, Con Rod little end bushes, Valve Lever bushes, Push Rod lifter bushes etc.

Configuration:

a) STEEL BACK: Remainder of thickness. Made of cold rolled steel, conforming to AISI C-1010 or C 1015 killed steel.

b) BRONZE OVERLAY: 0.015” to 0.030” thickness, Cold Rolled.

Metallurgy:
Cu: 77% (min), Pb: 8-11%, Sn: 8-11%, Zn: 0.75% (max), Sb: 0.50% (max)
Ni: 0.50%(max), Fe: 0.35% (max) and other elements 0.40% (max)

It is essential that Pb globules are uniformly distributed without showing of gravity segregation. The layer should show a uniform Eutectic structure.

ALCO TRIMETAL BEARING

Used in: Main Bearing Shells, Con Rod Big end Bearing Shells and Turbo Bearing Bushes.

Configuration:

a) STEEL BACK: Remainder of thickness. Made of cold rolled steel, conforming to AISI C-1010 or C 1020 killed steel.

b) INTERMEDIATE LAYER: Thickness: 0.015” to 0.035”
Cold rolled along with steel back
Material Specification:
Cu: 68-75%, Sn: 2-4%, Pb: 23-27%, Zn: 0.20%(max), Ag:0.20% (max), Fe: 0.50%(max), Ni: 0.50%(max), Sb:0.25%(max), other elements 0.35%(max).

c) NICKEL DAM
Thickness 0.000075” to 0.000100”, Centrifugally Cast.
It prevents tin migration from overlay to intermediate layer.

d) OVERLAY
Thickness 0.0015” to 0.002”, centrifugally cast.
Material specification: Cu: 2-3%, Sn: 8-12%, Pb: Remainder

A graphical analysis of Fatigue life in relation to babbit layer thickness and operating temperature is attached to understand the affect of babbit layer thickness and operating temperature on the fatigue life of bearings.

**FIG. 1. DEVELOPMENT OF FATIGUE CRACKS IN BIMETAL AND TRIMETAL BEARINGS.**

**Effect of babbit thickness and Temperature on Fatigue Life of Bearing**

BEARING TERMINOLOGIES (As per the sketch attached below, in fig 1 to 4)
Knowledge on bearing terminology of split type bearings will help in understanding correct fitment technique of split bearings.
Fig 1 Typical features of a thinwall half bearing

Fig 2 Typical material composition

Fig 3

Fig 4 Bore relief - Typical sizes for a 160 mm diameter bearing
FAILURE TREND

The failure trend of bearing can be compared with the human mortality graph (A bath tub design).

In case of bearings, infant mortality is caused either due to manufacturing and design defects or due to severe workmanship lapse (like blocked oil passages or dislocating of bearing with the oil passages) or due to severe abnormalities of the working behaviour of the engine.

The failure due to ageing death of bearing can be arrested by correctly formulating and following the maintenance & renewal schedule.

In the region other than ageing death and infant mortality a proper investigation is required to diagnose the problem and to find solution accordingly.

4. WORKMANSHIP IMPROVEMENT

Besides all other factors a good workmanship contributes a lot for saving failure. A few tips have been given below towards good maintenance practice: -

I. Maintain clean & dirt free working environment.
II. Do not rub or polish bearing surface.
III. Clean the bearing and its housing using clean clothes only.
IV. Ensure clean and free oil passage.
V. Make the locating Dowel/Nick free from burrs, to ensure correct seat of bearing at its housing.
VI. Never apply oil at the backside of bearing and its housing.
VII. Measure the bore dia & check the ovality and taperness of the housing and also the eccentricity of the shaft & bore.
VIII. Ensure positive Nip and Free spread for correct fitting of bearings.
Nip:- The difference of peripheral length of the bearing over its housing is called NIP. It should be +ve to ensure interference fit.

Free spread:- In the free state the split end of the bearing is spread over than the actual dimension of its housing. This is called free spread. This is to ensure conformity of the bearing with its seat.

IX. Clearly mark on bearing its location with in the engine.
X. Tighten bolts in correct sequence to the correct torque or stretch as defined in the engine instruction manual.
XI. Check that the shaft rotate freely inside the bearing after assembly
5. FAILURE MECHANISM & SUGGESTED REMEDIES

Besides bad workmanship many other reasons are there which lead to premature failure of bearings. As such proper failure analysis is essential for their remedies. Some of the typical defects and their suggested remedies are listed below:

1. **Fatigue Failure**: - Crack like appearance at initial stage. Starting from top surface reaches bond layer and then propagates horizontally. Babbit layer gets peeled off and forms cavities, on severe attack.

   Probable reason:
   (i) **Mechanical**: -
   (a) Excessive dynamic loading
   (b) Higher cyclic variation of load, due to:
       - Improper vibration damping.
       - Big range of variation of firing pressures in different cylinders.
       - Excessive torquing.
   (ii) **Thermal**: - Improper heat dissipation due to
       a) Less clearance
       b) Improper Lubricant – Dirty, Less/More Viscous. Coolant character of lube oil lost due to depletion of additives.
       c) Loss of heat conductivity between bearing and housing due to
           - Dirt/ Oil packing/air gap between bearing back and housing.
       d) Oil temperature high due to dirty improper heat exchanger.

   Remedial action can be taken accordingly.

2. **Chemical Corrosion**: - Can be viewed under microscope only. Black spots are noticed due to presence of PbSO₄ in Pb matrix.
   Reason: - Acidified Lube oil (PH value of Lube oil should not go below 4.5).

   This is due to:
   - Sulphur content of fuel oil high (should not be allowed more than 0.5%)
   - Excessive blow by of exh gas through sump.
   - Periodicity of lube oil changing not followed.

   Remedial measure can be taken accordingly.

3. **Water Corrosion**: - Whitish bordered localised shining surface at the loaded zone and remaining portion looks dull.

   Reason: - Mixing of water with lube oil due to lube oil cooler tube burst or damaged Liner O ring etc.
Lube oil should be changed if water mixed with lube oil goes above 0.25% and proper rectification of the source of leakage should be done.

4. **Cavitation erosion**: - Erosion of babbit layer in hen track pattern appears perpendicularly to the oil groove at the unloaded zone of the bearing. This is caused due to formation and collapsing of vapour bubbles in the oil film, under the state of rapid pressure variation during crank cycle.

   Reason:-
   (i) Lube oil improper due to the absence of proper antifoaming additives or antifoaming additive lost its character due mixing of water in lube oil.
   (ii) Aeration in lube oil system.
   (iii) Excessive hunting
   (iv) Improper vibration damping
   (v) Under designed or partly choked oil holes.

5. **Scoring/Mechanical wear**: - Score and localised wear marks are noticed due to

   - Bad filtration of lube oil. (Due to operating of by pass valve, clogged/damaged filter element).
   - Bad filtration of charge air.
   - Distortion in housing.
   - Rough journal.
   - Deformed journal.
   - Foreign material between bearing back and housing.
   - Biased wear due to wrong fitment of bearing, misaligned bearing housing / bend or twisted Con.Rod.

6. **Wiping & Seizure**: Starts with dislocation of the babbit layer and finally gets welded with the shaft causing seizure.

   It happens due to:
   (a) Failure of lubrication due to leakage in 'S' pipe or choked oil passage
   (b) Low lube oil pressure; insufficient to maintain required oil film thickness for hydro dynamic lubrication.
   (c) Heavy Fuel/Water contamination.
      5% Fuel Dilution leads to mechanical wear.
      10% Fuel dilution may cause scizure.
      20% variation in Lube oil viscosity causes wiping and seizure. (Viscosity of oil goes high due to water contamination, oxidation of lube oil, heavy blow by through crankcase).
   (d) In compatible or adulterated lubricant may lead to wiping and seizure.

   Zn additive in lube oil causes depletion of Ag lining from babbit layer. As such Zn additive should not be used where Ag is used as a constituent of babbit layer.
(e) Excessive Crank web deflection may lead to wiping and seizure
Crank web deflection should be restricted within ± .0008”.

7. **Split Line Fretting**: Relative motion between two halves at the split end develops fretting at the joint faces of split type bearings. Finally it leads to bond separation and seizure.
This is due to:-
(a) Excessive torquing, beyond the capacity of the bolts to sustain both static and dynamic loading.
(b) Low capacity bolts (Suffered plastic deformation)

Can’t sustain Nip stress and dynamic loading.

8. **Creep/ back fretting**: This is developed due to relative motion of the bearing with its housing. Fretting starts between bearing back and its housing and propagates upto the babbit layer. Thus it affects to heat dissipation and finally leads to seizure.
This is due to:
   i) Negative or lesser Nip, causing inadequate interference.
   ii) Incorrect torquing (Both high or low torque)
   iii) Use of low capacity bolt.

9. **Static Fretting**: Fretting developed at the loaded zone of bearing at static condition, due to prolonged vibration sustained by the bearing originated from third source. This happens mainly, if the assembled component or engine is kept for a long time in such area where ground vibration is very high or, it may develop during transportation of machinery or component with improper mounting and clamping.
To arrest such failure due to static fretting it is always advisable to check bearings in assembled engines or its subassemblies before use, after keeping them for long days in reserve. Especially where ground vibration from 3rd sources is very high.
6. SUMMARY

Plain bearing plays a vital role in diesel locomotive. Because of its sophisticated design and weaker structure knowledge of plain bearing about its design, working and maintenance aspects is very much essential for trouble free service of locomotive. Design, selection of material and manufacturing aspects of bearings are decided, based upon the desired properties of the bearings like load strength, fatigue life, embeddability, conformity, corrosion resistance etc. Plain bearings are either split or bush type depending upon their fitment requirement. Plain bearings are normally radially loaded, flanged bearings are also used to sustain both radial and axial loading. They are further classified to bi-metal or tri-metal bearings depending upon No of babbit layers used. Proper fitment technique in split bearings is very much important for the reliable service of bearings, as being discussed in this chapter. In addition to these, failure mechanism and their remedies as discussed in this unit will help in minimising the failure up to a great extent.

7. SELF ASSESSMENT EXERCISES

i) In what parameter performance of plain bearing supersedes roller bearings?

ii) What are Nip and free spread in a split bearing? What is their importance for fitment of split bearings?

iii) Discuss in brief about the following bearing failures:
   a) Fatigue failure
   b) Chemical corrosion
   c) Split line and back fretting