SECTION THREE

FRICTION BEARINGS

Journal Bearings

Introduction: Journal bearings offer one of the simplest and economical means of supporting rotating machinery parts. They have no moving parts and are normally designed to enclose a shaft. Journal bearings may sometimes be designated as friction bearings, plain bearings, sleeve bearings, fluid-film bearings, or bushings.

Journal Bearing Parts

A journal bearing consists of two basic parts: an inner member, the journal, and an outer member, the bearing. Illustration #75 identifies the parts of a simple journal bearing.

The journal section is a portion of the shaft which transfers the radial load to the bearing, acting as the support structure.

In the journal bearing, the part that moves is generally the journal, as with the shaft of a centrifugal pump, but sometimes both the journal and bearing move such as the connecting rod that joins a piston and crankshaft in a reciprocating engine.

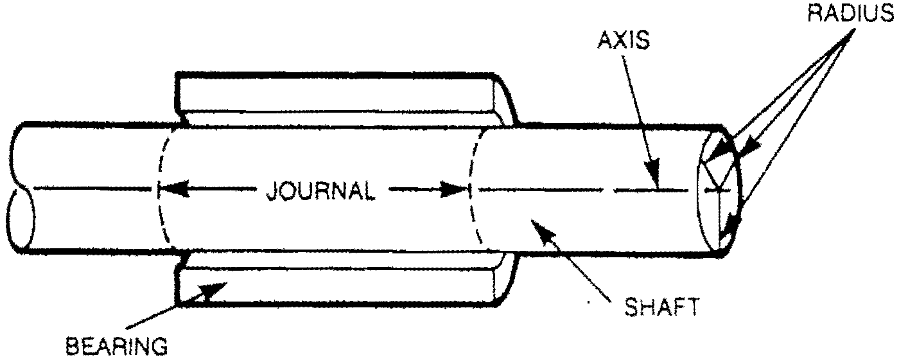


Illustration #75-Journal Bearing

Journal Bearing Classification

Journal bearings can be categorized according to the type of load that they carry: axial or radial. Most journal bearings are mounted so that they support rotating shafts. The center line of a shaft is its axis, and most shafts rotate about their axis. The distance from the center line to the outside of the shaft is its radius. The axial and radial direction referred to in this section relates to the axis and radius of the shaft on which a bearing is mounted. Axial loads on journal bearings are loads parallel to the shaft's axis and radial loads are 90 degrees to the shaft's axis.

Journal bearings which support radial loads provide a solid support structure for a rotating shaft in radial directions. Bearings which prevent the shaft from moving in an axial direction, that is, from moving through the bearing, are described as friction type thrust bearings. Illustration #76 refers to a friction type thrust bearing.

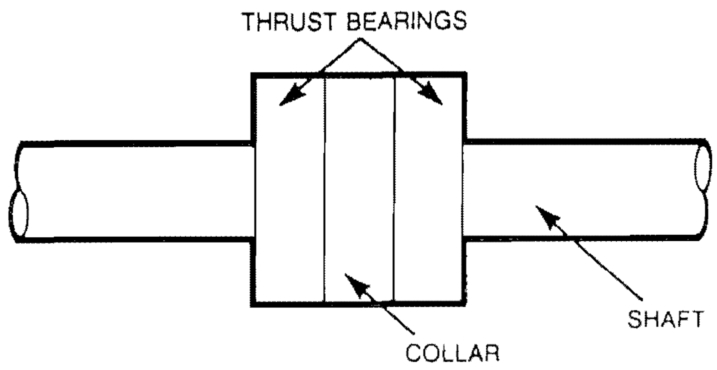


Illustration #76-Thrust Bearing

The thrust bearing which is shown in illustration #76 is used in conjunction with a thrust collar. The thrust collar, also called a thrust runner, is a fixed disc on the shaft. The collar may be a separate part, attached to the shaft through an interference fit and a key and keyway, or the collar may be an integral part of the shaft.

Operation of Journal Bearings

Fluid lubrication in radial load journal bearings depends upon the viscosity of the lubricant and its adhesion to the surfaces of the journal and the bearing. The radial clearance provided in the journal bearing automatically forms a wedge-shaped film between the journal and the bearing. The oil is dragged into the clearance space by the rotation of the journal. A hydrodynamic pressure is created in the oil film, as shown in illustration #77, sufficient to float the journal and carry the load applied to it.

The minimum film thickness, as shown in illustration #77, determines the closest approach of the journal and bearing surfaces with fluid film lubrication. The closest allowable approach depends upon the degree of finish of the journal and bearing surfaces and upon the rigidity of the journal and bearing structures.

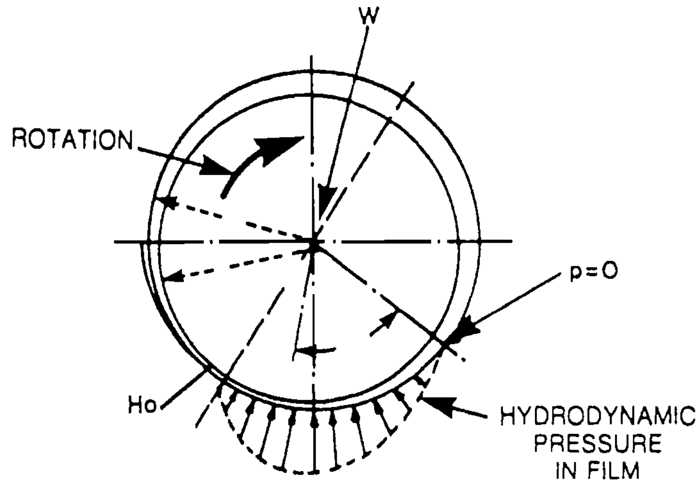


Illustration #77-Hydrodynamic Fluid Film

In practice, the minimum oil film thickness of .001 inch (.0254 mm) is common in electric motors with speeds of approximately 1800RPM where the steel shaft is supported in babbitted bearings. Minimum oil film thickness of .003 inch (.0762 mm) to .005 inch (.127 mm) are recommended for large steel shafts running at high speeds in babbitted bearings; for example, steam turbines, generators, and fans.

Operation of Journal Bearings

The minimum film thickness found on force feed lubrication journal bearings, such as in reciprocating engines, where quality of workmanship, smoothness and accuracy in surfaces are required, normally have film thicknesses as low as .0001 inch (.00254 mm) to .0002 inch (.00508 mm). With film thicknessess of low values it is important that the oil filters in the lubrication system be able to remove all foreign particles with diameters larger than the expected minimum film thickness.

Mechanism of Film Formation

With the journal at rest, as illustrated in drawing #78, practically all of the lubricant has been squeezed out from the load area. When rotation of the shaft begins, with the clearance space filled with oil, there is a tendency for the journal to roll or climb up the bearing due to friction between the journal and bearing.

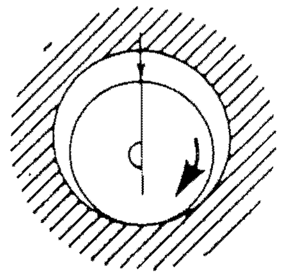


Illustration #78-Shaft at Rest

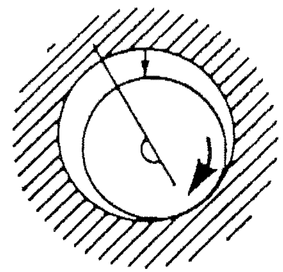


Illustration #79-Start up

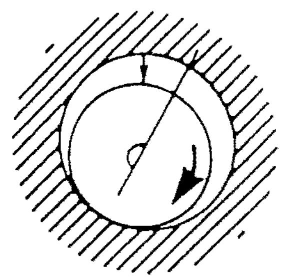


Illustration #80-Shaft up To Speed

Further rotation of the shaft journal causes the lubricant to be drawn into the clearance space, lifting the journal as shown in illustration #79. The action of the viscous forces causes pressure to be developed in the wedge-shaped clearance space and the journal is forced over toward the opposite side of the bearing to the position shown in illustration #80. In this new position, the fluid pressure supports the load carried by the shaft.

Illustration #81 demonstrates the pressure distribution in the oil film of a journal bearing running under load. The journal center does not coincide with the bearing center, but lies below and to the left of the bearing horizontal and vertical center line. The distance between the centers is known as the eccentricity.

Illustration #82 identifies how there is a loss of oil pressure within a journal bearing due to leakage. It demonstrates how the greatest amount of oil film pressure remains in the center of the longitudinal view of the bearing.

Illustration #82 also shows how the oil film pressure reduces as the load diverges away from the center of the journal bearing.

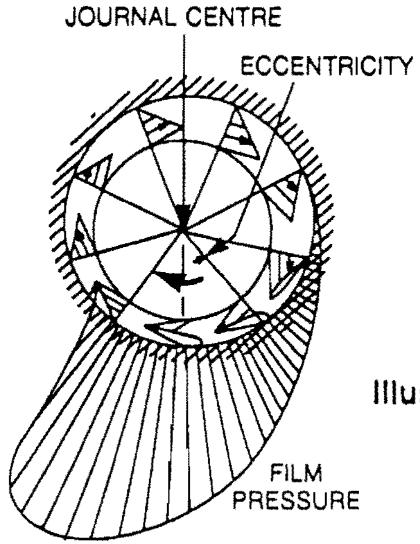


Illustration #81-Eccentricity

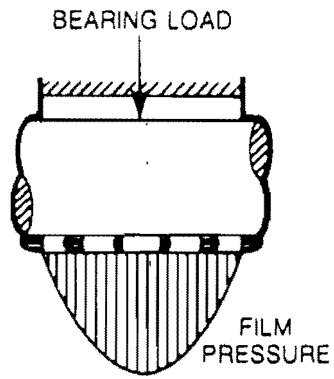


Illustration #82-Longitudinal View

Oil Grooves

Grooves are often cut into journal bearing surfaces in order to maintain continuous lubrication through the distribution of the lubricant over the entire length of the bearing. Properly designed oil grooves are considered to be the most dependable means of providing sufficient film lubrication in sliding friction bearings not fed under constant oil pressure.

In order to function properly, an oil groove must provide sufficient space for the lubricant as it flows into the bearing area from the oil reservoir. The oil groove is an effective method for distributing the oil lengthways along the bearing so that, as the moving surface passes the groove, it will take up a protective film of oil.

The oil groove must also retain the oil within the bearing, in some sleeve bearing designs oil leakage is excessive, therefore, only a small portion of the supplied oil actually serves to lubricate and cool the journal bearing.

There are two kinds of oil grooves used: circumferential and axial. Circumferential oil grooves distribute lubricant around the shaft at the oil hole. The oil flow through a journal bearing with a circumferential groove will be greater than the flow of oil through a journal bearing fed with pressurized oil through a single oil hole where no groove exists. For similar load and speed conditions, the oil flow may be four or more times as great. Illustration #83 identifies one type of journal bearing where a circumferential oil groove has been utilized.

Oil Grooves

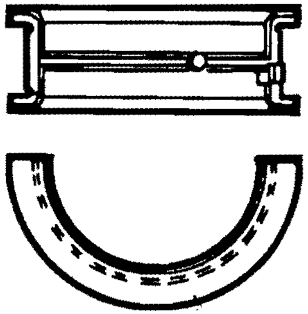


Illustration #83-Circumferential Groove

When circumferential oil grooves are placed at the ends of the bearing they act as collector rings and capture the lubricant that is ordinarily forced out at the ends of the bearing.

Axial oil grooves distribute lubricant lengthwise in the bearing. Illustration #84 shows an example of an axial oil groove located in the center of the bearing.

Oil grooves have often been placed in bearings indiscriminately, with the result that the groove scrapes off the oil, interrupts the film, and releases the hydrodynamic pressure. Illustration #85 demonstrates how the reduction in hydrodynamic pressure in a journal bearing occurs when an oil groove is improperly placed.

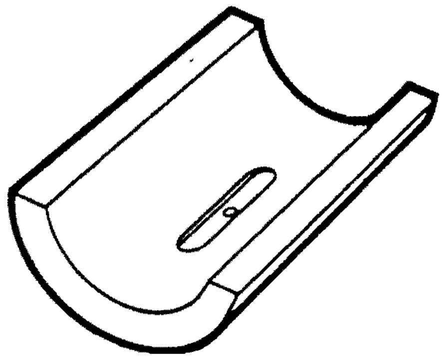


Illustration #84-Axial Groove

Oil Grooves

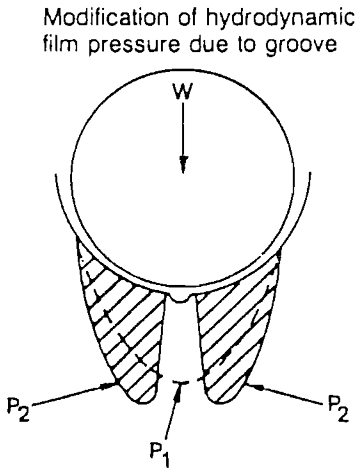


Illustration #85-Hydrodynamic Interruption

With the groove, as shown in illustration #85, the hydrodynamic film pressure that would normally be generated is bled off and the pressure falls to the value of the groove supply pressure. The groove supply pressure may be only 20 PSI (137.9 KPa), for example, as compared with a film pressure of many times this value. The destruction of the hydrodynamic film by such a groove may cause the bearing to fail if it is operating near the limit of its capacity.

If the bearing has enough reserve capacity, it may develop new maximum pressure peaks sufficient to support the load, as indicated by the pressure curves P1. *Deep, sharp-edged grooves should be avoided as should V-shaped grooves. Wide, shallow grooves with rounded edges are the most desirable.* In order to maintain an efficient oil film, the axial oil groove should be located in the unloaded sector of the journal bearing as indicated in illustration #86A and #86B.

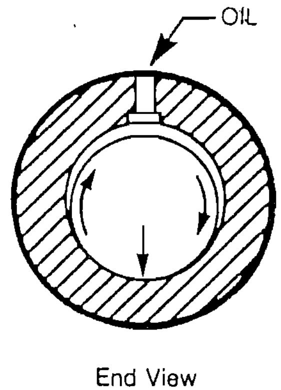


Illustration #86A-Proper Axial Oil Groove

Oil Grooves

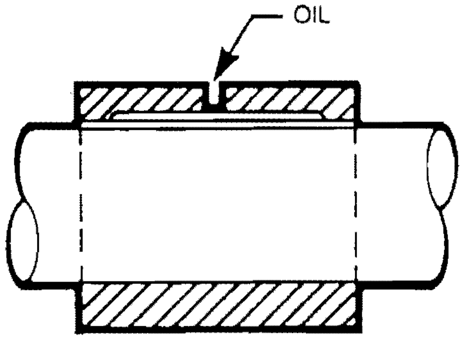


Illustration #86B-Proper Axial Oil Groove

Hydrostatic Journal Bearings

Journal bearings of the oil film type (hydrodynamic), after being brought up to desired speed, operate with high efficiency and reliability. However, difficulties arise when the rotational speed of the journal are too low to maintain a complete hydrodynamic film. This condition is evident during machine startup, shutdown, and reversing situations, or whenever the operating speed falls below a certain minimum value.

When this condition occurs, the oil film is disrupted, friction increases, and wear of the bearing increases.

Hydrostatic journal bearings are used when operating conditions require full film lubrication that cannot be developed hydrodynamically. The hydrostatically lubricated bearing, either thrust or radial, is supplied with lubricant under pressure from an external source. High pressure oil is introduced to the area between the bottom of the journal and the bearing, as shown in illustration #87. If the pressure and quantity of flow are in the correct proportions, the shaft, whether it is rotating or not, will be raised and supported by an oil film.

Friction drag is reduced, and in certain types of heavy rotational equipment where torque is low, this may be the difference between starting and not starting. *Hydrostatic lubrication can be referred to as oil lift.*

Hydrostatic Bearings

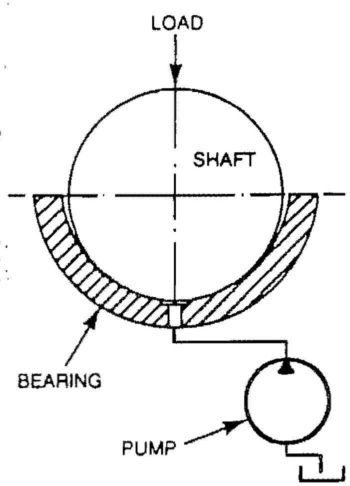


Illustration #87-Hydrostatic Oil Lift

Plain Thrust Bearings

Thrust bearings are used to either absorb axial shaft loads, or to position shafts. A plain thrust bearing performs the function of transferring thrust loads from the shaft to the frame of the machine where the load can be absorbed and kept from interferring with the internal parts of the machine itself.

By preventing lengthwise movement of the rotating shaft, a thrust bearing aids in maintenance of axial alignment. Vertical shafts always produce thrust loads and, therefore, require the use of a thrust bearing. With the shaft mounted horizontally, thrust loads may vary depending upon the design and operation of the machine. Illustration #88A and #88B exhibit an example of a journal bearing which is designed to support radial loads and axial loads. The side flanges have the capacity to accept moderate axial thrust loads.

The oil film thickness between the side flanges and the shaft collar could be from .001 inch (.0254 mm) to .01 inch (.254 mm) to protect the surfaces from severe metal to metal contact and to allow contaminants to pass through the bearing area without causing excessive scoring and wear. The film thickness establishes the oil-flow rate for a given viscosity and pressure.

Plain Thrust Bearings

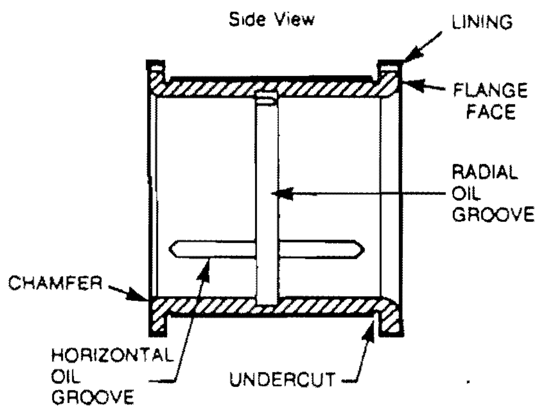


Illustration #88A-Flanged Insert Bearing

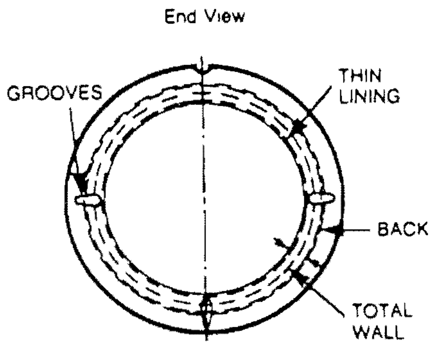


Illustration #88B-Flanged Insert Bearing

Thrust Bearing Clearances

Two methods are used to determine how much clearance exists between the face of the shaft collar and the face of the thrust bearing. By inserting feeler gages between the two faces one can determine how much clearance exists. *Care should be taken to avoid scratching or denting the thin bearing material.* Illustration #89 indicates the axial clearances that is maintained on thrust bearings by using a set of feeler gages.

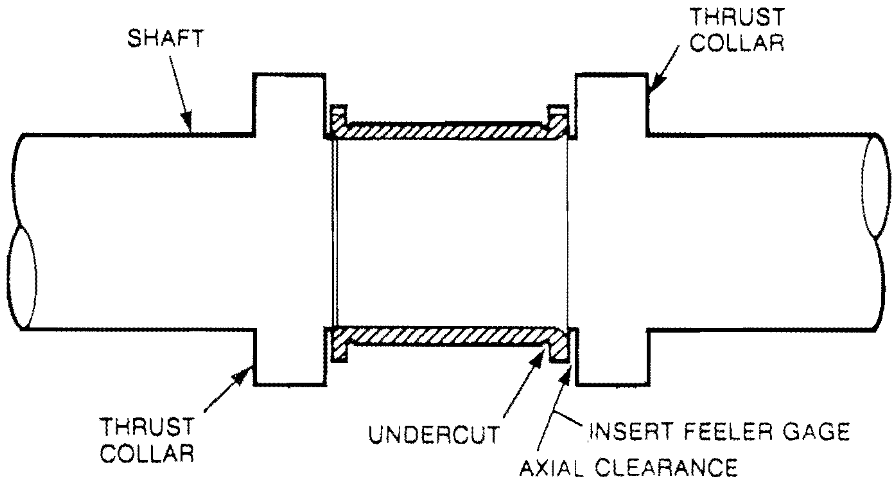


Illustration #89-Determine Thrust Bearing Clearance

Thrust Bearings

Illustration #90 identifies a second method for determining clearance in a thrust bearing. By placing a dial indicator point on the end of the shaft then pushing or pulling on the shaft in one direction one can accurately determine the axial movement. The advantage of this method is that the machine does not have to be dissassembled to perform this check.

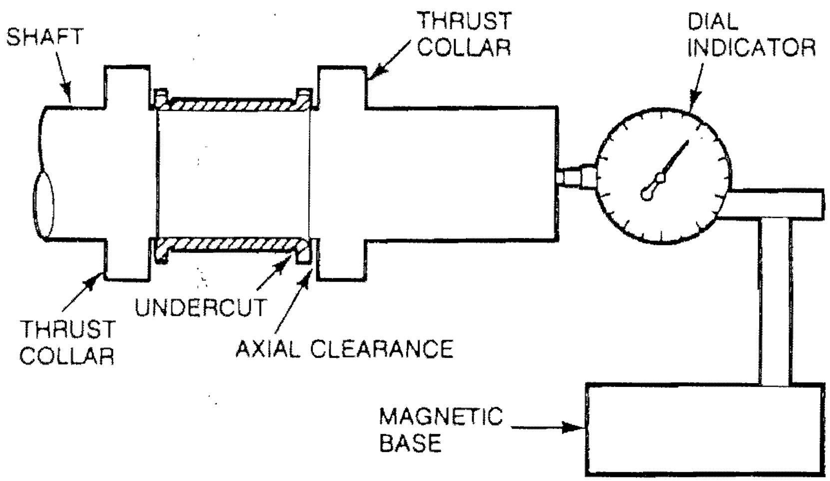


Illustration #90-Determine Thrust Bearing Clearance

Tilting Pad Thrust Bearings

The tilting pad thrust bearing is the most satisfactory thrust bearing for heavy axial pressures, regardless of whether the shaft speed is high or low or whether the shaft is horizontally or vertically mounted. Because of its construction a tilting pad bearing is more costly than a plain type thrust bearing. The tilting pad thrust bearing has the inherent advantage of being able to absorb significant amounts of misalignment without loss of performance.

Tilting pad bearings have similar advantages of any other hydrodynamic bearing. When operating normally at rated load and speed, practically no wear is encountered because the wedge-shaped oil film keeps the bearing surfaces separated. After the oil film is established, the only frictional loss encountered in the tilting pad thrust bearing is from oil shear.

Tilting Pad Thrust Bearings

Illustration #91 identifies a simple thrust bearing which consists of several stationary pivoted segments or shoes, against which is pressed the thrust collar which is fastened to the rotating shaft or an integral part of the shaft. The shoes rest on spherical supports or pivots and are free to tilt in any direction. The pivots support the segments, not at the center of gravity, but slightly forward in the direction of rotation. The thrust collar runs in an oil bath and its rotation draws in an oil film between it and the shoes which tilt automatically so that a fluid wedge is formed at the back edge.

Illustration #92 shows a tilting pad thrust bearing with two special features: one, it has a split bearing and two, it has a set of leveling plates. The bearing is divided into halves to simplify its removal, maintenance, and repair. A key is fitted into a slot in the machine housing to prevent the bearing from rotating.

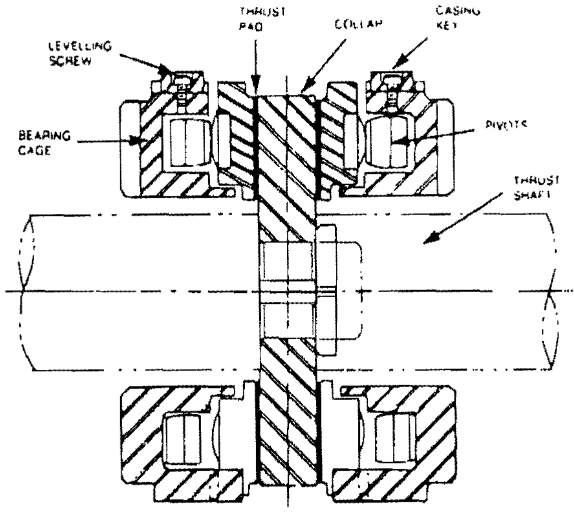


Illustration #91-Self Levelling Tilting Pad

The purpose of the leveling plates is to equalize the load on the bearing. Uniform distribution of load among the thrust shoes is important for proper bearing operation. The pivoted thrust shoes rest on the leveling plates.

Tilting Pad Bearings

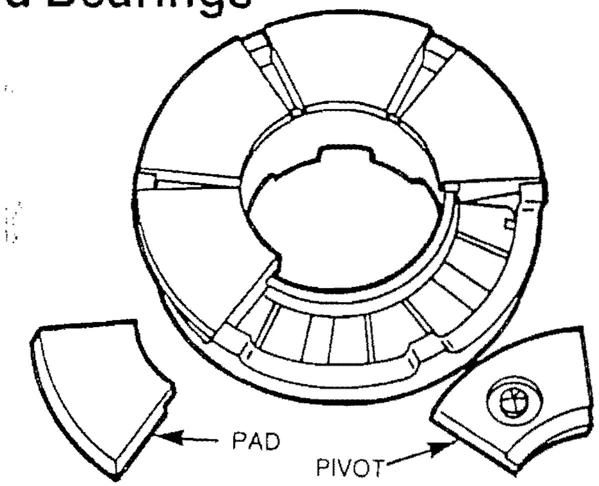


Illustration #92-Self Levelling Tilting Pad

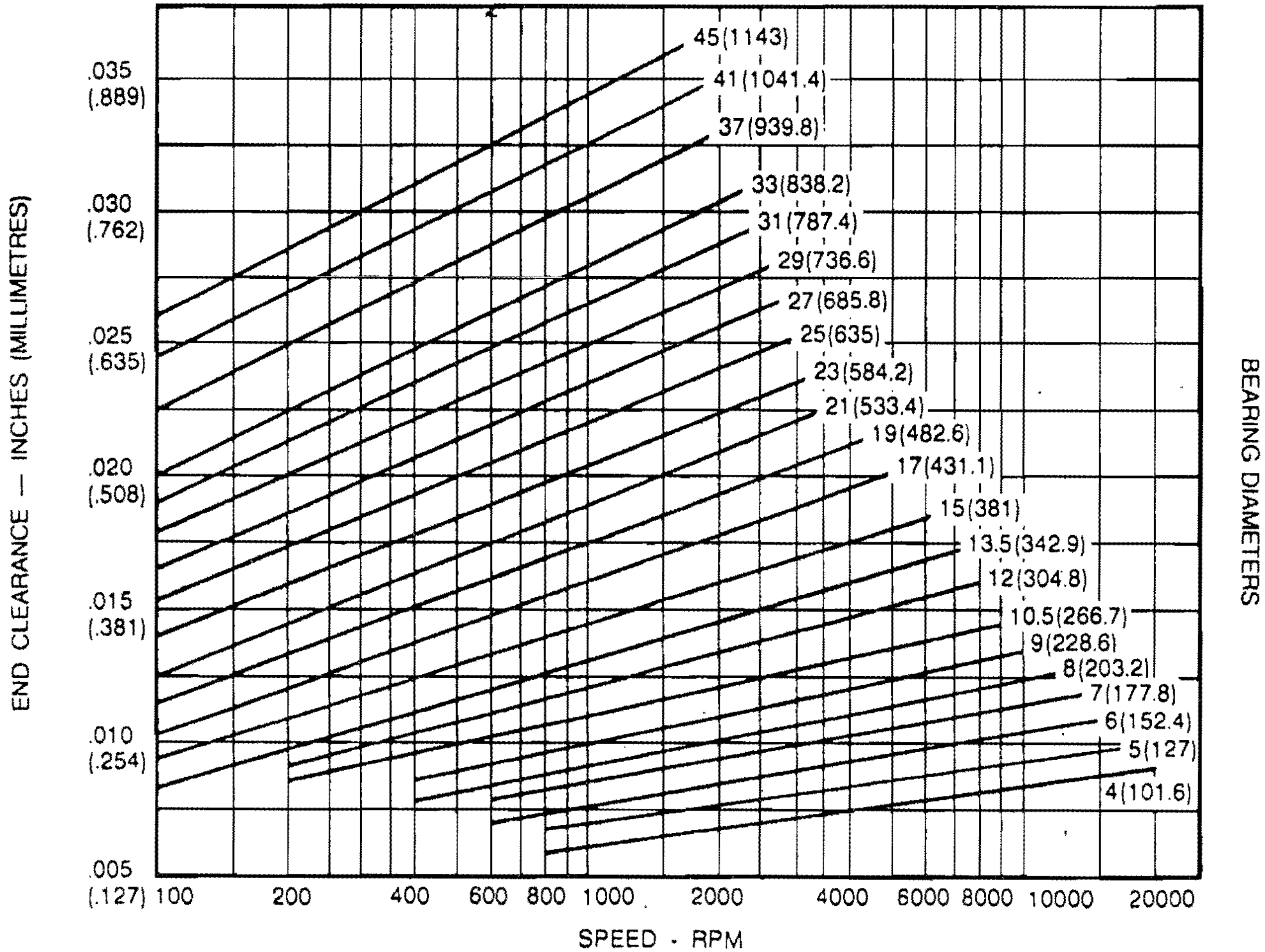
Between the leveling plates are machined rockers. The rockers force the leveling plates to move up and down. When pressure from the collar is transmitted to one thrust shoe, the rocker forces the shoes on either side to rise up to equalize the load. The leveling plates equalize the load on the bearing because they ensure that each of the shoes is in the same relative position to the thrust collar regardless of whether some of the shoes are worn, or thinner than others.

Tilting Pad Bearing Clearances

Tilting pad bearings are constructed in various styles for horizontal or vertical shaft positions and for carrying thrusts in either or both axial directions.

End clearance is essential in double axial thrust bearings to prevent the hydrodynamic action of the loaded bearing from inappropriately overloading the bearing resulting in excessive friction, wear and power loss. The end clearance is normally obtained by shim adjustment, and this should be checked by using feeler gages or dial indicators. The values of end clearance that are given in Table #5 are for double tilting pad thrust bearings having six pads and standard bore sizes.

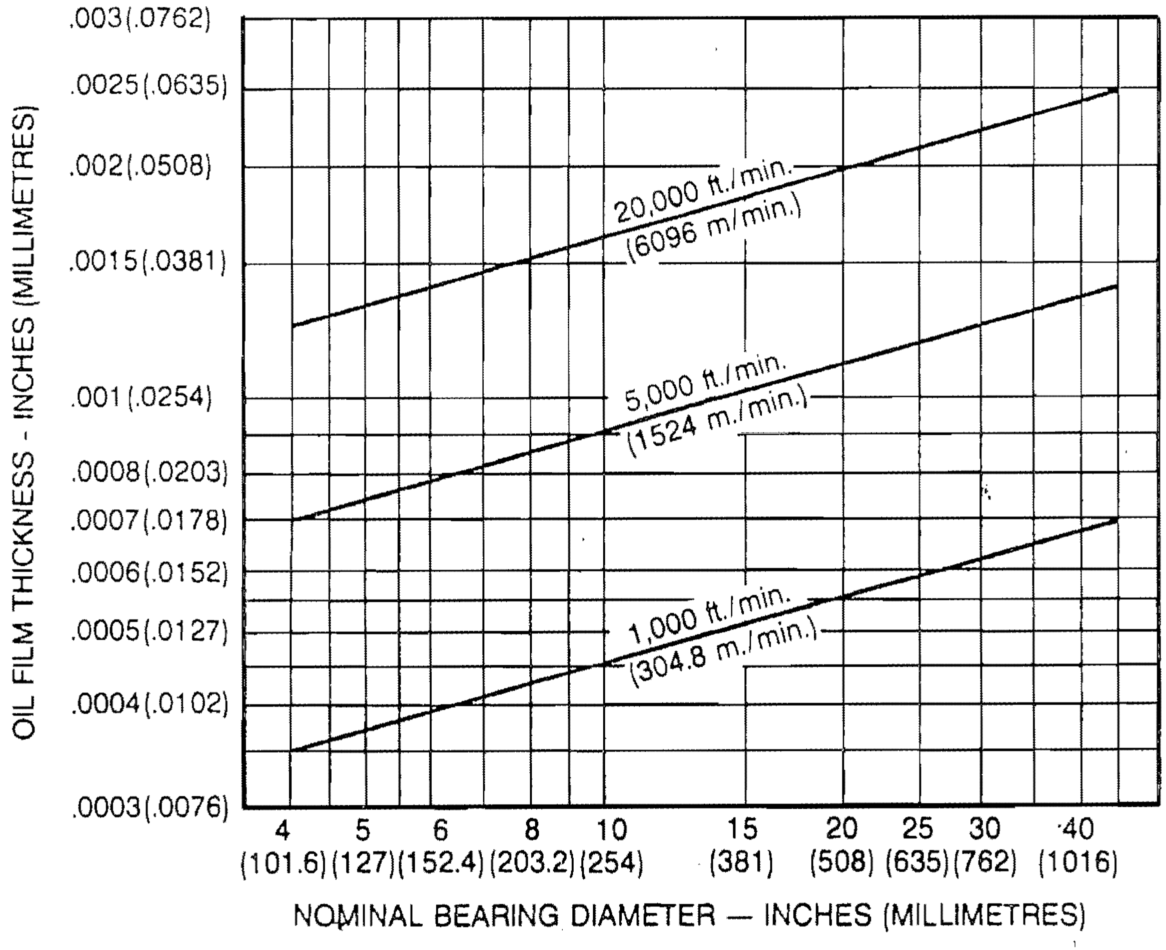
Tilting Pad Bearing Clearances



RECOMMENDED COLD END CLEARANCE FOR NORMAL CONDITIONS ON TILTING PAD THRUST BEARINGS

Table #5-Recommended Cold End Clearance on Tilting Pad Thrust Bearing

Tilting Pad Bearing Clearances



MINIMUM OIL FILM THICKNESS

Table #6-Oil Film Thickness

Tilting Pad Bearing Clearances

Table #6 provides the recommended amount of oil film thickness for double tilting pad thrust bearings having six pads and standard bore size.

Table #6 was designed using a light oil lubricant operating with an average viscosity at 135F (57.2C). For operating conditions having lubricant viscosity other than what is specified in Table #6, reference may have to be made to the equipment manufacturer. In applications of low oil film thickness the lubrication system and the lubricant must be completely free of harmful contaminants. Under normal operating conditions, minimum oil films below .0005 inch (.0127 mm) should not be considered for the full load or full speed operation.

Guide Bearings

A guide bearing is generally used as a positioning device or as a guide for linear motion such as in machine tools or on double acting air and gas compressors. Illustrations #93A, #93B, and #93C demonstrate several examples of guide bearings. A thin layer of bearing material is often found on the bearing surface to help reduce friction and wear. It is normal for this type of bearing to operate with oil film, grease, or dry lubricants, such as graphite.

In order to improve performance, increase bearing stability, and to reduce wear, the use of hydrostatic lubrication will ensure that an adequate oil film completely separates the sliding surfaces.

Tilting Pad Bearing Clearances

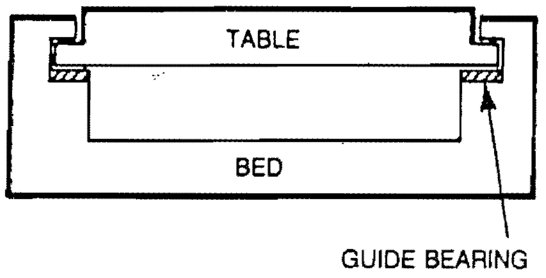


Illustration #93A-Guide Bearings

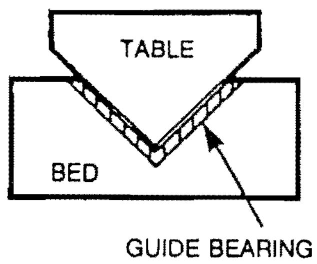


Illustration #93B-Guide Bearings

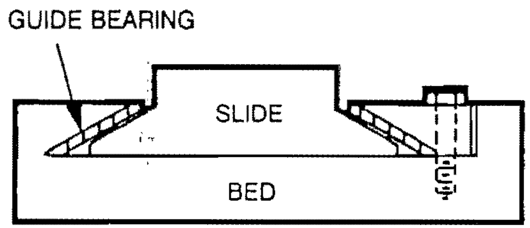


Illustration #93C-Guide Bearings

Pivoted Shoe Bearings

The pivoted shoe journal bearing is designed primarily for high peripheral speeds, such as high speed gear boxes, and shaft stabilization. The operation of a pivot shoe bearing is similar to a flat tilting shoe type thrust bearing. The shoes are positioned by cylindrical grooves in the retaining ring. The back of the shoes are machined cylindrically for a free fit in the grooves; thereby assuring effective tilting shoe action.

All surfaces of the steel shoes and aligning ring are impregnated with a friction reducing, corrosion proof material. The aligning ring must facilitate close tolerances and be made to accurate surface finishes. The shoes are hardened alloy steel with a rocking contour. A thin layer of high tin base babbitt material with good corrosion resistance and high embedability coats the shoe's inner surface. The shoe retaining plates are made from either bearing aluminum or bronze.

Pivoted Shoe Bearings

The plates are bored to regulate spent oil discharge from the bearing, without shaft contact. A separate oil inlet is provided for each shoe to help establish a lower and more uniform operating temperature. The bearing operates as a flooded type where the internal pressure is no greater than the weight of the oil in the bearing plus the slight back pressure created by the resistance to flow through the discharge holes.

A pivot shoe bearing is a split bearing. The split bearing is doweled in such a manner that the upper and lower halves cannot be reversed with respect to each other. The lower half of the aligning ring contains a dowel for positioning of the bearing axially and also serves as an anti-rotation device.

Pivot shoe journal bearing parts are identified in illustration #94.

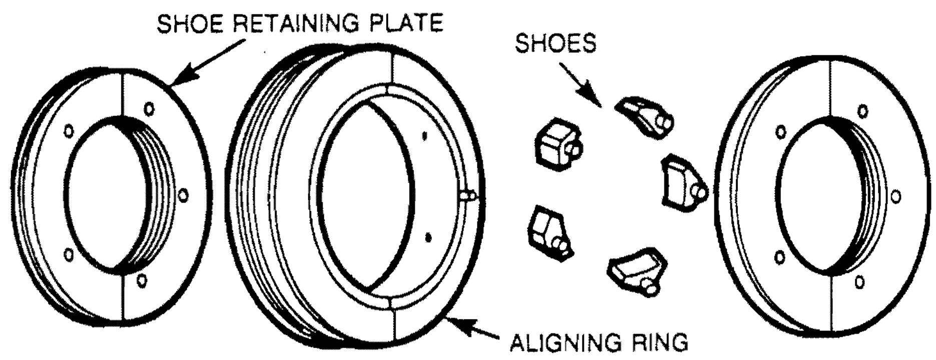


Illustration #94-Pivot Shoe Bearing

Pivot Shoe Maintenance

Five areas within a pivot shoe bearing are identified as essential areas for inspection for wear:

1. The babbitted surface of the shoe.
2. The pivoting surface of the shoe and the seat in the aligning ring.
3. The bore size of the shoe retaining rings.

Pivot Shoe Maintenance

4. The babbitted thrust plate face.
5. The diametral clearance between the shoes and journal.

Maintenance Recommendations

- Replace any shoe if the leading or back surface show signs of wear.
- Replace any shoe if the babbitted surface appears scored or has deep scratches.
- All leading edges of the pivoting shoes must have a uniform radius for the full length across the shoe. Radius will vary with the bearing size. File the radius to obtain uniformity and check with a radius gauge.
- Light scratches in the babbitt do not necessarily mean replacement. If no wear is detected, scrape lightly with a flat scraper any light roughness caused by the scratches. V-slots in thrust plate grooves can be opened with a sharp three cornered scraper.
- Pivot shoes are interchangeable so that any one shoe may be replaced or rotated.
- Replace any shoe if the radial clearance has increased beyond the manufacturer's maximum designed clearance.
- Replace the shoe retaining plates if the bore diameter becomes too large at any one point along the shaft.
- Ensure that the retaining plate faces are free of nicked edges, and deep scratches. Polish the faces with fine emery cloth, or scrape if necessary.
- Stone or lap the joint surfaces if burrs or raised edges exist.
- Check the pivoting surfaces of the shoe and aligning ring for erosion, scratches or wear. Polish with fine emery if necessary.
- Check the bearing for proper diametral clearances.

Pivot Shoe Clearance Checks

It is recommended that the pivot shoe bearing be completely disassembled and properly cleaned and inspected before clearance checks are made. Clean all of the bearing parts in a petroleum solvent and wipe them completely dry. Assemble all of the shoes in the bearing. Do not oil any parts as this may effect the clearance readings.

By using non-drying bluing applied to the pivot shoe surface one can check for the contact impression and position of the journal and shoes. Contacting surface must be in the center only and at the bottom portion of the pivot bore.

Clearance Check Methods

Illustration #95A and #95B demonstrate a recommended method for accurately determining the diametral clearance within a pivot shoe journal bearing.

A mandrel is made to within .0005 inch (.0127 mm) of the machine's shaft size. One end of the mandrel is faced square to the turned diameter. The faced end of the mandrel is bolted solidly to a heavy flat plate, preferrably a ground surface. The mandrel/plate assembly should be secured to a table.

Assemble the bearing around the mandrel carefully. Lightly tap the bearing in the back of each shoe to ensure that the shoes are properly seated in place. Set a dial indicator directly in back of a shoe and move the bearing back and forth in a direct line with the dial indicator and record the reading for that shoe. Repeat this procedure for each shoe. Remember to set the dial to zero for every new position and be sure that only the bearing movement is being recorded and not a possible shift of the mandrel or the dial indicator stand.

Clearance Check Methods

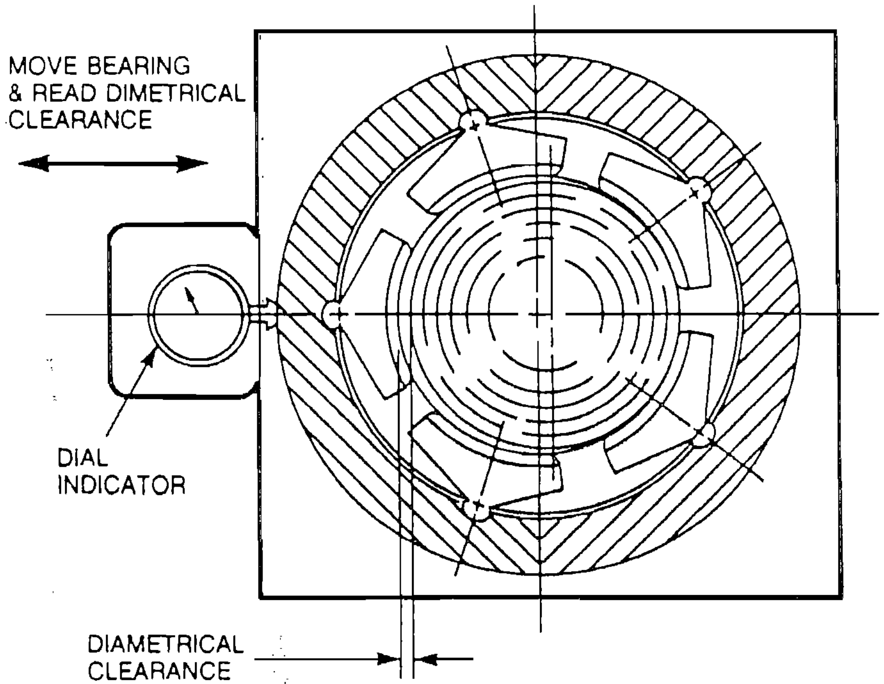


Illustration #95A-Pivot Shoe Diametral Clearance

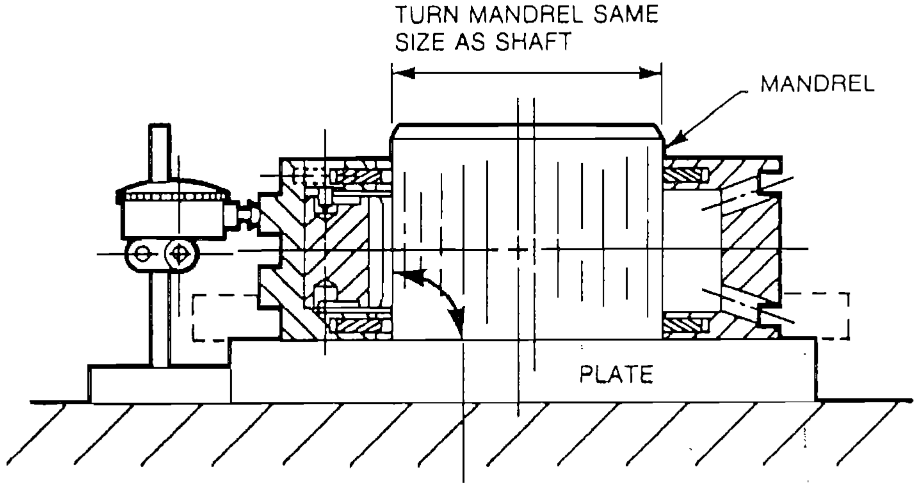


Illustration #95B-Mandrel Assembly

Journal vs Roller Bearings

Advantages:

- Journal bearings require less radial space than roller bearings.
- Journal bearings are quieter in operation.
- Journal bearings are usually less expensive than roller bearings.
- Journal bearings can be designed and manufactured at the plant site to meet a variety of equipment and operation needs.
- Journal bearings offer great rigidity and stability under extreme load conditions.
- Journal bearing life is generally not limited by fatigue.
- Journal bearings are easier to lubricate than roller bearings at high speeds.
- Journal bearings are much less sensitive to vibration, poor fits, corrosion, and contaminants than roller bearings.
- Journal bearings can operate at shaft speeds of 25,000 RPM or higher when properly designed.

Disadvantages:

- Journal bearings are more susceptible to damage from interrupted lubrication supply.
- Journal bearings require very stringent lubrication requirements and specifications.
- Journal bearing life is limited by the accuracy of the surface finish of the shaft journal.
- Journal bearings may not operate as efficiently in high temperatures as compared to some roller bearings.

Properties of Journal Bearings

For a material to be used as a plain bearing it must possess certain physical and chemical properties which permit it to operate properly. If a material does not have all of these characteristics it may not function effectively as a reliable journal bearing. There are few, if any journal bearing materials which are outstanding in all of the desired characteristics. Therefore, the selection of the optimum bearing material for a given application is at best a compromise to secure the most desirable combination of properties required for the application. The nine properties usually acknowledged to be the most significant for journal bearings are:

1. Resistance to scoring
2. Fatigue resistance
3. Corrosion resistance
4. Embedability characteristics
5. Compatibility characteristics
6. Conformability properties.
7. Thermal conductivity
8. Load capacity
9. Bondability properties

Resistance to Scoring: A journal bearing must be resistant to scoring, which arises in part from adhesion. No matter how carefully a journal and a bearing are machined, fitted and lubricated, the two surfaces do touch occasionally. At such times they suffer adverse wear which causes undesirable effects to both the journal and bearing surfaces.

Wear can take two major forms: adhesion and abrasion.

- Adhesive wear is the result of poor resistance to scoring. At the points of contact between the two surfaces, where the small points on each surface tend to adhere to one another, minute bits of metal are torn away as the journal rotates.

Properties of Journal Bearings

- Abrasive wear occurs when the surface of the journal is so rough that it abrades the bearing surface. Hard particles that commonly contaminate a journal bearing also abrade both surfaces.

Fatigue Resistance: Fatigue resistance is the ability of the bearing lining material to withstand repeated applications of stress and strain, without cracking, flaking or destruction. Fatigue is basically the development of cracks in the bearing surface, thereby loosening small pieces of metal. These "tiles" increase in number and are gradually washed out, leaving a surface that is inadequate to carry a load.

Corrosion Resistance: Corrosion resistance is required to resist attack by organic acids that are sometimes formed in oils during operating conditions. Certain metals react adversely to some lubricants. The reaction process can be compounded when moisture, air and heat are introduced to the bearing material and lubricant. Corrosive wear is a chemical process, but the mechanical working in the bearing contributes by continually exposing fresh surfaces to the destructive action of the chemical process.

Embedability: Embedability is the ability of the bearing lining material to absorb or embed within itself any of the larger dirt or metalic contaminants present in the bearing area or lubricant. Poor embedability permits particles circulating around the bearing to score both the bearing and journal surface. It is therefore desirable for the bearing material to have the property either of enabling the particles to be pushed into the bearing material itself or of allowing the particles to be partially embedded and then washed out a short time later.

Properties ofJournal Bearings

Compatibility: Compatibility or anti-scoring properties permit the shaft and bearing to function effectively with each other. Compatibility is the ability to resist galling or seizing under conditions of metal to metal contact, such as startup.

Conformability: Conformability is defined as malleability or as the ability of the bearing material to flow slightly under load, as in the first stages of startup. This permits the journal and bearing surface contours to conform with each other or to compensate for non-uniform radial loading due to misalignment conditions. Conformability is needed because a journal and bearing may be misaligned upon assembly or during operation due to load changes, shaft deflections, or thermal growth. The bearing material must be capable of undergoing limited wear. It must also be capable of deforming plastically so that it conforms to the journal.

Thermal Conductivity: High thermal conductivity characteristics of a bearing material are required to absorb and carry away the heat generated in the bearing during operation. The lubricant carries away most of the heat as the bearing and journal interact, but when both the load and speed are high, the journal and the bearing will also conduct heat. If the bearing material can efficiently conduct the heat then there is an increased chance that seizures can be prevented. Seizures are usually due to localized hot spots caused by poor bearing fits, surface breaks or the presence of foreign particles.

Load Capacity: Load capacity or strength is the ability of the bearing material to withstand the hydrodynamic pressures exerted upon it during operation.

Properties of Journal Bearings

A four-cycle engine is an example where two radial loads are particularly high on the bearing material. These are the combustion load which occurs during the power stroke, and the primary inertial loads which occur at the end of every stroke due to the piston's reversal of direction. The yield and fatigue strength of the bearing material must be high enough to support the combustion and inertial loads. If a journal bearing material is overdesigned in strength, conformability and embedability qualities can become troublesome problems.

Bondability: Bondability refers to the union between the lining and the backing material. As contrasted to grooves or holes which are mechanical bonding methods, metallurgical bonding is used to adhere the bearing material to the backing.

This type of bond makes it possible to take full advantage of the strength of the backing material. The bond should not be brittle and should resist breakdown under full operating conditions. The strength of the bond depends upon the type of bearing material and the metallurgical process used to adhere the material to the backing. Precision insert-type bearings are regarded as being effective in their location and securement to the backing.

Journal Bearing Materials

The material of a plain bearing should be softer than the material of the journal, but on some equipment and service requirements the manufacturer may modify this principle. *Journal bearing materials could be classified into two groups: metallic and non-metallic materials.*

Metallic Bearing Materials

Bronze: The major ingredient of bronze alloy is copper. The properties of copper are influenced by the presence of smaller percentages of many elements. Bronze bearings are suitable for heavy load applications and bronze withstands higher shocks than babbitt. It can be used in applications where temperatures may reach as high as 500F (260C), but it is a harder material than babbitt and has more tendency to score or damage shaft journals. Bronze is available in standard round bar stock sizes.

Tin Bronze: Tin bronze bearings contain approximately 10% tin, 10% lead and 80% copper.

Lead Bronze: This alloy contains approximately 70% copper, 5% tin and 25% lead.

Phosphor Bronze: When bronze contains 0.03% to .40% phosphorous it is known as phosphor bronze. It is widely used as a bearing material for high speed and heavy load applications.

Sintered Bronze: Sintered or metal powder self-lubricating bearings are used principally for bushings and thrust plates. In manufacturing this type of material, the fine powders of the desired materials are mixed and then molded in dies under high pressure. The formed composite is then sintered at the proper temperature. These bronze bearings have a porosity of about 25% to 35% and, when subsequently soaked in oil, absorb it to this extent. Self-lubricating bearings are particularly suitable for use in inaccessible places and other machinery applications where service is infrequent.

Metallic Bearing Materials

Aluminum Bearings: Aluminum bearings are either cast solid aluminum, aluminum with a steel backing or aluminum with a suitable overlay. The aluminum is deficient in antiseizure properties and in the strength necessary to carry heavy loads. Therefore, aluminum is usually alloyed with small amounts of tin, silicone, cadmium, nickel, or copper.

Aluminum bearings are best suited for operation on shafts with hard journals. Due to the high thermal expansion of aluminum (which results in diametral contraction when the aluminum bearing is confined in a rigid housing), large clearances are required between the journal and the bearing. This tends to make the bearing noisy, especially on startup. Overlays of lead, lead-tin, or lead-tin-copper may be applied to aluminum bearings to facilitate their use on machines using soft journals.

Silver Bearings: Silver bearings were developed for usage in heavy duty applications such as diesel engine main bearings. Silver has a higher fatigue rating than any of the other materials. Silver by itself does not possess many of the desirable bearing qualities except high fatigue resistance and high thermal conductivity. Overlays such as lead, or lead-tin improve the embedability and antiscore properties of silver.

Cast Iron Bearings: Cast iron is suitable as a bearing material for slow moving shafts, approximately 130 feet per minute (39.6 meters per minute), and for light loads usually under 150PSI (1034.21KPa). The wear limiting characteristics of cast iron is due to the free graphite flakes present in the alloy. When cast iron bearings are used, higher journal to bearing clearances are usually provided. Any large metal particles or foreign debris will not as easily jam the clearance spaces and seize the bearing.

Metallic Bearing Materials

Copper-Lead Bearings: Copper-lead bearings are a mixture of copper and lead containing from 20% to 40% lead. The higher the lead content, the lower the fatigue resistance and the better the antifrictional characteristics. The addition of tin increases the strength and reduces the fatigue cracking tendency. The lead is practically insoluble in copper, a cast micro-structure consists of lead pockets in a copper matrix.

A steel backing is commonly used with this material, and the material may have an overplate such as lead-tin or lead-tin-copper to increase basic bearing characteristics. The combination of good fatigue strength, high load capacity, and high temperature qualities has resulted in the use of copper-lead bearing materials for heavy duty main and connecting rod bearings on engines and compressors. They are also used for moderate load and speed services such as electric motors and turbines.

Cadmium Base Alloy Bearings: Cadmium alloy bearings contain 97% to 99% cadmium plus nickel and silver or copper. Cadmium alloy bearings have a greater resistance to fatigue than babbitt bearings, however, they are limited in use because of their poor resistance to corrosion. The prime attribute is their high temperature capability.

Trimetal Bearings: Fatigue resistance of the babbitt metals is affected by thickness and uniformity of metal thickness. The use of a high strength intermediate layer between the babbitt metal and the backing is helpful in improving this property. When these factors are controlled and combined in a single bearing, the resulting fatigue strength is greatly improved.

Metallic Bearing Materials

The fatigue strength of this type does not quite approach that of copper-lead journal bearings. Bearing life increases rapidly as the babbitt thickness decreases from approximately .015 inch (.381 mm) to .005 inch (.127 mm) and is even better between .005 inch (.127 mm) and .001 inch (.0254 mm). A typical trimetal bearing may consist of a steel back and an intermediate layer of copper-lead plated with a .001 inch (.0254 mm) babbitt overlay. The advantage of the intermediate layer is that , if the babbitt overlay should be removed, the copper-lead itself provides a good bearing surface, and has excellent resistance to fatigue and corrosion.

Babbitt Metal Bearings: These journal bearing materials are universally accepted as providing effective and dependable service, often under adverse conditions. Tin and lead base babbitts are the best known of the babbitt metals.

With excellent embedability and compatibility characteristics under hydrodynamic and hydrostatic conditions, babbitt bearings are used in a wide range of applications including engines, compressors, railroad cars, electric motors, generators, steam and gas turbines, fans and blowers, and industrial and marine gear units.

Compared to other bearing materials, babbitts generally have lower load carrying capacity and fatigue strength, are somewhat higher in cost, and require a more complicated design. Strength also decreases with increasing temperature.

Lead Base Babbitts: The lead base bearing alloys contain from 75% to 90% lead, 10% to 15% antimony, up to 10% tin, and traces of copper. The addition of tin increases the compressive strength of these alloys. Lead base babbitts have good antiseizure properties.

Metallic Bearing Materials

Lead based babbitts are generally better than tin base babbitt in embedability and fatigue resistence. The chief disadvantage, when compared to tin base babbitt, is rather low strength and susceptibility to corrosion.

Tin Base Babbitts: Tin base babbitt is composed of 80% to 90% tin to which is added approximately 3% to 5% copper and 4% to 14% antimony. An increase in copper or antimony produces increased hardness and tensile strength and decreased ductility.

Tin base babbitts have little tendency to cause wear to the journals because of good embedability qualities. They resist the corrosive effects of acids and they have good bondability characteristics. The major disadvantages of tin base babbitts as compared to lead base is a low fatigue resistance quality and the hardness and strength drop appreciably at low operating temperatures. Table #7 identifies several properties of various journal bearing alloys.

PROPERTIES OF BEARING ALLOYS			
Material	Recommended Shaft Hardness, Brinell	Load Carrying Capacity, psi	Maximum Operating Temp., °F
Tin Base Babbitt	150 or less	800-1500	300
Lead Base Babbitt	150 or less	800-1200	300
Cadmium Base	200-250	1200-2000	500
Copper Lead	300	1500-2500	350
Tin Bronze	300-400	4000 +	500 +
Lead Bronze	300	3000-4500	450-500
Aluminum	300	4000 +	225-300
Silver-Overplated	300	4000 +	500
Tri Metal-Overplate	230 or less	2000-4000 +	225-300

Table #7-Properties of Bearing Alloys

Metallic Bearing Materials

Table #8 provides a rating scale for several bearing alloys used in journal bearing.

Bearing Characteristics Ratings				
Material	Compatibility	Conformability and Embedability	Corrosion Resistance	Fatigue Strength
Tin Base Babbitt	1	2	1	4
Lead Base Babbitt	1	1	3	5
Cadmium Base	1	2	5	4
Copper Lead	2	2	5	3
Tin Bronze	3	5	2	1
Lead Bronze	3	4	4	2
Aluminum	5	3	1	2
Silver Overplated	2	3	1	1
Tri Metal-Overplated	1	2	2	3
Note: 1 is best; 5 is worst.				

Table #8-Characteristic Ratings

Non-Metallic Bearing Materials

Carbon-Graphite: Journal bearings of molded and machined carbon-graphite are often used where regular maintenance and lubrication of the bearing cannot be provided. Carbon-graphite bearings are dimensionally stable over a range of operating temperatures, may be lubricated if desired, and are not adversely affected by chemicals.

Carbon-graphite bearings may be used in machinery applications where the temperatures range from 700F (371.11C) to 1200F (648.9C) and operate at loads of a 20PSI (137.9KPa) maximum. In some applications metal or metal alloys are added to the carbon-graphite composition to improve such properties as compressive strength and density.

Non-Metallic Bearing Materials

Table #9 indicates the recommended normal running clearances for carbon-graphite bearings used with steel shafts operating at temperatures less than 200F (93.33C).

BEARING INSIDE DIAMETER	RECOMMENDED CLEARANCE
.187 inch to .500 inch 4.7 mm to 12.7 mm	.001 inch .0254 mm
.501 inch to 1.00 inch 12.725 mm to 25.4 mm	.002 inch .0508 mm
1.001 inch to 1.250 inch 25.425 mm to 31.75 mm	.003 inch .076 mm
1.251 inch to 1.500 inch 31.775 mm to 38.1 mm	.004 inch .101 mm
1.501 inch to 2.00 inch 38.125 mm to 50.8 mm	.005 inch .127 mm
NORMAL RUNNING CLEARANCES FOR CARBON-GRAPHITE JOURNAL BEARINGS	

Table #9-Carbon, Graphite Clearances

Wood Bearing Materials

Bearings made from such woods as lignum-vitae, rock maple or oak offer excellent self-lubricating qualities, low cost, easily machined and clean operation.

Wood bearings have frequently been replaced in recent years by various plastics, rubber and sintered bronze bushings. Table #10 identifies the application limits of wooden journal bearings.

Non-Metallic Bearing Material

Rubber Bearings

Rubber bearings provide excellent performance on equipment such as propellor shafts and rudders of ships, hydraulic turbines, multiple stage deep well pumps, sand and gravel washers, and other industrial equipment operating in water or slurry conditions. The resilience of rubber helps to isolate vibration and provide quiet operation, allows for large running clearances and helps to compensate for shaft deflections and misalignment. Flutes or slots in the rubber form a series of longitudinal grooves through which lubricant or, as generally found, water and contaminants such as sand and grit may pass through without damaging the lining or the journal.

Synthetic Bearings

Synthetic journal bearing materials are becoming increasingly popular as bearing materials in a wide variety of industrial machinery applications. This is due to resistance to corrosion, quiet and smooth operation, ability to be molded into many shapes and excellent compatibility which helps to either minimize or eliminate lubrication. There are many varieties of synthetics capable of operating as bearings, however, the most common materials are laminated phenolics, tetrafluoroethylene (TFE) or nylon. Table #10 identifies the general application limits for these synthetic materials.

Laminated Phenolics: These are a composite material consisting of cotton fabric, asbestos, or other fillers bonded with a glue-like material called phenolic resin. They have excellent compatibility with a variety of fluids as well as strength and shock resistance. Precautions must be taken to maintain adequate cooling because the thermal conductivity of these materials is low. Clearances of .001 inch (.0254 mm) per inch (per 25.4 mm) of diameter are recommended for these materials.

Non-Metallic Bearing Materials

Nylon: This type of journal bearing is used extensively in a wide range of equipment where light loads are found. Nylon has low frictional properties and may operate in conditions where lubrication cannot be provided. Partially lubricated or dry nylon bearings are given a clearance of .004 inch (.101 mm) to .006 inch (.152 mm) for one inch (25.4 mm) diameter bearing.

Teflon (TFE): These journal bearings have exceptional low coefficients of friction, they are self-lubricating, resist chemical attack and have a wide operating temperature range. Water, oil or grease can be used to lubricate teflon bearings, as well as nylon bearings.

Procedures For Babbitting

Babbitt metal is used extensively as a journal lining for bearings because of its excellent antifrictional qualities and ease at which it can be accurately fitted to meet the journal surface characteristics. Prior to pouring the molten babbitt, the bearing shell must be heated to prevent the babbitt from becoming chilled and adhering poorly. Bronze and steel shells which accommodate babbitt linings should first be tinned by coating the inner shell surface with a 50-50 solder and zinc chloride as the flux.

Application Limits – Semi-Lubricated Sintered-Metal and Nonmetallic Bearings

Type of Bearing	Load Capacity Psi	Max. Temp. °F	Max. Surface Speed Ft/Min
Porous Metals	4000/8000	150	1500
Rubber	50	150	1000
Graphitic Materials	600	700	2500
Laminated Phenolics	6000	200	2500
Nylon	1000	200	1000
Wood (Maple & Lignum Vitae)	2000	150	2000
TFE	500	500	50
Reinforced TFE	2500	500	1000
TFE Fabric	60,000	500	150

Table #10-Sintered Metal and Non-metallic

Procedures For Babbitting

The shells should be preheated to a temperature of 200F (93.3C) to 300F (148.9C). The shells should be babbitted immediately after the tinning and preheating operation. Babbitt itself, should not be used for tinning because it has a very high melting point, which makes it difficult to maintain a molten film on the surface to be tinned.

Babbitt in a bearing shell may also be held in position by having the molten babbitt flow into holes or slots in the shell's inner surface. The holes should prevent the lining from turning and hold it firmly against the shell. The holes or slots must be thoroughly cleaned and be free from moisture before babbitting begins.

Molten Babbitt Temperatures

Depending on the alloy, babbitt melts at between 495F (257.2C) and 550F (287.8C) and is poured at between 700F (371C) and 1000F (537.8C). Babbitt should be kept at approximately 870F (465.6C), as a constant temperature is important to achieving effective metal composition and bonding.

The temperature of the molten babbitt should be increased slowly and the babbitt thoroughly stirred, especially when new babbitt is being melted, or when old babbitt has been left to solidify in the melting pot and is being reused. This is necessary in order to prevent the various babbitt ingredients from rising to the top and becoming oxidized, as well as to prevent the heavier metals from sinking to the bottom of the babbitt pot, thus producing a non-uniform alloy. A pyrometer can be used to determine the recommended pouring temperature of the babbitt.

Procedures For Babbitting

Preheating The Mandrel

The mandrel is the dummy shaft machined to a smaller diameter than the shaft journal where the newly poured babbitt bearing is to be fitted. The mandrel must be accurately aligned and centered in the bearing shell. Whenever practical, the bearing shell and mandrel should be placed in a vertical position while the babbitt is poured. The surface of the mandrel which contacts the molten babbitt should be coated with either the soot from an acetylene (carburizing) flame or by wrapping paper around the mandrel. The coating preparation facilitates the removal of the bearing from the mandrel.

The mandrel should be preheated to a temperature of 200F (93.3C) to 300F (148.9C) when pouring babbitt into the shells.

Pouring Babbitt Metal

Before the molten metal is poured into the bearing shell, ensure that the ends of the bearing are sealed with putty and that all of the oil holes in the bearing shells are filled with putty or wooden plugs. If the bearing is a split half design, thin pieces of tin or shim material must be inserted between the two bearing halves and fitted tightly up to the mandrel. This allows the bearing shell and babbitt lining to be poured as two separate halves.

The molten babbitt should be poured from a ladle having a rounded spout rather than a sharp or pointed spout. A broad, thin stream or one that is intermittent tends to produce porous areas or blow holes in the babbitt.

For best results, the babbitt must be poured at the correct temperature. If the babbitt is poured at too high a temperature, extreme shrinkage will occur, resulting in porous areas in the lining.

Procedures For Babbitting

The babbitt will also oxidize, be quite soft, dirty and its antifrictional qualities will be reduced. If the babbitt is poured at too low a temperature, the lining will appear coarse and granular. If the bearing shells and mandrel are too cold, blow holes will form, and the babbitt lining will shrink away from the shell in the cooling process. If the temperature of the shell or mandrel is too high, the babbitt will cool too slowly, giving the heavier metals time to settle, producing a bearing which will be soft in one section and brittle in another.

Babbitting Safety Procedures

Observe the following safety factors when babbitting a bearing:

- Remove any free water, oil or surface moisture from the bearing shell and mandrel as any moisture will cause a *"blow back"* or explosion.
- Do not pour molten babbitt into a bearing/ mandrel assembly that has not been thoroughly cleaned and preheated.
- Do not pour molten babbitt in a location where there is a chance of water dropping into the bearing or ladle area.
- Wear approved protective safety clothing and equipment during pouring procedures.
- *When heating a ladle or pot of cold babbitt, apply heat to the sides and bottom of the container. Do not apply concentrated heat to the bottom only, as the babbitt on the bottom will melt and expand first which may cause the sides and bottom of the container to blow out.*
- Because of the serious fire hazards created by molten babbitt, ensure that approved fire protection equipment is accessible at all times during and after the pour.

Procedures For Babbitting

- Make certain that there is a vented escape path on the bearing/mandrel assembly for any heated air or fumes to easily discharge, preventing an explosion.
- Pour the babbitt at a steady rate, allow some overflow over the end dams, but be careful not to spill the metal to the floor area.

Babbitt Bearing Fitting

Any journal bearing, regardless of its shape, diameter or material, must be accurately prepared in the following areas:

- The surface finish and area of journal to bearing contact.
- The running clearances.
- The lubrication entry area which enables an effective oil wedge to form on hydrodynamic bearings.
- The oil grooves which help distribute the lubricant.

After a bearing has been babbitted, it has to be prepared several ways before it can be operated. Illustration #96 indicates how the top edge of the bearing half must be chamfered almost to the bearing end to ensure that the lubricant is channeled to the shaft. The amount of angle to the chamfer is usually specified by the equipment manufacturer. For large journal diameters the chamfer is usually extended on the oil entry side, almost down to the area of contact between the shaft and bearing. The chamfer should not extend into the load area or high pressure section of the bearing.

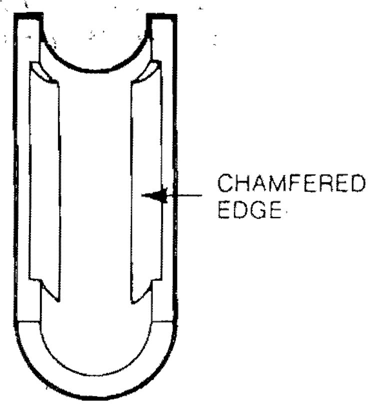


Illustration #96-Chamfered Edge

Bearing Contact Checking

To properly check a journal bearing for contact, use either a mandrel or the machine's shaft. For a good contact impression, the shaft can be lightly coated with non-drying mechanics bluing. As the shaft is slowly rotated in the bearing, the bluing wipes off at the points of contact and transfers to the bearing surface to identify the significant high spots.

Illustration #97 shows a journal bearing which has no contact on its bottom half. Only high spots along the top edges appear. The top edges must be scraped down to allow the shaft to make contact with the bottom of the bearing. Fitting for all contact is usually performed after the chamfers and oil grooves have been cut. Illustration #98 identifies a journal bearing which has been relieved and chamfered. The contact points are mostly below the chamfer but not sufficient enough in the bottom area of the bearing.

Illustration #99 demonstrates a properly fitted bearing where sufficient contact has been made between the shaft and the bearing half. Equipment and bearing manufacturers may recommend a contact area from 75% to 90%. This will depend upon loads, speeds, bearing materials, and the type of lubrication system used.

To ensure that a good distribution of lubricant occurs, the bearing cap should also be relieved and chamfered in the same manner as the base.

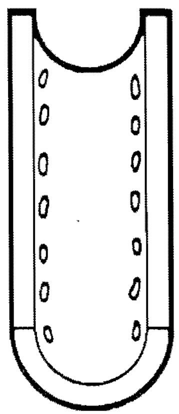


Illustration #97-No Contact

Bearing Contact Checking

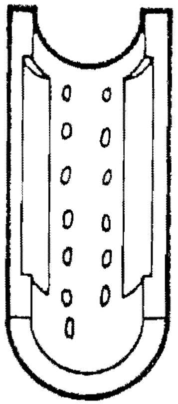


Illustration #98-Insufficient Contact

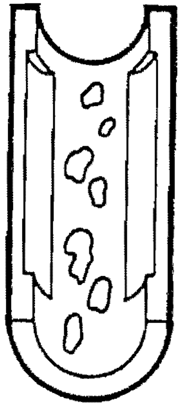


Illustration #99-Proper Contact

Journal Bearings Scraping

A scraper is used to remove minute amounts of metal in order to reduce the high spots on the bearing surface which may have previously been made as true as possible by machining.

Scrapers are made of hardened carbon steel and are shaped to suit different scraping and fitting operations. Three types of scrapers in general use are shown in illustrations #100A,B,C.

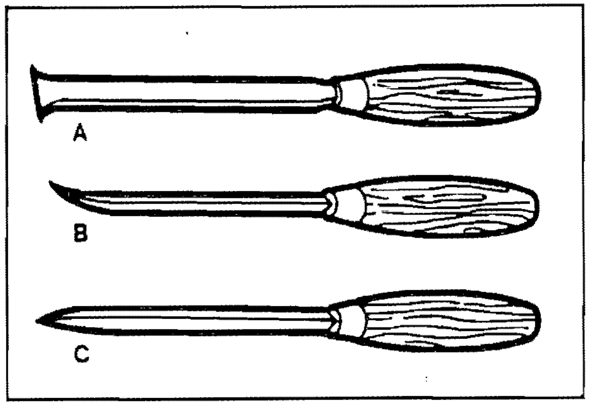


Illustration #100A,B,C-Bearing Scrapers

Journal Bearing Scraping

Flat Scrapers

Flat scrapers are generally used to remove high spots on flat surfaces. The end of the blade is ground to form an accurate cutting edge. Illustration #101 demonstrates the use of a flat scraper.

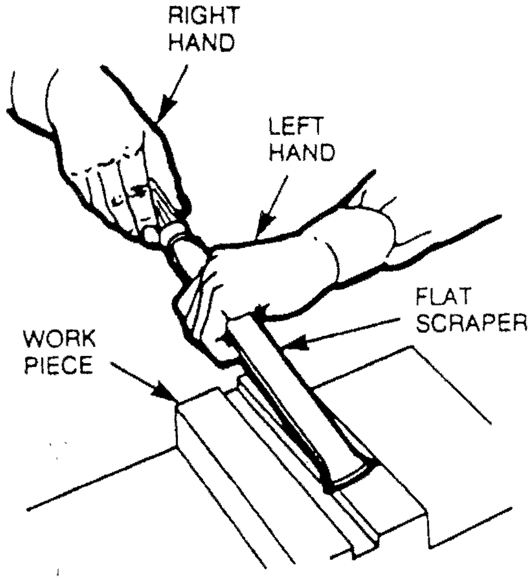


Illustration #101-Using A Flat Scraper

Using a Flat Scraper

- Hold the handle in the right hand, with the thumb and first finger running along the handle in the direction of the blade.
- Lay the cutting edge of the blade on the surface and raise the handle to approximately 20 degrees from the horizontal.
- Place the left hand approximately half way along the blade, fingers pointing downwards.
- Push the scraper forward with the right hand and, at the same time, apply light downward pressure with the left hand. The stroke should be less than one inch (25.4 mm).
- Keep the blade in contact with the surface, release the pressure and draw back the scraper into position for the next stroke.
- When the high spots have been scraped in one direction, scrape them a second time at right angles to the original direction until the desired surface finish is reached.

Journal Bearing Scraping

- Test the surface frequently with a straight edge or block until the contact markings indicate that the complete surface is in contact.

Note: Accurate scraping of any type of surface requires the scraper cutting edge to be in good condition. They are easily damaged and should be prevented from coming into contact with other tools or hard surfaces. It is advisable to keep each scraper in a protective sheath or case. A scraper must have a smooth sharp edge, free of burrs and nicks. The scraper edge should be "touched up" on an oilstone every few minutes.

Curved Scrapers and Spoons

Curved scrapers and spoons are normally used to scrape hollow surfaces such as the inner surface of a journal bearing. Illustration #102 shows an example of a babbitt spoon. The sides and point of curved scrapers and spoons are ground to form an accurate cutting edge.

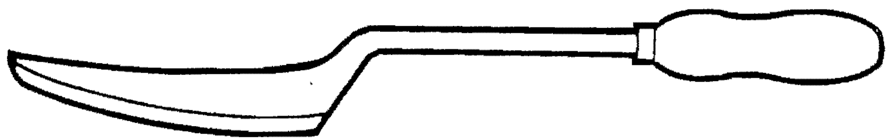


Illustration #102-Babbitt Spoon

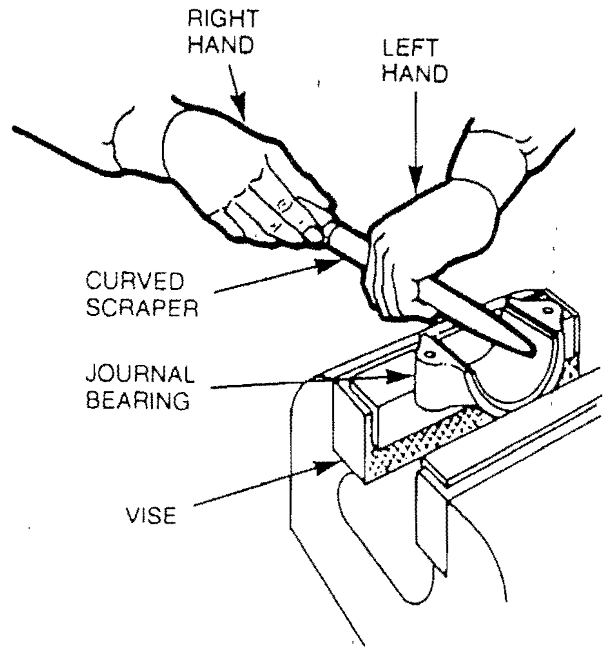


Illustration #103-Using a Curved Scraper

Journal Bearing Scraping

Using a Curved Scraper

- Hold the scraper handle in the right hand, thumb and first finger along the handle in the direction of the blade.
- Grip the blade with the left hand near the workpiece, fingers curled under the blade to allow the cutting edge to contact the bearing surface.
- Draw the blade upwards with the left hand with even pressure, and, at the same time, turn the handle slightly with the right hand to keep the cutting edge at the correct angle.
- Keep the blade in contact with the surface, move it without applying pressure into position to make the next cut.

The following is an alternative scraping method. Hold the scraper in the same method as previously described, but now rest the left hand on the vice.

In this position, the left hand is used as a fulcrum and the right hand controls the cutting action of the scraper by rotary lever movement of the handle.

Metal removal must be done evenly without "chatter" marks. The bearing surface should be checked frequently in conjunction with the part with which it has to be fitted.

Note: Scraping a journal bearing must be confined to the areas indicated by the visible high spots. A general scraping of a surface will not make the bearing surface any truer and will only remove metal from places where it is needed. Metal cannot be replaced after removal.

Three Cornered Scrapers

Three cornered scrapers are triangular in cross section giving three cutting edges. These scrapers are generally used for deburring and chamferring bored and drilled holes on small bushings and bearings and to chamfer journal bearing edges.

Journal Bearing Clearance

The establishment of correct bearing clearance is essential for reliable performance of journal bearings. Excessive bearing clearance will result in poor load distribution within the bearing, decreased fatigue life, and excessive shaft deflections. Insufficient bearing clearance may produce excessive operating temperatures, thermal growth, increased journal and bearing wear, poor oil flow, and eventual bearing failure and equipment seizure.

Journal bearings may be manufactured with an initial clearance. The initial clearance can be altered by the fits utilized on the shaft and/or housing and by the thermal growth developed during operation. The clearance remaining in the journal bearing during full operation is often termed *running clearance.* Running clearance requirements will vary with the nature of the application, load, operating speeds, and type of bearing material.

Bearings for high speed applications, over 3600RPM, will be designed for greater running clearance. The additional clearance allows for less predictable thermal differentials. Low speed equipment, under 3600RPM, often involve heavier loads and the journal bearings are designed for reduced running clearances to obtain optimum load distribution and increased fatigue life.

Note: As a general rule, for any journal bearing assembly with a constant one direction load and operation, the bearing clearance can be in the medium to loose fit range. For equipment which reverses rotation periodically, and where fluctuating loads are present, the bearing clearances can be in the medium to tight fit range. For high speed internal combustion engine bearings, using a force feed lube system, medium fits are recommended.

Journal Bearing Clearance

Table #11 provides suggested journal bearing clearances for journals operating at speeds under 600 RPM.

Also where "medium fit" recommendations are indicated, and for journals above 600RPM where "free fit" recommendations are identified.

Recommended Clearance for Lubricated Bearings; Diameter Difference In Inches				
	Medium Fit Below 600 rpm		Free Fit Above 600 rpm	
Journal Diam (In.)	Tightest Fit	Loosest Fit	Tightest Fit	Loosest Fit
¼	0.0004	0.0014	0.0006	0.0022
½	0.0006	0.0018	0.0009	0.0029
¾	0.0007	0.0021	0.0012	0.0036
1	0.0009	0.0025	0.0014	0.0040
1¼	0.0010	0.0028	0.0016	0.0044
1½	0.0012	0.0030	0.0018	0.0047
1¾	0.0013	0.0033	0.0020	0.0052
2	0.0014	0.0034	0.0022	0.0054
2¼	0.0015	0.0035	0.0024	0.0058
2½	0.0017	0.0039	0.0026	0.0062
2¾	0.0018	0.0041	0.0028	0.0065
3	0.0019	0.0043	0.0029	0.0067
3¼	0.0021	0.0045	0.0032	0.0072
4	0.0023	0.0049	0.0035	0.0077
4½	0.0025	0.0051	0.0038	0.0080
5	0.0026	0.0054	0.0041	0.0085
6	0.0030	0.0060	0.0046	0.0094
7	0.0033	0.0063	0.0051	0.0101
8	0.0036	0.0068	0.0056	0.0108

Table #11-Bearing Clearances

Journal Bearing Shims

Shims are inserted between the bearing halves to provide the required amount of journal bearing clearance. Shims should not contact the journal and should be made so they do not interfere with the chamfered edge of the bearing halves.

Shims are normally made from brass or stainless steel stock. These materials do not compress easily and are not affected by the lubricant.

Illustration #104 identifies the slip-in style of shim often used on gib joints or flat joints. The advantage of slip in shims is that they can be inserted or removed after loosening off the bearing cap bolts. Illustration #105 shows a shim that will not slip out of place. The bearing cap must be removed to adjust the amount of shim for setting clearances.

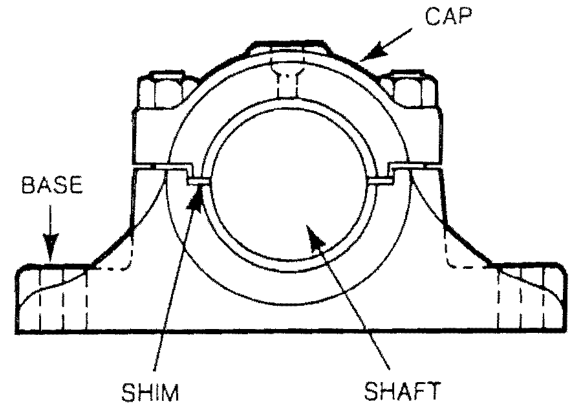


Illustration #104-Slip in Shim

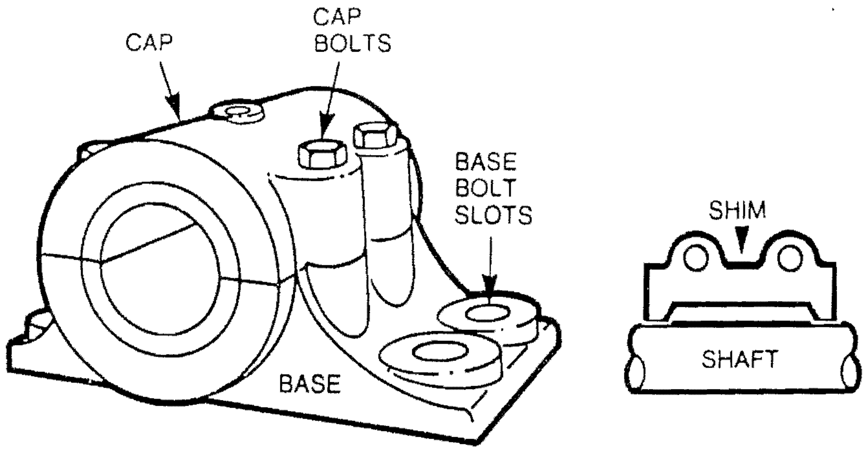


Illustration #105-4 Bolt Shim

Clearance Checks

Several methods can be used to determine the clearance in a journal bearing.

Feeler Gage Method: With the two bearing halves properly tightened and torqued to required specifications, initial clearances can be found on some equipment by inserting feeler gages between the journal and the shimmed bearing cap. This method works well if the bearing is open at either end, allowing the feelers to be inserted.

Dial Indicator Method: When a journal bearing is shielded at either end by housings, gears, etc. the simplest method to check for bearing clearance is by mounting a dial indicator on a magnetic base and having the indicator point contact the shaft. By carefully prying or lifting up on the shaft and closely watching the dial, one can determine the bearing clearance. It is recommended that jacks be used at both ends to lift the shaft evenly for an accurate dial reading.

If only one jack is used, the shaft may tilt within the journal bearing and give a false dial reading.

Illustration #106 demonstrates the dial indicator method for determining the clearance within a journal bearing. A dial reading will indicate the total clearance in the bearing but will not identify the high and low spots. Any wear checks must be performed visually.

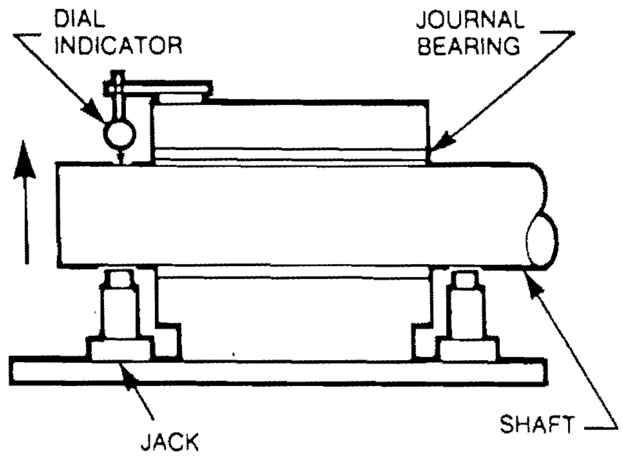


Illustration #106-Checking Clearances

Clearance Checks

Plasti-Gage Method: Plasti-gage is a soft material which will easily deform when squeezed between the journal and the bearing with the cap bolts properly torqued. A small length of plasti-gage is placed on the bearing half. The plastic sits on the center-bottom portion of the bearing parallel to the shaft's axis. Be careful not to roll the shaft.

After removal of the bearing cap, the flattened material is compared with a prepared gage chart and the tolerance can be read in thousandths of an inch or hundredths of a millimeter directly from the chart. Illustration #107 shows how a plasti-gage reading is taken from the bearing half and compared to the standard chart.

Note: *Avoid Lubrication Contamination — Remove Used Plasti-Gage*

Lead Wire Method: With the bearing cap removed, lengths of lead wire are placed across the shaft in several positions. The cap is torqued to the recommended amounts, then removed again.

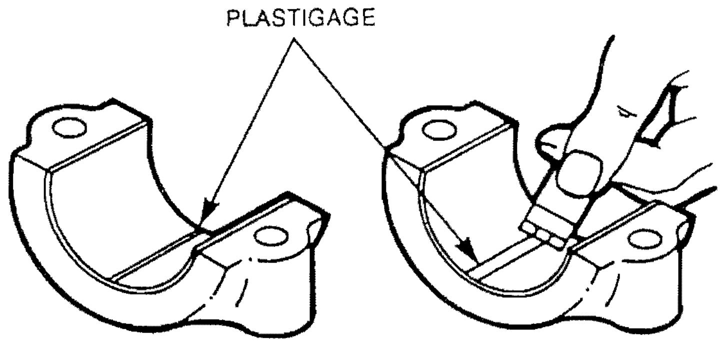


Illustration #107-Using Plasti-Gage

The thickness of the squeezed lead wire is measured with a micrometer to determine the amount of bearing clearance. Care must be taken when removing the cap as some wire may adhere to the cap and some to the journal. Record the thickness of each compressed wire to help determine if there are any high and low spots in the bearing/journal assembly. Use a small diameter soft lead wire to avoid damaging the bearing material.

Journal Bearing Crush:

When using replaceable journal bearing inserts it is important that the inserts have positive contact with the housing or seat. To assure this, the diameter of the two matching inserts, when placed together at right angles to the parting line, is slightly larger than the diameter across the parting surface when the bearing is in place; thereby requiring this amount to be compressed when the bearing cap is torqued in place.

Illustration #108 identifies two connecting rods from an internal combustion engine where proper crush height exists. *The excess height is called the crush and its primary purpose is to permit the insert to be positively locked into the bearing seat.* If the bearing has insufficient crush it will not be held securely and will have a slight amount of play during operation. Loose inserts will allow the lubricant to work its way between the back of the bearing and the housing.

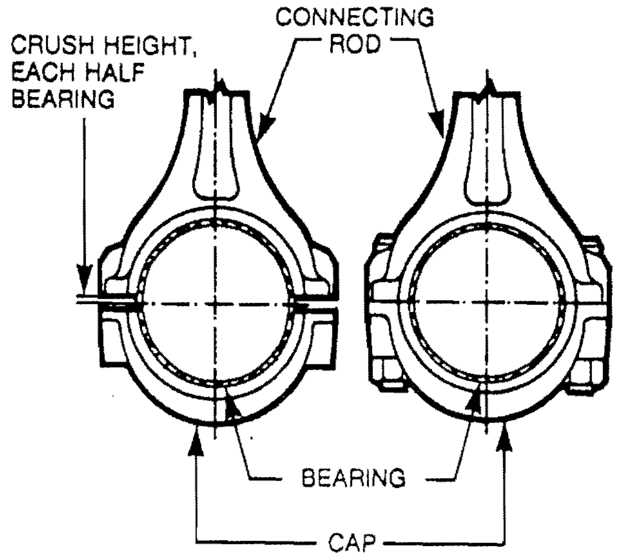


Illustration #108-Bearing Crush

This reduces heat conductivity and eventually raises the bearing temperature.

Insufficient bearing crush can be caused by filing or grinding of the parting surfaces of the shells or because of the presence of foreign particles lodged between the parting faces of the bearings and bearing caps. The dirt acts as a shim which prevents the faces from coming together.

Journal Bearing Crush

Under no circumstances are the parting surfaces of the inserts, the caps or the saddle to be ground or filed. Do not attempt any operation on the bearing insert other than correcting the spread, and this only when necessary. The spread is built into the bearing so that the inserts have to be lightly pressed into position. If the inserts have excessive spread, they can be tapped lightly on the end to close up the spread. If the inserts have insufficient spread they can be opened by placing them on a wooden block with a convex side and gently tapping the insert with a hammer.

Bearing Bolt Torque

It is necessary to use recommended bolt torque values and a torque wrench when locking a bearing cap down during assembly. Any variations in torque amounts and sequence can affect the bore size, bearing crush, clearances, and bearing performance.

Journal Bearing Housings

The proper mounting of a journal bearing to the shaft and machine frame is a critical factor in the performance of the unit. The journal bearing is sensitive to shaft deflections, misalignments, distortions, vibrations, and surface imperfections of the mating machine elements.

The choice of bearing housing style will depend on the load, speed, direction of load, and the support design of the housing.

Bearing Housing Styles

Flat Bearings: Flat bearing housings are intended to be used to support rotating shafts that are in flat-horizontal positions, such as flat belt conveyors or live roll conveyors.

There are two types of flat bearings: *solid bearings, as indicated in illustration #109 or split bearings.* Solid bearing housings must be slid on or off of the journal.

Bearing Housing Styles

Solid bearings can have bronze, babbitt or synthetic material liners and they have a recommended load range of approximately 300 degrees.

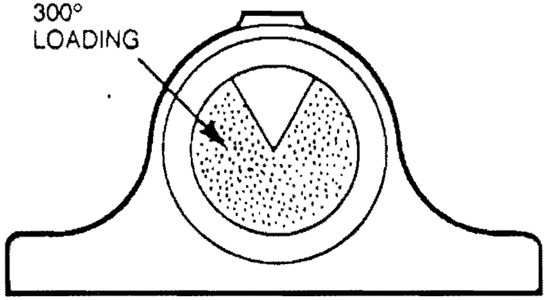


Illustration #109-Solid Bearing Housing

Split Style: Illustration #110 shows an example of a four bolt split bearing. This bearing is considered a flat bearing as it is recommended for supporting journals that are in flat-horizontal positions. Split bearing designs could be either two bolt, used for light to medium loads, or four bolt, used for medium to heavy loads.

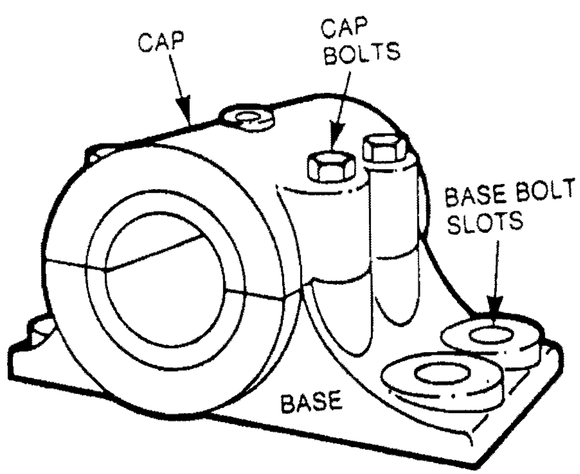


Illustration #110-4 Bolt Split Housing

Split journal bearing housings can have two joint styles: *flat joint and gib joint.*

Flat Joint: The split bearing housing may have the joint flat (horizontal) as shown in illustration #111 or with a slight V-joint as shown in illustration #112. These housings should have no loads on their sides, therefore their recommended loading range is 120 degrees.

Bearing Housing Styles

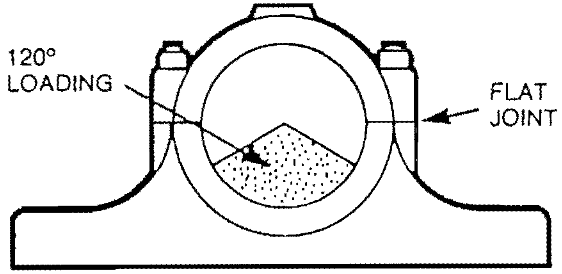


Illustration #111-Flat Joint Split

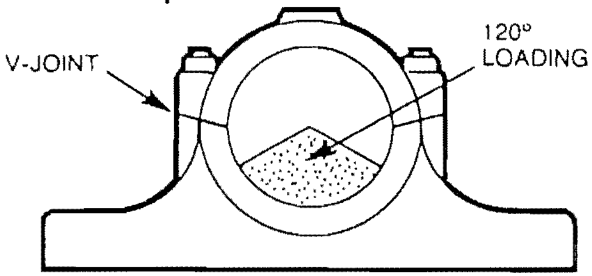


Illustration #112-V-Joint Split

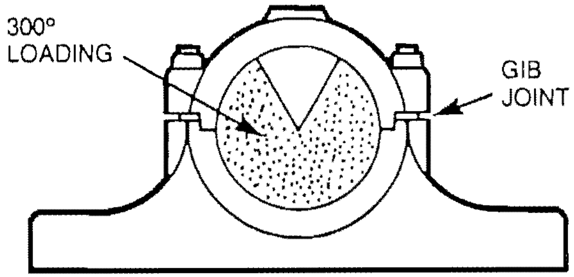
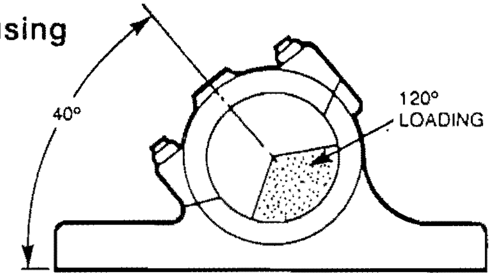


Illustration #113-Gib Joint Housing

Illustration #114-40 Degree Housing



Gib Joint: The gib in the joint of the flat style journal bearing housing helps to positively locate the cap and prevent it from shifting sideways. A gib joint housing combines the rigidity of a solid bearing with the advantages of split construction and is suitable for side loading of up to 300 degrees. Illustration #113 identifies a gib joint split half flat bearing housing.

Angle Journal Bearing Housings

Angle bearings are used for drives where the load is applied parallel to, or slightly above the horizontal. The special shape of the bearing will secure the shaft in position without applying the load to the bearing cap.

Bearing Housing Styles

These housings, as shown in illustration #114, are especially suited for angular loads, with the recommended load range being approximately 120 degrees.

Integrated Journal Bearings

Some industrial equipment is cast with the journal bearing housing as an integral section of the machine. The line bore of the bearing housing must be accurate, even tightening of the machine parts and foundation supports is also very critical as any amounts of unevenness or twisting on the machine frame will cause internal misalignment to the journal bearings.

Integral bearings can be babbitted in place, or the housings can be fitted with removable inserts or bushings made from a variety of metallic and non-metallic bearing materials.

Journal Bearing Lubrication

There are numerous methods used on industrial equipment to supply sufficient lubricant to the journal bearings. The more common of these methods are described as follows:

Oil Ring Lubrication: Oil is supplied to the bearing by a ring in contact with the rotating shaft. The ring rotates and will, within reasonable limits, supply enough oil to the bearing to maintain hydrodynamic lubrication. *If the shaft speed is too low, minimal oil will follow the ring to the bearing; and if the rotational speed is too high, the ring speed will have difficulty keeping pace with the shaft.* A high speed ring can lose oil by the action of centrifugal force. For best results, the peripheral speed of the shaft should be between 200 and 2000 feet per minute (61 to 610 meters per minute). Illustration #115 identifies a ring oiler in a journal bearing.

Journal Bearing Lubrication

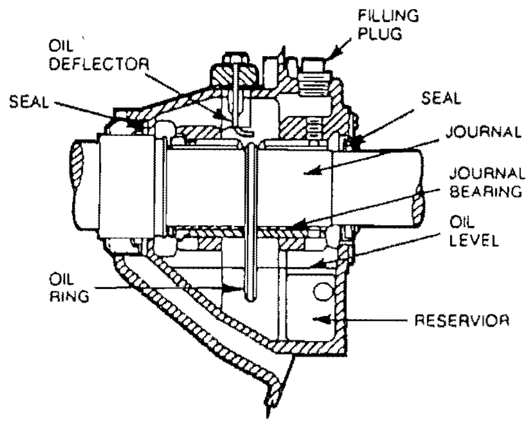


Illustration #115-Ring Oiler System

Oil Bath Lubrication: An oil bath lubrication system is one in which the bushing is partially or fully submerged in oil. It can be a practical method of lubrication if the housing can be made oil tight, and if the shaft speed is not so great as to cause excessive churning of the oil.

Splash Fed Lubrication: Splash fed is a term applied to a variety of intermittently lubricated bushings or journal bearings. The bearings could be splattered with oil from the action of various moving parts regularly dipped in the lube oil. Like oil bath systems, splash feeding is practical when the housings can be positively oiltight and when the rotating parts do not churn up the oil too much.

Wick Lubrication: This method delivers oil to a bushing or bearing by the capillary action of a wick; the amount delivered being proportional to the size of the wick. This system is recommended for small, slow turning shafts, and where the loads are light. This system does not provide for any great amount of hydrodynamic lubrication.

Journal Bearing Lubrication

Pressure Lubrication: Oil under pressure is fed to the journal bearing from a positive displacement pump via a central oil groove, single or multiple holes, or axial grooves. The flowing oil assists in flushing contaminants from the bearing.

Bearing Lubrication

It also helps to dissipate the heat from the bearing. The oil supply pressure required for journal bearings carrying medium loads is dependent upon the shaft speed, load, and type of oil used in various operating temperatures. For most journal bearing installations 50PSI (344KPa) will be adequate.

Journal Bearing Failure

- Incorrect manufacturing procedures.
- Selection of unsuitable shaft and bearing material.
- Incorrect oil grooving.
- Unsuitable bearing and journal surface finishes.
- Equipment overloading.
- Equipment overspeeding.
- Loss of oil supply.
- Insufficient clearances between the journal and bearing.
- Faulty relining (babbitting) practices.
- Improper preparation of bonding surfaces for babbitting.
- Poor babbitt pouring techniques.
- Contamination in the babbitt alloy materials.
- Poor practice of reclaiming babbitt from worn out bearings.
- Presence of dirt between the insert and the bearing shell.
- Excessive operating temperatures.
- Partially restricted oil circulation from oil coolers.
- Oil viscosity too high or too low.
- Abrasive contaminants in the oil supply.
- Corrosion of the bearing material.
- Bearing fatigue under cyclic loads.
- Use of unsuitable lubricants.

SECTION THREE QUESTIONS

FRICTION BEARINGS

1. *A journal bearing consists of two major parts. These are:*
a. ______________________________
b. ______________________________

2. *What two loads can journal bearings carry?*
a. ______________________________
b. ______________________________

3. *Fluid lubrication in a journal bearing depends mainly upon:* ____________________ .
a. the load
b. viscosity of the lubricant
c. adhesion to the surfaces of the journal and bearing
d. both "b" and "c"

4. *What is considered one of the best methods for providing film lubrication to friction bearings not fed under constant oil pressure?*
a. oil wedge
b. oil grooves
c. oil holes
d. external wipers

5. *Which type of oil groove should be avoided?*
a. wide, shallow grooves
b. grooves with rounded edges
c. sharp edged v-grooves
d. circumferential grooves

6. *To maintain an efficient oil film, the axial oil groove is best located in the ______________ sector of the journal bearing.*
a. loaded
b. unloaded

7. *Hydrostatically lubricated journal bearings: ____________________.*
a. use lubricant supplied under pressure from an external source
b. rely on an oil wedge to draw the oil between the journal and the bearing surfaces
c. are recommendend for uses requiring frequent machinery startup/shutdown and operating at minimal speeds
d. both "a" and "c"

8. *High pressure oil is usually supplied to a journal bearing: ____________________.*
a. between the top of the journal and the bearing
b. between the bottom of the journal and the bearing

9. *A plain thrust bearing: ______________________ .*

a. transfers thrust loads from the shaft to the radial bearings
b. transfers thrust loads from the shaft to the frame of the machine
c. absorbs shaft loads
d. both "a" and "c"
e. both "b" and "c"

10. *What type of shafts always produce thrust loads, therefore require the use of a thrust bearing.*

a. horizontal
b. vertical

11. *Indicate two methods of finding the bearing clearance in a thrust bearing.*

a. ____
b. ____

12. *The tilting pad thrust bearing: ______________________ .*

a. can be mounted vertically or horizontally
b. can be used for low and high speed applications
c. can absorb significant amounts of misalignment without loss of performance
d. all of the above

13. What keeps the tilting thrust pad's surface separated from the shaft collar?

a. bearing cage
b. pivots
c. levelling screw
d. oil wedge

14. Refer to Table #5, page 118, to determine what the end clearance shouldbe for a 25 inch diameter thrust bearing mounted on a machine operating at 500 RPM.

Answer: ______________________________

15. Which type of bearing is often used as a positioning device?

a. roller bearing
b. thrust bearing
c. journal bearing
d. guide bearing

16. Which type of bearing used to support radial loads uses shoes positioned by cylindrical grooves in a retaining ring?

a. tilting pad thrust bearing
b. guide bearing
c. pivoted shoe journal bearing
d. none of the above

17. Journal bearings are easier to lubricate than roller bearings at high speeds.

a. true

b. false

18. Journal bearings require less radial space than roller bearings.

a. true

b. false

19. Poor resistance to scoring in journal bearings is called: ______________ .

a. fatigue resistance

b. cohesive wear

c. adhesive wear

d. abrasive wear

20. A journal bearing material's ability to absorb contaminants and particles within itself is called:

a. conformability

b. embedability

c. compatibility

d. absorbability

21. The ability of a bearing material to flow slightly under load is called: ______________ .

a. conformability
b. load capacity
c. embedability
d. fatigue resistance

22. Seizures in journal bearings usually occur because of: ______________ .

a. localized hot spots
b. poor thermal conductivity
c. poor bearing fit
d. all of the above

23. The material of a plain bearing should be ______________ than the material of the journal.

a. harder
b. softer

24. Which bronze bearing material has the ability to absorb oil?

a. tin
b. lead
c. phosphor
d. sintered

25. *Refer to Table #7, page 135, to determine the three properties of lead base babbitt.*

a. ________________________________

b. ________________________________

c. ________________________________

26. *Refer to Table #8, page 136, to determine which bearing material has the worst conformability and embedability qualities.*

Answer ________________________________ .

27. *Which bearing material is classed as being self lubricating?*

a. teflon
b. babbitt
c. bronze
d. aluminum

28. *Prior to pouring molten babbitt, the bearing shell must be heated.*

a. true
b. false

29. *The "tinning" process, as applied when preparing to pour babbitt bearings, refers to:*

________________ .

a. applying 50-50 solder to the mandrel
b. inserting thin pieces of tin or shim stock between two bearing halves
c. coating the mandrel with soot from a carburizing flame
d. applying a coating of 50-50 solder to the bearing shells

30. *A pyrometer can be used to determine the recommended pouring temperature of the babbitt.*

a. true
b. false

31. *The mandrel is the dummy shaft machined to a larger diameter than the actual shaft journal.*

a. true
b. false

32. *What material must not be present on any metal parts in contact with molten babbitt?*

a. water
b. oil
c. grease
d. all of the above

33. *To ensure good distribution of the lubricant the edge(s) of each bearing half must be:* ______________________ .

a. squared
b. rounded
c. chamfered
d. roughened

34. To check for the amount of contact between the journal and the bearing use: ______________________.

a. plasti gage
b. lead wire
c. dial indicator
d. mechanic's bluing

35. Equipment and bearing manufacturers may recommend a contact area from 75% to 90%.

a. true
b. false

36. What is one of the most accurate methods for removing high spots from a babbitt bearing?

a. machining
b. lapping
c. hand scraping
d. grinding

37. Shims are inserted between the bearing halves to:

a. establish the oil wedge
b. provide the required amount of journal bearing clearance
c. assist in aligning the bearing halves
d. insulate the bearing from the shaft

38. *Identify four methods used to determine journal bearing clearances.*

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

39. *"Bearing crush" refers to:* ______________ .

a. an overloaded journal bearing
b. overtightening journal bearing caps/covers
c. the bearing inserts having positive contact with the bearing seat in the housing

40. *A split journal bearing housing having a gib joint is suitable for:* ______________ .

a. a maximum of 180 degree loading
b. a maximum of 120 degree loading
c. a maximum of 300 degree loading

41. *Which method of lubrication uses centrifugal force to distribute the oil to the bearing?*

a. splash fed
b. oil bath
c. pressure lubrication
d. oil ring