PDHonline Course M422 (2 PDH)

Introduction to Roller-Bearings and Damage Analysis

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Course Content

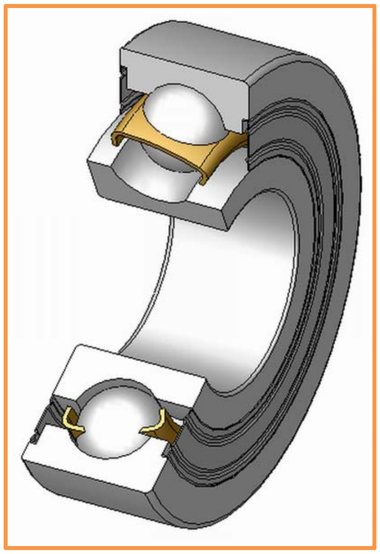
Bearings are designed to support and locate rotating shafts or parts in machines. Rolling-element bearings use rolling elements (either balls or rollers) interposed between two raceways, and relative motion is permitted by the rotation of these elements with very little rolling resistance and with little sliding. Raceways that conform closely to the shape of the rolling elements are normally used to house the elements. The rolling elements are usually positioned within the bearing by a retainer, cage or separator; in ball bearings of the filling-slot type and in needle bearings, they occupy the available space, locating themselves by contact with each other. Rolling bearings are also sometimes referred to as antifriction bearings. A variety of bearings are manufactured with seals on one or both sides. When the seals are on both sides, the bearings are lubricated at the factory. Although a sealed bearing is supposed to be lubricated for life, a method of re-lubrication is sometimes provided.

Rolling-element bearings have the advantage of a good tradeoff between cost, size, weight, carrying capacity, durability, accuracy, friction, and so on. Other bearing designs are often better on one specific attribute, but worse in most other attributes, although fluid bearings can sometimes simultaneously outperform on carrying capacity, durability, accuracy, friction, rotation rate and sometimes cost. Only plain bearings are used as widely as rolling-element bearings. There are five types of rolling-elements that are used in rolling element bearings: balls, cylindrical rollers, tapered rollers, spherical rollers, and needles.

TYPES OF ROLLING ELEMENTS

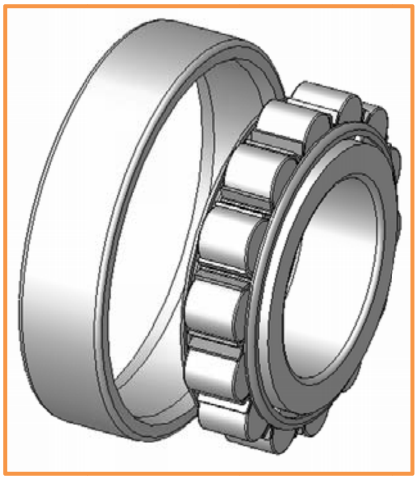
Bearings are manufactured to take pure radial loads, pure thrust loads, or a combination of these two. A particularly common kind of rolling-element bearing is the ball bearing. The bearing has inner and outer races and a set of balls. Each race is a ring with a groove where the balls rest. The groove is usually shaped so the ball is a slightly loose fit in the groove. Thus, in principle, the ball contacts each race at a single point. However, a load on an infinitely small point would cause infinitely high contact pressure. In practice, the ball deforms (flattens) slightly where it contacts each race, much as a tire flattens where it touches the road. The race also dents slightly where each ball presses on it. Thus, the contact between ball and race is of finite size and has finite pressure. Note also that the deformed ball and race do not roll entirely smoothly because different parts of the ball are moving at different speeds as it rolls. Thus, there are opposing forces and sliding motions at each ball/race contact. Overall, these cause bearing drag. Most rolling element bearings use cages to keep the balls separate. This reduces wear and friction, since it prevents the balls from rubbing against each other as they roll, and precludes them from jamming. Ball bearings can be divided into three categories: radial contact, angular contact, and thrust. Radial-contact ball bearings are designed for applications in which loading is primarily radial with only low axial (thrust) loads. Angular-contact bearings are used in applications that involve combinations of radial loads and high axial loads and require precise axial positioning of shafts. Thrust bearings are used primarily applications involving axial loads. For lightly loaded bearings, balls offer lower friction than rollers. Ball bearings can operate when the bearing races are misaligned. Precision balls are typically cheaper to produce than shapes such as rollers; combined with high-volume use, ball bearings are often much cheaper than other bearings of similar dimensions. Ball bearings may have high point loads, limiting total load capacity compared to other bearings of similar dimensions.

Roller bearings have higher load capacities than ball bearings for a given envelope size and are usually used in moderate-speed heavy-duty applications. However, in recent years improved materials and special designs have allowed use of cylindrical and tapered-roller bearings in high-speed applications. The principal types of roller bearings are cylindrical, needle, tapered, and spherical.



Ball bearing

Cylindrical roller bearings have rollers with approximate length-to-diameter ratios of 1:1 to 3:1. Roller bearings typically have higher load capacity than ball bearings, but a lower capacity and higher friction under loads perpendicular to the primary supported direction. If the inner and outer races are misaligned, the bearing capacity often drops quickly compared to either a ball bearing or a spherical roller bearing.

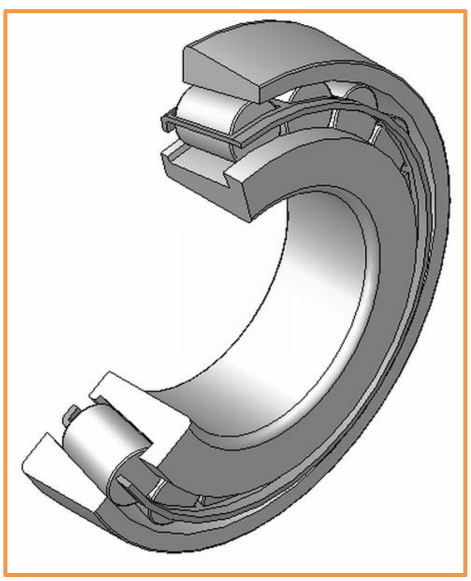


Cylindrical roller bearing

Needle roller bearings have cylindrical rollers with greater length-to-diameter ratios (approximately 4:1 to 8:1). Often the ends of the rollers taper to points, and these are used to keep the rollers captive, or they may be hemispherical and not captive but held by the shaft itself or a similar arrangement. Since the rollers are thin, the outside diameter of the bearing is only slightly larger than the hole in the middle. However, the small-diameter rollers must bend sharply where they contact the races, and thus the bearing experiences fatigue failure relatively quickly.

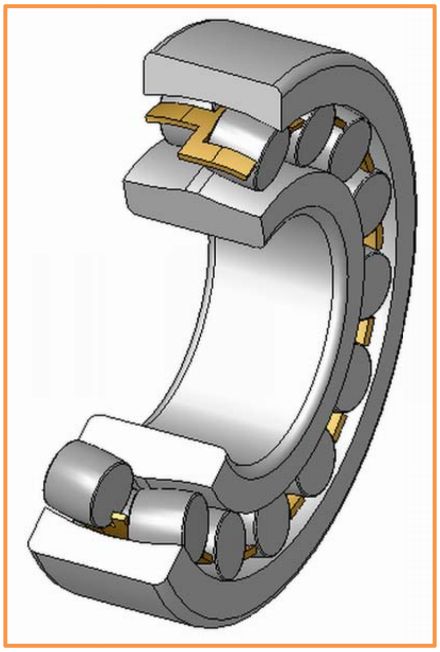
Needle bearing

The rolling elements of tapered roller bearings are truncated cones. Tapered roller bearings use conical rollers that run on conical races. Most roller bearings only take radial or axial loads, but tapered roller bearings support both radial and axial loads, and generally can carry higher loads than ball bearings due to greater contact area. Taper roller bearings are used, for example, as the wheel bearings of most wheeled land vehicles. The downsides to this bearing is that due to manufacturing complexities, tapered roller bearings are usually more expensive than ball bearings; and additionally under heavy loads the tapered roller is like a wedge and bearing loads tend to try to eject the roller; the force from the collar which keeps the roller in the bearing adds to bearing friction compared to ball bearings. The nomenclature for a tapered roller bearing differs in some respects from that of ball and straight roller bearings. The inner ring is called the cone, and the outer ring is called the cup.



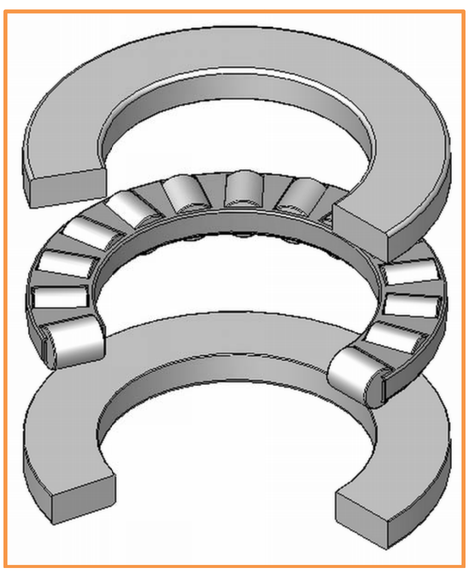
Tapered roller bearing

Spherical roller bearings are available with both barrel and hourglass-shape rollers. Spherical roller bearings use rollers that are thicker in the middle and thinner at the ends; the race is shaped to match. Spherical roller bearings can thus adjust to support misaligned loads. However, spherical rollers are difficult to produce and thus expensive, and the bearings have higher friction than a comparable ball bearing since different parts of the spherical rollers run at different speeds on the rounded race and thus there are opposing forces along the bearing/race contact.



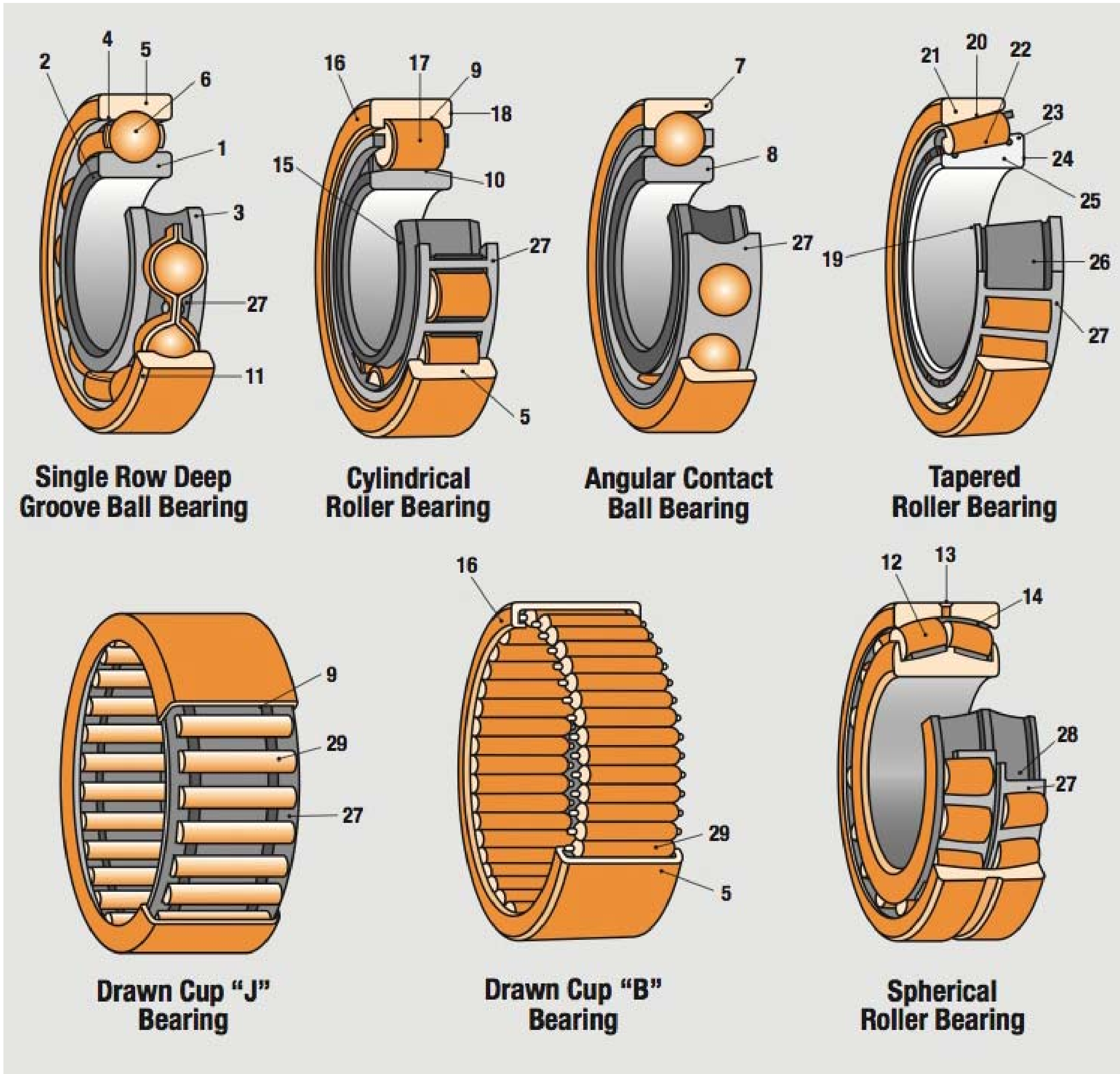
Spherical double roller bearing

Thrust bearings are used to support axial loads, such as vertical shafts. Commonly spherical, conical or cylindrical rollers are used; but non-rolling element bearings such as hydrostatic or magnetic bearings see some use where particularly heavy loads or low friction is needed.



Thrust cylindrical bearing

Types of Bearings and Nomenclature:



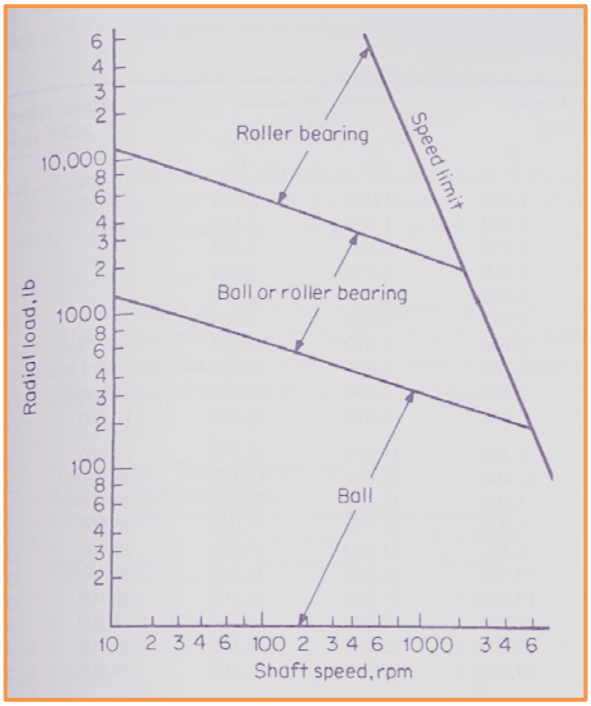
1. Inner Ring
2. Inner Ring Corner Radius
3. Inner Ring Land
4. Outer Ring Land
5. Outer Ring
6. Ball
7. Counter Bore
8. Thrust Face
9. Outer Ring Race
10. Inner Ring Race
11. Outer Ring Corner Radius
12. Spherical Roller
13. Lubrication Feature (Holes and Groove)
14. Spherical Outer Ring Race
15. Inner Ring Face
16. Outer Ring Face
17. Cylindrical Roller
18. Outer Ring Face
19. Cone Front Face
20. Cup Race
21. Cup (Outer Ring)
22. Tapered Roller
23. Cone Large Rib
24. Cone Back Face
25. Cone (Inner Ring)
26. Cone Race
27. Cage
28. Spherical Inner Ring race
29. Needle Roller

Selection of Ball or Roller Bearing

Selection of the type of rolling-element bearing is a function of many factors, such as load, speed, misalignment sensitivity, space limitations, and desire for precise shaft positioning. However, to determine if a ball or roller bearing should be selected, the following general rules apply:

- Ball bearings function on theoretical point contact. Thus they are suited for higher speeds and lighter loads than roller bearings.
- Roller bearings are generally more expensive except in larger sizes. Since they function theoretically on line contact, they will carry heavy loads, including shock, more satisfactorily, but are limited in speed.

The below figure may be used as a general guide to determine if a ball or roller bearing should be selected for the application (the figure is based on a rated life of 30,000 hours).



BEARING MATERIALS

A significant improvement has occurred in steel making in recent years where the quality is approaching that of special melting technologies which produce clean steel. However, high reliability applications such as aircraft engines still require secondary refining processes (electroslag or vacuum arc remelting).

The bearing industry has used through-hardened material, such as 52100 steel, for ball bearings and carburized materials such as 8620, for roller bearings for quite sometime. A commonly accepted minimum surface hardness for most bearing components is 58 Rockwell C (HRC). The carburizing grades have a core hardness range of 25 to 45 HRC.

At surface hardness values below the minimum 58 HRC, resistance to fatigue is reduced, and the possibility of brinelling (denting) of raceways is increased. Because hardness decreases with increasing operating temperature, the conventional materials for ball and roller bearings can be used only to temperatures of approximately 150°C (300°F). Although ball bearings made of high-temperature materials, such as M50 (Fe-Cr-V-Mo alloy), or roller bearings made of CBS1000M (Cr-Ni-Mo-V alloy) are usable upto approximately 315°C (600°F), the practical limit is actually determined by the breakdown temperature of the lubricant, which is 205 to 230°C (400-450°F) for the synthetic lubricants that are widely used at elevated temperatures.

Molybdenum high-speed tool steels, such as M1, M2 and M10 are suitable for use to about 425°C (800°F) in oxidizing environments. Grades M1 and M2 maintain satisfactory hardnesses to about 480°C (900°F), but the oxidation resistance of these steels becomes marginal after a long exposure at this temperature. Also, regardless of operating temperature, bearings require adequate lubrication for satisfactory operation.

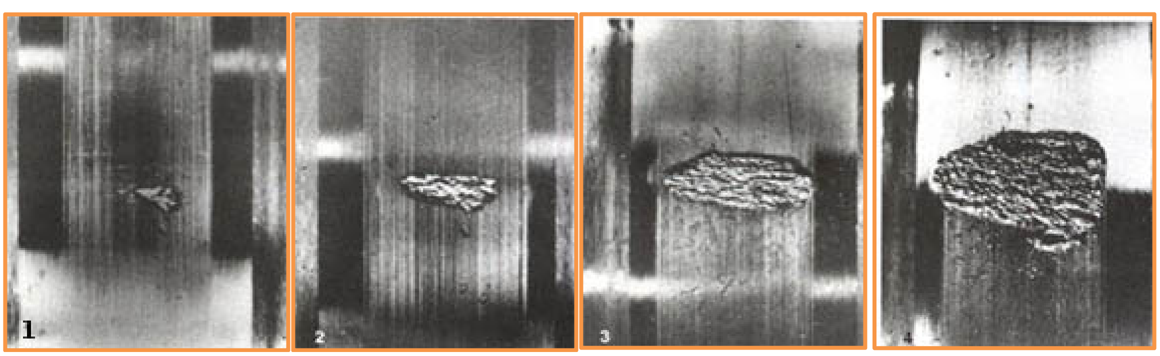
For bearings that operate in moderately corrosive environments, AISI type 440C stainless steel should be considered. Its maximum obtainable hardness is about 62 HRC, and it is recommended for use at temperatures below 175°C (350°F). However, the dynamic load capacity of bearings made from type 440C stainless steel is not expected to be comparable to that of bearings made from 52100 steel. The carbide structure of 440C is coarser and the fracture toughness is about half of 52100 steel.

Cages, sometimes called separators or retainers are used to space the rolling elements from each other. Cages are furnished ina wide variety of materials and construction. Most common types are steel, nylon or bronze.

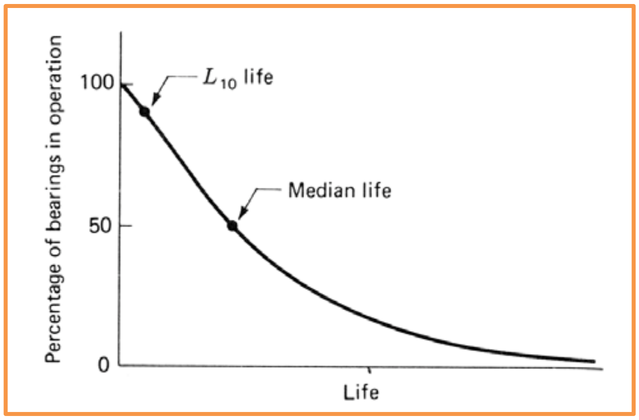
BEARING SERVICE LIFE

Even when bearings are used under ideal conditions failures can be caused by deterioration of the material due to rolling fatigue. Unless operating conditions are ideal and the fatigue load limit is not reached, sooner or later material fatigue will occur. The period until the first sign of fatigue appears is a function of the number of revolutions performed by the bearing and the magnitude of the load.

Fatigue is the result of shear stresses cyclically appearing immediately below the load carrying surface. After a time these stresses cause cracks, which gradually extend up to the surface. As the rolling elements pass over the cracks fragments of material break away and this is known as flaking or spalling. The flaking progressively increases in extent as shown below and eventually makes the bearing unserviceable.



Generally, the service life of a bearing is expressed as the number of revolutions, or the number of hours at a given speed, a bearing will complete before developing fatigue spalling in the inner ring, outer ring or the rolling element. Life may vary from bearing to bearing, but conforms to a statistically predictable pattern for large numbers of bearings of the same size and type operating under the same conditions. The L_{10} rating life of a group of such bearings is defined as the number of revolutions at which at least 90% of the tested bearings will survive. Similarly, the life reached or exceeded by 50% of the tested bearings is called the L_{50} life, or median life. The L_{50} life is about 3.5 to 5 times the L_{10} life.



Typical curve of bearing life expectancy

Formulas used by most manufacturers to calculate basic load ratings of rolling-element bearings are given in Anti-Friction Bearing Manufacturers Association (AFBMA) standards. The basic load-rating life may be modified by life-adjustment factors, such as reliability, material, lubrication, alignment, temperature, and other environmental factors.

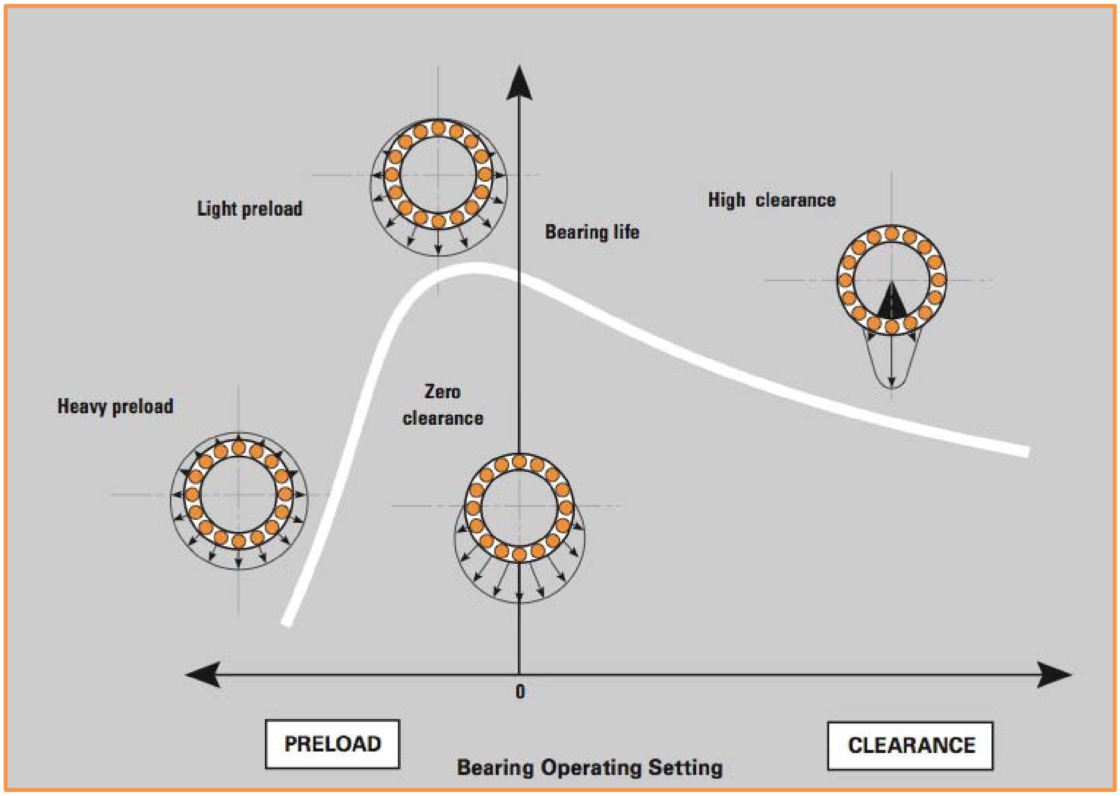
Experimental data have provided a simple relationship between load and bearing life. The bearing life, L_{10}, in millions of revolutions equals the ratio of bearing rating, C, to applications load, P, raised to an exponent, y, expressed as $L_{10}=(C/P)^y$, where y=3 for ball bearings and y=3.33 for roller bearings. The exponential character of this relationship between basic load and bearing life indicates that, for any given speed, a change in load may have a substantial effect on life in hours.

Bearing service life is dependent on many factors. Depending on the application requirements, the actual service life can vary greatly. For example, a machine tool spindle bearing may be unfit for further service due to minor wear that affects spindle accuracy. In contrast, a rolling mill roll neck bearing may provide satisfactory service life even if the bearing has developed spalling damage, provided the spalls are properly repaired in a timely fashion.

Reduced service life (premature failures) can be caused either individually or by any combination of:

- Faulty mounting
- Improper adjustment
- Insufficient lubrication
- Contamination
- Improper or abusive handling
- Poor housing support
- High-static misalignment or shaft and housing deflection
- Poor or inconsistent maintenance practices

The life of a bearing is dependent on the load zone obtained under operating conditions. Generally speaking, the greater the load zone, the longer the life of the bearing under stabilized operating conditions. Figure below illustrates this relationship for tapered roller bearings; other roller bearings with radial loads would have a similar performance relationship.



Bearing Life vs. Bearing Operating Setting

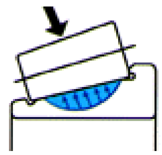
Bearing Loading Patterns

Damage to bearings usually results from subjection to loads or conditions other than those for which the bearings were designed. For example, misalignment or improper fit can result in loading that differs considerably, both in magnitude and direction, from that anticipated by the designer. Determination of such abnormal conditions by inspection of the location and distribution of damage on bearing components is often helpful. Most types of damage to ball bearings will be located on the path of ball travel. Because each type of loading produces its own characteristic ball path, the conditions of loading under which the damage occurs can be determined from an inspection of this ball path. Similar observations can be made on roller bearings.

Satisfactory operation of a bearing that has functioned under radial loads can be easily recognized. In radial ball bearings that have been properly mounted, operated under good load conditions, and kept clean and adequately lubricated, the paths of the balls on the highly polished raceways appear as dulled surfaces on which microscopic grinding scratches have been smoothed out. No appreciable amount of material has been removed from the surface of the raceways or balls, as indicated by the fact that there is no measurable decrease in the diameter of the balls, although the entire surface has been dulled. Other indications of satisfactory operation are uniformity; exact parallelism with the side of the raceway, which indicates correct alignment; and centering of the ball path in the raceway, which indicates that loading of the bearing has been purely radial.

Normal loading

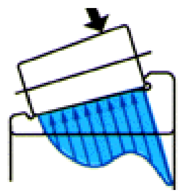
When the bearings are installed properly, with the correct bearing pre-load, the load pattern will be symmetrical (blue area).



Under this condition, with proper sealing and lubrication, the bearing should easily run for the life of the main component.

Improper loading

Overtightening the adjusting nut, or not seating the bearing properly, causes a shift in the load pattern on the bearing surfaces.



Wear becomes uneven on the roller surfaces -- roller, inner ring flange and race -- because the pressures on the surfaces are very distorted (blue area). In this situation the bearing fails prematurely.

Lubrication

Rolling-contact bearings need a fluid lubricant to obtain or exceed their rated life. In the absence of high-temperature environment, only a small amount of lubricant is required for excellent performance. Excess lubricant will cause heating of the bearing and accelerate deterioration of the lubricant. Optimum lubrication can be predicted since it has been shown that film thickness is sensitive to bearing speed of operation and lubricant viscosity properties and, moreover, that the film thickness is virtually insensitive to load.

Grease is commonly used for lubrication also because of its convenience and minimum maintenance. A high quality lithium-based grease should be used for temperatures up to 180°F (82°C), or polyurea-based grease for temperatures up to 300°F (150°C). In applications involving high speed, oil lubrication is often necessary.

EXAMINATION of FAILED BEARINGS

If a bearing fails to meet its predicted life requirement, the analyst must discover the cause of damage that led to failure and recommend measures that will eliminate or control this damage. The influenece of uncontrolled or unknown factors that can overshadow the effect of the controlled variable in tests must be determined.

For an accurate and complete analysis, not only the bearing but also the shaft, housing and the lubricant used with the bearing should be investigated and the following steps taken in order to determine the cause of the bearing damage and system breakdowns.

- Obtain operating data from bearing monitoring devices; analyze service and maintenance records and charts; and secure application diagrams, graphics or engineering drawings.
- Prepare an inspection sheet to capture all observations. Take photographs throughout the procedure to assist documentation or description of damaged components.
- Extract used lubricant samples from bearings, housing and seal areas to determine lubricant conditions. Package separately and label properly.
- Secure a sample of new, unused lubricant. Record any specification or batch information from the container. Obtain technical specifications and any related material safety data (handling, disposal, toxicological) documentation to accompany lubricant shipments.
- Check bearing environment for external influences, including other equipment problems that preceded or were occurring at the time bearing damage was reported.
- Disassemble equipment (either partially or completely). Record an assessment of the mounted bearing condition.
- Inspect other machine elements; in particular the position and condition of components adjacent to the bearing, including locknuts, adapters, seals and seal wear rings.
- Mark and record the mounted position of bearings and components prior to removal.
- Measure and verify shaft and housing size, roundness and taper using certified gauges.
- Following removal, but before cleaning, record observations of lubricant distribution and condition.
- Clean parts and record manufacturer's information from marking on the bearing rings (part number, serial number, date code).
- Analyze condition of the internal rolling contact surfaces, load zones and the corresponding external surfaces.
- Apply preservative oil and repackage bearings to avoid corrosion.

Not all of this information may be needed for every analysis, but it is desirable because the necessary data cannot be established until considerable analytical work has been done. Later acquisition of pertinent data is frequently difficult of impossible. Information regarding overheating, excessive noise, frequency of replacement, vibration, looseness and resistance to shaft rotation should also be sought from the bearing user. If you are a bearing user and you are concerned that your bearing is deteriorating then you should look for the following signs: Vibrations – whether felt by hand or measured with a frequency analyzer; Abnormal noises; Displacement of rotational centerline; Running temperature increase; Odd smells; Lubricant deterioration; Lubricant leakage, and any other abnormalities during routine visual maintenance check. A brief summary of typical failures and their causes is given in the following table.

	Failure	Cause
Flaking	Circumference on one side (Fig. 1)	Excessive axial load
	Symmetrical flaking on each side (Fig. 2)	Inclined mounting, or shaft or housing not in the shape of a circle
	Flaking on one side or flaking in the form of an oblique line on raceway surface of bearing ring on fixed side (Fig. 3)	Distortion of shaft, insufficient centering, bearings not installed on shaft at the correct angle
	Partial flaking on thrust bearing	Eccentric mounting
	Flaking found on part only	Contamination by foreign matter(s), flaws, initial stage of flaking
Scratches, Scuffing	Scuffing on roller end face and guide rib face (Fig. 4)	Excessive axial load, improper lubrication
	Scraches on raceway surface	Grease of too high viscosity, excessive acceleration in starting
	Scratches on raceway surface oh thrust bearing	Sliding of rolling element caused by centrifugal force during rotation
Cracks, Chips	Cracks or chips of rolling element (Fig. 5)	Improper bearing material, excessive impact too wide internal clearance of cylindrical roller bearing
	Cracks or chips of inner ring or outer ring (Fig. 5)	Advanced stage of flaking, improper bearing material, interference too large, housing of inaccurate design
	Cracks, chips of rib (Fig. 5)	Impact in mounting, axial impact, load too heavy
	Cracks, chips of cage	Improper lubricant or lubrication method, high speed operation, vibration impact too strong, advanced stage of wear
Creep	Creep on inner/outer rings	Insufficient interference
Wear	Wear on inner/outer rings	Sliding abrasion, bearing of insufficient hardness, contamination by foreign matter(s), shortage of lubricant, improper lubrication
	Wear caused by creep	Creep
	Wear on cage	Contamination by foreign matter(s), improper lubrication, inclined bearing
Rust, Corrosion	Rust on inner ring bore surface or outer ring O.D. surface	Fretting, water, humidity
	Rust covering whole bearing surface, corrosion	Defective washing oil or lubricant, water, humidity
Others	False brinelling (Fig. 6)	Progressing stage of flaws caused by load from vibration when machine is not running.
	Fluting on raceway surface or roller rolling surface (Fig. 7)	Passage of electricity
	Discoloration	Heat generation, chemical action

Sketches of failures

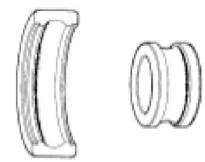


Fig.1 Flaking along circumference on one side. (Deep Groove Ball Bearing)

Fig.2 Symmetrical flaking on each side. (Tapered Roller Bearing)

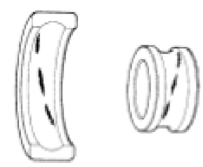


Fig.3 Flaking in the form of an oblique line. (Deep Groove Ball Bearing)

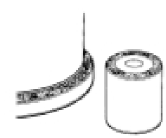


Fig.4 Scuffing on roller end face and guide rib face. (Cylindrical Roller Bearing)

Fig.5 Cracks and/or chips on inner ring or roller. (Spherical Roller Bearing)

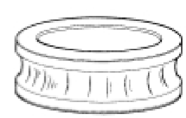


Fig.6 False brinelling on inner ring. (Deep Groove Ball Bearing)

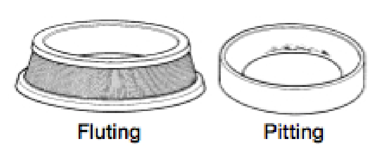


Fig.7 Type of Electric pitting.

TYPES of BEARING DAMAGE

Bearing damage can occur as a result of a number of different operating conditions. Those listed in this section are the most commonly found for anti-friction bearings, including cylindrical, spherical, needle, tapered and ball designs. It is important to remember that proper bearing maintenance and handling practices are critical to ensure optimum performance.

Wear – Foreign Material

One of the most common sources of trouble in anti-friction bearings is wear, and damage caused by foreign particles. Foreign particle contamination can cause abrasive wear, bruising and grooving, circumferential lining or debris contamination.

Abrasive Wear

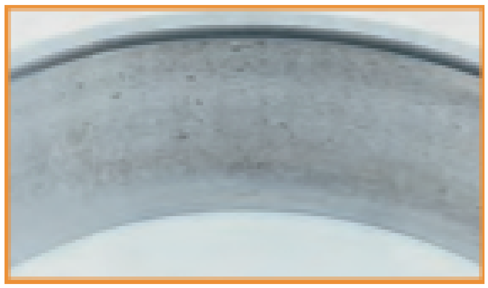
Abrasive wear due to fine particle contamination

Fine particle abrasive wear on inner race, commonly known as frosting

Fine foreign material in the bearing can cause excessive abrasive wear. Sand, fine metal from grinding or machining, and fine metal or carbides from gears will wear or lap the rolling elements and races. In tapered bearings, the roller ends and cone rib will wear to a greater degree than the races. This wear will result in increased endplay or internal clearance, which can reduce fatigue life and resultin misalignment in the bearing. Abrasive wear also can affect other parts of the machine in which the bearings are used. The foreign particles may get in through badly worn or defective seals. Improper initial cleaning of housings and parts, ineffective filtration or improper filter maintenance can allow abrasive particles to accumulate.

Appearance	Small indentations around the raceways and rolling elements. Dull, worn surfaces. Grease discolored green.
Cause	Lack of cleanliness before and during mounting operation. Ineffective seals. Lubricant contaminated by worn particles from brass cage.
Action	Do not unpack bearing until just before it is to be mounted. Keep workshop clean and use clean tools. Check and possibly improve the sealing. Always use fresh, clean lubricant. Wipe the grease nipples. Filter the oil.

Pitting and Bruising



Bruising: debris from other fatigued parts, inadequate sealing or poor maintenance

Hard particles rolling through the bearing may cause pitting and bruising of the rolling elements and races. The source may be debris from other fatigued parts, inadequate sealing or poor maintenance. Metal chips or large particles of dirt remaining in improperly cleaned housings can initiate early fatigue damage.

Grooving

Grooving due to large particle contamination embedding into soft cage material

Grooving is caused by extremely heavy wear from chips or metal particles. These contaminants become wedged in the soft cage material and cause cut grooves in the rolling elements. This condition results in improper rolling contact geometry and can reduce service life.

Debris Contamination

Gross contamination resulting from harsh operating conditions and/or seal failure

Common causes of external debris contamination include dirt, sand and environmental particles. Common causes of internal debris contamination include wear from gears, splines, seals, clutches, brakes, joints, housings not properly cleaned, and damaged or spalled components. These hard particles travel within the lubrication, through the bearing and eventually bruise (dent) the surfaces. Raised metal around the dents that act as surface-stress risers cause premature spalling and reduced bearing life.

Corrosion

Corrosion is one of the most serious problems encountered in anti-friction bearings. The high degree of surface finish on races and rolling elements makes them susceptible to corrosion damage from moisture and water if not adequately protected.

Corrosion is most often caused by condensate collecting in the bearing housing due to temperature changes. The moisture or water oftentimes gets in through damaged, worn or inadequate seals. Improper washing and drying of bearings when they are removed for inspection also can cause considerable damage. After cleaning and drying or whenever bearings are put into storage, they should be coated with oil or another preservative and wrapped in protective paper. Bearings, new or used, should always be stored in a dry area and kept in original packaging to reduce risk of static corrosion appearing before mounting.

Lubrication grease compromised by water ingress


Chemical reaction of grease and moisture in a prolonged static condition resulting in pitting and corrosion as evidenced by witness marks generated at each ball location on the inner race

Rusting with pitting: corrosion from moisture/water exposure

Appearance	Greyish black streaks across the raceways, mostly coinciding with the rolling element spacing. At a later stage, pitting of raceways and other surfaces of the bearing.
Cause	Presence of water, moisture or corrosive substances in the bearing over a long period of time.
Action	Improve sealing. Use lubricant with better rust inhibiting properties.

Inadequate Lubrication

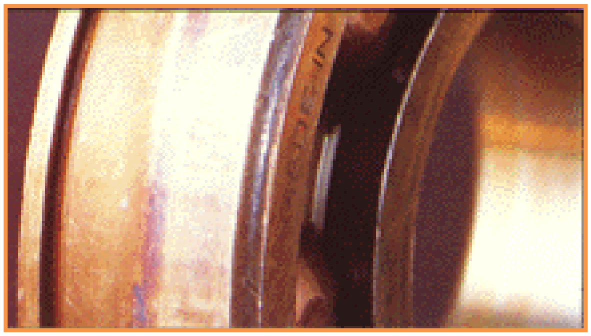
Inadequate lubrication can create a wide range of damage conditions. Damage happens when the lubricant intended for a bearing is not sufficient to separate the rolling and sliding contact surfaces during service.It is very important that the right lubricant amount, type, grade, supply system, viscosity and additives be properly engineered for each bearing system. The correct selection is based upon history, loading, speeds, sealing systems, service conditions and expected life. Without proper consideration of these factors, less than adequate bearing and application performance may be expected.

The damage caused by inadequate lubrication varies greatly in both appearance and performance. Depending on the level of damage, it may range from very light heat discoloration to total bearing lockup with extreme metal flow.

The section below demonstrates the progressive levels of bearing damage caused by 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 itself is discolored from high heat.

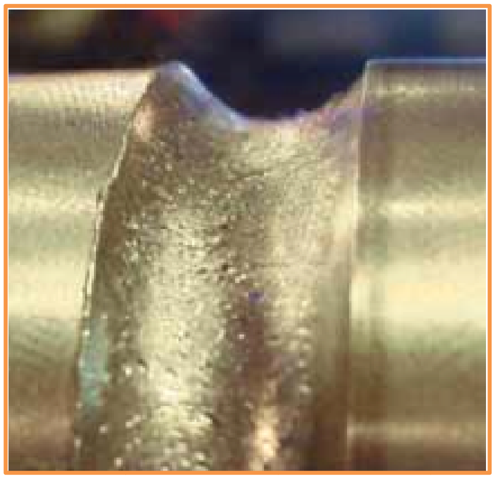


Heat discoloration on race

Level 2 – Scoring and Peeling

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

Roller end scoring due to metal-to-metal contact from breakdown of lubricant film



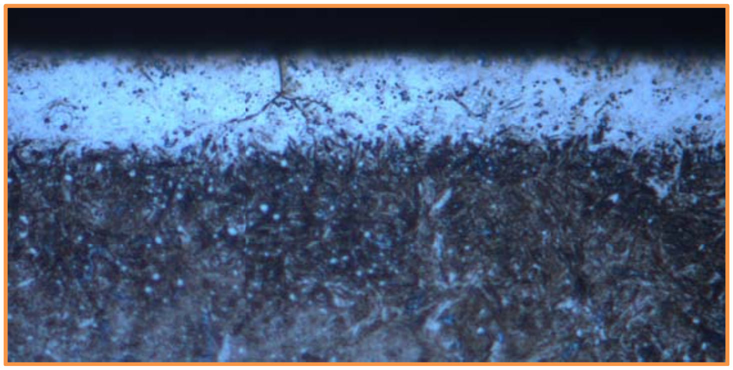
Metal-to-metal contact from lubricant breakdown resulting in polished appearance on the inner race followed by an orange peel texture and raised edge on the thrust shoulder

Level 3 – Excessive Roller End Heat

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

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. Once seizure occurs the bearing should not be used again because the hardness has most likely deteriorated due to metallurgical changes occurring at the surfaces due to excessive heat.



Micrograph showing the cracks in the untempered martensite zone (white layer) formed due to excessive frictional heat

Total bearing lock-up due to skewed rollers

Appearance	Worn, frequently mirror-like, surfaces; at a later stage blue to brown discoloration.
Cause	Lubricant has gradually been used up or has lost its lubricating properties.
Action	Check that the lubricant reaches the bearing. More frequent relubrication.

Fatigue Spalling

Spalling is simply defined as the pitting or flaking away of bearing material. Spalling primarily occurs on the races and the rolling elements, and the cracks typically initiate subsurface where contact stresses are the highest. They then propagate and reach the surface causing spalling.

Cross section showing subsurface cracking

It is important to realize that there are many types of “primary” bearing damage shown throughout this course, and they will eventually deteriorate into a secondary damage mode of spalling. This is a progressive failure mode and once initiated will spread as a result of further operation. It will always be accompanied by a marked increase in vibration. There are three distinct spalling damage modes that are classified by bearing manufacturers:

Geometric Stress Concentration (GSC) Spalling

Spalling from misalignment or heavy loading. This mode typically leads to deflection or edge loading that initiates high stress at localized regions of the bearing. The damage occurs at the extreme edges of the race/roller paths. It also can be the end result of machining errors with the shaft or the housing.

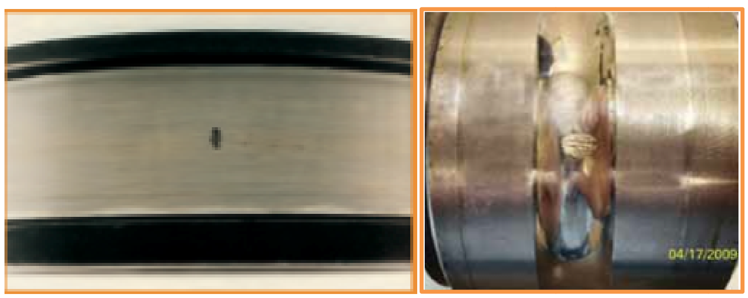
Point Surface Origin (PSO) Spalling

This mode is the result of very high and localized stress.The spalling damage is typically from nicks, dents, debris, etching and hard-particle contamination in the bearing. It occurs when debris or raised metal exceeds the lubricant film thickness. PSO spalling is the most common spalling damage, and it often appears as arrowhead shaped spalls, propagating in the direction of rotation.

Spalling from debris or raised metal

Inclusion Origin Spalling

This is the result of bearing material fatigue at localized areas of sub-surface, non-metallic inclusions, following millions of load cycles. The damage is observed in the form of localized, elliptically shaped spalls. Bearing steel cleanliness has improved over the past two decades to the extent that this type of spalling is seldom encountered.



Spalling from oxides or other hard inclusions in bearing steel

Excessive Preload or Overload

Excessive preload can generate a large amount of heat and cause damage similar in appearance to inadequate lubrication damage. Often the two causes may be confused, so a very thorough check is required to determine the root problem. A lubricant that is suitable for normal operation maybe unsuitable for a heavily preloaded bearing, as it may not have the film strength to carry the very high loads. The breakdown of lubricant caused in high preloads can cause the same type of damage as shown in the previous description of inadequate lubrication damage.

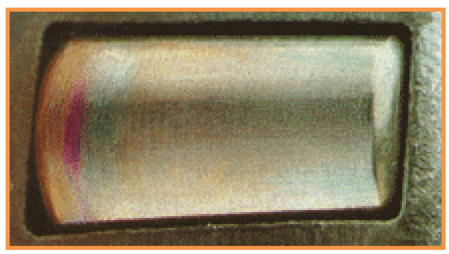
Another type of damage can result from heavy preloads, even if a lubricant, such as an extreme pressure type of oil that can carry heavy loads, is used. Although the lubricant can take care of the loads so that no rolling element or race scoring takes place, the heavy loads may cause premature sub-surface fatigue spalling. The initiation of this spalling, and subsequentlythe life of the bearing, would depend upon the amount of preload and the capacity of the bearing.

Rapid and deep spalling caused by unusually high stresses (left) and fullrace widthfatigue spalling caused by heavy loads (right)

Overheating

Overheated bearing steel develops very characteristic patterns. The colors reflect the temperatures. A strawberry brown indicates a 300°F temperature and deep purple means the heat went over 700°F.

The cause of overheating is lack of lubrication, over tightening during bearing adjustment, or overloading the carrying capability of the bearing. Temperatures exceeding 400°F can anneal the bearing components and result in reduced hardness, which in turn causes the bearing the loose its load carrying capacity. High temperatures also degrade the lubricant and destroy its effectiveness.



Overheated roller

Excessive Endplay

Excessive endplay results in a very small load zone and excessive looseness between the rollers and races outside the load zone. This causes the rollers to be unseated, leading to roller skidding and skewing as the rollers move into and out of the load zone. This movement causes scalloping in the cup race and cage wear from excessive roller movement and the impact of the rollers with the raceway.

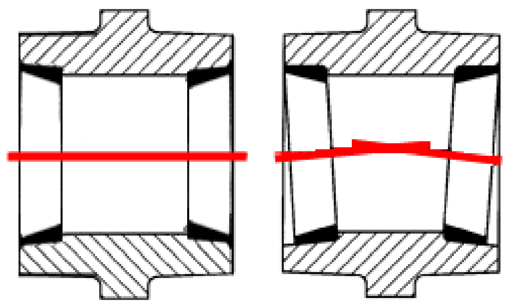
Scalloping: uneven localized wear resulting from excessive endplay

Cage pocket wear due to heavy contact between the rollers and cage pocket surfacescaused by bearing operating too loosely

Misalignment

Proper bearing alignment

When bearings are in proper alignment their center lines are parallel to each other.
In most designs, the center lines of a pair of bearings should be represented by only one line.



Improper bearing alignment

If the bearings are not seated properly their center lines will be at an angle to each other. This problem may be noticeable if you look closely for a flush mounted bearing surface before you remove it.

A few of the most common problems that produce a cocked installation are:

- dirt or burrs preventing a flush mount
- outer cup installed without proper tools
- a warped shaft
- nut faces that are out of line

Misalignment can be detected on the raceway of the nonrotating ring by a ball wear path that is not parallel to the raceway edges.

Misaligned bearings will shorten bearing life. The reduction in service will depend on the degree of misalignment. To get full life from the bearing, the seats and shoulders supporting the bearing must be within specified limits set by the bearing manufacturer. If the misalignment exceeds the limits, the load on the bearing will not be distributed along the rolling elements and races as intended, but will be concentrated on only a portion of the rollers or balls and races. In cases of extreme misalignment or off angle, the load will be carried only on the extreme ends of the rolling elements and races. A heavy concentration of the load and high stresses at these points will result in early fatigue of the metal.

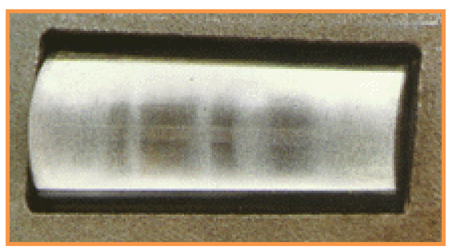
Irregular roller path from misalignment

Most common causes of misalignment are:

- Inaccurate machining or wear of housings or shafts
- Deflection from high loads
- Out-of-square backing shoulders on shafts or housings

Roller Damage

Worn at an angle. If wear patterns of any type are not parallel with the flat ends of the rollers, it indicates that the rollers are not running true. This type of wear is produced when the bearing is cocked in the housing.



Race Damage

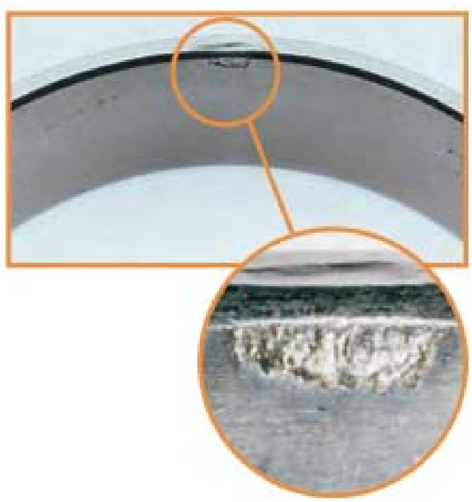
Worn on one side. When the bearing is cocked it will run crooked, creating an uneven wear pattern on both the rollers and the race. If you observe severe wear on one side of the race, but little on the other, you can be certain that something kept the bearing from being properly seated in the housing.

Handling and Installation Damage

Care must be taken in handling and assembling bearings so the rolling elements and race surfaces and edges are not damaged. Deep gouges in the race surface or battered and distorted rolling elements will cause metal to be raised around the gouge or damaged area. High stresses will occur as the rolling elements go over these surfaces, resulting in premature, localized spalling. The immediate effect of the gouges and deep nicks will be roughness, vibration and noise in the bearing.

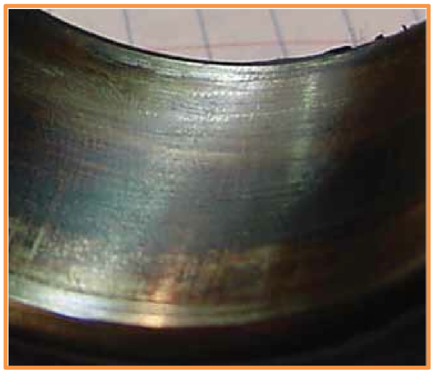
Roller spaced nicking: raised metal on race from contact with roller edges

Roller nicking/denting: rough handling or installation damage



Cup-face denting: indentations from hardened driver

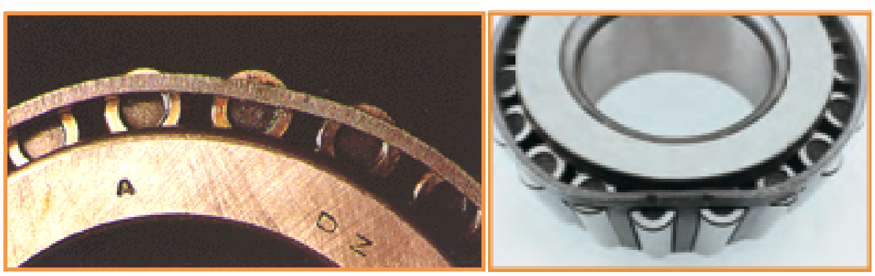
Bearing supported by only one-third of its outer ring width within housing



Loose inner ring fit on a rotating shaft resulting in discoloration from heat generation

Damaged Bearing Cages or Retainers

Careless handling and the use of improper tools during bearing installation may cause cage or retainer damage. Cages or retainers are usually made of softer mild steel, bronze or brass and can be easily damaged by improper handling or installation, resulting in premature bearing performance problems. In some applications, fractured cages or retainers may be caused by environmental and operating conditions.



Cage deformation due to improperly installed or dropped bearing

Rollers binding and skewing due to the cage ring being compressed during installation or interference during service

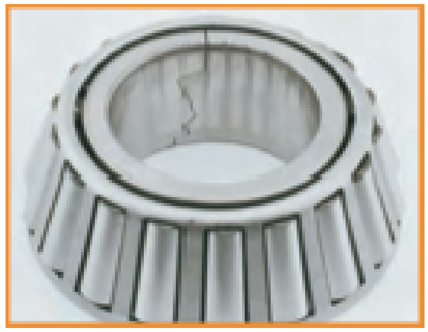
Cage damage due to misalignment or excessive speed

High Spots and Fitting Practices

Careless handling or damage when driving outer races out of housings or wheel hubs can result in burrs or high spots in the outer race seats. If a tool gouges the housing seat surface, it will leave raised areas around the gouge. If these high spots are not scraped or ground down before the outer race is reinstalled, the high spot will transfer through the outer race and cause a corresponding high spot in the outer race inside diameter. As the rolling elements hit this high area, stresses are increased, resulting in lower than predicted service life.

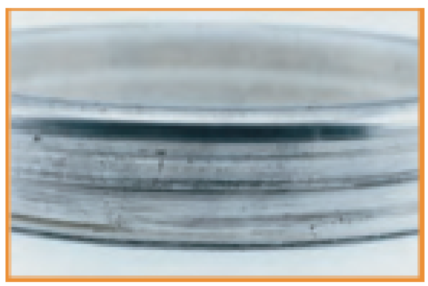
Improper Fit in Housings or Shafts

A manufacturer's recommended bearing fit should be followed to ensure proper bearing performance. In general, the bearing race where the rotating load exists should be applied with a press or tight fit. An example is a wheel hub where the outer race should be applied with a press fit. The races on a stationary axle would normally be applied with a light or loose fit. Where the shaft rotates, the inner race should normally be applied with a press fit and the outer race may be applied with a split fit or even a loose fit, depending on the application.



Cone bore fracture due to out-of-round or oversized shaft

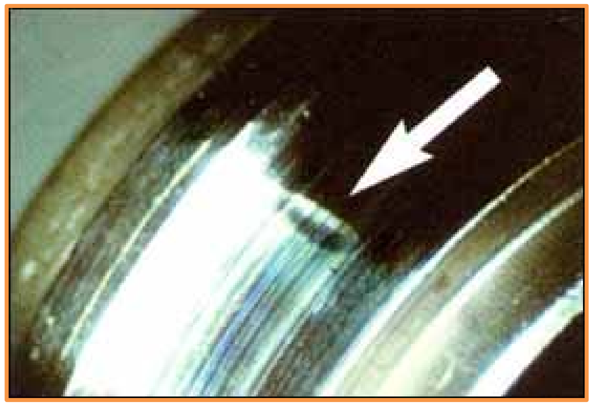
Axial crack on inner ring due to over-sized or out-of-round shaft

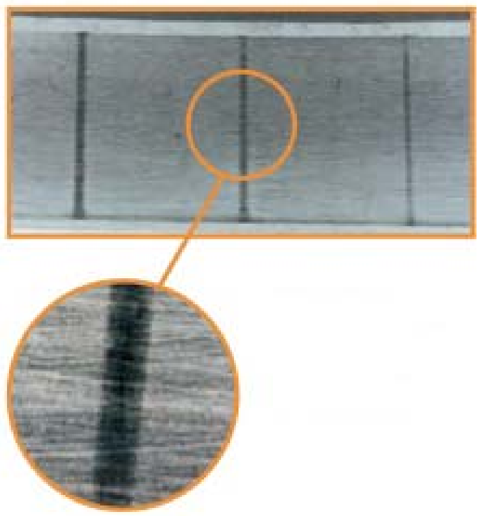


Cup spinning due to loose fit in a rotating wheel hub

Brinelling and Impact Damage

Improper mounting practices and/or extremely high operational impact or static loads may cause brinelling. Brinelling due to improper mounting is caused where a force is applied against the unmounted race. When mounting a bearing on a shaft with a tight fit, pushing the outer race will exert an excessive thrust load and bring the rolling elements into sharp contact with the race, causing brinelling. In a needle bearing, typical causes are static overload and shock load, although end loading and geometry defects also play a role. Extremely heavy impact loads, which may be short in duration, can result in brinelling of the bearing races and sometime even fracture the races and rolling elements.





Damage from shock or impact

False Brinelling/Vibration

False brinelling is, as the name implies, not true brinelling or denting. False brinelling is actually fretting wear. It is caused by slight axial movement of the rolling elements while the bearing is stationary. A groove is worn into the race by the sliding of the rolling element back and forth across the race. Vibration causes the sliding movement.There are times when this cannot be prevented, such as when automobiles or other types of equipment are shipped by rail or truck for relatively long distances. It also can occur during shipment by ocean freight. The vibration present may cause enough movement to produce some of this false brinelling. It can be greatly reduced or eliminated by reducing the potential for relative movement and decreasing the static weight present during shipment or storage.

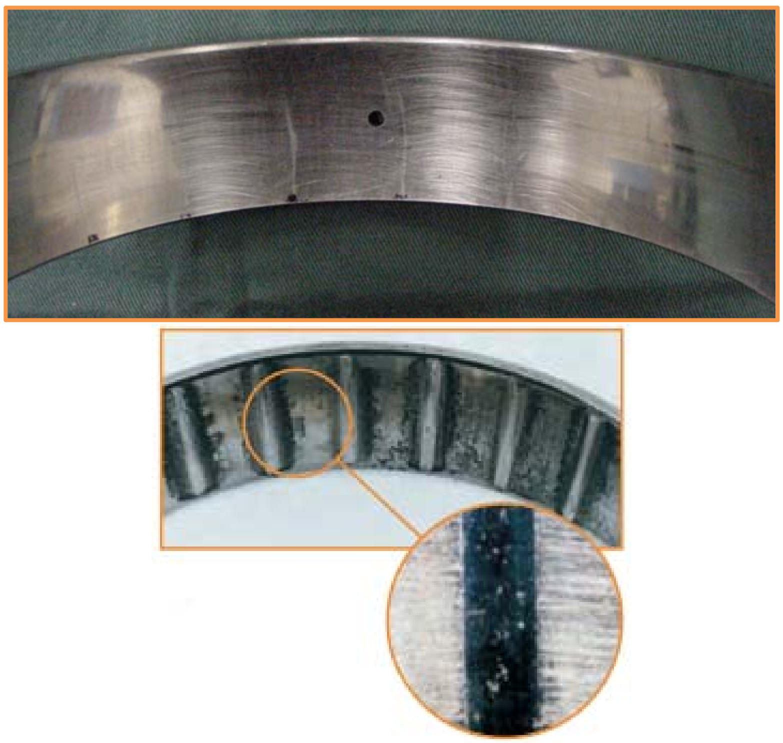
Rolling element bearings also exhibit false brinelling when used in positions that encounter very small reversing angular oscillation (less than one complete rotation of the rolling element). False brinelling can be distinguished from true brinelling by examining the depression or wear area. False brinelling will actually wear away the surface texture whereas the original surface texture will remain in the depression of a true brinell.

The following factors influence the rate at which false brinelling occurs:
Slip- False brinelling cannot occur unless relative motion is sufficient to produce slip between the surfaces.
Frequency - Frictional wear rates increase at lower frequencies and become almost constant as

frequency increases.
Normal Load - Frictional wear generally increases with applied load.
Duration - False brinelling increases almost linearly with the number of cycles.
Temperature - Generally, false brinelling tends to increase with decreasing temperatures.
Environment- False brinelling is more severe in an air or oxygen atmosphere than in an inert atmosphere.
Surface Finish - False brinelling is generally more serious when the surfaces are smooth because a smooth finish has smaller and fewer lubricant pockets.
Lubricant - Lubricants that restrict the access of oxygen reduce frictional wear.
Hardness - Generally increased hardness reduces frictional wear.

The primary way to prevent false brinelling is to eliminate the source of vibration. In addition, steps can be taken to remove the relative displacement between parts by:

- Decreasing internal clearances if it does not adversely affect bearing operation
- Locking bearings with a light thrust load (not double-row bearings)
- Keeping all surfaces lubricated by periodically rotating stationary equipment
- Pumping grease into the bearing while rotating it if this is a grease application
- Reducing lubricant viscosity so that the lubricant can wet and separate contact surfaces better



Wear caused by vibration or relative axial movement between rollers and races

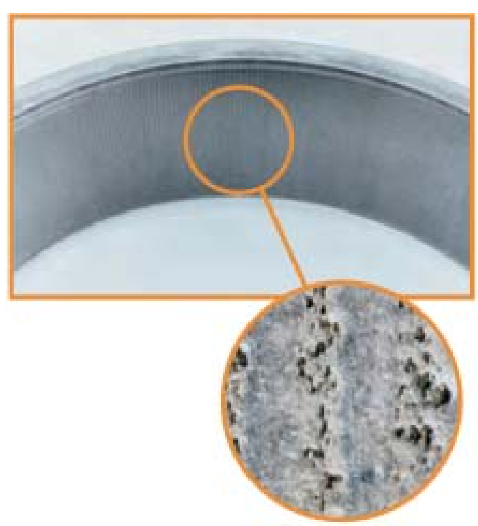
Appearance	Depressions in the raceways. These depressions are rectangular in roller bearings and circular in ball bearings. The bottom of these depressions may be bright or dull and oxidised.
Cause	The bearing has been exposed to vibration while stationary.
Action	Secure the bearing during transport by radial preloading. Provide a vibration-damping base. Where possible, use ball bearings instead of roller bearings. Employ oil bath lubrication, where possible.

Burns from Electric Current

Arcing, which produces high temperatures at localized points, results when an electric current that passes through a bearing is broken at the contact surfaces between the races and rolling elements. Each time the current is broken while passing between the ball or roller and race, a partially melted zone (pit) is produced on both parts. Eventually fluting develops. As it becomes deeper, noise and vibration result. A high-amperage current, such as a partial short circuit, will cause a rough, granular appearance. Heavy jolts of high-amperage charges will cause more severe damage, resulting in the welding of metal from the race to the ball or roller. These protrusions of metal on the roller will, in turn, cause a crater effect in the race, resulting in bearing noise and vibration.

Causes of arcing include static electricity from charged belts or processes that use calendar rolls, faulty wiring, improper grounding, welding, inadequate or defective insulation, loose rotor windings on an electric motor and short circuits.

Electric arc pitting: small burns created by arcs from improper electric grounding while the bearing is stationary

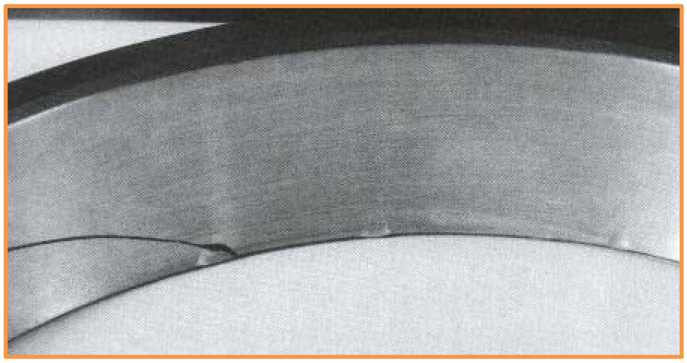


Fluting shows up as a series of small axial burns caused by current passing through the bearing while it is rotating

Appearance	Dark brown or greyish black fluting (corrugation) or craters in raceways and rollers. Balls have dark discolouration only. Sometimes zigzag burns in ball bearings raceways. Localised burns in raceways and on rolling elements.
Cause	Passage of electric current through the bearing.
Action	Re-route the current to by-pass the bearing. When welding, arrange earthing to prevent current passing through the bearing. Use insulated bearings.

Fractures, cracks and other failures

Cracks may form in bearing rings for various reasons. The most common cause is rough treatment when the bearings are being mounted or dismounted. Hammer blows, applied directly against the ring or via a hardened chisel, may cause fine cracks to form, resulting in pieces of the ring to break off when the bearing is put into service. Excessive drive up on a tapered seating or sleeve is another cause of ring cracking. The tensile stresses, arising in the rings as a result of the excessive drive-up, produce cracks when the bearing is put into operation. The same result may be obtained when bearings are heated and then mounted on shafts manufactured to the wrong tolerances.



Fractured outer ring of a self-aligning ball bearing. The indentations visible at the bottom edge of the ring were caused by rough treatment and the crack originated at one of these indentations.

Cam Fracture: Wide Inner Ring Ball Bearings

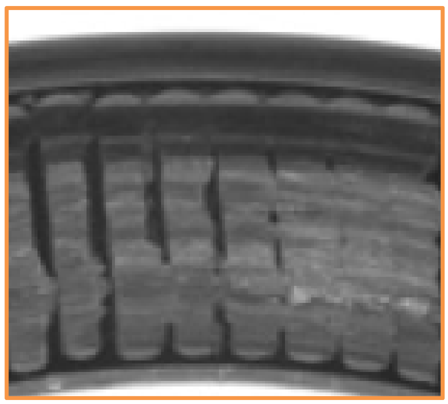
An undersized shaft or an outer ring that cannot be aligned due to the housing may cause a broken cam, a misaligned travel path or bearing wobble.This type of bearing damage may be prevented by using the correct size shaft and by using a self-aligning featured bearing with a spherical outer ring to compensate for initial misalignment and correctly mount bearings.

Roll Out: Sub Case Yielding, Case Crushing

When a needle bearing is grossly overloaded, the stress is driven deep into the race. If it is a case-hardened race, the stress may then exceed the strength of the relatively soft core. When this happens, the race's core will plastically deform in the axial direction (it is constrained in the radial direction by the housing). As the core expands axially, it carries the case with it, causing the case to fracture circumferentially. Also, if a case-hardened race is subjected to severe wear, it can wear away. The stress from a normally loaded bearing will then reach the core and cause roll out.

Rollers Locked in Place

Bearing damage may also be caused if the pilot in the tool used to install the full complement bearing does not have a functional ball detent. In shipping, a full complement bearing's rollers often settle into a slightly skewed position. If the bearing's rollers are not aligned prior to pressing the bearing into the housing, the rollers will lock into place at installation. The shaft then skids on the locked rollers resulting in smeared flats. The bearing components may be severely discolored (black or blue).



Damage on locked rollers

Bearing Stamping Lip Fractured Off

A bearing's lip may be fractured off if the tool used to install the bearing lacks the required 15-degreeback angle. Without this back angle, the installation force is directed through the lip of the cup and will fracture it. Often the lip is only cracked at installation and then breaks in service. With the proper 15-degreeback angle, the installation force is directed through the cup's wall, eliminating the possibility of fracturing the cup's lip.

Lip damage caused by improper installation

Bearing Cage Damage

If, on examination of a failed bearing, the cage is found to be damaged, it may in many cases prove difficult to ascertain the cause. Usually other components of the bearing are damaged too and this makes it even more difficult to discover the reason for the trouble. However, there are certain main causes of cage failure, such as vibration, excessive speed, wear and blockage.

Vibration

When a bearing is exposed to vibration, the forces of inertia may be so great as to cause fatigue cracks to form in the cage material after a time. Sooner or later these cracks lead to cage fracture.

Excessive speed

If the bearing is run at speeds in excess of that for which the cage is designed, the cage is subjected to heavy forces of inertia that may lead to fractures. Frequently, where very high speeds are involved, it is possible to select bearings with cages of special design.

Wear

Cage wear may be caused by inadequate lubrication or by abrasive particles. The idea with rolling bearings is of course to avoid sliding friction. However, where the cage is concerned, sliding cannot be eliminated in the contacts with the other components of the bearing. This explains why the cage is the first component to be affected when the lubrication becomes inadequate. The cage is always made of softer material than the other components of the bearing and consequently it wears comparatively quickly. As the cage pockets increase in size, due to wear, the rolling element guidance deteriorates and this also applies to the cage in cases where the cage is centered on the rolling elements. The resultant forces may lead to cage failure within a short period of time.

Blockage

Fragments of flaked material or other hard particles may become wedged between the cage and a rolling element, preventing the latter from rotating around its own axis. This leads to cage failure.

Other causes of cage damage

If the rings of a deep groove ball bearing are fitted out of alignment with each other, the path of the balls has an oval configuration. If the cage is centered on the balls, it has to change shape for every revolution it performs. Fatigue cracks then form in the material and sooner or later they lead to fractures. There is a similar case when a thrust ball bearing is fitted together with radial plain bearings. If clearance arises in the plain bearings, the washers of the thrust bearing become displaced in relation to each other. Then the balls do not follow their normal path and heavy stresses may arise in the cage. Cages in bearings subject to severe acceleration and retardation, in conjunction with fluctuations in speed, are affected by forces of inertia. These give rise to considerable pressure between the contacting surfaces, and consequently lead to heavy wear.

FACTORS THAT IMPACT LUBRICATION PERFORMANCE

As noted on earlier in the course, the life of a bearing depends to a great extent on the proper lubrication of the bearing. The contacting surfaces in rolling bearings have a relative motion that is both rolling and sliding, and so it is difficulty to understand exactly what happens. If the relative velocity of the sliding surfaces is high enough, then the lubricant action is hydrodynamic (load carrying surfaces are separated by a relatively thick film of lubricant so as to prevent metal-to-metal contact). Elastohydrodynamic lubrication (EHL) is the phenomenon that occurs when a lubricant is introduced between surfaces that are in pure rolling contact. When a lubricant is trapped between such surfaces, a tremendous increase in the pressure within the lubricant film occurs. But viscosity is exponentially related to pressure and so a very large increase in viscosity occurs in the lubricant that is trapped between the surfaces.

The purposes of a bearing lubricant may be summarized as follows:

- To provide a film of lubricant between the sliding and rolling surfaces
- To help distribute and dissipate heat
- To prevent corrosion of the bearing surfaces
- To protect the parts from the entrance of foreign matter

Common oils used in bearing applications are synthetic or mineral. Mineral oil is derived from refining crude petroleum and can contain unstable compounds such as nitrogen, oxygen or sulfur, which can affect service life. Synthetic oils are free of impurities and are designed for use in special circumstances where normal petroleum products can't cope with temperatures. In most cases, additives are used in the oils to resist oxidation, reduce foaming and improve lubricity.

Although lubricating oils are uniform in many characteristics, knowing and understanding the viscosity of oil is critical in determining its operating limits. Viscosity is the measure of the flowability of a liquid at a definite temperature. The faster the flow, the lower the viscosity, and vice versa. The oil viscosity must be high enough to provide a continuous film but not too high to generate excessive heat.

Either oil or grease may be employed as a lubricant. The following basic rules may help in deciding between them:
Use grease when: The temperature is not over 200°F, the speed is low, unusual protection is required from the entrance of foreign matter, simple bearing enclosures are desired, operation for long periods without attention is desired.
Use oil when: Speeds are high, temperatures are high, oil-tight seals are readily employed, bearing type is not suitable for grease lubrication, the bearing is lubricated from a central supply which is also used for other machine parts.
When bearings must be operated at extreme temperatures, a solid-film lubricant such as graphite or molybdenum disulfide must be used because the ordinary mineral oils are not satisfactory.

Re-greasing Intervals

Certain applications, such as electric motors utilizing double shielded or double sealed bearings, which are typically of the lubricated-for-life design, usually do not require re-greasing. On the other hand, all others, those being open or single shielded or sealed bearings, should be re-lubricated periodically to replace grease that has deteriorated, leaked away, or become contaminated. Generally, operating conditions will dictate the re-lubrication interval required. All greases deteriorate at some rate, even under moderate operating conditions. The principal causes are oxidation, excessive oil bleeding, and mechanical working. At high temperatures, oil evaporation may also be a factor. Oxidation eventually increases the oil viscosity and hardens the soap. Some oil bleeding is desirable, but too much reduces the ability of the grease to maintain an effective lubrication film. Mechanical working, or shearing, may change grease properties such as consistency, making the grease less suited to the application. Excessive oil evaporation may harden the grease. Deterioration often ends in hard, dry, deposits that can neither lubricate bearings nor protect them against contaminants.

Operating and other factors that influence re-lubrication frequency include: temperature, continuity of service, quantity of grease in housing, size and speed of bearing, vibration, exposure to contaminants, effectiveness of seals, and the grease's suitability for the particular service. The re-lubrication process typically requires scheduled machine downtime, which increases maintenance costs and causes loss in production. In addition, re-lubrication maintenance practices often fall short. While some processes are automated, the majority of re-lubrication is performed manually using a grease gun. This seemingly simple task actually involves a number of critical steps, including correct amount of lube, the right grease gun, proper cleaning, and careful storage and handling conditions, just to name a few. In addition, it is critical to use the same grease for the entire lifespan of a bearing.

As mentioned earlier, lubricants aid in protecting bearing surfaces from corrosion and reducing friction. A very high percentage of all bearing damage can be attributed to inadequate lubrication. Although a very broad term, inadequate lubrication can be classified into eight basic categories:

- Overfilling
- Underfilling
- Incorrect grease
- Mixing greases
- Incorrect lubrication systems and intervals
- Worn-out grease
- Water contamination
- Debris contamination

Overfilling

Overfilling a bearing with too much grease can cause excess churning during operation and high temperatures, resulting in overheating and excess grease purging (leaking). Overheating occurs because the heat generated cannot dissipate correctly, continually building until damage occurs. As the operating temperature of the bearing rises, the oxidation (breakdown) rate of the grease sharply increases – doubling every 10° C (18° F).

During initial start-up, it is common for a properly greased bearing to purge a small amount of grease. A slight grease purge is often recommended by original equipment manufacturers, as it acts as a barrier seal to help keep out external debris contamination. Always follow original equipment manufacturers' recommendations regarding grease purging and correct replenishment amounts. An overfilled bearing may also purge grease during initial start-up. However, over time and as temperature rises, excess grease will continue to purge from an overfilled bearing and have a darkened color.

Underfilling

Underfilling a bearing with grease also can have adverse consequences. As in overfilling, heat can be generated but for different reasons. When the grease amount is low, a grease starvation condition may be created, causing heat generation or excessive metal wear during operation. If a bearing suddenly becomes noisy and/or the temperature increases, excessive wear may be taking place.

Incorrect Grease

The base oil in a particular grease may have a different thickness (viscosity) than what is recommended for your application. If the base oil viscosity is too heavy, the rolling elements may have difficulty in pushing through the grease and begin to skid. If this occurs, excessive grease oxidation (breakdown) may cause premature grease degeneration and excessive wear of bearing components. If the viscosity is too light, peeling (micro-spalling) and wear may result due to thin lubricant film from elevated temperatures. In addition, the additives contained in a particular grease may be inappropriate or even incompatible with surrounding components in your system.

PREDICTING FAILURE

There are many predictive technologies with varying levels of sophistication that can spot the degeneration of a bearing before it fails. Some common ones are outlined below.

Vibration analysis can detect and analyze the condition of various components, including rolling-element bearings. By analyzing vibration signatures produced by bearing components, a vibration analyst can pinpoint bearing damage caused during operation. Any unusual pattern generated at one of these suspected frequencies is cause for immediate concern.

Today's vibration analysis tools include handheld data logger/analyzers with features to facilitate the detection, analysis, and correction of machine problems. A frequency analysis feature can overlay bearing defect frequencies on collected spectra to facilitate the detection and identification of machine and component problems.Handheld computers support operator-based maintenance. Online systems can constantly monitor bearings and other components. Powerful analysis software can manage, manipulate, and analyze machine condition data.

Lubricant analysis can reveal the condition of bearings lubricated by either a static oil sump or circulating oil by the amount of contamination present in the system. In addition to obtaining an indication of the bearing components' condition, the analysis also gives an indication of whether the oil in the lubrication system is degrading.

Temperature monitoring, while providing insight into potential bearing problems, does not reveal the actual condition of bearing components as accurately as vibration monitoring and lubricant analysis. An elevated bearing temperature affects the lubricant's viscosity and can lead to failure. Therefore, the maintenance professional should attempt to find out why a bearing is overheating and try to correct the situation.