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Purpose, Use & Care of Roller Bearings.

Training for Plant and Equipment Operators, Maintainers and, Technicians.





Objective

This training teaches users and maintainers of roller bearings why they are used, how they work, what causes them to go wrong and what is necessary to keep them operating properly.

Outcomes of the Training

This training makes trainees clear and knowledgeable in the proper use and installation of roller bearings. It gives them in-depth knowledge of the equipment and factors that affect operation. They will use their new know-how to better operate, tend and maintain such equipment.

Training Contents

- Purpose of the equipment.
- The principles of how the equipment works.
- Important parts and assemblies.
- In-service design and operation.
- How the equipment achieves its purpose and the necessary operating conditions.
- Most likely failure modes, their causes and what to do about them.
- On-Site, workshop or test bench observations of an equipment installation.
- Conduct site tests and trails on the equipment operation.
  - Compare the installation to the minimum design required.
  - Predict effect of changes.
  - Observe actual changes.
  - Identify impact of changes to the equipment operation.
- Learning Assessment
  - Explain purpose and use of equipment.
  - Identify how the equipment achieves its purpose.
  - Specify the required operating conditions for proper performance.
  - List what failures are possible at the workplace and how to fix them.
  - Training Supervisor reviews.

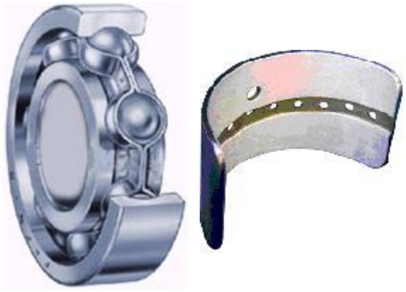
Time Required

The training takes one hour to complete for literate people with some industry experience.

The Purpose, Use and Care of Roller Bearings.

Purpose of the Equipment

Roller bearings were invented for the first marine clocks around 1750. The inventor of the first accurate marine clock, John Harrison, needed a high precision timepiece so that sailing ships could locate their global longitudinal positions within a few hundred meters. The existing clocks of the period lost too much time due to internal friction loses in their plain bearings and a new way to allow clock parts to move with less friction was needed.



Ball Bearing Plain Bearing
Figure 1

Figure 2 Bearing on a Shaft

Harrison, a self-taught clockmaker, came up with the idea to place rolling metal balls running around a race. The modern equivalent ball bearing is shown in Figure 1, with a modern plain bearing beside it.

The purpose of roller bearings has not changed since they were invented. They position and locate a rotating shaft with the least loss of energy due to friction.

Principles of How the Equipment Works

Roller bearings trap a thin lubricant film between the rolling element and the race on which they roll. The thin film keeps the two parts separated and they roll over each other without direct contact. As the rolling element moves along the race it creates a pressure 'wedge' of lubricant in front of itself. Figure 3 is an illustration of the lubricant wedge that develops between the parts.

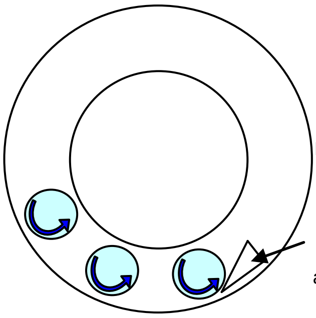


Figure 3 Creation of a Lubricant Wedge

The pressurised lubricant slips in-between the roller and the race and lifts the roller from the race a very small amount. This stops the two parts touching and wearing each other out.

The lubricant is a critical element in good roller bearing operation. It must retain its lubricating properties in a range of operating conditions. For it to form a layer that continually separates the parts it must retain its cohesiveness, or willingness to remain together, while still offering lubrication of the parts.

Important Parts and Assemblies

A roller bearing is typically made of the rolling elements; an inner and outer race that they run in; a cage to contain, locate and align the rolling elements and the lubricant fill. In the majority of cases the lubricant is either oil or grease.

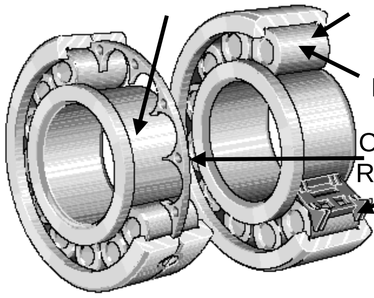


Figure 4 Roller Bearing Construction

The lubricant coats the rollers and the running walls of the races. Its function is to keep the metal parts separate and allow the rollers to glide over the races. This is not always the case for all bearing designs. Some bearings take high thrust loads and the metal parts are forced against each other and generate heat when they contact. Bearings in high thrust situations are designed to take the hotter temperatures. The lubricants for high temperature applications are infused with extreme pressure (EP) additives to maximise the chance to develop a lubricant film.

A roller bearing inner race sits on a shaft, as shown in Figure 1, while the outer race sits inside a bearing housing. The bearing housing encloses the bearing and keeps lubricant around it. The shaft entry into the housing is sealed to protect the bearing from dirt and water ingress.

The shaft and the bearing housing are vitally important for supporting and locating the bearing during operation. The seal stops dirt and water entering the housing and then the bearing.

In-Service Design and Operation

Figure 5 shows a common arrangement for a bearing mounted in a bearing housing. Where the shaft goes into the machine internals and the bearing is lubricated from within the machine there is no internal seal. If the shaft comes out of the machine at the other side, there will be a shaft seal.

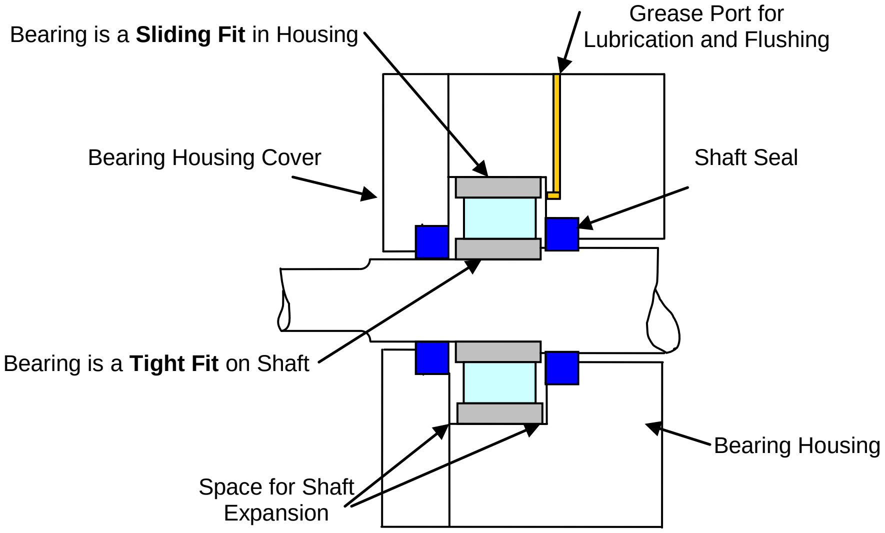


Figure 5 Typical Arrangement for a Greased Roller Bearing Located in a Housing

The Bearing

Roller bearings are available in a multitude of designs to accommodate the types of loads applied to the shaft which they support. There are designs for mainly radial loads, i.e. those loads that act to push the bearing sideways, and designs for purely axial loads, i.e. those loads that act along the direction of the shaft. In fact it is the direction, size and movement of the load which is used to select the bearing for a situation.

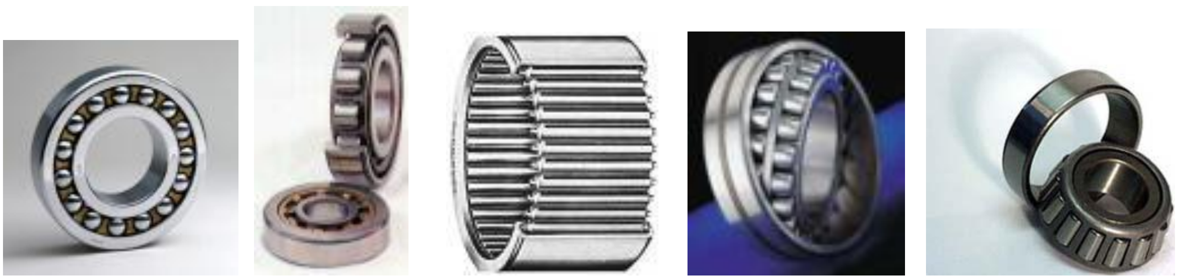


Figure 6 Ball Bearing Cylindrical Needle Spherical Taper

Figure 6 shows the range of roller shapes used in bears. They can be ball, cylinder, needle, spherically, or taper shaped. The shape, size, number and orientation of rollers determine the amount and direction of load the bearing can take. The rolling elements can be arranged as single or double rows. The double row increases their load carrying capacity and also allows the bearing to take fluctuating loads and those loads coming from more than one direction.

Figure 7 shows a range of bearing roller arrangements and orientations designed to take forces and loads in machinery. The captions indicate the directions that the bearing can be loaded. The twin row spherical roller bearing in the middle picture are a ceramic roller bearing. Ceramics can run hotter and faster than all-metal bearings and need less lubrication.

High Axial Load   High Axial Load   Radial & Axial Load   Only Radial   Radial & Axial

Figure 7

It is clearly important to choose a bearing matched to the loads and operating forces it will see.

The Shaft

The bearing must sit firmly on the rotating shaft. It must sit tight enough on the shaft so that it will not slip. If the bearing slips it will wear the material on the shaft it contacts. A spinning bearing will also heat-up from the rubbing friction as it turns. The lubricant in the bearing will melt, thin-out or burn, thus allowing the rollers to contact the race and generate even more heat to make the situation worse.

Bearings are designed for a limited amount of shaft misalignment. Figure 8 shows shaft misalignment.

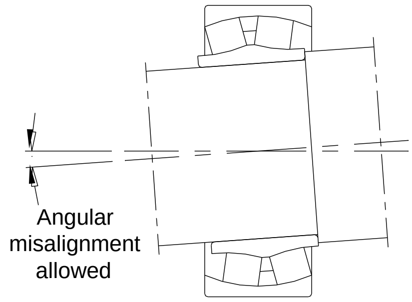


Figure 8 Shaft Misalignment

It is important where shaft misalignment occurs that the right choice of bearing is installed so that the shaft can bend. If the shaft bending movement is stopped by the bearing the shaft will deform the bearing and apply high loads on the rollers, races and housing to cause early operating life failure and breakdown results.

The Bearing Housing

To keep the bearing in a clean environment it must be sealed in. The lubricant must be retained around the bearing and all dirt, water, chemicals and dust kept out. The outer race of the bearing must also be solidly located and rigidly positioned so that the whole bearing holds and supports the shaft. The bearing housing provides the protection and mounting support a bearing needs.

Figure 9 - Bearing Housings and Shaft Seals

Figure 9 shows different styles of bearing housings. In all cases the bearing is fully enclosed within a protected environment that keeps contamination out and lubricant within.

The Shaft Seal or Bearing Isolator

The shaft runs right through the centre of the bearing and out through the housing. The opening in the bearing housing must be sealed. Otherwise dirt, moisture, dust and rubbish find their way into the housing, then into the lubricant, contaminating it and destroying the bearing. To stop contamination getting into the bearing, shaft seals are used.

Rubber Lip Seal   Metal Ring Lip Seal   Mechanical Seal   Labyrinth Seal   Bearing Isolator

Figure 10 Shaft Seal Types

A shaft seal or bearing isolator allow the shaft to both rotate and flex without letting a gap open up between it and the shaft. Several seal types are available. The cheapest and worst choices are the rubber or plastic lip seals that rub on the shaft. They corrode the shaft and become impregnated with metal dust that then acts to wear the shaft. A better choice is the labyrinth seal which are grease purged to flush through and wash-out contaminants. Best of all are mechanical seals and bearing isolators that use a stationary and a rotating seal pushed together. Figure 10 shows several shaft seal types.

How The Equipment Achieves Its Purpose And The Necessary Operating Conditions.

Bearing Loads and Deflection Stresses

Roller bearings are used to support rotating shafts. The weight of the shaft and the equipment on it is taken by the bearings. The bearings are themselves fixed into a bearing housing, and the housing itself is mounted and supported in a frame. All of which is supported on a base and foundation.

The combined assembly of bearing, housing, frame and support must all be firm and rigid so they safely transmits forces created in the equipment without deforming. The combined assembly must also prevent deflection of the bearing when under load. The base on which a machine sits must be firm and rigid and permit no deflection of the bearing housing. If the housing is bent out of shape the bearing will also be bent out of shape. Once the rolling elements and race are twisted the wear rate increases dramatically.

An overloaded or deformed bearing will force the rollers to contact the raceways and start wearing and destroying itself.

Vibration

Out-of-balance equipment causes vibration. Vibration occurs when a mass is spinning off-centre from its true axis. An important factor in getting maximum bearing life is to have smooth running equipment with minor vibration. A vibrating shaft knocks the races and rollers together. Much like the vibrating roller in Figure 12, shaking causes

Figure 12 – Impacting Roller

compaction and impact of the parts which quickly destroy the bearing rollers and raceways.

Make sure that rotating shafts are balanced to top-class engineering standards for the speed and weights involved so that negligible vibration is present. Where there is vibration install bearings designed for vibrating equipment. These bearings are sturdier and designed to keep the roller fitting true in the races

Possible Failure Modes Causes, Prevention and Corrective Actions

There are several key factors that must be confirmed to insure successful bearing operation. Fortunately when a bearing is failing there are signs that we can detect, monitor and use.

The Four Stages of Bearing Failure
A roller bearing progresses through four stages to failure. Vibration analysis permits the monitoring of the bearing's progression through each stage and to estimate when failure will actually occur. In the case of a raceway failure these would be the four progressive stages.

- The bearing is new and has no defects. This is the time to record its frequency 'signature' and normal operating acceleration and velocity values.

- If examined at this stage there would be no visible defects. However under the surface of the raceway sub-surface defects have started. The frequency signature has changed, the overall base level noise has risen and the velocity spectrum (graph) has risen higher.

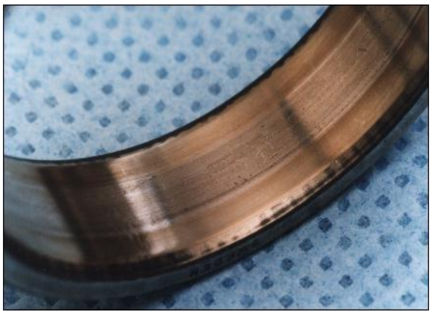
- At this point the raceway shows visible signs of surface failure. The extent of the failure increases and grows with metal coming off in tiny sheets (delaminating). The velocity spectrum is much higher and there is much more background noise. Within the background noise particular frequencies start to standout and indicate failure is fast approaching.

- If the bearing is still in service everyone knows it is time to change it out because they can hear it. More vibration frequencies appear and more velocity frequencies develop. Vibration readings indicate volume changes and the noise moves into the range of human hearing.

Wear and Abrasion
This is a major and often occurring reason for bearing failure. Keep lubricant clean, change shaft seals when there is evidence that they have failed. Replace lubricant with new after a new machine has been operating for a few days.

Figure 14 shows pictures of bearing damage with explanations of why they failed.

Overloaded bearing
in axial direction
Figure 14 A



Outer race of a spherical roller
bearing worn by abrasive particles
Figure 14 B

Overloaded bearing
wear damage to shaft
Figure 14 C

Misalignment

Bearings and shafts are designed to run perfectly true to their axis. The first thing a designer does when designing a machine part is to draw the centre line of the shaft and bearings. Then she draws in the shaft and the bearings. In doing that she has assumed that throughout its operating life the machine will have perfect alignment!

When the alignment of a shaft is not perfect orbital motion occurs and vibration is noticed. The shaft starts throwing its weight about. The bearings get unexpected loads fluctuating at different positions. Instead of the load being carried in the load zone of the bearing where lubrication is present, the loads may occur at the top unlubricated part of the bearing. Or the hammering ruptures the film and squashes the lube from the load zone allowing roller to contact raceway.

Imbalance

Rotating out-of-balance parts produces vibration. The vibration produces undesigned force in the bearing. The bearing can experience loads in unlubricated locations. The shaft begins to rattle and bounce about. In roller bearings the rollers are smashed into the raceways and start hammering the metal. The metal surfaces dimple and roughen (brinell) and failure happens soon after.

High Temperatures

Temperature rise causes lubricant viscosity, or slipperiness, to fall and lube film become thinner. External heat sources, like oven, sunshine, heaters, burners, boilers, etc may also cause temperature rise. Is there a process radiating heat onto the bearing housing, or is there hot, direct sunshine on the bearing housing, preventing internally generated heat from dissipating (shedding) out of the bearing?

Is there heat being transferred down the shaft and into the bearing? Is the bearing housing covered in dust, dirt, rags or rubbish and the heat cannot escape? Does it need an extra flow of cooling air to remove the heat? If oil lubrication is used should an oil cooler be installed? Does the housing need more surface area for radiation and convection cooling?

It is important to keep the temperature at the required viscosity for the lubricant in use.

Shaft Expansion

When a metal shaft gets hot it expands and grows longer. The bearings mounted on the shaft must let the shaft grow. If the bearings trap the shaft they will be pushed hard against the housing and receive huge axial loads that produce the damage shown in Figure 14A.

On shafts with more than one bearing it is necessary to mount one of the bearings firmly to the shaft and also solidly in the housing so that it the shaft and bearing cannot move. This fixes the shaft in place at that point. But all other bearings on the shaft must be allowed to move with shaft growth.

On-Site Test, Workshop or Lab Test of an Installation and Learning Assessment

It is now time to do some 'hands-on' training in the field, or with a spare, or on the test-bench. To thoroughly understand this topic it is best to see what happens in a working situation and make and control changes. You will learn how to better run a thing well if you can understand it. Locate suitable equipment in your plant or spares that you will be allowed to inspect and fiddle with it.

1. If available locate a manufacture's operating manual for equipment at your workplace that has bearings in it, or find it on-line over the Internet. Take the time to read the section on bearing care and lubrication. Secondly get hold of a roller bearing and a bearing housing or plumber block that you can inspect and strip apart.

2. Hand-sketch below the bearing installation and write the name of the individual component items on the sketch. If there are components missing when compared to the minimum basic design, write down what each extra and needed and their use in the space under the drawing.

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3. Close Inspection

3.1. Open up the bearing housing or plumber block and look inside. If that is not possible get a manufacturer's manual for the equipment. Using the manufacture's manual, or information from other sources, name and describe each part.

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3.2. Write a short description of how the bearing is built and how it is designed to work.

3.3. Describe in some detail how the bearing is put onto the shaft and fitted into the housing?

4. If at all possible, and once you have supervisor permission, operate the equipment to see what effects happen as the operating conditions change. If you cannot operate a real item of equipment, then describe as best you can using information from your reading and discussion with others, what will happen to the bearing due to the change.

4.1. Start-Up Conditions.

Describe what happens to the bearing inside the equipment as it goes from a cold start-up to normal running temperature. What can you see, hear and feel during running of the equipment?

4.2. Condition Monitoring.

Describe the ways that bearing condition is monitored at your workplace. What do they look for to tell them the condition of the bearing? Describe what is done to decide when to change bearings in the equipment at your workplace.

5. Possible Modes of Failure

5.1. List the ways that bearings have failed to perform properly at your workplace. Talk to the experienced operators and maintainers if necessary.

5.2. Getting the Equipment Back to Proper Operation.

For each failure mode listed above, describe in detail what needs to be done to correct them.

This is the end of this training. Please record the following details and hand your answers back to the supervisor in charge of this training.

Trainee ________________________________ **Signature** ______________________________
(Print Name) (Trainee)

Supervisor ______________________________ **Signature** _____________________________
(Print Name) (Supervisor)

Assessment Result: Pass ☐ Repeat ☐

Completion Date ___________________ 'Pass' recorded in the Trainee's training records ☐