TRINATH SAHOO
Indian Oil Corporation Ltd
Paradip Refinery

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a

presentation

on

Bearing failure causes and cure.

11-12 Oct ' 2017, Dortmund
Germany

API process pumps- Bearing life

- Pump users and manufacturers have collectively estimated that 33% of all pump failures are due to bearing distress.(Ref- reliabilityweb)
- Pump MTBF in chemical process plants is less than 18 months.
- The average cost to repair a process pump is approximately 3500USD without the cost of process upsets and lost production cost.
- With a typical 20 years installation life pump maintenance cost can exceed 4500USD.
- This is far greater than initial acquisition and installation cost.

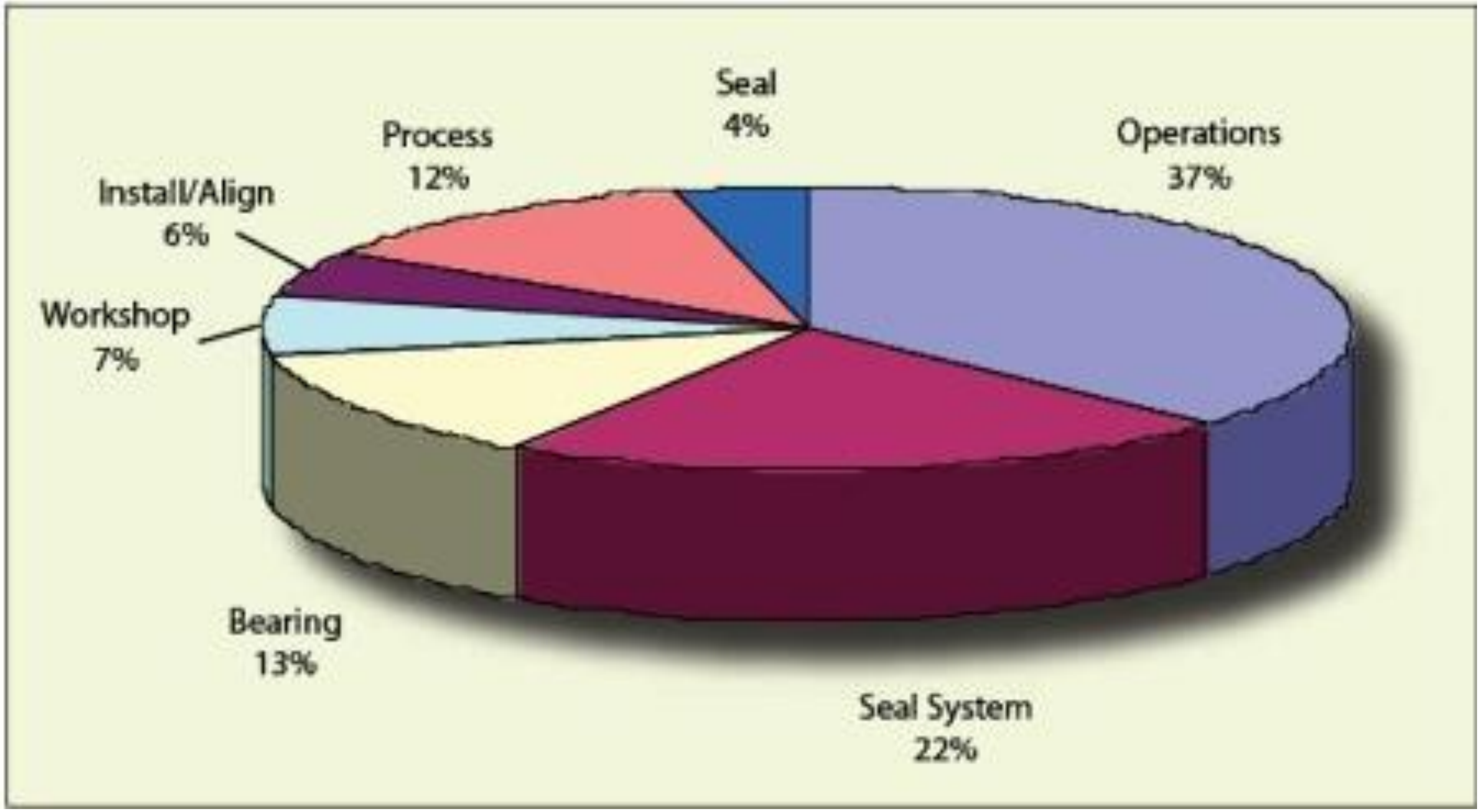
API process pumps- Bearing life

Two reasons pump industry is concerned about rolling element bearing lubrication.

- **First ,bearing failure often leads to most devastating type of pump failure, loss of shaft control.**

- **Second ,as mechanical seal life continues to improve bearing life will increasingly limit pump life.**

API process pumps- Seal failure



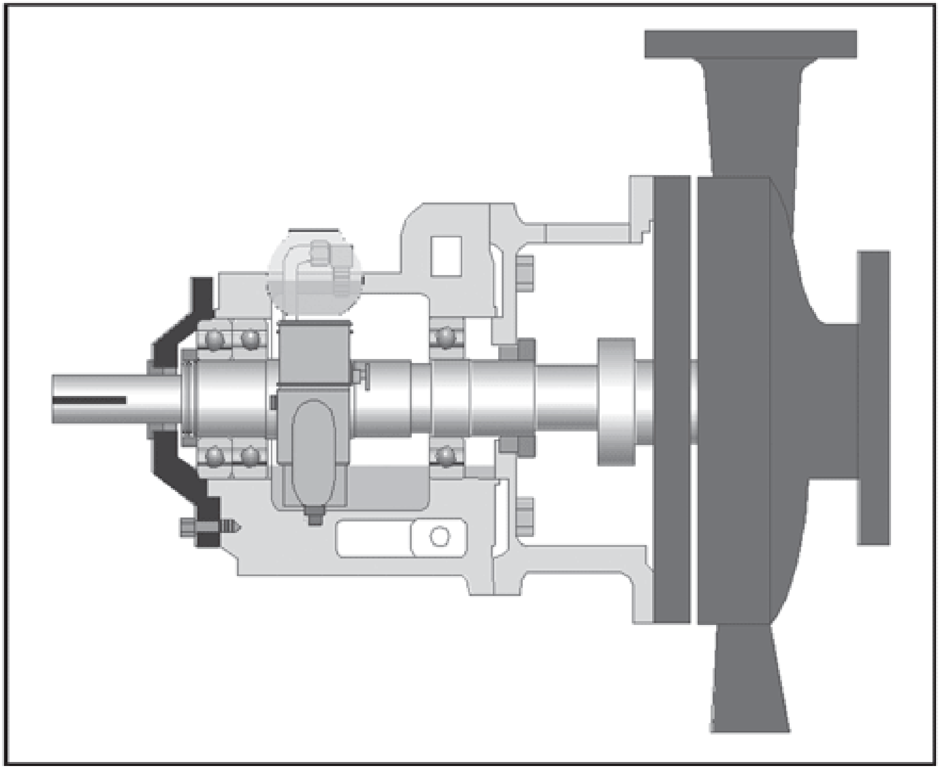
Seal failure cause distribution- Source –Imech-London

API process pumps- Bearing life

- ❖ Maximizing the lubrication effectiveness in API process pumps will be a big contributor for enhancing MTBF of process plants .

- ❖ The API Standard 610 requires a minimum bearing life (L10) of 25,000 hours with continuous operation at rated conditions and at least 16,000 hours at maximum loads and speed.

- ❖ Poor lubrication will cause 50 percent of these bearings to fail before any signs of fatigue occur.



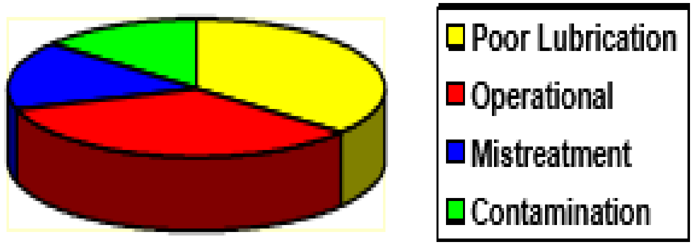
Bearing failure causes

- A large bearing manufacturer has estimated that about 16% of bearings failures are because of mistreatment. (improper storage, transportation or installation of the bearing)

- 34% of bearings fail due to wrong operation, misalignment, unbalance or other maintenance requirements.

- 36% of rolling element bearing fail due to poor lubrication

- 14% fail due to contamination

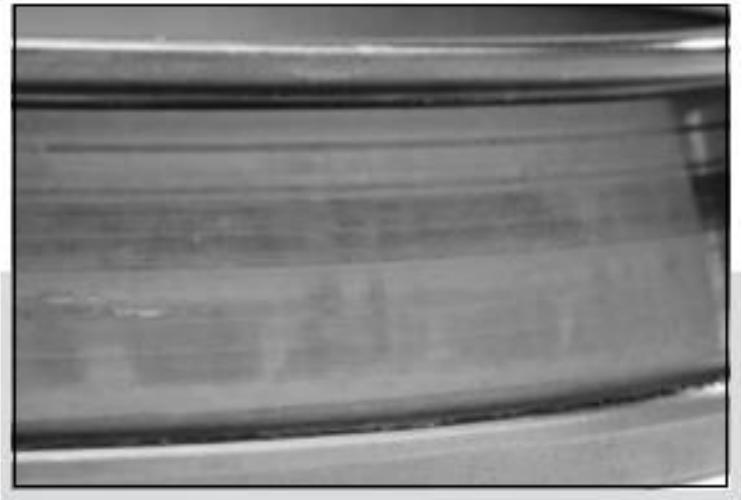


If we consider one centrifugal pump 50% of the failure occurs due to improper lubrication and contamination.

inadequate lubrication

Level 1 – Discoloration

- Metal-to-metal contact results in excessive bearing temperature.
- High temperatures result in discoloration of the races and the roller.
- In mild cases, the discoloration is from the lubricant staining the bearing surfaces.
- In severe cases, the metal is discoloured from high heat.



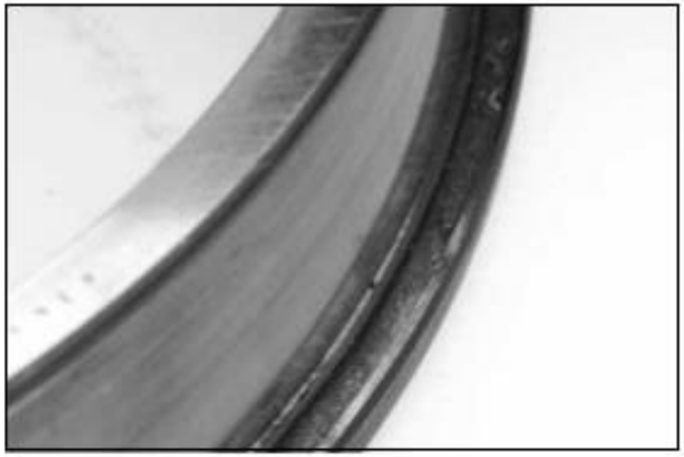
Level 1 – Discoloration due to elevated operating temperatures.

inadequate lubrication

- Insufficient or complete lack of lubricant.
- Selecting the wrong lubricant or lubrication type.
- Temperature changes.
- Sudden changes in running conditions.

Level 2 – Scoring and Peeling

Level 2 – Micro-spalling or peeling results from thin lubricant film due to high loads/low (RPM) or elevated temperatures.



Level 2 – Advanced rib scoring is due to inadequate lubricant film

inadequate lubrication

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Level 3 – Excessive Roller End Heat

Inadequate lubricant film results in localized high temperatures and scoring at the large ends of the rollers..

Level 3 – Heat damage on these tapered rollers was caused by metal-to-metal contact

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inadequate lubrication

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Level 4 –Total Bearing Lockup

- High localized heat produces metal flow in bearings, altering the original bearing geometry and the bearing's material.

- This results in skewing of the rollers, destruction of the cage, metal transfer and complete seizure of the bearing

Level 4 – Excessive heat generation caused advanced metal flow of the rollers, cone rib deformation .

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Factors that Impact Lubrication Performance

Cause of Poor lubrication may be due to :

- Incorrect type of lubricant
- improper lubrication method
- Incorrect quantity of lubricant
- Contaminated lubricant
- Lubricant degradation

Selection of Lubricant -Grease

The selection of grease for a specific application depends on five factors

Speed - For high speeds, stiffer grease, NLGI no. 3, should be used, where no. 2 would usually be hard enough. For lower speeds, softer grease such as no. 1 or no. 0 should be used.

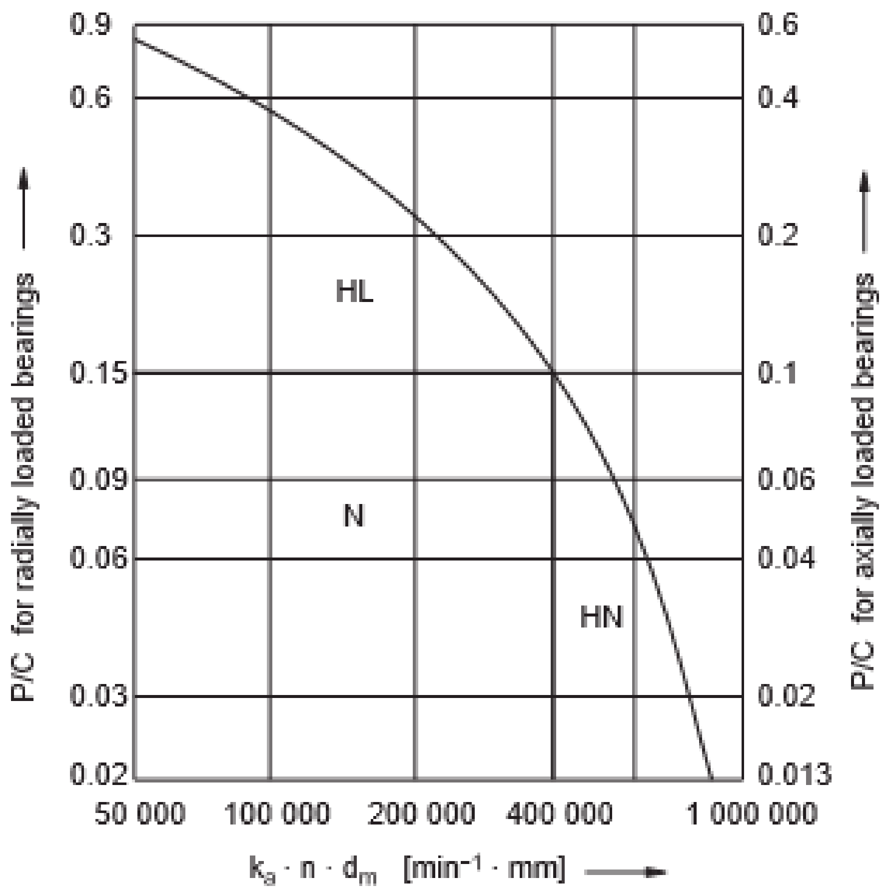
Load - For high loads, it may be advantageous to use EP additives or molybdenum disulfide. Because higher loads will lead to higher power consumption and therefore higher temperature, a stiffer grease such as no.3 or a synthetic-base oil may help.

Size - For large systems, use a stiffer grease, no. 3 or no. 4. For very small systems, use softer grease, such as no. 1 or no. 0.

Temperature range - The drop point should be higher than the maximum predicted operating temperature. For sustained operation at higher temperatures, synthetic-base oil may be necessary.

Feed systems - If the grease is to be supplied through a centralized system, usually it is desirable to use one grade softer than would otherwise be chosen (i.e., use a no. 0 instead of a no. 1).

Criteria for grease selection



ka values ka = 1 deep groove ball bearings, angular contact ball bearings, self-aligning
ka = 2 spherical roller bearings, tapered roller bearings, needle roller bearings

Range N Normal operating conditions. Rolling bearing greases K according to DIN 51825.

Range HL Range of heavy loads. Rolling bearing greases KP according to DIN 51825 or other suitable greases.

Range HN High-speed range. Greases for high-speed bearings. For bearing types with ka > 1 greases KP according to DIN 51825 or other suitable greases.

Criteria for grease selection

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The stresses in Range HN are characterized by high speeds and low loads. At high speeds, the friction caused by the grease should be low, and the grease should have good adhesion properties. These requirements are met by greases with ester oil of low viscosity as base oil.

Generally, the lower the base oil viscosity of a grease, the higher are the permissible speed indices recommended by the grease suppliers.

High temperatures occur if the bearings are exposed to high stressing and/or high circumferential velocities and to extraneous heating.

The critical temperature limit is approximately 70°C for lithium soap base greases and approximately 80 to 110°C for high-temperature greases containing a mineral base oil and a thermally stable thickener.

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Criteria for Oil selection

The selection of oil for a specific application depends on five factors:

Viscosity- Viscosity grade is critical because the oil must be viscous enough at operating temperature to separate the rolling surfaces but not so viscous as to create increased heat generation through viscous shear and churning.

Speed - The Stribeck curve is a graph showing the relationship between coefficient of friction , dynamic viscosity, speed, and the load per unit area. According to this curve, there is an optimum speed for the lubricated contact.

Temperature - All lubricants have specific temperature ranges for optimal performance.

Load- In a light loaded bearing a lubricant would have to be selected to minimize the fluid friction while still providing protection from metal-to-metal friction. On the other hand ,in a heavily loaded application, which could require specific additives to help protect from pitting, galling and extreme wear.

Operating Environment -. If the environment includes moisture or water, the lubricant must provide good anticorrosion properties as well as resistance to water washout or contamination

Type of lubrication method

Grease. Grease is easy to apply, can be retained within a bearing's housing, and offers extra sealing protection.

Oil bath. This option establishes an oil level at the center of the bearing's bottom rolling element and represents the comparative baseline of bearing friction among the lubrication methods. Best results over time can be achieved using a constant-level oiler

Oil lubrication via slinger disc or oil ring . In this method, an oil ring is suspended from the horizontal shaft into an oil bath positioned below the bearings. The rotation of the shaft and ring flings oil from the bath into the bearings.

Oil mist and air-oil. In this case, oil is atomized and carried by an air stream to the bearing. Among all pump bearing lubrication approaches, this process generates the least amount of friction and creates a positive pressure within the bearing housing (preventing invasive contaminants).

Overfilling

Overfilling a bearing with too much grease can cause excess churning and high temperatures during operation. This can create overheating and excess grease purging (leaking). The oxidation (breakdown) rate of the grease sharply increases – doubling every 10° C (18° F).

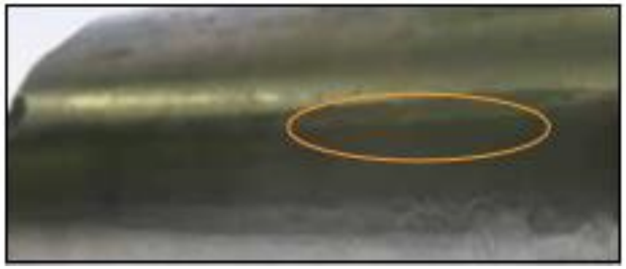
- During initial start-up, slight grease purge is often recommended by original equipment manufacturers, as it acts as a barrier seal to help keep out external debris contamination

Heavily oxidized grease, which purged from an overfilled bearing has a black color and burned odor.

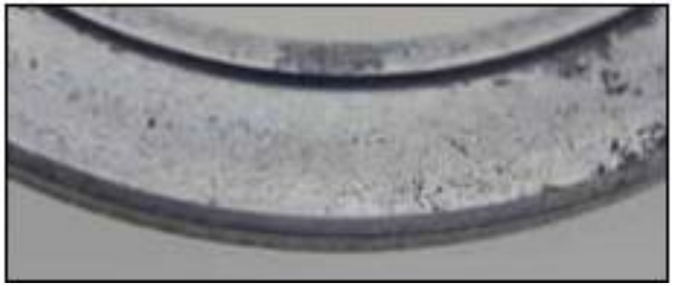
Incorrect Grease

The base oil in a particular grease may have a different thickness (viscosity) than what's recommended for your application. If the base oil viscosity is too heavy, the rolling elements may have difficulty pushing through the grease and begin to skid .

Excessive grease oxidation (breakdown) may cause premature grease degeneration and excessive wear of bearing components.



This cylindrical roller flattened as a result of skidding



Micro-spalling in a tapered roller bearing outer race was due to thin lubricant film

Mixing Greases

If you use an incompatible grease, or one with the wrong consistency, this new mixture may:

1. Soften and leak out of the bearing because of the incompatibility of the grease thickener.

2. Become lumpy, discolored and hard

Grease A and Grease B are not compatible. When mixed together they become lumpy, discolored and hard in composition (Grease C).

Worn-Out Grease

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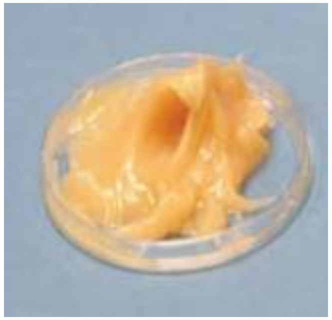
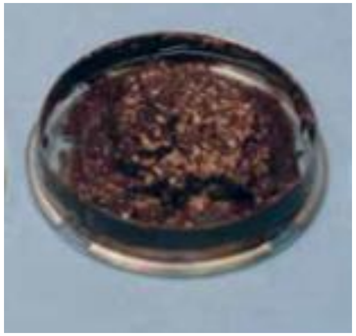
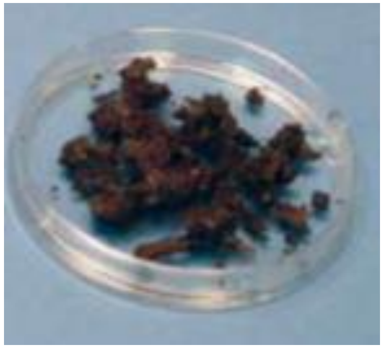
Grease is a precise combination of additives, oil and thickener .Time and temperature conditions can deplete oil release properties. When this occurs, the grease is worn-out .



1)new grease



2) heavily oxidized grease



3) worn-out (failed) grease

The same grease at three stages

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Incorrect Lubrication Systems and Intervals

To help prevent bearing components from wearing prematurely, it's critical to maintain the correct bearing lubrication systems and intervals.

If you don't follow maintenance schedules, excessive oxidation may cause the lubrication to deteriorate.

A technician records key bearing lubrication data on a maintenance sheet.

OIL BATH LUBRICATION METHOD

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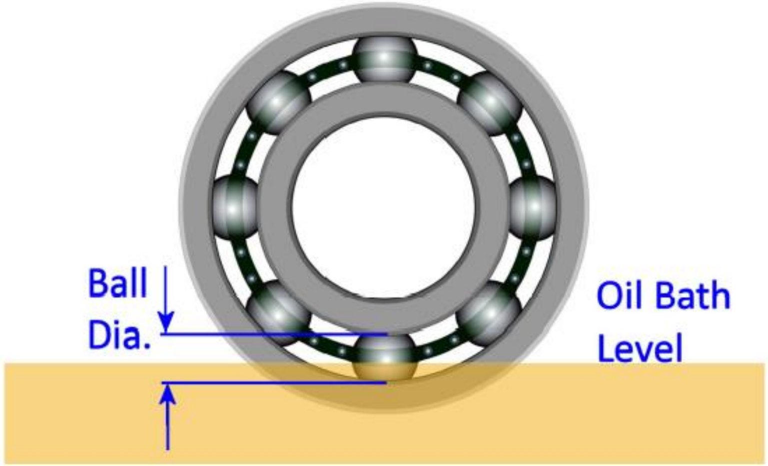
For smaller bearing arrangements and slower speeds oil bath lubrication arrangements are commonly employed. In these arrangements the normal oil level is set at around 1/3rd to ½ of the diameter of the rolling element ball (or roller) as shown on Figure.



Oil bath lubrication showing a typical oil level

If the oil level is higher than this, the bearing temperature may increase at high circumferential speeds and losses due to splashing may occur. The oil churning account for about 50% of the total heat generated in the bearing. Furthermore, foaming of the oil may occur

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Factors that Impact Lubrication Performance

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The life of a bearing depends on the proper bearing lubrication. Grease lubricants help protect surfaces against corrosion while reducing friction. Inadequate lubrication classified as below.

- Overfilling.
- Incorrect grease.
- Worn-out grease
- . • Incorrect lubrication systems and intervals.
- Under filling.
- Mixing greases.
- Water contamination.
- Insufficient lubricant quantity available in the bearing

- The viscosity of the lubricant is insufficient for the operating temperature and speed .

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Lubricant Degradation

Black oil formation- causes

Wear related issue
a) Oil ring stability issue
b) Bearing fits
c) Low oil delivery to bearings
d) Oil viscosity and additives

Chemistry related issue
a) Changes in lubricating oil and additives
b) Reaction of oil with preservatives of housing

Cleanliness related issue
a)Housing cleanliness after manufacture
b)Contamination during operation

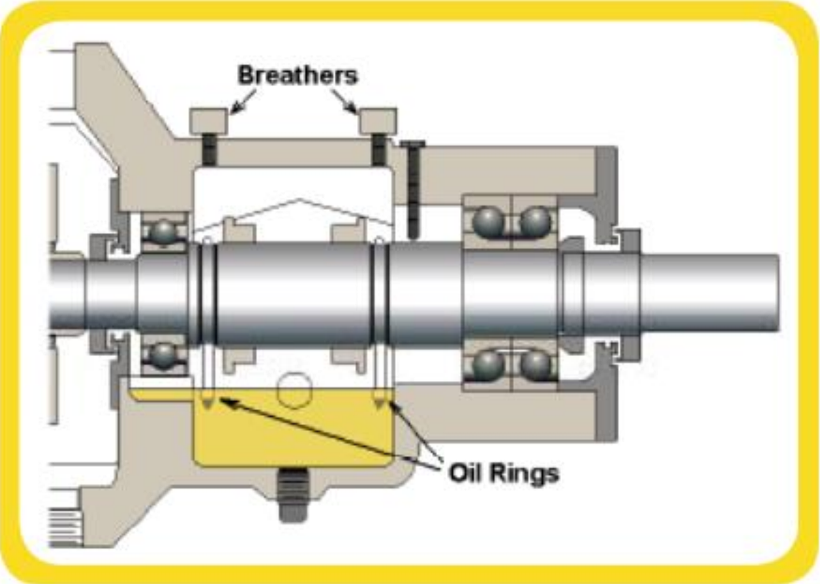
BEARING FAILURE DUE TO CONTAMINATION

Contamination type–

1)Solid contamination
2)Liquid contamination
3)Corrosion related contamination

Source of contamination –

1) Generated contamination
2) External ingressed contamination
3) Maintenance induced contamination



Moisture and dust often enter bearing housings through old-style labyrinth seals or lip seals as airborne water vapor.

SOLID CONTAMINATION -OIL RING

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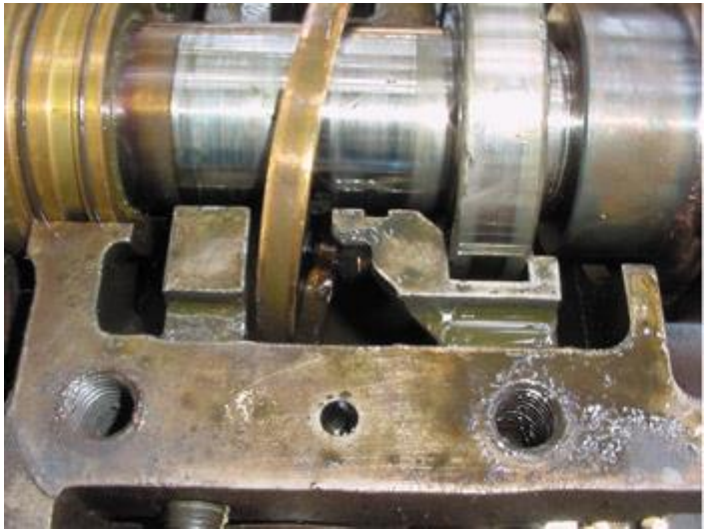
Oil rings ("slinger rings can be a source of INTERNAL contamination. Operating oil rings on rotating shaft systems that are not horizontal will cause the bronze slinger ring to spin and rub against the low side of the housing, resulting in severe wear on the ring.



Oil rings can have a tendency to malfunction if they contact stationary housing parts

Oil rings typically operate best in an as-designed speed range with closely maintained depth of immersion, ring concentricity, shaft system horizontality and surface roughness of contacting parts.

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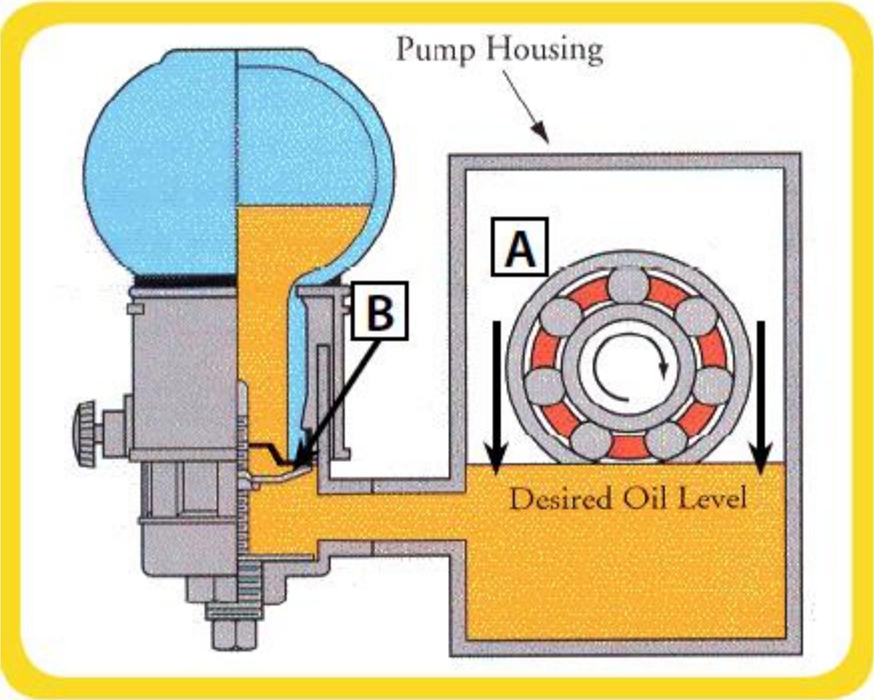
LIQUID CONTAMINANT AND MOISTURE - CONSTANT LEVEL LUBRICATOR

Contaminants can also enter through a breather vent, or from the widely used non-pressure balanced constant level lubricators.



Typical Bearing housing without modern protector seals.

Contaminated Lubricant

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The quality of lubrication is affected by contamination, which is a large contributor to premature bearing failures.

Generated contamination → External ingression → Maintenance induced

Generated contamination

generated during operation.
Bronze oil ring hang up and wear.

External ingression

Press. differentials between housing and atmosphere
housing temperature fluctuations occur during frequent on/off running conditions
contamination (dirt, water, etc.) "breathed" into housing

Maintenance induced

new oil is not clean
proper dispensing containers
pump rebuild process

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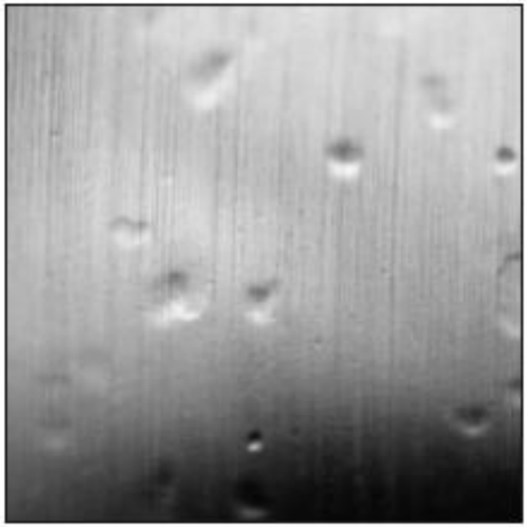
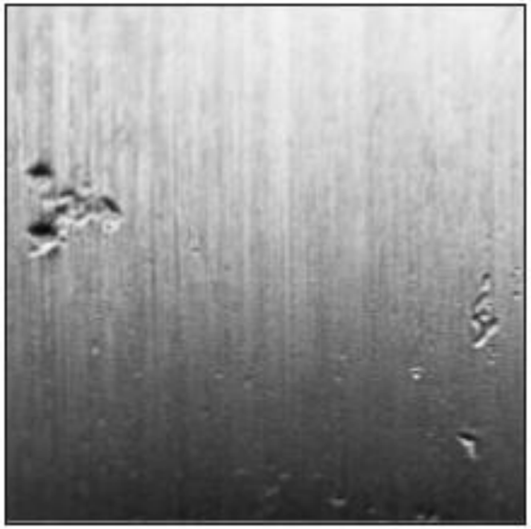
CONTAMINATION IN LUBRICANT(solid contamination)



indentation of soft foreign particles



indentation of hard mineral particles

Indentations are the result of foreign particles being cycled on the raceway. By means of the indentations, microscopic inspection of the tracks allows the differentiation between particles made of soft material, hardened steel and hard minerals.

CONTAMINATION IN LUBRICANT(liquid contamination)

Water is one of the main liquid contaminants. It can be taken up by the lubricant in some small amounts. It degrades the effect of lubrication, however, and often leads to tracks like those illustrated in fig.

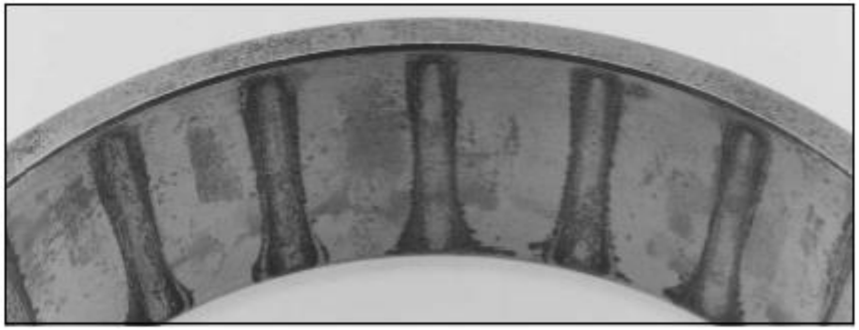
pressure polished track in liquid contamination

CORROSION DAMAGE

Corrosion) remains one of the most serious problems anti-friction bearings encounter.

Without adequate protection, the high degree of surface finish on races and rolling elements makes them susceptible to corrosion damage from moisture and water. Caused by condensate collecting in the bearing housing from temperature changes.

Moisture can get in through damaged, worn or inadequate seals.



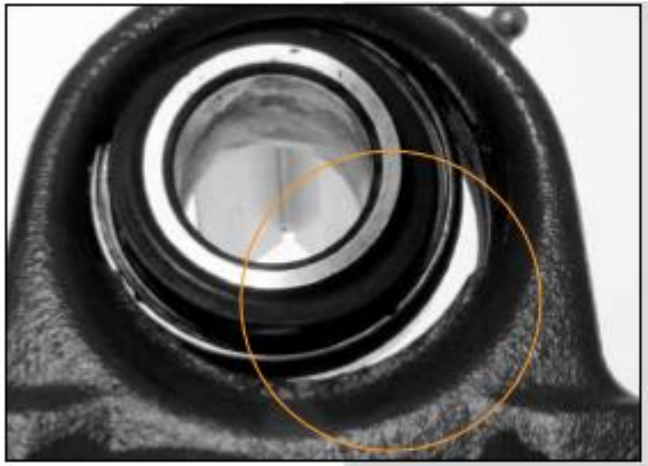
This cup has heavy corrosion on the race. surface stain without pitting

Advanced spalling initiated at water etch marks on the cup race

CORROSION DAMAGE

Cause

- Debris or Dirty Surroundings
- Abrasive Waste
- Moisture
- Without adequate protection
- Moisture or water can get in through damaged, worn seals
- Improperly washing and drying bearings
- Coat them with oil or another preservative and wrap them for storage



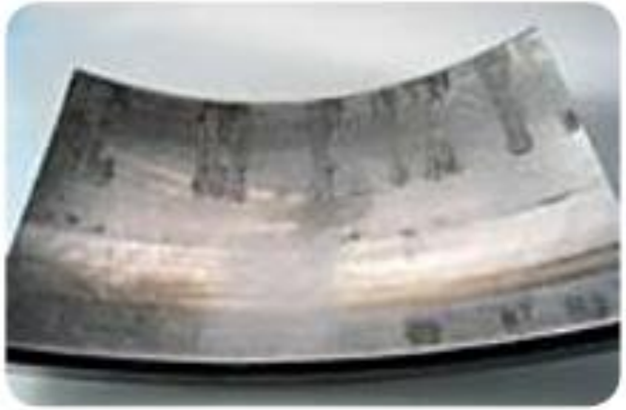
Exposure to abrasives and water in a severe environment caused extreme wear on this pillow block bearing.

MOISTURE CORROSION

Rust will form if water or corrosive agents reach the inside of the bearing in such quantities that the lubricant cannot provide adequate protection for the steel surfaces .

This process will soon lead to deep-seated rust .This produces greyish black streaks across the raceways, mostly corresponding to the rolling element distance

.The risk of corrosion is highest in non-rotating bearings, such as during standstill .

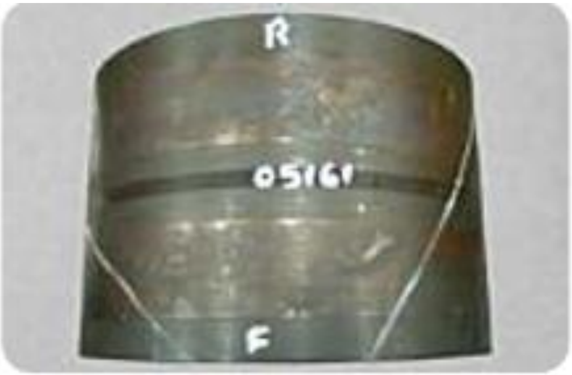


rust marks

FRICTIONAL CORROSION

Frictional corrosion is a chemical reaction activated by relative micro movements between contacting surfaces under certain conditions inside a bearing .

Railway axle bearings usually suffer from either fretting corrosion or wear caused by vibration which is also known as false brinelling .



Fretting corrosion marks on the outer ring.The outer ring has a clearance fit in the housing.

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FRETTING CORROSION

Fretting corrosion occurs when there is a relative movement between a bearing ring and shaft or housing, because the fit is too loose, or inaccuracies are formed .

The relative movement may cause small particles of material to become detached from the surface .These particles oxidize quickly when exposed to the oxygen in the atmosphere (or air trapped between the surfaces) .

Fretting corrosion on a rear seal and rear inner ring.The grease is discoloured brown due to the fretting debris.

MONITORING AND MAINTENANCE

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Three-Step Approach

1. Prevention
   a) Contamination
   b) Degradation
   c) Improper Quantity
2. Detection
   a)viscosity
   b)contamination
3. Correction
   a)configuration
   b)change oil if required

Bearing housing

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Particle count

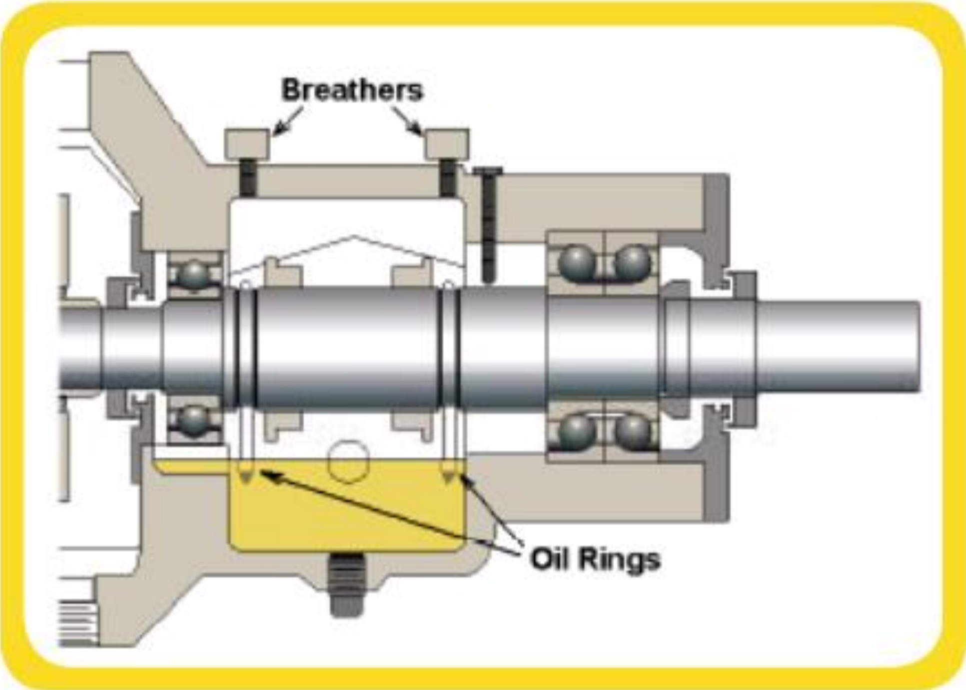
Reducing particle counts significantly extend the life expectancy of equipment. For example, by reducing contamination levels from ISO 21/18 to ISO 14/11, the life of a 50-gpm pump may be extended by a factor of seven.

Particle contamination can occur from ingress from the surroundings, improper cleaning of the bearing housing during maintenance cycles, or corrosion products from the high water content in the oil.

Properly specified housing components, including oilers, seals and vents, can be effective in preventing contamination

BEARING HOUSING

Moisture and dust often enter bearing housings through old-style labyrinth seals or lip seals as airborne water vapor.

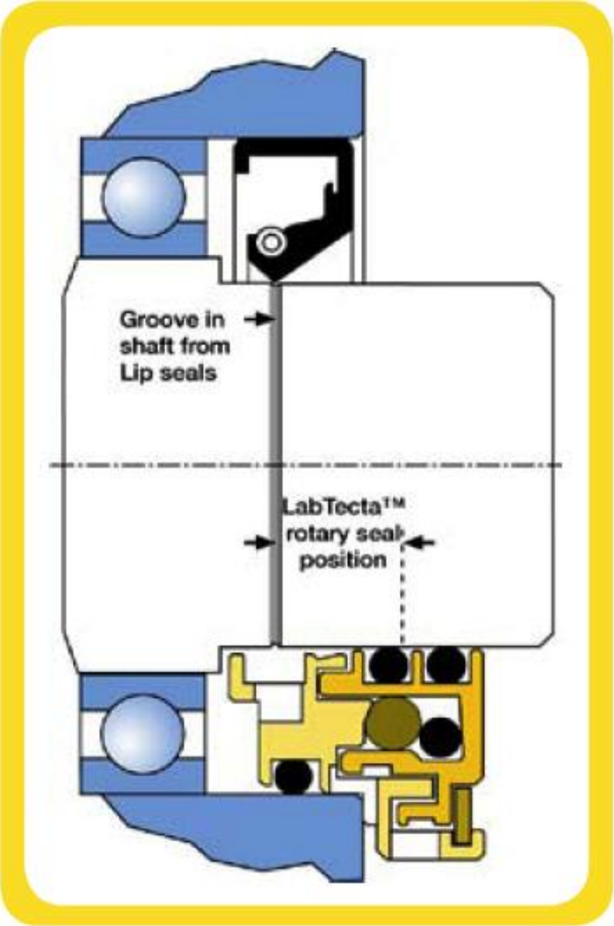


Typical Bearing housing without modern protector seals.

Lip Seals vs. Rotating Labyrinth Seals

Lip seals will seal only while the elastomer material (the lip) makes full sliding contact with the shaft .Lip seals show leakage after about 2,000 operating hours . To prevent contaminant intrusion, one would have to replace lip seals just before they fail --- four times per year.

Full sealing of the bearing housing requires the use of face seals. An API-610 compliant magnetically-activated dual-face seal .

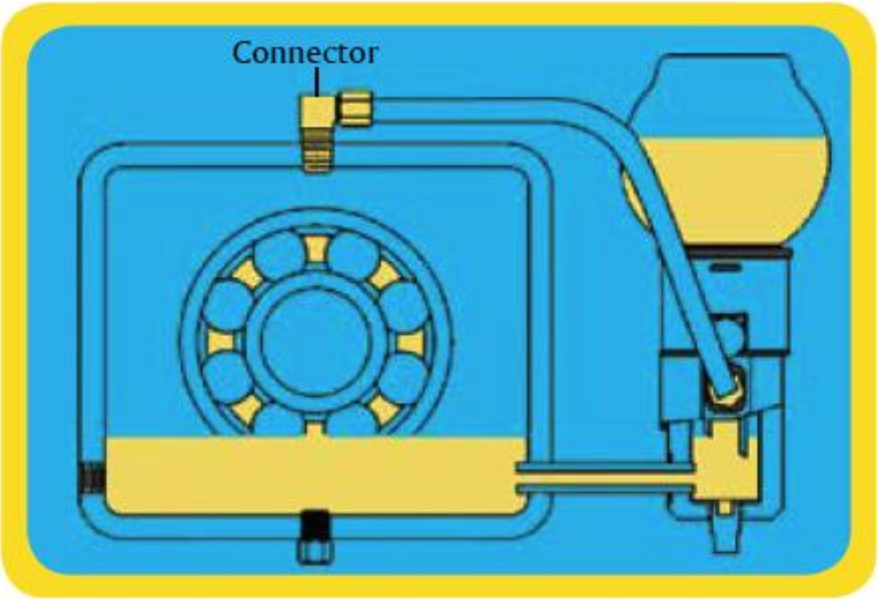


Lip seal –upper illustration, rotating labyrinth seal lower illustration

PRESSURE BALANCED LUBRICATOR-

To stop this breathing and resulting contamination, there should be no interchange between the housing interior air and the surrounding ambient air.

Instead of the widely used (non-pressure-balanced) constant level lubricators which allow the oil to come in contact with dirty air, a pressure-compensated (or "balanced") constant level lubricator should be installed.



Pressure balanced constant lubricator


THANK YOU