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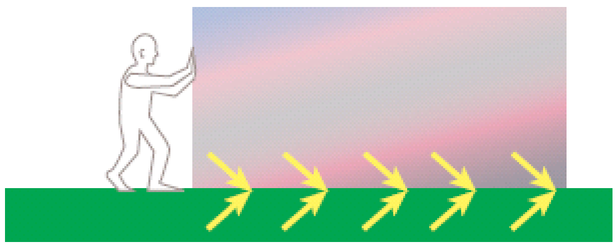
NEWSLETTER FOR MANUFACTURING COMMUNITY

Introduction

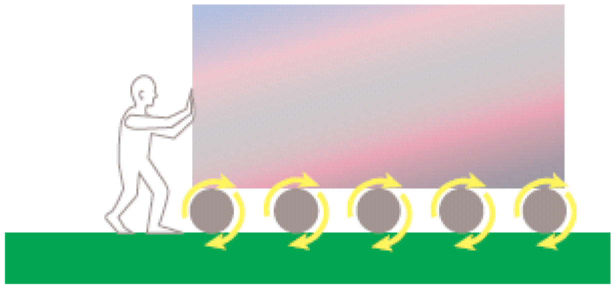
Whether we have worked with bearings for many years or using it for first time, we all will be likely aware that bearings have been in use for centuries. Historians have found existence of bearings, in very basic form, as far back as 2000 years!! Because they work so well and seem to be such a relatively simple component within an application, they are taken for granted. They are also often blamed incorrectly as the cause for equipment and product failure. Our objective, here therefore, is to provide you with a basic understanding of the principles of bearing design and function. We will not attempt to discuss everything about bearings. Independent of level of familiarity, we can find at least one piece of new information and, for those who have more experience with the subject it will serve as a refresher. Let us begin by addressing some of the basic elements and principles common to bearings.

Principles of Friction

Let us try to move a one ton, smoothly polished block of granite to another location. During initial attempt to move the block, two surfaces in contact (the base of the granite block and the ground) resist movement. This is called static friction. Trying harder, exerting greater force, enough so that the surfaces begin to slide against one another. Once in motion, the resisting force is from kinetic, or sliding friction, rather than static friction. If that same block is now placed on five equally spaced rollers the force required to move is significantly decreased. Why? The rollers, in contact with both the surfaces of the roadway and block, still encounter friction; however, the rotating action of the rollers carries the block forward with less effort. The rollers eliminate the need to slide the block and have eliminated the resisting force of kinetic friction: the friction encountered is now classified as rolling friction. Rolling element bearings are designed to take advantage of this principle. They eliminate sliding friction and utilize the efficiencies of rolling friction to carry a load.



Sliding friction



Rolling friction

Rolling Element Bearings

Rolling element bearings consist of two circular steel rings and a set of rolling elements. One of the rings is much larger than the other—in fact, it is large enough for the other to fit well within its perimeter. This larger ring is referred to as the outer ring. The smaller or the inner one the inner ring. A predetermined number of solid balls or rollers are formed into geometric shapes and placed at equal intervals in the open space between the two rings. These components are usually made of steel and are referred to as rolling elements. A cage, or retainer, is then used to maintain the intervals between the elements. This basic terminology will be used and elaborated in subsequent pages to describe the simple design and construction of a bearing.

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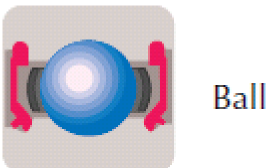
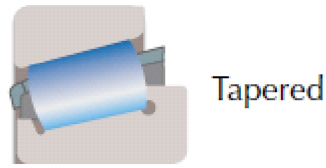
Rolling Element Bearing Classifications

The rolling elements are formed as standard geometric shapes which include:



Balls
Cylindrical Rollers
Needle Rollers
Tapered Rollers
Spherical Rollers



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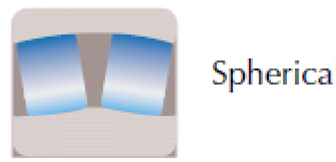
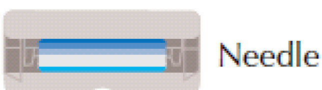
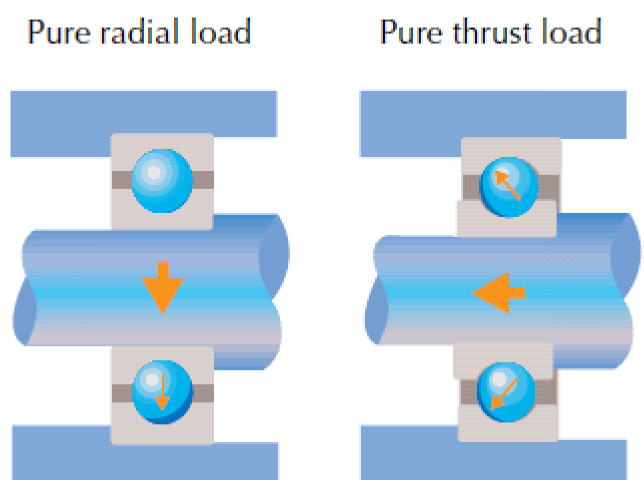
The geometric shape of these rolling elements is used to define the classification, or name, of each rolling element bearing type. Ball bearings use perfectly round balls as their rolling elements, cylindrical roller bearings use cylindrical rollers, so on.





Rolling Element Bearings and Tolerances

The precise operation of a rolling element bearing increases incrementally as each of the individual components approach “perfection” in its manufacture. The American Bearing Manufacturing Association (ABMA) has established two sets of tolerance classes that define the acceptable minimum and maximum manufacturing ranges for rolling element bearings. These are the ABEC (Annular Bearing Engineering Committee) tolerance classes for ball bearing and RBEC (Roller Bearing Engineering Committee) tolerance classes for roller bearings. The international bearing community also has an association to regulate international standards, the ISO, or International Standards Organization. ISO and ABMA standards are identical with respect to these tolerances, although they use different class designations. Some manufacturers refer to ABMA designations, while others use ISO designations. Either way, the tolerances are identical. Bearings manufactured within tighter tolerance ranges provide greater accuracy of shaft rotation and contribute to higher speed capability.



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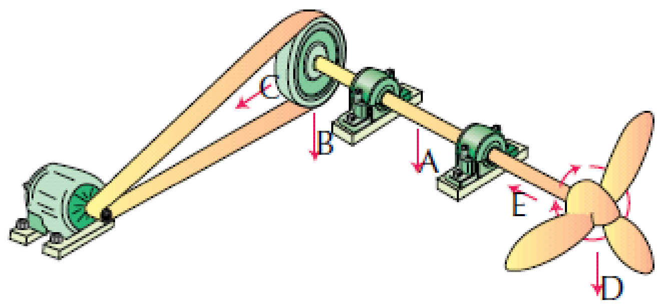
Bearing Loads

The rolling element in bearing is subject to forces from gears, pulleys, or similar components. These forces simultaneously act on the bearing from many different directions (angles). The direction in which force is exerted on the bearing helps identify the type of load on the bearing: Radial loads are exerted on the bearing on a plane perpendicular (90°) to the shaft. Axial loads or thrust loads are exerted on the bearing on a plane parallel to the center of the shaft. Combination loads exert both of these on the bearing. The adjacent illustration shows a shaft mounted fan driven by a belt and powered by motor. Two bearings support the shaft and are subjected to loads as follows:

Radial loads originate from the: (A) weight of the shaft; (B) weight of the pulley; (C) tension of the belt; and, (D) weight of the propeller. Note: Radial loads exerted on the ends of the shaft, outside of the two bearings supporting the load (i.e. the belt tension, pulley weight and propeller weight), are compounded by a lever affect and are referred to as overhung loads. Axial loads originate from the wind (E) induced by the propeller rotation. Combination loads are the result of both radial and axial loads being combined and exerted on a single bearing.



Radial, axial and combination loads

Bearing Life

Bearing life refers to the amount of time any bearing will perform in a specified operation before failure. Bearing life is commonly defined in terms of L-10 life, which is sometimes referred as B-10. This is the life which 90% of identical bearings subjected to identical usage applications and environments will attain (or surpass) before bearing material fails from fatigue. The bearing's calculated L-10 life is primarily a function of the load supported by (and/or applied to) the bearing and its operating speed. Many factors have a profound affect on the actual life of the bearing. Some of these factors are:

- Temperature
- Lubrication
- Improper care in mounting resulting in:
  - Contamination
  - Misalignment
  - Deformation

As a result of these factors, an estimated 95% of all failures are classified as premature bearing failures. The bearing life is usually specified in hours.

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Applications

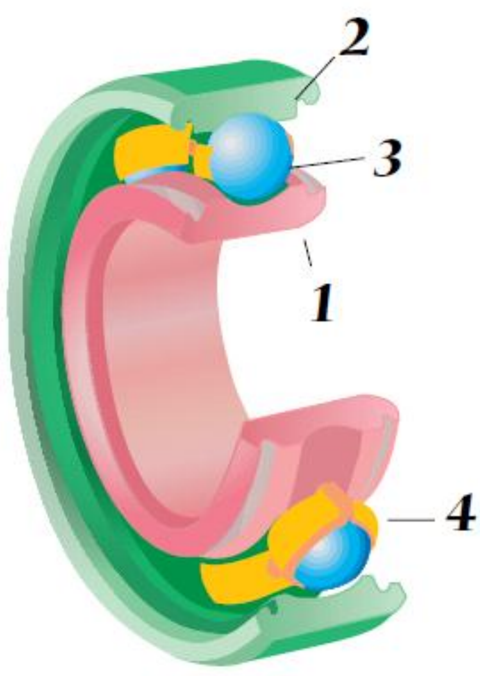
Making a list of equipments using rolling element bearings is a futile exercise since it could go on and on. They are used in fans, gear boxes, transmissions, axles, compressors, electric motors, engines, final drives, jet engine main shafts, blenders, saws, mixers to name few. Most rotating shafts use a rolling element bearing. Having addressed concepts common to bearings, let us now turn our attention to the specific principles and functions of ball bearings.

Standard Ball Bearing Components

Bearings have a lot in common with cars. A car's basic design begins with number of essential components for normal operation and can include additional components which may enhance performance. The same is true for bearings. The essential components of a ball bearing are defined as follows.

The Inner Ring (1)

This is the smaller of the two bearing rings and gets its name from the position it holds. It has a groove on its outside diameter to form a path for the balls. The surface of this path is precision machined to extremely tight tolerances and is honed to attain very smooth, mirror-like finish. The inner ring is mounted on the shaft and is usually the rotating element.



The Outer Ring (2)

This is the larger of the two rings and, like its counterpart the inner ring, its name is derived from the position it holds. Conversely, there is a groove on its inside diameter to form a pathway for the balls. This surface also has the same high precision finish as of the inner ring. The outer ring is normally placed into housing and is usually held stationery.

The Balls (3)

These are the rolling elements that separate the inner and outer ring and permit bearing to rotate with minimal friction. The ball radius is slightly smaller than the grooved ball track on the inner and outer rings. This allows the balls to contact the rings at a single point, appropriately called point contact. Ball dimensions are controlled to very tight tolerances. Ball roundness, size variations, and surface finish are very important attributes and are controlled to a micro (or micron) inch level (1 micro inch = 1/1,000,000th, or one-millionth of an inch. 1 micron = 1/100000 of a meter or one millionth of a millimeter).

The Cage (Retainer) (4)

The main purpose of the cage is to separate the balls, maintaining an even and consistent spacing, to accurately guide the balls in the paths, or raceways, during rotation, and to prevent the balls from falling out.

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Lubrication (5)

The lubricant is an integral part of any bearing. Lubrication, by itself, is a vast subject and hence we will not explore it in this newsletter. Let us just remember that bearings are available in two types: Externally lubricated types which demand regular greasing at pre-determined intervals. Internally lubricated or sealed types which do not demand any specified lubrication but bearing itself gets replaced after pre-determined interval.

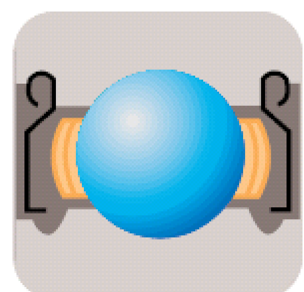
Optional Bearing Components

The following ball bearing components enhance the performance and life of the bearing. These components are not added to the bearing unless specifically requested. Each component is assigned an alphabetical or alpha-numeric code for clarity when ordering.

Shields and Seals

Shields and seals are most commonly used on grease lubricated bearings in applications where the bearing can be exposed to external elements. The main function of the shields and seals is to keep possible contamination away from the most critical internal working components while keeping the lubricant clean and contained within the bearing.

Shield (ZZ)

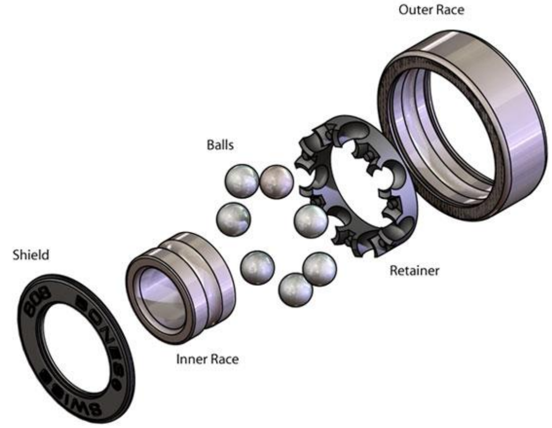


Shields

The shield is a stamped, profiled sheet metal disc. It is pressed into a very small groove on the inside edge diameter of the outer ring. A small space or gap remains open between the outside diameters of the inner ring and shield. Because the shield does not contact the inner ring, there is no added friction between the shield and bearing. This results in a bearing that has a very low torque (the amount of twisting force required to rotate the inner ring of the bearing relative to the outer ring). Shields keep larger particles of contamination from entering the bearing and are effective for many general bearing applications. Designation for a shield applied to only one side of the bearing is the suffix Z; if shields are needed on both sides the suffix designation is ZZ.

Seals

Seals are available in a variety of types and composition, the most common being synthetic rubber molded to a steel plate. The seal is also inserted into the very small groove on the inside, edge diameter of the outer ring. The inner edge of the seal is molded into a specifically designed lip configuration. Generic suffix designation for any type of seal applied to one side of the bearing is L; for seals required on both sides it is LL. Standard seals are provided in two different configurations, contact and non-contact.



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The Non-Contact Seal

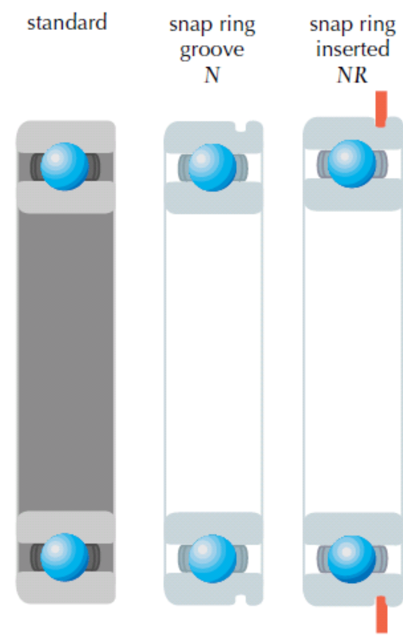
The non-contact seal is single lip seal design. When assembled into the bearing, molded single lip of seal fits into a specially designed seal groove machined on the outside edge diameter of the inner ring. The lip of the seal does not come into contact with the inner ring of the bearing, hence the name non-contact seal. The circular concave lip of the seal combines with the V-shaped trough of the inner ring to create an open area where grease is allowed to collect. These factors combine to form a very effective labyrinth seal—so called because the combination of the seal's design, the groove in which it fits and the grease combine to create a difficult maze through which the contaminants must pass to penetrate the seal. There are many unique benefits associated with the non-contact seal: it requires very little torque to rotate, it is highly resistant to dust buildup, and operating temperatures are comparable to that of a shielded bearing. The non-contact seal offers the benefits that are usually provided by a shield with the additional advantages offered by seals. This type of seal was specially designed to meet the demanding requirements of modern day electric motors. Bearing manufacturers generally mold the synthetic rubber non-contact seal in the color black, visually simplifying the identification process in comparison with other types of seals.

The Contact Seal

The contact seal is another option. When assembled in the bearing, inner lip of the seal contacts inside edge of seal groove on the inner ring and hence name, contact seal. A slight gap remains between the outer lip of the seal and the inner ring of the bearing, forming an area for grease to accumulate (hence a secondary labyrinth seal). Should friction cause the inner lip of the seal to wear, the outer lip will compensate for the wear by constricting around the outer landing of the bearing's inner ring. This preserves the perfect protection afforded by contact seal. Contact seal manufactured by many manufacturers encounter sliding friction as the seal rubs the inner ring of the bearing requiring a higher torque to rotate the bearing, subsequently generating heat (thus causing the bearing to operate at a slightly higher temperature). This implies reduced operating speed for contact seal type bearings.

Outer Ring Modifications

Most applications require the outside surface of the bearing's outer ring to be straight (without channels or lips, etc.). This is to be considered "normal" and needs no designation as a specifier. Some application designs call for the bearing to be held in place by using a snap ring, a narrow, thin steel external ring applied (or snapped) to the bearing for positioning purposes. This requires a groove to be machined into the outer ring of the bearing that will accept the snap ring. This modification is referred to as the snap ring groove and is generally designated with suffix N. If the ring is fitted, it will be usually identified with suffix, NR. Other application designs specify the bearing to be supplied with a flange or flanged outer ring (The ring is formed with a flat extension to the outside edge of the outer ring which is used for positioning purposes.) generally identified with suffix, FL. The primary purpose of both the snap ring and flanged outer ring is to position and hold the bearing's outer ring in its proper position in the housing.



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Inner Ring Modifications

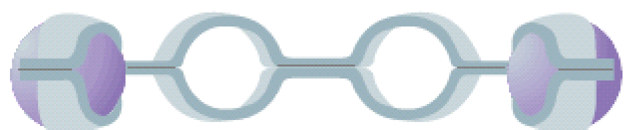
Most applications require the inside surface of the inner ring (bore) to be straight. This is considered “normal” and needs no designation as a specifier. Some applications demand bearing to be held in place by a lock nut and washer to make field service and replacement much easier. In these cases, the shaft is normally made with a slight taper of 1/12” (for every 12” of distance, the shaft’s diameter would be reduced by 1 inch). Therefore, the bore of the bearing must also be tapered to match the taper of the shaft. This is identified usually with suffix, K.

Cage (Retainer) Composition

The cage is an essential bearing component. It may be constructed using a variety of different materials (steel, brass, nylon) and manufacturing techniques (pressed, machined and molded).

Pressed Steel Cages

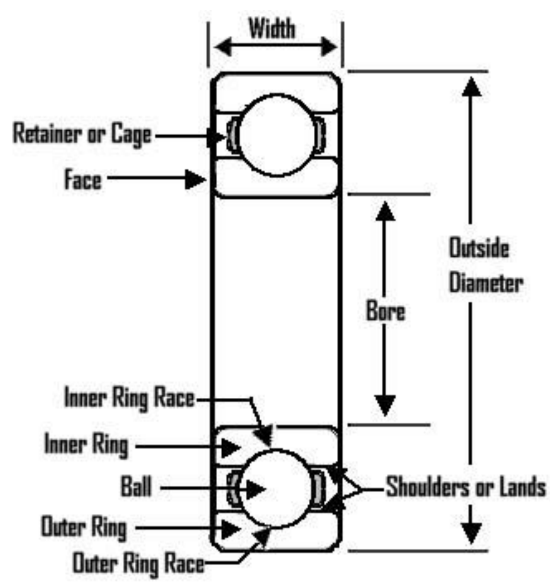
Pressed steel cages are the most common of enclosure for bearing balls. In this process, steel is formed (pressed) into the proper shape and size to fit the rolling elements, their spacing, etc. Some steel cages are pressed as a one-piece retainer while others are pressed as two separate halves and assembled to form a two-piece retainer. The assembly methods used for two-piece steel retainers are spot welds, rivets, or bent finger joints. (The bent finger joints are designed into the stamped cage halves and are created when they are folded, or bent, over each other to hold the cage together). Although suffix for a pressed steel cage is J, it is never mentioned since it has become a standard, unless otherwise specified.



Pressed steel cage

Nylon Cages

Nylon cages are designed as a one-piece cage and created by an injection molding process. Typically glass-reinforced Nylon 66 (GF PA 66) is used for making cages; they are identified with the suffix designation T2. Machined Cages Machined cages may be specified for larger, heavier, more precise bearing applications and are made of brass, steel or phenolic (a polymer capable of withstanding high temperatures). Since they are machined, they have much tighter dimensional specifications and controls.



Basic Boundary Dimensions

The ABMA and ISO assign bearing dimensional specifications for basic boundary dimensions, sometimes referred to as the bearing’s envelope dimensions. These dimensions are established for all types and sizes of bearings and are normally listed in every bearing manufacturer’s catalog as the outside

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diameter, inside diameter and width. Note: Most basic boundary dimensions are measured in millimeters (mm), or a fraction thereof. (One millimeter = 1/1,000 (.001) of a meter and 25.4 mm = 1 inch)

Outside Diameter (D)
Outside diameter (OD) is the straight line measurement from the outside edge of the outer ring across the entire distance of the bearing to the opposite, outside edge of the outer ring. This dimension is noted usually as D. The outside diameter normally fits “tight” into housing.

Inside Diameter (d)
The inside diameter (ID) sometimes referred to as the bearing’s bore, is the straight line measurement from the inside edge of the inner ring across the hole in the center of the bearing to the opposite inside edge of the inner ring. This dimension is noted as a d. The shaft normally fits into the bore of the bearing.

Width (B)
The width is the straight line measurement from one side of the outer ring across the outside surface to the opposite side of the outer ring. This measurement may also be taken from one side of the inner ring, across its surface, to the opposite side. In most cases, the width of the inner and outer rings will be identical; however, it does not have to be the same. It is usually designated by B.

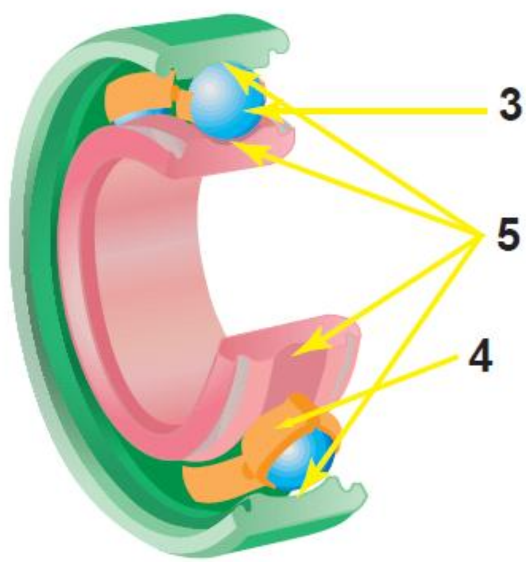
Chamfer (r)
The chamfer refers to the corner (edge) formed when the outside surface of the outer ring intersects the edge surface (or face) of the outer ring. It also refers to the corner (edge) formed, when the inside surface of the inner ring intersects the edge surface (or face) of the inner ring.

Load Carrying Surfaces

As noted earlier, a bearing is designed to carry a load and reduce friction. The critical surfaces involved in supporting or carrying the load are mentioned below.

Balls (3)
Balls have been defined previously as one of the essential bearing components. They are subjected to the full brunt of load carried by the bearing.

Cages (4)
Under normal conditions, cages carry very little load. However, when a bearing is not installed properly, being subjected to loads and speeds exceeding recommended values, the cage may be subjected to loads far beyond what it is able to carry. These conditions can lead to premature cage failure.



Load carrying surfaces

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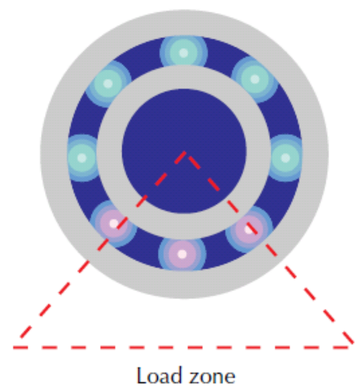
Raceways (5)

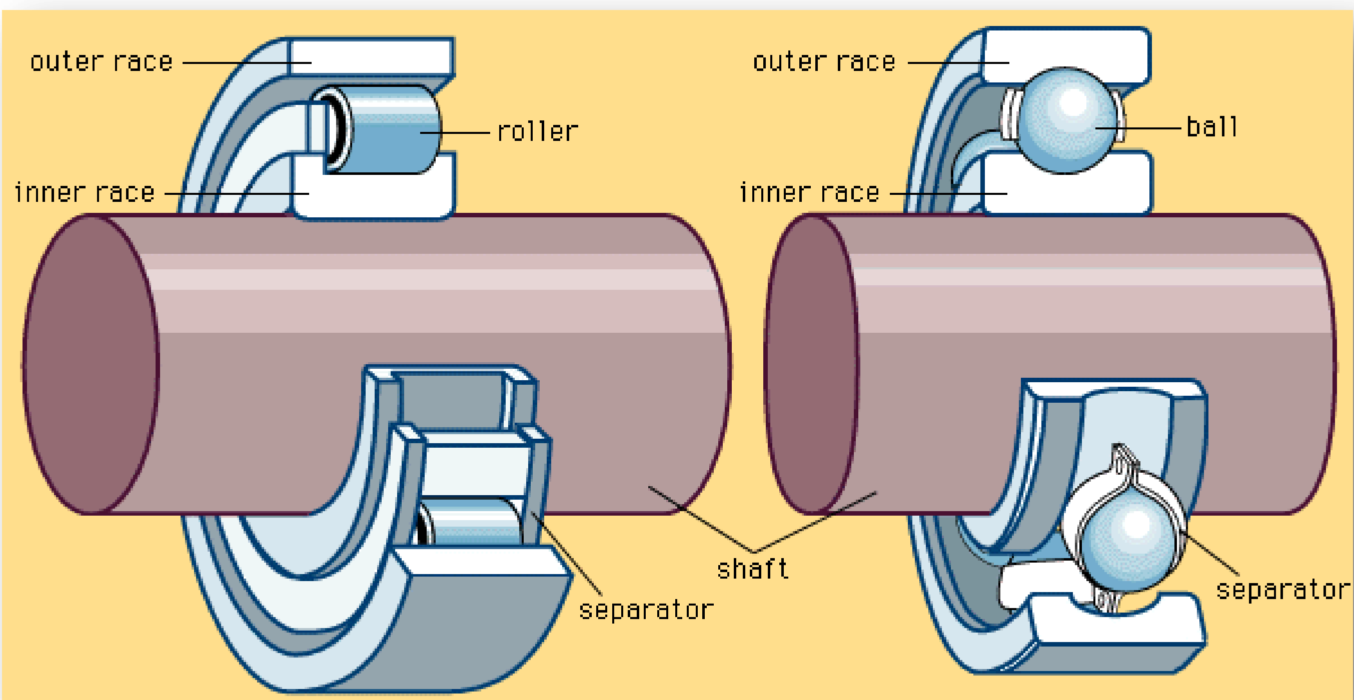
Raceways are the large, honed (highly polished), track surfaces on the inside of the outer ring (referred to as the outer raceway) and the outside of the inner ring (the inner raceway), that form a closed circle around the circumference of the ring. As the bearing rotates the rolling elements run on these surfaces.

The Load Zone and Contact Points

When a bearing is supporting a radial load, the load is distributed through only a portion of the bearing—approximately one-third (1/3)—at any given time. This area supporting the load is called the bearing load zone. Every point or surface where loads are supported by the bearing is load carrying contact points or surfaces. These include the outer Ring O.D., inner Ring I.D., the adjacent surfaces that form right angles to each other, raceways and rolling elements.

Ensuing week, we will discus about different types of ball bearings.





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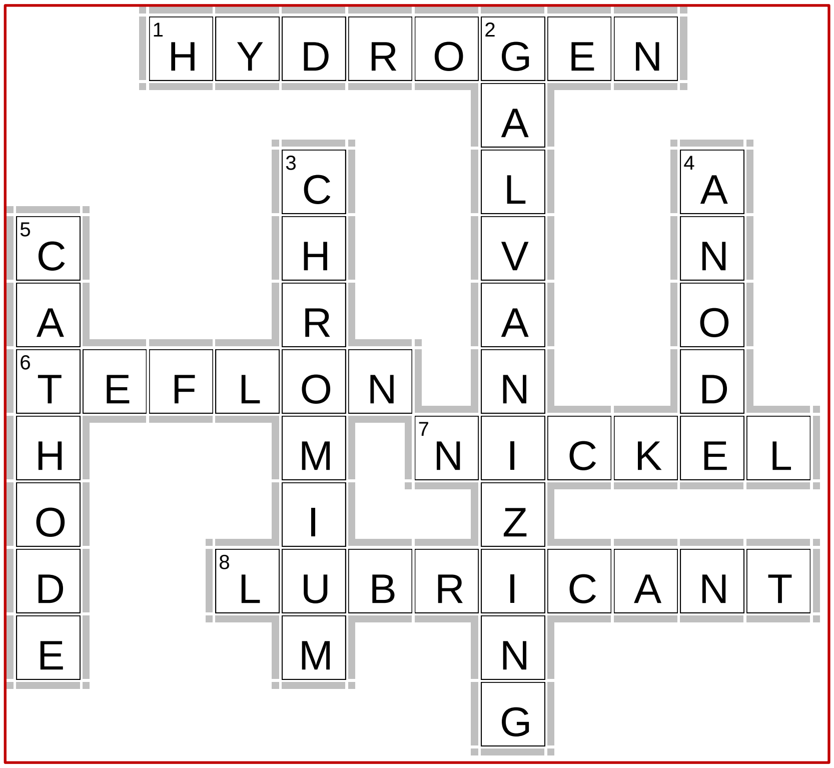
Solution for Last fortnight Techuzzle



Across

1. **HYDROGEN**—This chemical, commonly causes embrittlement ____
6. **TEFLON**—PTFE is popular known as _____
7. **NICKEL**—One of the oldest metals used for plating ______
8. **LUBRICANT**—This materials reduce friction _____

Down

2. **GALVANIZING**—Zinc Plating is commonly known as _____
3. **CHROMIUM**—Most common metal for plating Steel _____
4. **ANODE**—Applying metal becomes _____ in Electro Plating
5. **CATHODE**—Base Metal becomes _____ in Electro Plating Process

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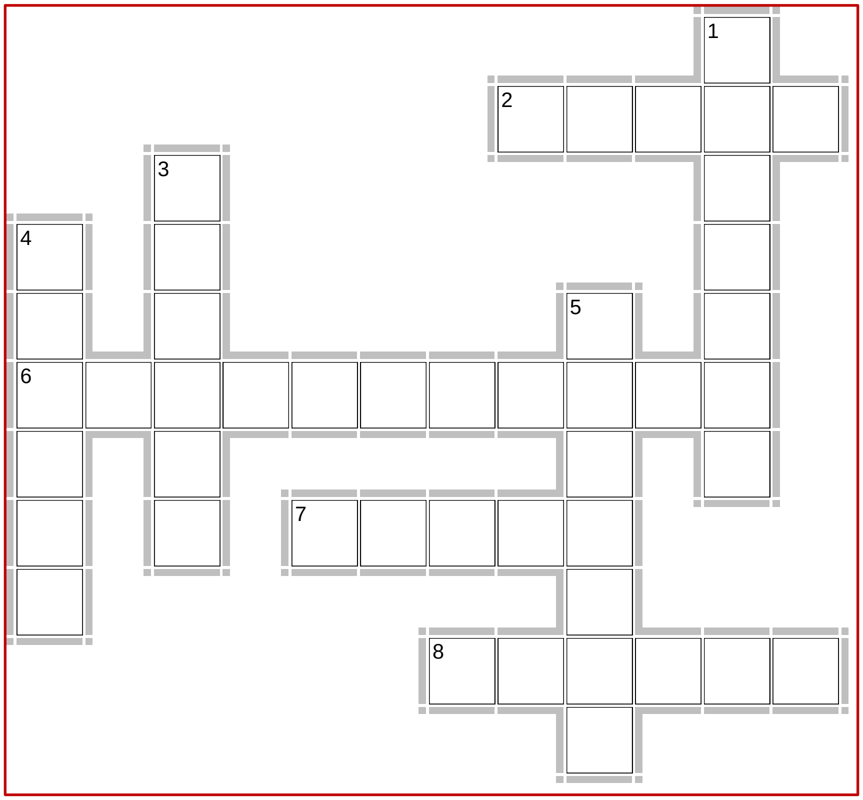
This fortnight Techuzzle



Across

2. The dent in bearing is called ____ for calculating L10 Life
6. DG means _____ in SRDG
7. Wind from a fan produces ___ load on bearing
8. Balls are inserted using this popular method _____

Down

1. The most common _____ block for supporting long shafts
3. Z or ZZ refers to ____ for a bearing
4. Fan weight produces ____ load on bearing
5. Bearing converts sliding friction to ____ friction

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L10 - Bearing Life Indicator

Bearing life is generally defined as length of time or number of revolutions (for specified time) until "fatigue" occurs on the bearing housing. This "fatigue" is called SPALL and indicates formation of a "dent" equivalent to 6 square millimeter (0.01 square inch) area, INDEPENDENT of bearing size. L10 (or B10), technically is defined as the life that 90% of similar bearings go thru before showing any signs of "fatigue." Stated otherwise, it also means 10% of similar bearings fail before reaching desired life. Obviously, life of bearing depends on loading (overload), type of load, lubrication, temperature and other factors. The L10 (or B10) is very scientifically and statistically calculated. This newsletter is not intended to handle such extensive details, but here is the formula to calculate L10 life for a bearing.

$L10 = (C / P)^{10/3} \times (B / n) \times a$ C = Radial rating of bearing in LBF or N; P = Radial load or Dynamic Equivalent load; B = factor dependent on testing method; a = life adjustment factor; n = rotational speed in revolutions per minute

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Leonardo da Vinci - Scientist, Artist

Mona Lisa - A painting that very few of us would not have seen in our life. A painting that has been considered as the masterpiece even today. Although Leonardo da Vinci, born in Italy in 1452, has been recognized for his many paintings including Mona Lisa, he was extremely creative and was a scientist as well. One of his relevant imaginations has been regarding "ball bearings" to help reduce friction. His other visualizations include Cams, Flywheel, Levers. His design of three spheres for a rotating element has been one of the earliest ideas of converting sliding friction into rolling friction. However, design of ball bearing was officially patented in 1700s and is one of the indispensible methods of reducing friction till date.

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