Bearing Damage Analysis

with Lubrication Reference Guide

Featuring:

Ball
Cylindrical
Needle
Spherical
Tapered
Timken stands behind its products and the customers it serves. Whether training a team of maintenance personnel on proper bearing installation in the Powder River Basin area of Wyoming or providing application engineering assistance from our technology center in Bangalore, India, Timken friction management knowledge and expertise spans the globe, supporting major industries.

Providing bearing damage analysis not only demonstrates our commitment to friction management, it is also one of Timken’s core competencies. More than 100 years of expertise in material science and tribology — along with our long history of being a quality steel manufacturer — makes Timken uniquely qualified. Our sales and service teams are trained to both assess bearing damage issues on site, as well as work with customers to offer preventive maintenance techniques to improve performance.

The purpose of this guide is to help maintenance and operations personnel identify some of the more common types of bearing damage, possible causes and corrective actions. In many cases, the bearing damage may be due to a combination of causes. The guide also contains useful bearing references and lubrication guidelines.

For more information on bearing damage analysis, contact your Timken sales or service representative, or visit www.bearing.sg.
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**Bearing Life**

**Life Expectancy**

Bearing life expectancy based on material fatigue can be calculated if the operating loads and speeds are known. These calculations must assume that the bearing is correctly mounted, adjusted, lubricated and otherwise properly handled.

**Bearing Fatigue Life**

Bearings are laboratory tested to establish an $L_{10}$ life. $L_{10}$ life is the life that 90 percent of a group of apparently identical bearings will complete or exceed before the area of spalling reaches the defined 6 mm$^2$ (0.01 inch$^2$) size criterion.

If handled, mounted, adjusted, maintained, lubricated and used in the right way, the life of your bearing will normally reach and even exceed the calculated $L_{10}$ life.

When a sample of apparently identical bearings is run under specific laboratory conditions, 90 percent of these bearings can be expected to exhibit lives greater than the rated life. Then, only 10 percent of the bearings tested would have lives less than this rated life.

Figure 1 shows the distribution of bearing survival at the respective lives. This shows bearing life scatter following a Weibull distribution function with a dispersion parameter equal to 1.5.
**Bearing Service Life**

Bearing service life is dependent on many factors other than the calculated $L_{10}$ fatigue life. 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 have significant extended service life even if the bearing has developed spalling damage, provided the spalls are properly repaired.

Additionally, premature service life is most often caused by faulty mounting, improper adjustment, insufficient lubrication, contamination, improper handling and improper maintenance.

The life of your bearing is dependent on the load zone obtained under operating conditions; the higher the load zone (up to a slight preload), the higher the life of the bearing (See Figure 2).

*Fig.2: Operating bearing life vs. bearing setting*
For an accurate and complete analysis, the following steps should be taken when investigating bearing and system failures.

1. Obtain operating data from bearing monitoring devices; analyze service and maintenance records and charts; and secure application diagrams, graphics or blueprints.

2. Extract used lubricant samples from bearings, housing and seal areas to determine lubricant conditions. Package separately and label properly.

3. Secure new lubricant sample (1 lb.), label and package. Obtain specification and MSDS sheets and other documentation.

4. Check bearing environment for external influences, including equipment problems.

5. Take photos of bearings in the “as-found,” mounted condition.

6. Assess all bearings in mounted conditions.

7. Assess any gears, seals, pulleys/sheaves, etc.

8. Mark the position of the bearings in their mounted states.

9. Remove bearings and surrounding components. Package separately and label properly.

10. Check and verify bearing seats for size, roundness, taper, etc.

11. Examine and assess damage of all bearings and bearing parts. Use 5X-20X magnification.

12. Record all bearing damage using proper nomenclature.

13. Analyze load zones, roller paths and operating clearance.

14. For assistance with a bearing damage analysis, contact Timken’s Service Engineers.
Bearing Damage Analysis

Wear – Foreign Material

One of the most common sources of trouble in anti-friction bearings is wear from bruising or pitting caused by foreign particles. They can cause three types of damage: abrasive wear, bruising and grooving or circumferential lining.

Abrasive Wear

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 end play or internal clearance which can reduce fatigue life and result in misalignment in the bearing. This 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 and dirty lubricant. Improper cleaning of housings and parts may also allow foreign particles to accumulate.
**Pitting and Bruising**

Hard particles rolling through the bearing may cause pitting and bruising of the rolling elements and races. Metal chips or large particles of dirt remaining in improperly cleaned housings are the most common causes of trouble.

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**Grooving**

Grooving is caused by extremely heavy wear from chips or metal particles. These contaminants become wedged in the soft cage material and cut grooves in the rolling elements, resulting in grooving of the races.
**Etching – Corrosion**

Etching or corrosion is one of the most serious problems encountered in anti-friction bearings. The high degree of finish on races and rolling elements makes them susceptible to corrosion damage from moisture and water.

Etching is most often caused by condensate collecting in the bearing housing due to temperature changes. Moisture or water may get in through damaged, worn or inadequate seals. Improper washing and drying of bearings when they are removed for inspection causes considerable damage. After cleaning and drying or whenever bearings are put into storage, they should have a coating of oil or other rust preventative and be wrapped in a protective paper or covering. Bearings, new or used, should be stored in a dry area.

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**Fig. 12:** Advanced corrosion and pitting on the cone race and rollers. This amount of corrosion makes the bearing unsuitable for further service.

**Fig. 13:** Heavy water damage on a ball bearing inner ring and cage.

**Fig. 14:** A cup with considerable corrosion on the race. This type of corrosion is usually surface stain and pitting is not evident. If the staining can be cleaned with a fine emery cloth or crocus cloth, the bearing may be reused. If there are pits that cannot be cleaned with light polishing, the bearing should be discarded.

**Fig. 15:** Etching and corrosion on a ball bearing.
Inadequate Lubrication

Inadequate lubrication can damage the bearings very rapidly and cause extremely premature trouble. Inadequate or improper lubrication may include:

- No lubrication in bearing
- Not enough lubricant to sustain a film
- The wrong kind of lubricant for the speed and load
- The wrong grade of lubricant
- The wrong type of lubricant system, such as the use of an oil level and splash system when operating conditions require a circulating system.

- In a few high-speed applications, an over supply can cause excessive heat and expansion of parts that may preload bearings excessively. Such heat and overload might cause a rapid deterioration or even a breakdown of the lubricant.

In general, any condition that allows metal-to-metal contact in a bearing can be regarded as inadequate lubrication. Various degrees of inadequate lubrication damage may be described as micro-spalling (peeling), scuffing, scoring, galling and seizing.

These examples show various types of bearing damage caused by inadequate lubrication. (see the Lubrication Reference Guide on page 24.)
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. It is important to realize that there are many types of “primary” bearing damages shown throughout this booklet, and they will eventually deteriorate into a secondary damage mode of spalling. Timken classifies three distinct primary spalling damage modes as follows:

- Geometric Stress Concentration (GSC) Spalling – The result of misalignment or edge loading that initiates high stress at localized regions of the bearing. The result is spalling at the extreme edges of the race/roller paths. It is usually the end result of machining problems with the shaft, the housing, or from high loads, deflection, etc.

- Point Surface Origin (PSO) Spalling – The result of very high and localized stress causing the bearing to prematurely fatigue. This spalling damage is typically from nicks, dents, debris and hard particle contamination in the bearing. PSO spalling is the most common spalling damage, and it appears as arrowhead shaped spalls.

- Inclusion Origin Spalling – The result of the bearing material wearing out after millions of loading cycles, at localized areas of sub-surface inclusions. The damage is observed in the form of localized elliptically shaped spalls. Bearing steel cleanness has improved so significantly over the past decade that this type of spalling is almost never observed.
Excessive Preload or Overload

Excessive preload can cause damage similar to inadequate lubrication damage. Often the two causes may be confused, so a very thorough check is required to determine the real problem. A lubricant that is suitable for normal operation may be 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 fatigue spalling of the metal in the rolling elements and races. The initiation of this spalling and subsequently the life of the bearing would depend upon the amount of preload and the capacity of the bearing.
**Misalignment and Inaccurate Machining of Seats and Shoulders**

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. If the misalignment exceeds the limits set by the bearing manufacturer, the load on the bearing will not be distributed along the rolling elements and races as intended, but will be concentrated on a portion of the rollers 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.

**Causes of misalignment:**
- Inaccurate machining or wear of housings or shafts
- Deflection from high loads
- Out-of-square backing shoulders on shafts or housings
Handling & 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 rolling elements will cause metal to be raised around the gouge or damaged area. High stresses will be set up as the rolling elements go over these bumps in the surface, resulting in premature spalling at these spots. The immediate effect of the gouges and deep nicks will be roughness and noise in the bearing.

Fig. 37: Rough handling or installation damage resulted in nicks and dents on the tapered bearing roller.

Fig. 38: A hardened driver caused cup face denting on the tapered roller bearing.

Fig. 39: Spherical roller bearing inner race with fractured toe flange from improper installation tools.

Fig. 40: A hardened driver caused a broken rib on cylindrical roller bearing.
Fig. 41: Needle bearing with hardened punch dents.

Fig. 42: Inaccurate housing bore machining caused metal pick-up and galling on needle roller bearing.

Fig. 43: Tapered roller spaced nicking caused by raised metal on races coming in contact with roller edges.
Careless handling and the use of improper tools during bearing installation may cause cage or retainer damage. Cages or retainers are usually made of 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. This type of damage is too complex to cover in this manual. If you experience this problem, contact your Timken sales representative.
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 (I.D.). As the rolling elements hit this high area, stresses are set up, resulting in early fatigue.
Improper Fit in Housing or Shafts

The recommended bearing fits should be followed to get proper bearing performance.

In general, the bearing race on or in the rotating element 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.

Fig. 53: Ball bearing inner ring fracture as a result of being installed on top of a metal contaminant or raised metal nick.

Fig. 54: The tapered roller bearing cup is fractured as a result of the housing cracking during service.

Fig. 55: Bearing damage from a loose cup fit in a rotating wheel hub.

Fig. 56: A fractured tapered roller bearing cone due to an out-of-round or oversized shaft.
False Brinelling

False brinelling is, as the name implies, not true brinelling or denting. False brinelling is actually wear. It is caused by the rolling elements sliding axially back and forth on the race, while the bearing is stationary or while the race is stationary with respect to the rolling element. 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, vehicles and machines in general, are shipped by rail or truck for relatively long distances. It can also occur when shipments are made by boat. The vibration present may cause enough movement to produce some of this wear or false brinelling. It can be eliminated or at least greatly reduced by blocking up equipment so that weight is removed from the bearings.

Vibration is also a cause of false brinelling in needle bearings, as is small angle oscillation, improper lubrication and contamination.

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.
Brinell and Impact Damage

Improper mounting practices and/or extremely high operational impact or static loads may cause brinelling.

Brinell 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 brinell.

In a needle bearing, typical causes are static overload and shock load, although end loading and geometry defects also play a role.

Figures 62A and B shows diagrams of improper mounting and proper mounting arrangements for pressing a bearing on a shaft.

Extremely heavy impact loads, which may be short in duration, can result in brinell of the bearing races and sometime even fracture the races and rolling elements.

Fig. 59: Brinell and impact damage resulting from a heavy impact load on a tapered bearing cup race. These same indentations are evident on the cone race. This is true metal deformation and not wear as with false brinelling. The close-up view of one of the grooves shows the grinding marks in the groove.

Fig. 60: Inner ring of spherical roller bearing showing roller impact damage from shock loading.

Fig. 61: Cylindrical roller bearing inner ring is crushed by an application failure during service.

Fig. 62B: Proper Mounting Procedure

Fig. 62A: Incorrect Arbor Press Dismounting

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Fig. 63: Needle roller bearing outer ring race with roller spaced indents from impact during installation.

Fig. 64: Ball bearing inner ring showing brinell damage from shock loading.
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 races and rolling elements. Each time the current is broken while passing between the ball or roller and race, a 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 in the ball track. Heavy jolts of high amperage charges will cause a more severe failure, 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, inadequate or defective insulation, loose rotor windings on an electric motor and short circuits.

Fig. 65: Electric arc pitting or small burns created by arcs from improper electric grounding while the bearing is stationary.

Fig. 66: Fluting or series of small axial burns caused by an electric current passing through the bearing while it is rotating.

Fig. 67: Roller on spherical roller bearing with electric arc fluting caused by welding being performed on machine while bearings were rotating.
Cam Failure – 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 the Fafnir® self-aligning feature, a spherical outer ring to compensate for initial misalignment and correctly mount bearings. The proper mounting procedure is to:

- Align the bearing in its housing and slide unit into position on the shaft.
- Bolt the housing tightly to its mounting support.
- Engage and tighten locking collar and setscrew.

Roll Out (Sub Case Yielding, Case Crushing)

When a 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. If a case hardened race is subjected to severe wear, the case can wear away. The stress from a normally loaded bearing will then reach the core and cause roll out.
Rollers Locked in Place

Bearing failure 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, blue).

Fig. 72: When the bearing was installed using a pusher without a ball detent to align the rollers, the rollers locked in place as the cup shrunk during installation. The shaft then spun against the locked rollers. (See Fig. 73 below.)

Fig. 73: Tool with 15 degree backangle, for drawn cup bearing installation.

Fig. 73 Key:
A = 1/64 in. (0.4 mm) less than housing bore
B = .003 in. (0.06 mm) less than shaft diameter
C = distance bearing will be inset into housing; minimum of .008 in. (0.2 mm)
D = pilot length should be length of bearing less 1/32 in. (0.8 mm)
E = Approximately one half of D

Fig. 74: The drawn cup bearing was installed with an improper tool, damaging the lip. Lip damage this severe may lock-up the bearing.

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 degree backangle. Without the 15 degree backangle, 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 degree backangle, the installation force is directed through the cup’s wall, eliminating the possibility of fracturing the cup’s lip.

Fig. 74: When the bearing was installed using a pusher without a ball detent to align the rollers, the rollers locked in place as the cup shrunk during installation. The shaft then spun against the locked rollers.
Inadequate Grease Lubrication in Bearings:

The life of a Timken® bearing depends to a great extent on the proper lubrication of the bearing. Lubricants aid in carrying away heat, protecting bearing surfaces from corrosion and reducing friction.

Statistics show that nearly 50 percent of all bearing damage can be attributed to inadequate lubrication. Although a very broad term, inadequate lubrication can be classified into eight basic categories: 1) overfilling, 2) underfilling, 3) incorrect grease, 4) mixing greases, 5) incorrect lubrication systems and intervals, 6) worn-out grease, 7) water contamination, and 8) debris contamination.

Overfilling

Overfilling a bearing with too much grease can cause excess churning of the grease 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 18º F.

*NOTE: During initial start-up, it is common for a properly lubricated 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 (Figure 1). 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 (Figure 2).

Underfilling

Underfilling a bearing with grease can also 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.

Effects of Inadequate Grease Lubrication in Bearings

Ball bearing inner race (above) and outer race (below) burn-up: metal-to-metal contact from breakdown of lubricant film.

Tapered roller bearing cone large rib face deformation: Metal flow from excessive heat generation.

Cylindrical bearing outer race and rollers with peeling and moderate wear due to underfilling of lubricant.
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 (Figure 1). If this occurs, excessive grease oxidation (breakdown) (Figure 2) may cause premature grease failure and excessive wear of bearing components. If the viscosity is too light, peeling (micro-spalling) and wear (Figures 3 and 4) 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.

Mixing Greases

A bearing may be running well with the correct grease. However, while performing routine maintenance, a technician may decide to lubricate the bearing with a different type of grease. If the greases are not compatible, the grease mixture will do one of two things: 1) soften and leak out of the bearing due to grease thickener incompatibility, or 2) become lumpy, discolored and hard in composition (Figure 5).

Incorrect Lubrication Systems and Intervals

Maintaining correct bearing lubrication systems and intervals is critical to help prevent premature wear of bearing components.

If maintenance schedules are not followed (Figure 6), lubrication may deteriorate through excessive oxidation (breakdown). Figure 2 shows excessive bearing grease oxidation.

Worn-Out Grease

Grease is a precise combination of oil, thickener and additives (Figure 7). Grease acts like a sponge to retain and release the oil. As a result of time and temperature conditions, the oil release properties can become depleted. When this occurs, the grease is worn-out (Figure 8).
**Water Contamination**

Figure 1 shows the effect of water on grease by comparing fresh grease (left) to a grease emulsified with 30 percent water (right). The fresh grease is smooth and buttery compared to the water laden grease, which is milky white in appearance. As little as 1 percent water in grease can have a significant impact on bearing life.

![Fig. 1: Effect of water on grease.](image)

**Quick & Easy Field Test to Determine Water in Grease**

An easy, non-technical method of determining the presence of water in grease is known as the ‘crackle test.’ To perform this test, place a sample of grease on a piece of aluminum foil (Figure 4) and put a flame under the foil (Figure 5). If the grease melts and lightly smokes, the presence of water is minimal or absent. However, if the grease crackles, sizzles and/or pops, the grease contains a considerable amount of water. Note: Always wear safety glasses or goggles. Ensure adequate ventilation and wear protective clothing.

![Fig. 4: Grease sample](image)  
![Fig. 5: Crackle test](image)

**Debris Contamination**

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 and failed or spalled components. These hard particles travel within the lubrication, through the bearing, and eventually bruise (dent) the internal surfaces. The dents form shoulders that act as surface-stress risers, causing premature surface damage and reduced bearing life.

![Fig. 6: Debris contamination bruise on a bearing race – photo taken via a microscope (Fig. 6) – and corresponding surface map of the dent (Fig. 7).](image)

![Fig. 7](image)

**Fig. 2**

A tapered roller bearing (Fig. 2) and ball bearing outer race and balls (Fig. 3) rusting with pitting and corrosion from moisture/water exposure. This condition is referred to as etching.

**Fig. 3**

This information is not intended to substitute for the specific recommendations of your equipment suppliers.
Glossary

Abrasive Wear
Usually occurs when foreign particles abrade or cut the bearing surfaces.

Adhesive Wear
Caused by metal-to-metal contact, resulting in scuffing or scoring of the bearing surfaces.

Angular Contact Ball Bearing
Ball bearing whose internal clearance and race location result in predetermined angle of contact. Usually of counterbore construction.

Axial Internal Clearance
In ball or roller bearing assembly, total maximum possible movement parallel to bearing axis of inner ring in relation to outer ring. Also called bearing end play.

Axial Load
Load acting in direction parallel with bearing axis.

Brinelling
A dent or depression in the bearing raceway due to extremely high impact or static loads.

Brinelling – False
Wear grooves in the raceway caused by minute movement or vibration of the rolling elements while the bearing is stationary.

Bruising
The denting or plastic indentation in the raceways and rolling elements due to the contamination of foreign particles in the bearing.

End Play-Internal Clearance
The relative movement of the inner race and rolling elements to the outer race. In single ball and cylindrical bearing, it is the radial movement or the internal clearance. In a tapered bearing it is the axial movement to the two cone assemblies relative to the cups.

Etching – Corrosion
Usually caused by moisture or water contamination and can vary from light staining to deep pitting.

Fatigue
The fracture and breaking away of metal in the form of a spall. Generally, there are six modes of contact fatigue recognized:
- Inclusion origin
- Geometric stress concentration
- Point surface origin
- Micro-spalling or peeling
- Subcase fatigue
- Transverse cracking

Fillet Radius
Shaft or housing corner dimension which bearing corner must clear.

Fixed Bearing
Bearing which positions shaft against axial movement in both directions.

Floating Bearing
Bearing so designed or mounted as to permit axial displacement between shaft and housing.

Fluting
Electro-etching on both the inner and outer ring.

Fretting Corrosion
Usually occurs on the bores, outside diameters (O.D.) and faces of bearing races due to minute movement of these surfaces and the shaft or housing. Red or black oxide of iron is usually evident.

Housing Fit
Amount of interference or clearance between bearing outside surface and housing bearing seat.

Life
“Life” of individual rolling bearing is number of revolutions (or hours at some given constant speed) which bearing runs before first evidence of fatigue develops in material of either ring or washer or any rolling elements.

Misalignment
A bearing mounted condition whereby the centerline of the inner race or cone is not aligned with the centerline of the outer race or cup. Lack of parallelism between axis of rotating member and stationary member. Some of the causes of misalignment are, machining errors of the housing/shaft and deflection due to high loads.

Preload
The absence of end play or internal clearance. All of the rolling elements are in contact or in compression with the inner and outer races or cups and cones. Internal load on the rolling elements of bearing, which is the result of mounting conditions or design. Can be intentional or unintentional.

Radial Internal Clearance
In ball or roller bearing assembly, total maximum possible movement perpendicular to bearing axis of inner ring in relation to outer ring. Also called radial play or diametrical clearance.

Radial Load
Load acting in direction perpendicular with bearing axis.

Rating Life
$L_{10}$ of group of apparently identical bearings is life in millions of revolutions that 90 percent of group will complete or exceed.

Scoring
Caused by metal-to-metal contact, resulting in the removal and transfer of metal from one component of a bearing to another. Various degrees of scouring can be described as scuffing, smearing or galling.

Shaft Fit
Amount of interference or clearance between bearing inside diameter and shaft bearing seat outside diameter.

Spalling- Flaking
A breaking away of metal on the raceway or rolling elements in flake or scale-like particles.
Types of Bearings and Nomenclature

**Bearing Nomenclature Key**

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) (W33)  
14. Spherical Outer Ring Race  
15. Floating Guide Ring  
16. Inner Ring Face  
17. Outer Ring Face  
18. Cylindrical Roller  
19. Outer Ring Flange  
20. Cone Front Face  
21. Cup Race  
22. Cup (Outer Ring)  
23. Tapered Roller  
24. Cone Large Rib  
25. Cone Back Face  
26. Cone (Inner Ring)  
27. Cone Race  
28. Cage  
29. Spherical Inner Ring Race  
30. Needle Roller
**Lubrication Guidelines**

**Lubrication – Required Grease Quantity**

To avoid the generation of heat, the bearing must not be “overgreased.”

The required quantity of grease is based on the free volume of the bearing calculated as follows:

\[
V = \frac{\pi}{4} (D^2 - d^2) (T) - \frac{M}{A}
\]

Where:
- \( V \) = free volume in the bearing (cm\(^3\) – inch\(^3\))
- \( D \) = outer race O.D. (cm – inch)
- \( d \) = inner race bore (cm-inch)
- \( T \) = overall width (cm – inch)
- \( M \) = bearing weight (kg – lb)
- \( A \) = average steel density
  - \( 7.8 \times 10^{-3} \text{ kg/cm}^3 \)
  - \( 0.2833 \text{ lb/inch}^3 \)
- \( \pi \approx 3.1416 \)

Depending on the application (speed…), we suggest to fill the bearing with a quantity of:

- 1/3 to 1/2 of \( V \) for conventional mineral grease

Consult the original equipment manufacturer for all lubricant information.

---

**Grease Compatibility Chart**

- ■ = Best Choice
- □ = Compatible
- □ = Borderline
- ■ = Incompatible

<table>
<thead>
<tr>
<th></th>
<th>Al Complex</th>
<th>Ba Complex</th>
<th>Ca Stearate</th>
<th>Ca12 Hydroxy</th>
<th>Ca Complex</th>
<th>Ca Sulfonate</th>
<th>Clay Non-Soap</th>
<th>Li Stearate</th>
<th>Li12 Hydroxy</th>
<th>Li Complex</th>
<th>Polyurea</th>
<th>Polyurea S S</th>
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</table>
Speed Capability Guidelines

The usual measure of the speed of a bearing is the circumferential velocity of the midpoint of the inner race large end rib. This may be calculated as:

\[ V_r = \frac{\pi D_m n}{60000} \text{ (m/s)} \]
\[ V_r = \frac{\pi D_m n}{12} \text{ (ft/min)} \]

where:

- \( D_m \) = Inner race rib diameter \( \text{mm, in} \)
- \( n \) = Bearing speed \( \text{rev/min} \)
- \( \pi \) = 3.1416

**Rib speed:**

- Special high speed bearings with circulating oil
- Oil jets
- Oil-mist/oil-air
- Circulating oil
- Oil level
- Grease

**Where:**

- \( V_r \) = Inner race rib speed \( \text{m/s, ft/min} \)

**Speed capability guidelines for various types of lubrication systems.**

Fig. 74 is a summary of guidelines relating to speed and temperature. There are no clear-cut speed limitations for bearings regardless of the bearing design or lubrication systems. The Timken Company recommends that testing be performed for all new high-speed applications.
<table>
<thead>
<tr>
<th>Measurement</th>
<th>When you Know</th>
<th>Multiply by</th>
<th>To get an equivalent in</th>
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<td>millimeters (mm)</td>
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<td>kilometers (km)</td>
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<td>square millimeters</td>
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<td></td>
<td>Newton-meters</td>
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<td>pound-feet</td>
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<td>Newton-meters (N•m)</td>
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<td>inch-pounds (in-lb)</td>
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<td>foot-pounds</td>
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<td>Newton-meters</td>
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<td>Newton-meters</td>
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<td>kilogram-meters</td>
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<td>kilogram-meters</td>
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<td></td>
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<td></td>
<td>kilopascals</td>
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<td>pounds/square inch</td>
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</table>

Conversion Chart Showing Millimeter, Fractional and Decimal Inch Sizes
### Temperature Conversion Table

This conversion table can be used to convert temperature to centigrade (°C) or to Fahrenheit (°F). The center column is the base temperature. If you want to convert from °F to °C, you would look up the number in the center column and the number in the left column would show the conversion in °C. To convert °C to °F, you would look up the base number and the conversion to °F is shown in the right column.

As an example, to find the °F for 100°C, look up 100 in the base temperature column. The column to the right shows the equivalent °F value.

<table>
<thead>
<tr>
<th>°C</th>
<th>°F</th>
<th>°C</th>
<th>°F</th>
<th>°C</th>
<th>°F</th>
<th>°C</th>
<th>°F</th>
<th>°C</th>
<th>°F</th>
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<td>16.40</td>
<td>-5</td>
<td>-41</td>
<td>-3</td>
<td>-36.2</td>
<td>15.56</td>
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<tr>
<td>67.83</td>
<td>161.40</td>
<td>31.56</td>
<td>88.11</td>
<td>10</td>
<td>38.99</td>
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<td>23</td>
<td>86.11</td>
<td>161</td>
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<td>6.67</td>
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<td>28.89</td>
<td>80.89</td>
<td>96.11</td>
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<td>46.11</td>
<td>25</td>
<td>87.22</td>
<td>155</td>
<td>32</td>
</tr>
</tbody>
</table>

As an example, to find the °F for 100°C, look up 100 in the base temperature column. The column to the right shows the equivalent °F value.
As a Timken customer, you receive an uncompromising standard of quality across the broadest range of bearings and related products. Brands like Timken®, Torrington® and Fafnir® reflect an extensive line of tapered, needle, spherical, cylindrical, ball bearings and mounted units ideal for virtually every industrial application. Complementing our core products is an ever-growing line of friction management solutions including lubricants, single-point lubricators, maintenance tools, safety equipment, condition monitoring systems and repair services that help keep operations running smoothly.

**Safety End Caps**
These easily installed caps offer a high degree of protection to maintenance personnel as well as to the bearings integrated within a housing.

**Housed Units**
Ball and spherical roller bearing pillow block units, featuring a unique sealing design, are easily installed and maintained in heavy-duty environments.

**Condition Monitoring Devices**
From wireless units to online systems, conditioning monitoring devices give you powerful diagnostic tools to help
**WARNING:**
Proper bearing maintenance and handling practices are critical. Failure to observe the following warnings could lead to a risk of serious bodily harm:

- Never spin a bearing with compressed air. The rollers may be forcefully expelled with great velocity.
- If a hammer and bar are used for bearing removal, fragments from the hammer, bar or the bearing can be released with high velocity. The seals and tools can be applied in a full range of equipment used in thousands of applications, including manufacturing, off-highway, power transmission and oil refineries.
- When installing or removing bearings, always wear safety glasses or goggles.
- Cleaning solvents may be toxic or flammable. Ensure adequate ventilation and wear protective clothing.
- Remove oil or rust inhibitor from parts before heating to avoid fire or fumes.

**Repair and Replacement Options**
By choosing to have bearings and other mill elements re-manufactured, customers save money in replacement costs and maintain a steady supply of parts instead of purchasing new parts during downtimes.

**Lubricants**
Industrial lubricant formulas have been specifically developed by our tribology experts. These lubricants keep bearings running smoothly in a variety of industrial conditions, including high heat, food processing and high speed. Timken also offers a line of single-point lubricators to simplify the delivery of grease.

**Maintenance Handling Tools**
Convenient handling devices give technicians the tools they need to install, remove and service bearings. Products include: impact fitting tools, induction heaters and hydraulic pullers.

**Industrial Seals**
Timken industrial seals are available in small-bore sizes, zero- to 13-inches, as well as in metric and high-temperature varieties.

We also provide tools to speed installation, deter seal and bearing damage and prevent premature seal leakage. The seals and tools can be applied in a full range of equipment used in thousands of applications, including manufacturing, off-highway, power transmission and oil refineries.