Advanced Diploma in Engineering and Technology

EAL
EMTA Awards Limited

VRQ3

Maintenance of Mechanical Systems

Unit 29.3

(Bearings)

NEATH PORT TALBOT COLLEGE
COLEG CASTELL NEDD PORT TALBOT
NPTC

Rolling Element Bearings

Rolling element bearings, or anti-friction bearings as they are often called, differ from plain bearings in that they incorporate rolling elements, either balls or rollers, which are held between two raceways as shown below. A soft metal cage or retainer separates the rolling elements and ensures that they are evenly spaced, but does not carry any load. As a result of the very small of contact between the rolling elements and the races, the frictional resistance to relative motion is comparatively low.

Because the relative motion between the moving elements is one of rolling rather than sliding, the material requirements are quite different from plain bearings. Instead of requiring bearing materials to be soft in comparison with the journal, both the rolling elements and the raceways of rolling element bearings are made of specially hardened steel. The harder the elements, the smaller the indentation and deformation of the surface and hence the lower the frictional resistance. However, although sliding action between the two moving elements is much reduced, in comparison to plain bearings, it cannot be eliminated entirely, and therefore lubrication is just as critical to rolling element bearings as to plain bearings.

Rolling element bearings are manufactured to very precise standards of accuracy to ensure good performance and long life. Tolerances are held to a thousandth or in some cases a tenth of a thousandth part of a millimetre in order to minimise run-out and to ensure the proper radial and axial clearances required for smooth operation.

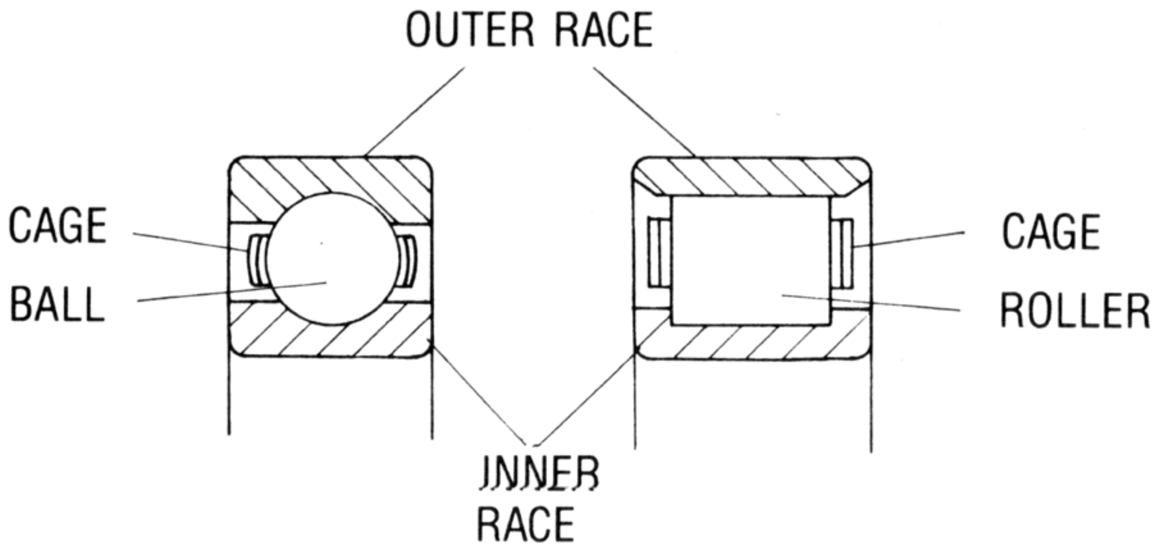
The choice of balls or rollers as the rolling elements depends on the operating conditions and the following

Ball Bearings

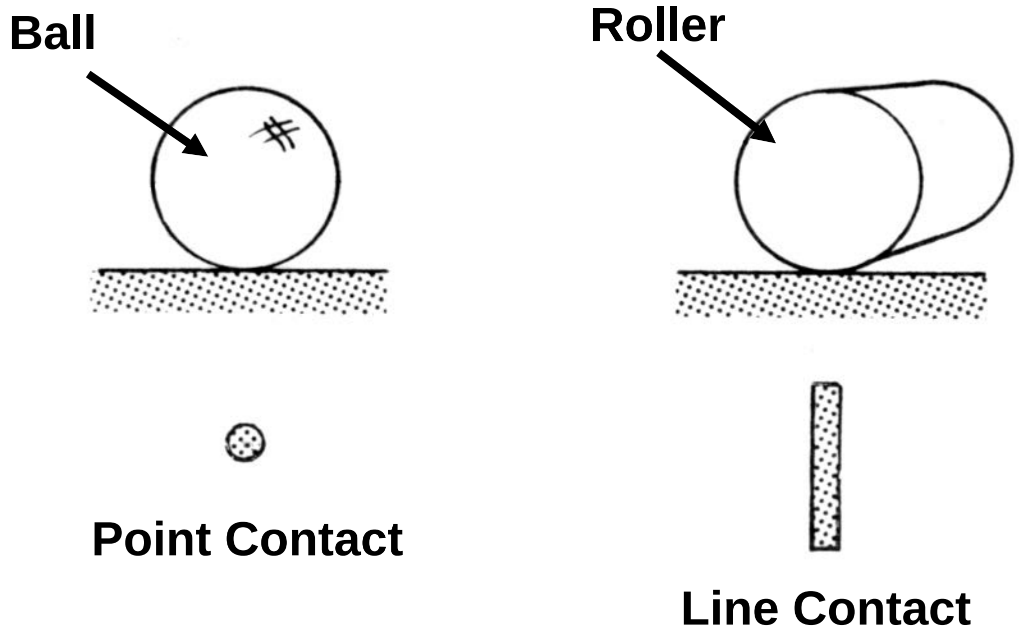
Ball bearings can operate at higher speeds without overheating, are less expensive for lighter loads, have lower frictional resistance at light loads, are available in a wider range of sizes.

Roller Bearings

Roller bearings can carry heavier loads, are less expensive for heavier loads and larger sizes, are superior under shock or impact loading, provide greater rigidity.



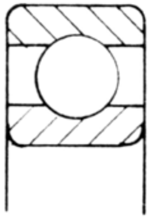
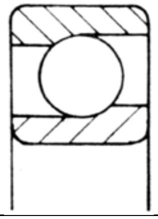
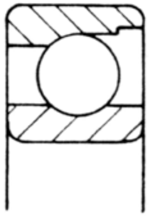
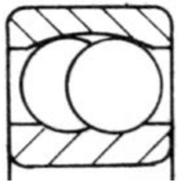
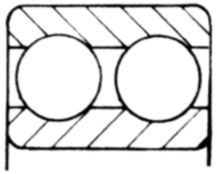
The important physical difference between balls and rollers that gives rise to the differences in performances indicated above is the variation in area of contact between the rolling elements and the raceway. The ball has a small area of contact which resembles point contact depending how much deformation of the ball and raceway occurs. The roller, by comparison, has a greater area of contact which resembles line contact. (***see below***).



The greater area of contact of the roller makes it better able to carry heavy loads and withstand impact, but tends to increase frictional resistance at low loads. Ball bearings generate lower resistance at low loads but deform more significantly at high loads which causes frictional resistance to increase. Ball bearings can run at higher speeds due to the smaller area of contact.

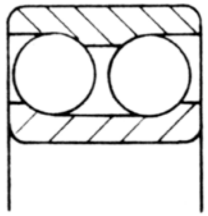
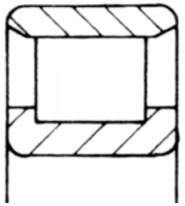
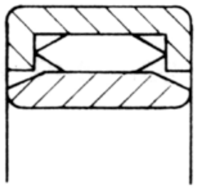
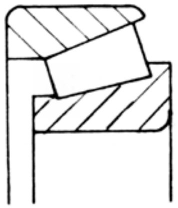
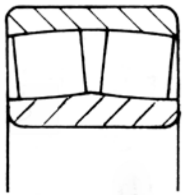
Types of Bearing

Rolling Element Journal Bearings

	Type	Radial Load	Axial Load	Speed	Misalignment Tolerance	Axial Location
	Single row deep groove ball	very good	good	excellent	good	both directions
	Single row angular contact ball	very good	very good	good	fair	one direction
	Magneto	fair	fair	very good	poor	one direction, both directions when used in pairs
	Self aligning ball	good	very poor	very good	excellent	both directions
	Double row deep groove ball	very good	good	excellent	fair	both directions

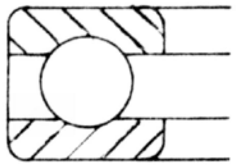
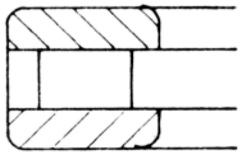
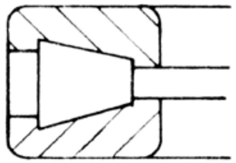
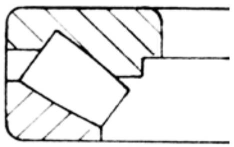
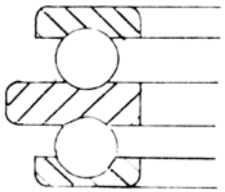
Types of Bearing

Rolling Element Journal Bearings

	Type	Radial Load	Axial Load	Speed	Misalignment Tolerance	Axial Location
	Double row angular contact ball	very good	very good	good	fair	both directions
	Roller	excellent	very poor	very good	poor	---------
	Needle roller	excellent	very poor	fair	very poor	---------
	Tapered roller	excellent	very good	good	poor	one direction
	Spherical roller	very good	good	fair	excellent	both directions

Types of Bearing

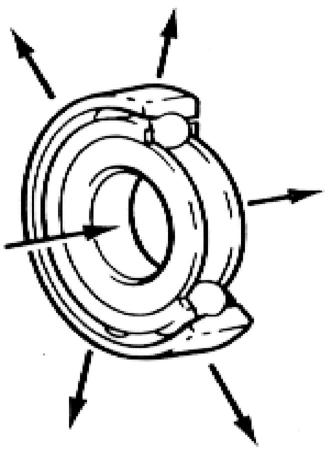
Rolling Element Thrust Bearings

	Type	Radial Load	Axial Load	Speed	Misalignment Tolerance	Axial Location
	Single row ball	---------	very poor	fair	poor	one direction
	Cylindrical roller	---------	excellent	poor	very poor	one direction
	Tapered roller	---------	excellent	poor	very poor	one direction
	Spherical roller	poor	very good	poor	very good	one direction
	Double row ball	---------	good	poor	poor	both directions

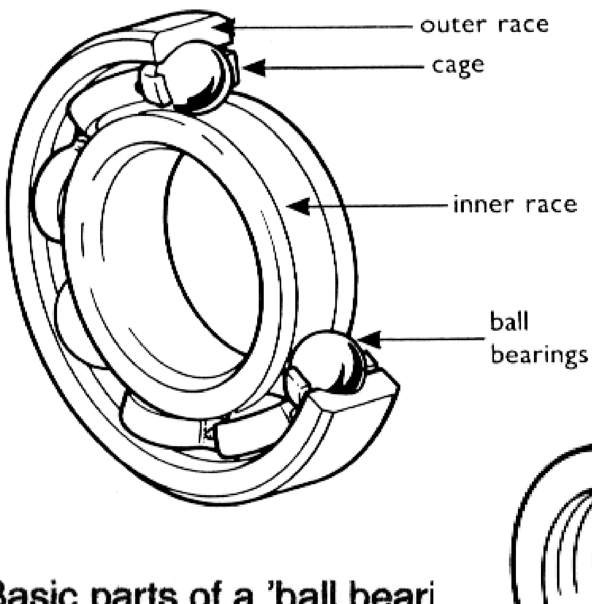
Rolling Bearings

Ball Bearings

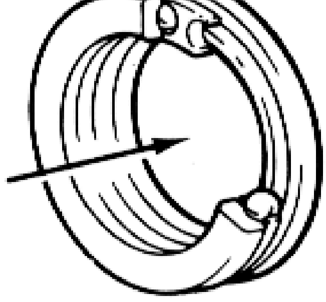
Ball bearings get over the problem of having a shaft rubbing against a bearing. A row of hardened steel spheres, fitted between the shaft and the component, roll around as the shaft spins. The illustrations below show the basic parts of a ‘ball bearing’. The outer race is firmly fixed to the component and the inner race is firmly fixed to the shaft. They are usually a tight ‘press’ fit. The spheres, running in grooves inside the two races, are kept from rubbing against each other by the cage. The cage can be made of steel, brass or plastic. Ball bearings are usually lubricated using grease. Some have shields fitted to keep the grease in and the dust out. Ball bearings can also be used to take axial loads or both radial and axial loads at the same time. They are widely used on all types of machinery.



Takes axial and radial loads



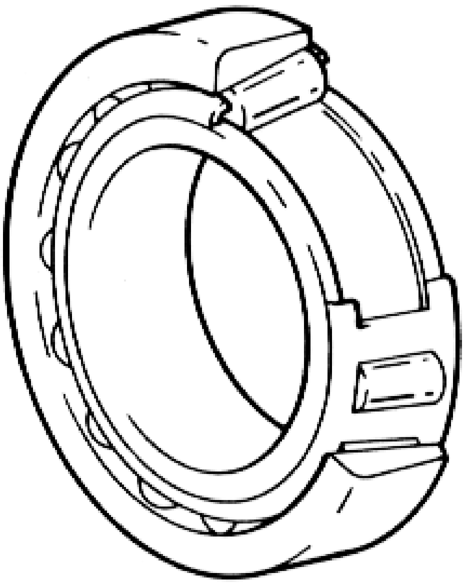
Basic parts of a ’ball beari

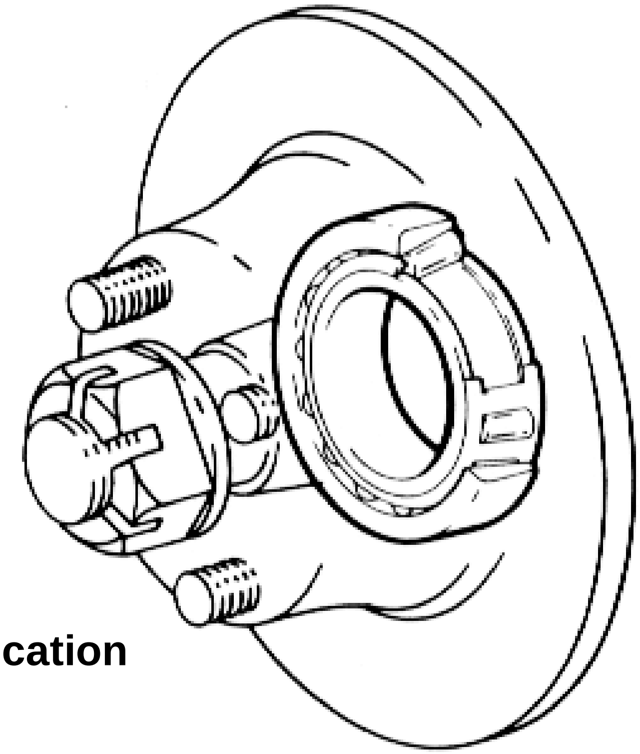


Takes axial loads

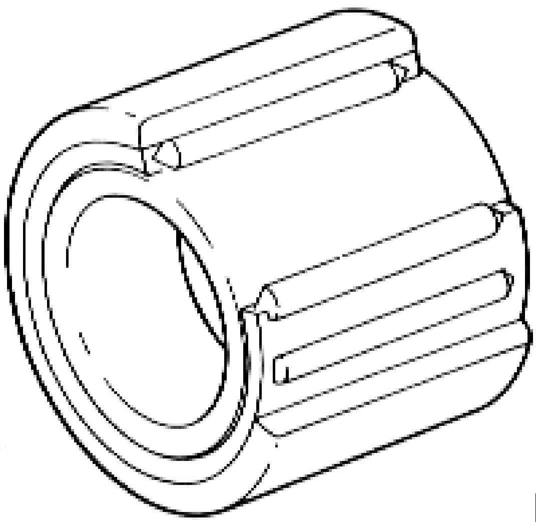
Roller Bearings

Roller bearings are similar to ball bearings in many ways. The basic difference is that they use steel rollers instead of balls. They are used where greater loads have to be carried or where there is limited space. Where space is really limited needle roller bearings are used. Taper roller bearings, which will cope with radial and axial loads, are used for wheel bearings of most vehicles.





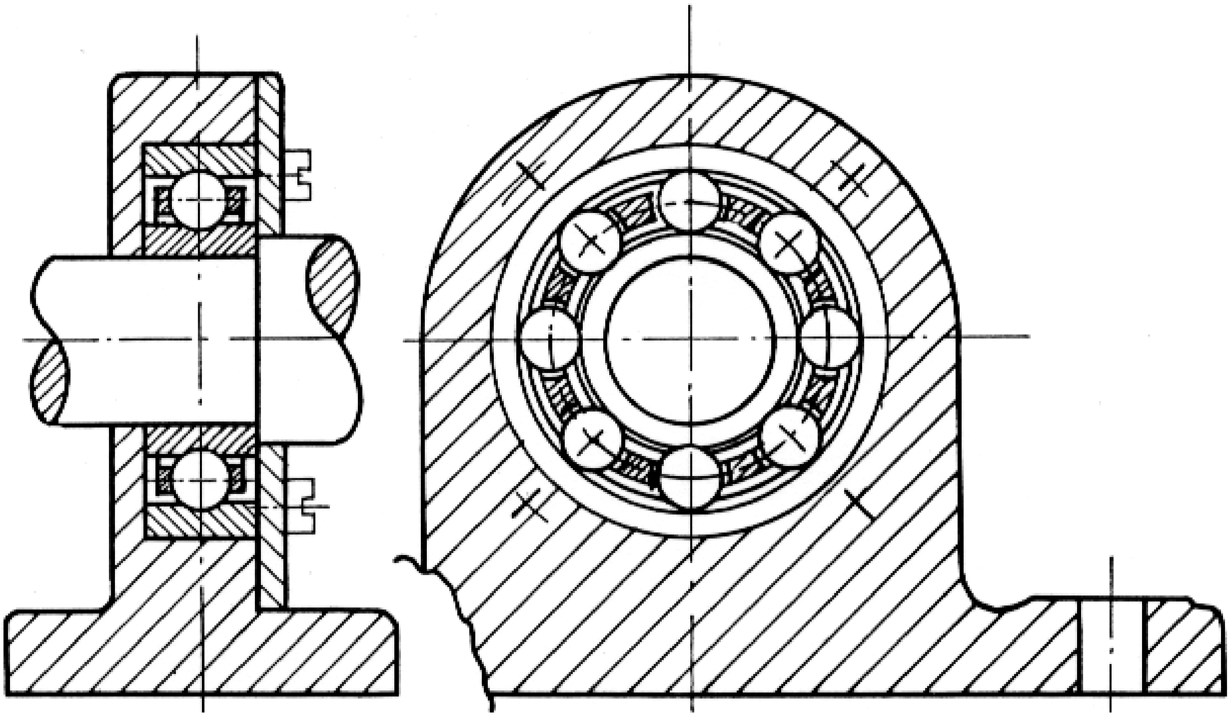
Taper roller bearing and application



Needle roller bearing

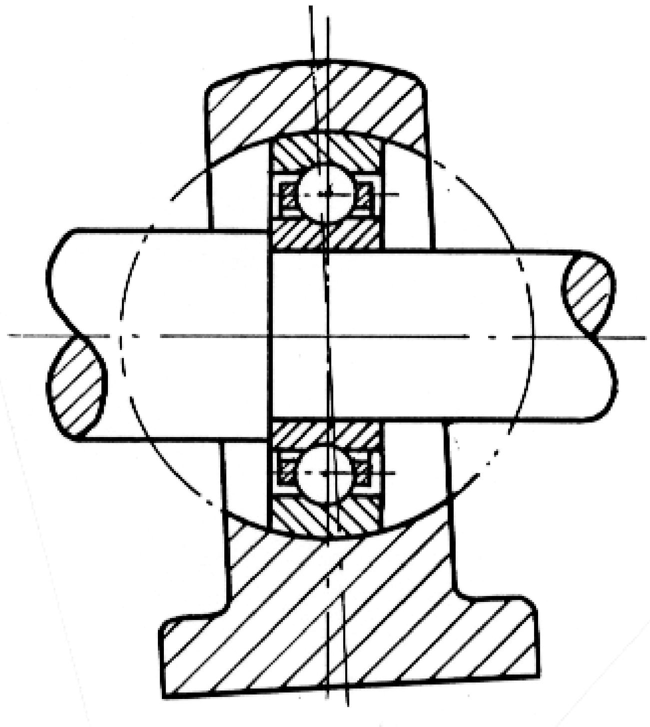
Single Row Ball Bearings

The race is composed of an inner and outer hardened grooved ring between which run hardened steel balls carried and spaced in a cage. Ball bearings are made in a wide range of sizes, the smallest are found in watches whilst the largest are used in turrets of heavy naval guns. The simple type shown below usually fits into a recess turned in the housing and is retained by a collar or by shoulders on the shaft

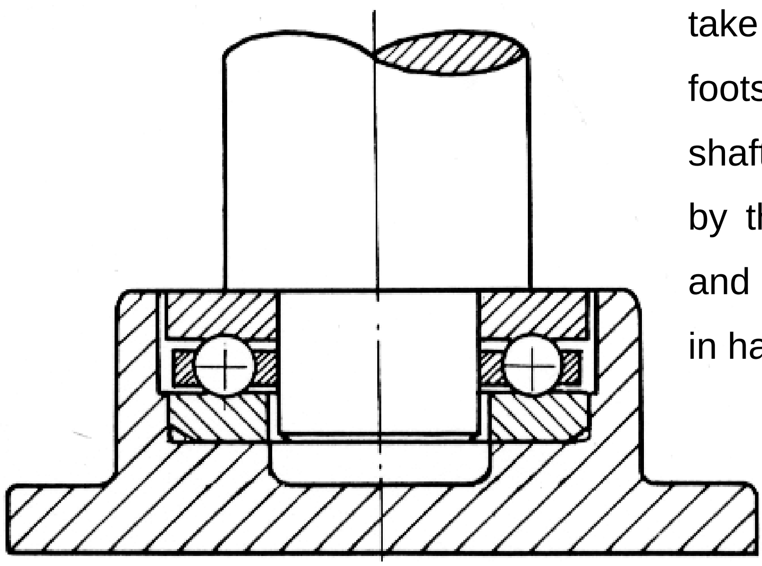


Self-aligning Ball Bearings

The outer shell is ground to the same spherical line as the housing enabling the bearing to align itself to the shaft line which may vary as the load is applied. The bearing also adjusts itself to small in exactitudes if the housing is incorrectly laid.



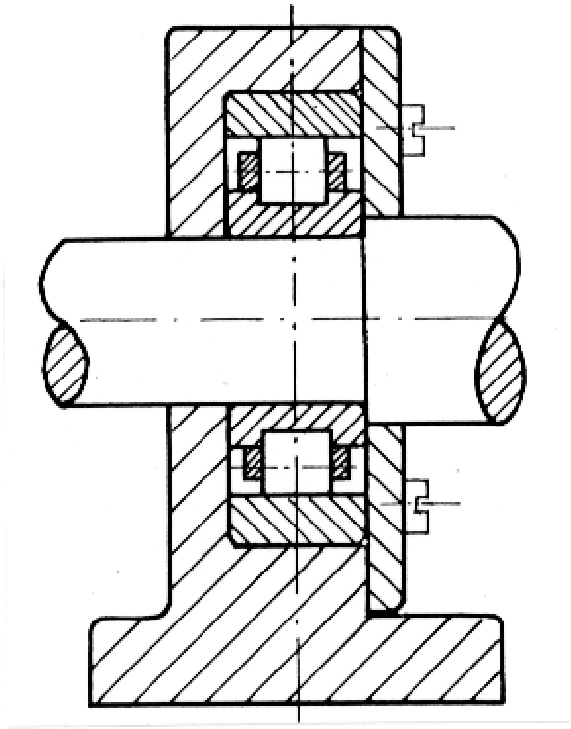
Thrust Race



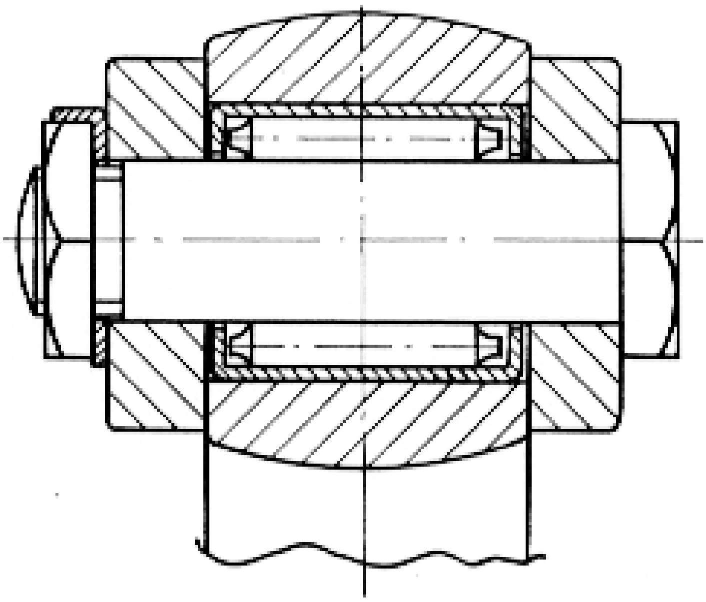
Ball bearings may be used to take end thrust as shown in this footstep bearing for a vertical shaft. The axial thrust is taken by the walls carried in a cage and moving in circular grooves in hardened steel plates.

Roller Bearings

In bearings which carry heavier loads, roller bearings are used, the line contact of the roller and shell giving better radial capacity. Rollers are spaced in cages and may be arranged to run in a groove cut in the inner shell whilst the outer shell being plain, allows some axial movement. The rollers may be arranged in single, double or triple rows to carry greater loads.



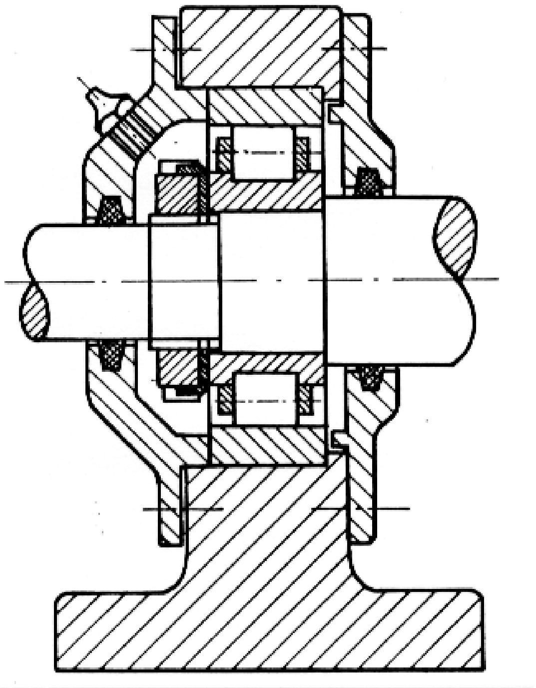
Needle Roller Bearings



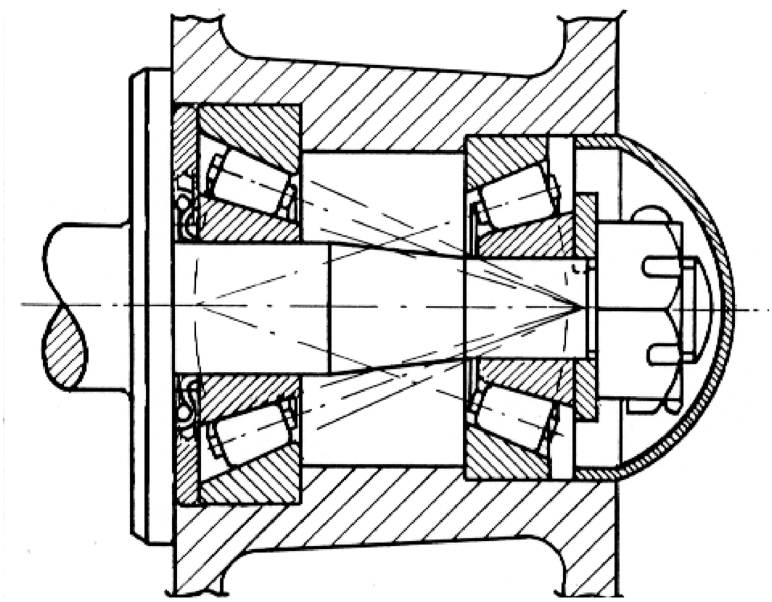
Caged needle roller bearings can be used where space is restricted. The end of the roller is reduced and rounded to prevent it acting as an end mill and cutting the cage. The rollers run on the shaft which requires to be hardened.

Sealed Roller Bearings

This illustration shows a heavy duty roller bearing. The inner shell is secured to the shaft by a screwed collar and tab washer. The housing is sealed by synthetic rubber or plastic rings set in grooves. The housings acts as an oil reservoir.



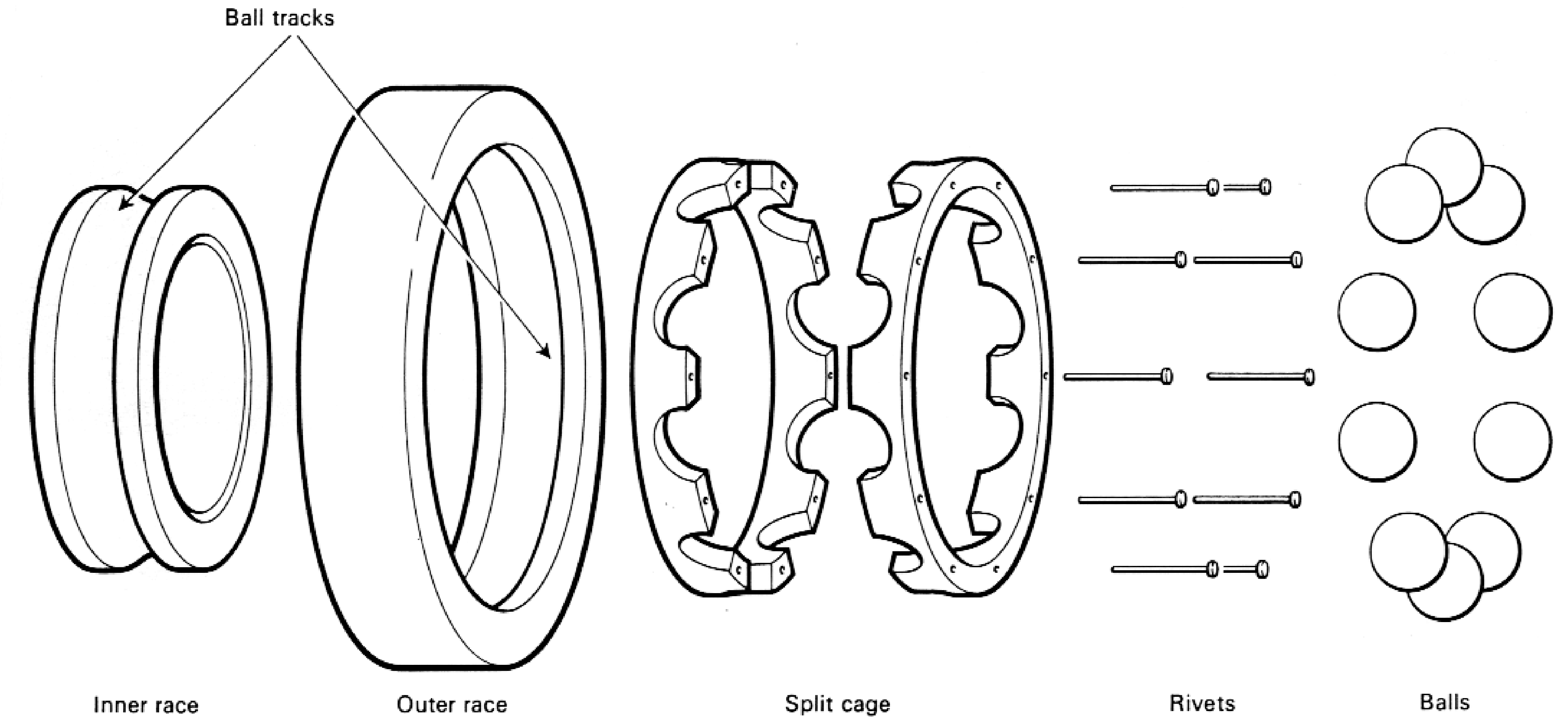
Tapered Roller Bearings



Where radial and axial thrust is present, tapered rollers can be used. The diagram shows a bearing with double tapered rollers used in automobile front wheels capable of absorbing radial and double axial thrust at high speeds. The bearing is lithium grease packed and sealed with a garter spring seal, the bearings are secured and adjusted by a slotted nut and split pin.

Single Row Ball Journal Bearings

These types of bearing usually carry radial loads but can carry axial loads or both radial and axial loads at the same time. It consists of an inner ring which must be a tight or ‘interference’ fit on the shaft. The outer race should be a push fit in the housing and the balls are maintained by a light cage, retaining ring or separator which ensures equal distribution of the load when the shafts rotates, the revolving inner race moves with the shaft, the balls rotate between the surface of this race and the surface of the outer race.



Roller Bearings

Typical Applications

Railway axle boxes, heavy electric motors, automotive transmissions, heavy fans, pumps and compressors, rolling mill shafts, heavy duty spindles on machine tools, gearbox pinion drives, rod and wire mill shafts, heavy duty pulleys, rotating dryers, large radar and telescope tracking systems, turbines, generators and compressors.

Construction

Generally the rings and rolling elements are made from high grade, direct hardened, carbon chromium steels producing a surface hardness of between 59 and 65 HRC. The cages of small and medium size bearings are normally made from pressed steel or brass. Cages machined from solid material, usually brass, are used on larger sizes. Various plastics materials and, in some cases, special cast irons, are also specified depending on bearing size and duty.

Notes on selection and use

These bearings are usually used for medium and heavy load applications in the radial direction only. Although commonly used in the larger diameter range, their general resistance to dynamic radial loads makes them particularly attractive for all applications where shafts suffer continuous shock loading.

Some shaft misalignment is tolerable and high speed running is common but there are limitations to permissible operating temperatures which may effect material hardness and lubrication and hence maximum load carrying capacity. There will be cases e.g. high speed machinery, where selection is a compromise between bearings large enough to give the desired life before onset of fatigue, and those with dimensions which allow effective lubrication. Avoidance of axial loads through rolling elements is essential during assembly, and purpose made tools are advisable both for assemble and extraction. The maximum permissible temperature to be used with shrink fitting bearings of all metal construction onto shafts is around 120^0. Cleanliness is of major importance during handling, assembly, running and maintenance. Consideration should be given to separate shields or seals for these bearings when operating environments are harsh and access for lubrication and maintenance is difficult. Other factors worthy of careful attention are: method and type of lubrication, fitting clearances and allowable shaft misalignment. Manufacturers or suppliers advice must always be sought before final selection is made and although the cylindrical roller bearing is the most popular of its type, a range of variants is available which may be more suitable for specialist applications.

Radial Ball Bearings

Typical Applications

Spindles for turning, milling, drilling and grinding machines, automotive transmissions, electric motors and dynamo spindles, pumps, fans and compressor shafts, aircraft control linkages, high speed processing and packaging machinery, conveyor belts, mechanical handling equipment, production machinery, heavy duty shakers and mixers, precision instruments.

Construction

Generally the rings and rolling elements are made from high grade, direct hardened, carbon chromium steels producing a surface hardness of between 59 and 65 HRC. The cages of small and medium size bearings are normally made from pressed steel or brass. Cages machined from solid material, usually brass, are used on larger sizes. Various plastics materials and, in some cases, special cast irons, are also specified depending on bearing size and duty.

Notes on selection and use

These bearings are generally used for light and medium load applications, and will take moderate axial loads in either direction alone or in combination with radial load. High speed running is common but there are limitations arising from permissible operating temperatures which may effect material hardness and lubrication and hence maximum load carrying capacity.

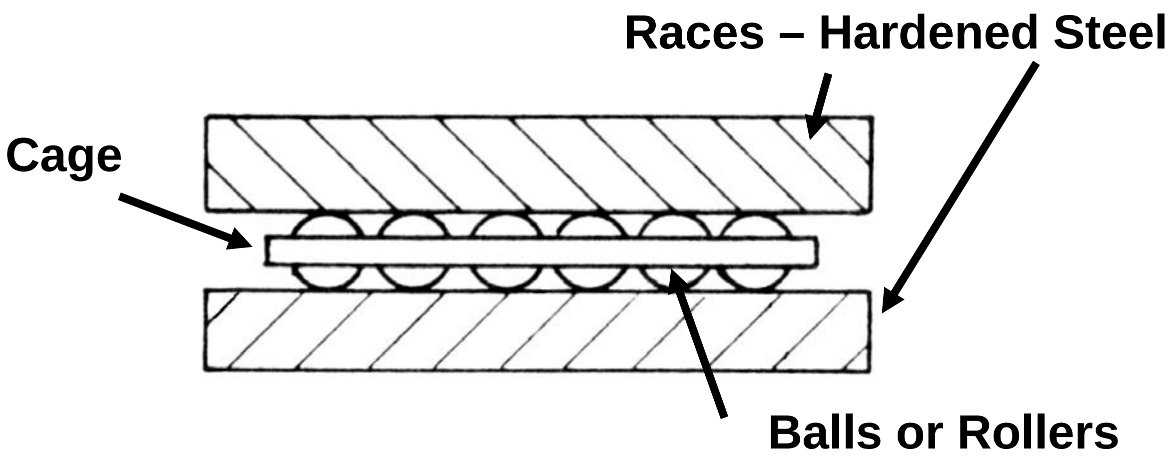
There will be cases e.g. high speed machinery, where selection is a compromise between bearings large enough to give the desired life before onset of fatigue, and those with dimensions which allow effective lubrication. Avoidance of axial loads through rolling elements is essential during assembly, and purpose made tools are advisable both for assemble and extraction. The maximum permissible temperature to be used with shrink fitting bearings of all metal construction onto shafts is around 120^0. Cleanliness is of major importance during handling, assembly, running and maintenance. Consideration should be given to separate shields or seals for these bearings when operating environments are harsh and access for lubrication and maintenance is difficult. Other factors worthy of careful attention are: method and type of lubrication, fitting clearances and allowable shaft misalignment. Manufacturers or suppliers advice must always be sought before final selection is made and although the cylindrical roller bearing is the most popular of its type, a range of variants is available which may be more suitable for specialist applications.

Linear Bearings

The construction of slider or linear bearings is slightly different from that of journal and thrust bearings.

Ladder Bearings

These consist of two hardened steel plates that are separated by a series of balls or rollers held in a cage as shown below. They may be used either vertically or horizontally.



Some Advantages of Plain Bearings

1. Heavy load bearing capability (although at relatively low speeds). Will withstand shock loads
2. Quiet running
3. Compact where radial space is limited
4. If the assemble is difficult, the bearing may be designed in two halves and bolted together after inserting the shaft.
5. High thermal conductivity, and permit controlled distribution of oil under pressure.
6. Not sensitive to corrosion, or local high pressure fatigue as is known in rolling type bearings.

Some Advantages of Rolling or Anti-friction Bearings

1. Much lower friction, particularly advantageous where starting torques are high.
2. More compact than plain journal bearings in axial dimensions.
3. Clearances can be much less than in plain bearings, providing accurate positioning between shafts.
4. Rolling bearings may be pre-loaded to further reduce deflection and provide more accuracy.
5. Can be pre-loaded with grease for maintenance free installation.
6. Rolling bearings can take high overloads for short periods.
7. Rolling bearings give warning of imminent failure by gradually becoming more noisy.
8. Do not require any hand fitting (i.e. scrapping as in plain bearings).
9. Assembly and production made simpler
10. Standard units of bearings available

Maintenance of Rolling Element Bearings

Inspection of Bearings

Listening to Machinery

Develop the habit of listening to the sound made by machinery. By recognising the sounds machinery makes when running normally one can detect the sounds made by bearing faults.

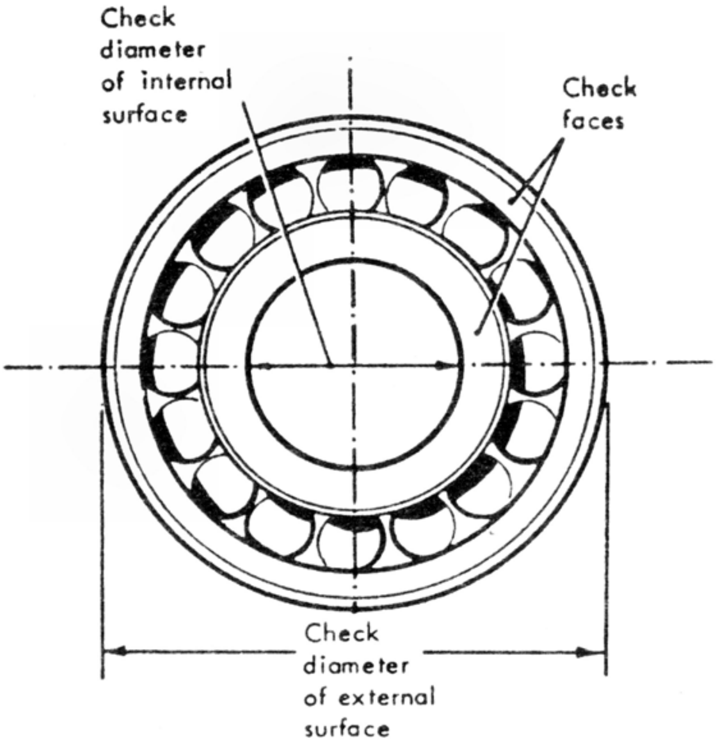
Bearing Replacement Decision

Faulty machinery running may be traced to a suspect bearing and it may be necessary to remove the bearing for complete examination. When examining a bearing removed from a machine compare it with a new, identical bearing. If there is the slightest doubt about the serviceability of a removed bearing it should be replaced by a new one.

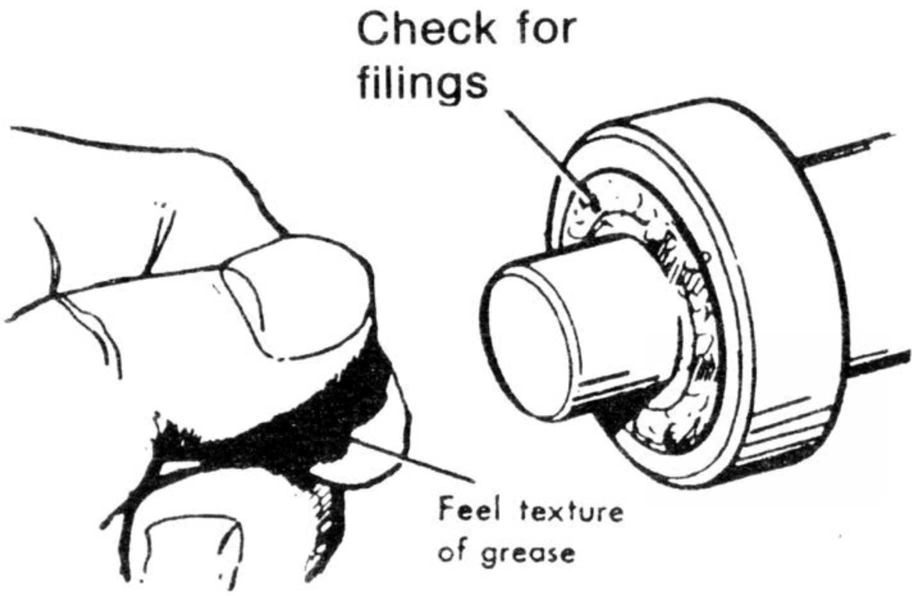
Do not spin a bearing after its removal from the shaft or housing, because dirt or other debris may have penetrated to the rolling elements during removal.

Preliminary Inspection

Check the working faces and sides of the bearing for obvious signs of damage.



Preliminary Inspection

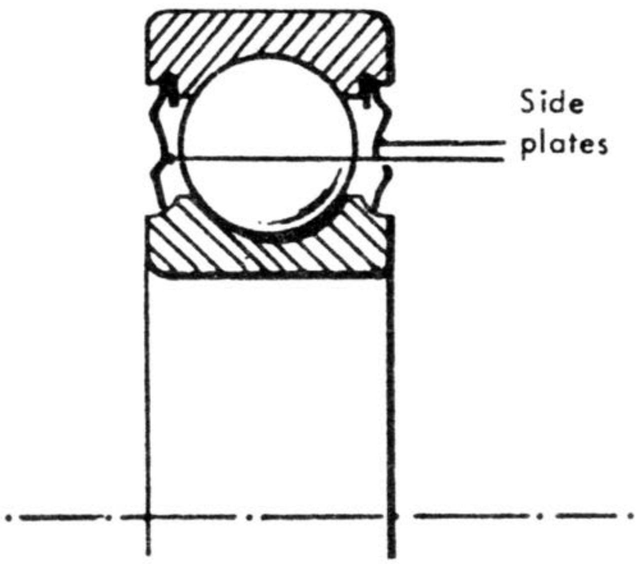


Check the lubricant, oil or grease for the presence of steel or brass filings. Check the texture by feel for condition of lubricant.

A bearing which is to be sent to the manufacturers for examination should not be cleaned, but should be packed immediately it is removed.

Cleaning

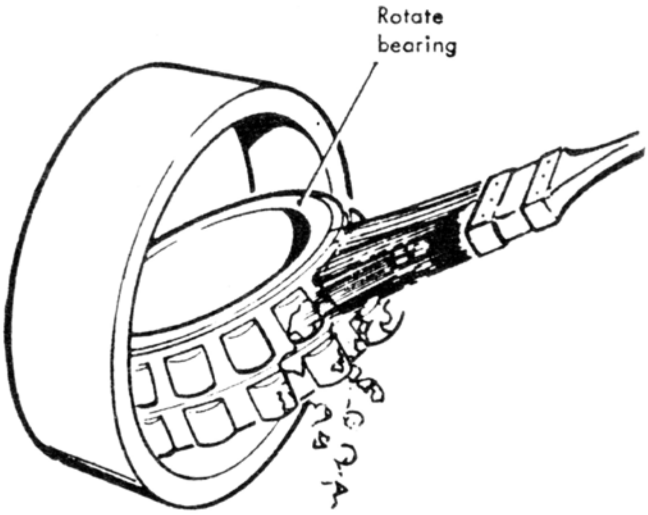
If a bearing is fitted with two side plates or seals, clean the outside only. Only recommended cleaning agents must be used.



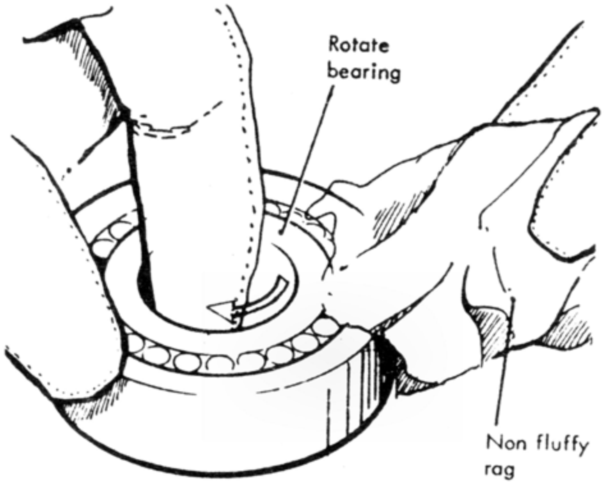
Cleaning

The procedure for hand cleaning is as follows:

- Remove as much of the old lubricant as possible before immersing the bearing in the cleaning bath.
- Immerse the bearing in the cleaning bath and allow to soak if necessary to soften any hard lubricants remaining.



- After soaking, hold the bearing in the fluid and clean it with a brush while rotating the bearing. Ensure that no hairs from the brush stick in the bearing.
- Change the cleaning fluid as often as necessary until the bearing ceases to leave any trace of dirt in the bath.

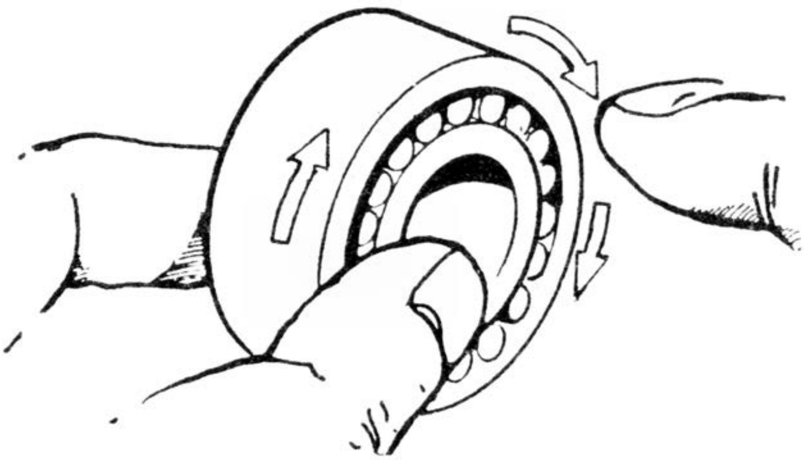


- Dry off the bearing with a clean non-fluffy rag. Clean cotton gloves should be worn when handling the clean bearing.
- Smear the clean bearing with a suitable oil or grease immediately after it has been dried.

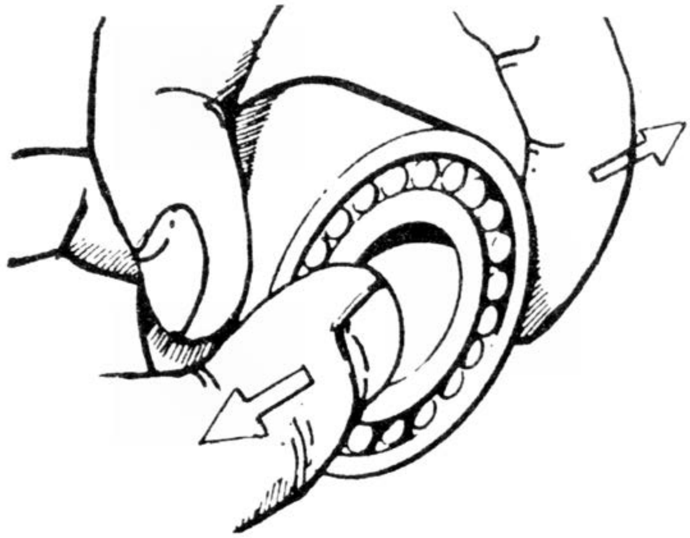
Inspection

When inspecting a used bearing for signs of wear, compare it with a new bearing of identical type and size.

Inspection should always be carried out methodically and the bearing inspected for obvious physical damage before going on to check for signs of wear.

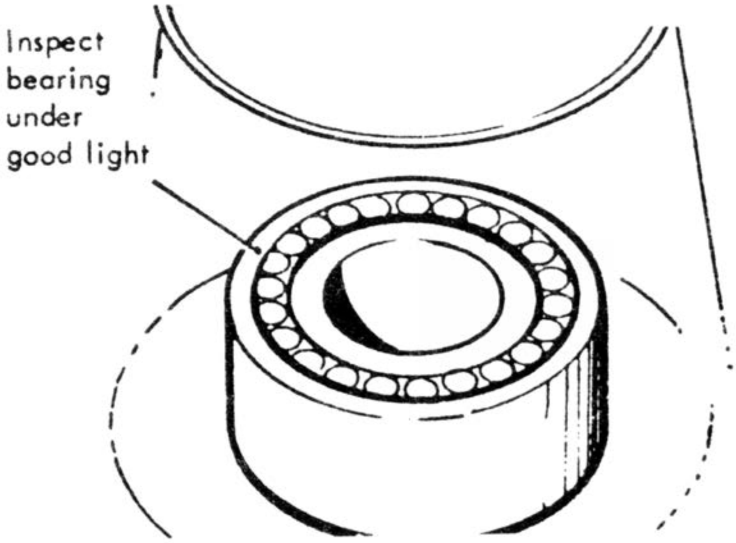


- Spin the bearing and listen to the noise it makes, compare it with the noise of a replacement bearing. Damage to the rolling surfaces may be heard.

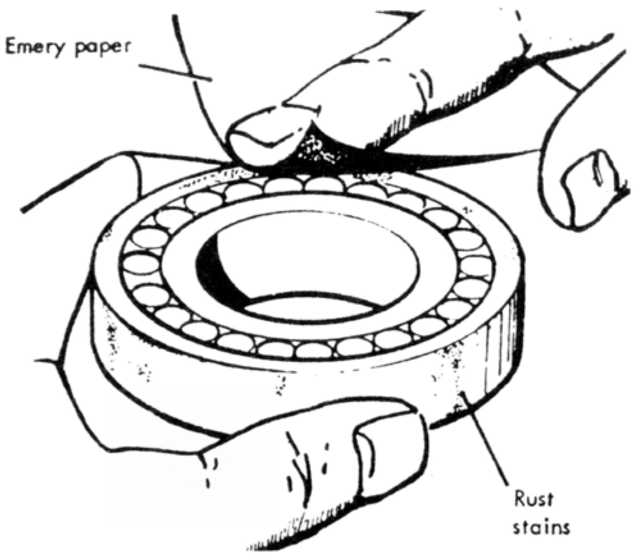


- Feel the clearance of the bearing and compare it with a replacement bearing.

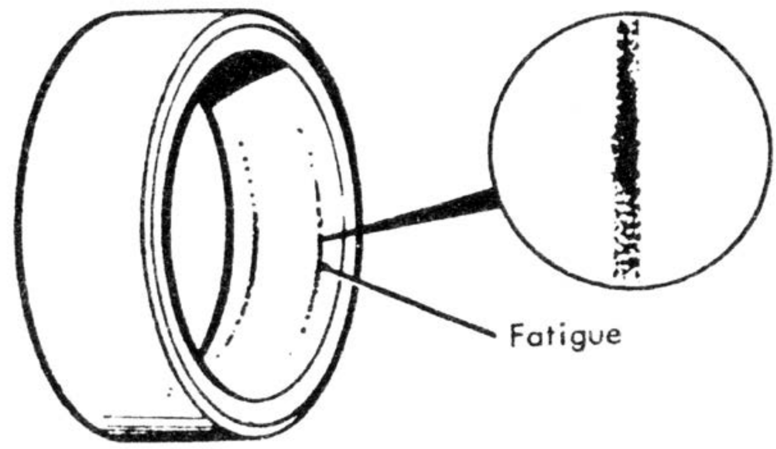
- Inspect the bearing visually for signs of damage and defects such as rust stains, discolouration, cracks, abnormal wear, indentations and marks caused by careless mounting. If any of these faults are found, apart from rust stains under the following conditions, the bearing must be replaced.



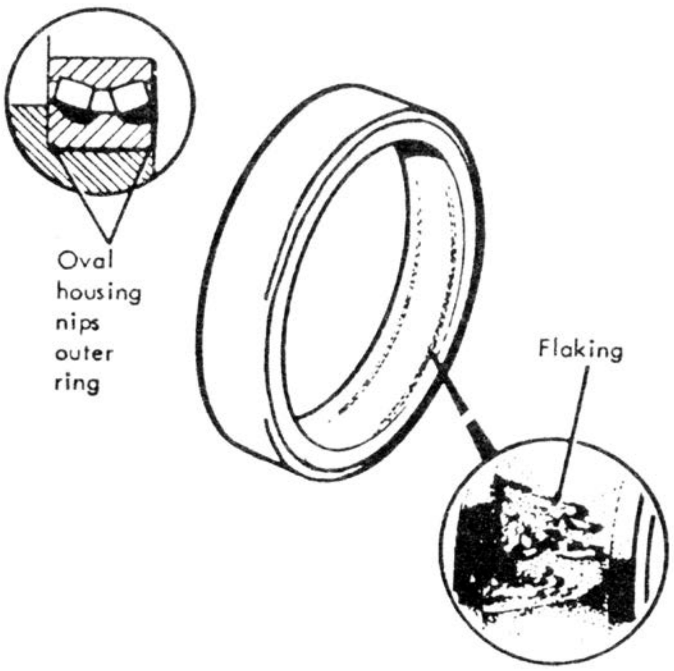
- Rust stains on the outer face or sides of a bearing may be removed using fine grade emery paper, provided the rust is not so deep seated that the fit will be destroyed. The bearing must be cleaned again after this treatment. Rust on the tracks, race or rolling elements renders the bearing unserviceable.



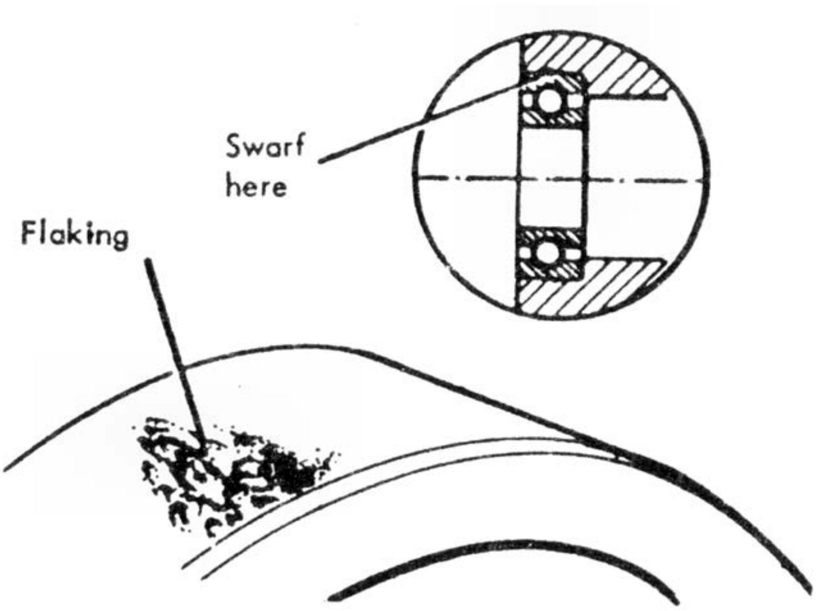
The following are some faults which may be discovered during the visual inspection:



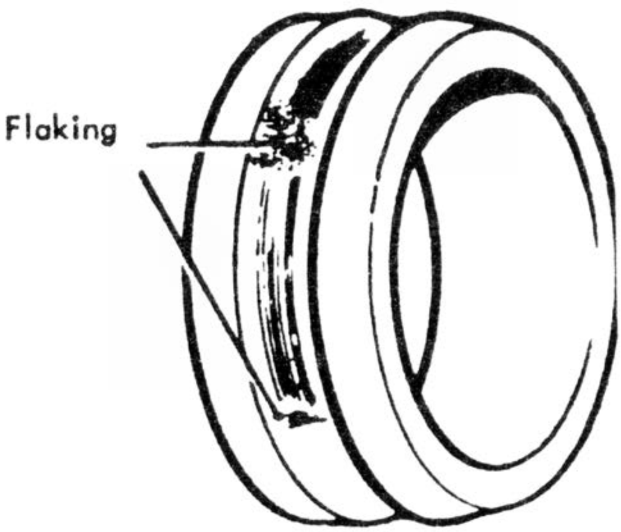
- Normal fatigue. The bearing has reached the end of its useful life and must be replaced.



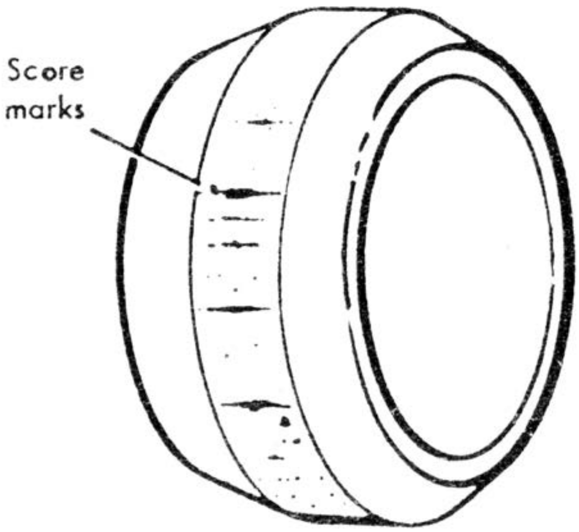
- Faulty housing. Flaking at diametrically opposite points caused by nipping the outer ring in an oval housing. Housing must be rectified and a new bearing fitted.



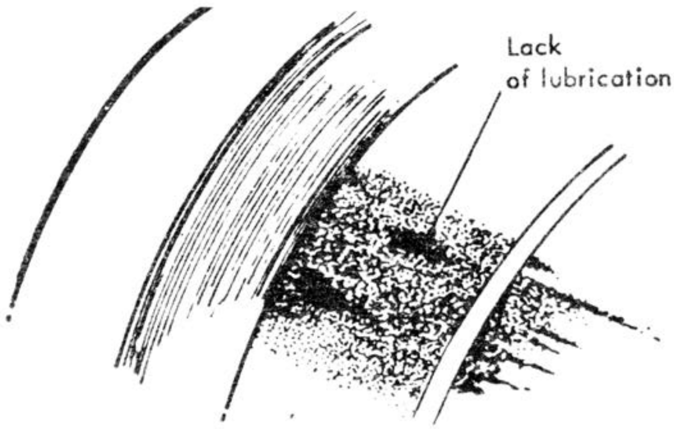
- Dirt between the housing and bearing. A piece of swarf trapped between the outer ring and the housing seating causing flaking of the track. Bearing must be replaced.



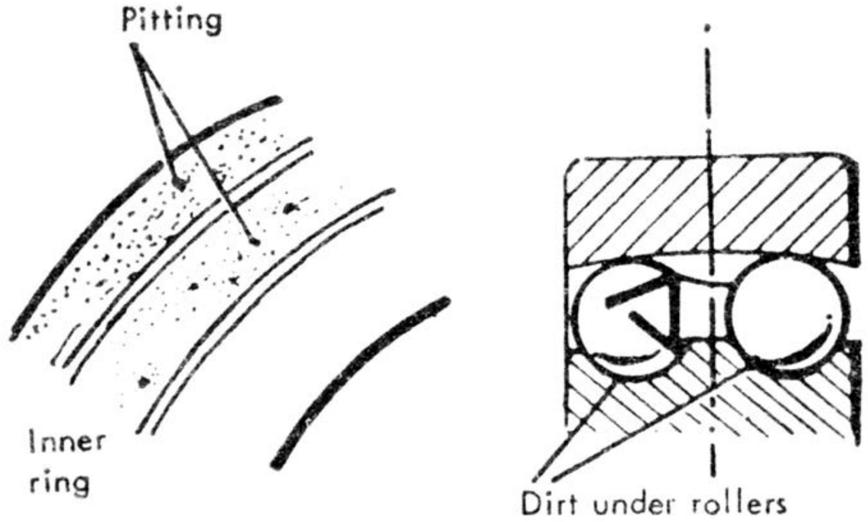
- Track flaking. This can be caused by striking the outer ring when forcing the inner ring onto the shaft. Renew the bearing.



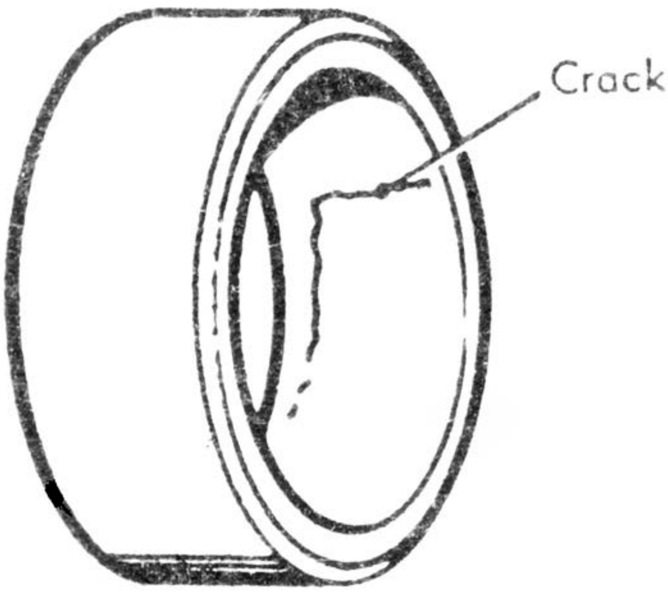
- Scored track. This could be caused by the roller set being pushed into position without being rotated. Renew the bearing.



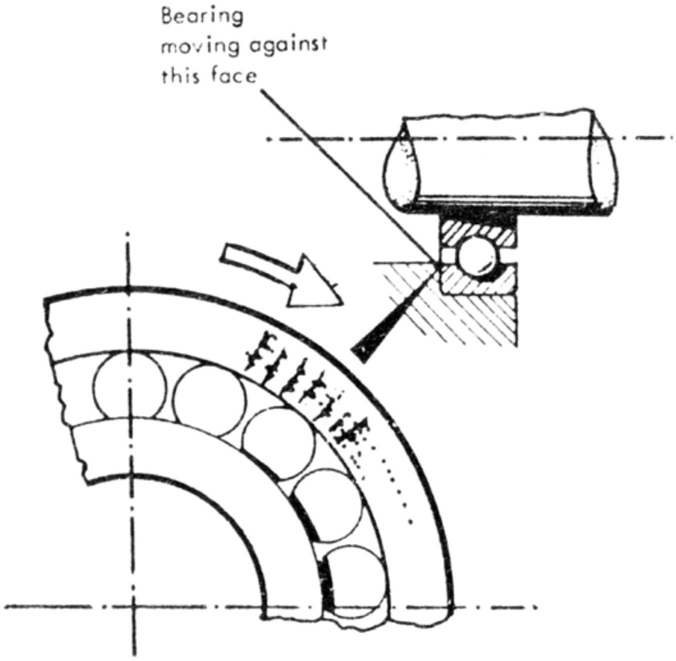
- Insufficient lubrication. This can result in a badly flaked track requiring renewal of the bearing.



- Dirty bearing. Track badly pitted due to the presence of foreign particles. Renew the bearing.

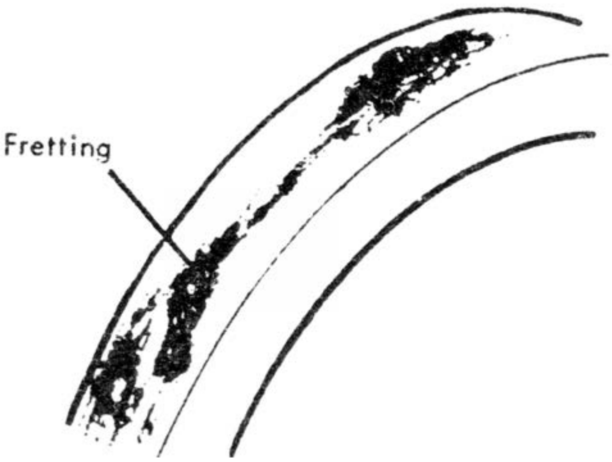


- Cracks. A cracked track may result if the ring is not fully supported. Housing seating requires attention before fitting a new bearing.



- Creep. This is the result of an incorrect fit between the inner ring and the shaft, or the outer ring and the housing.

The fit between the shaft and inner ring or housing and outer has been too loose resulting in a slight displacement of the ring in relation to the shaft or housing during each revolution. Ensure that a correct fit is obtained when fitting a replacement bearing.

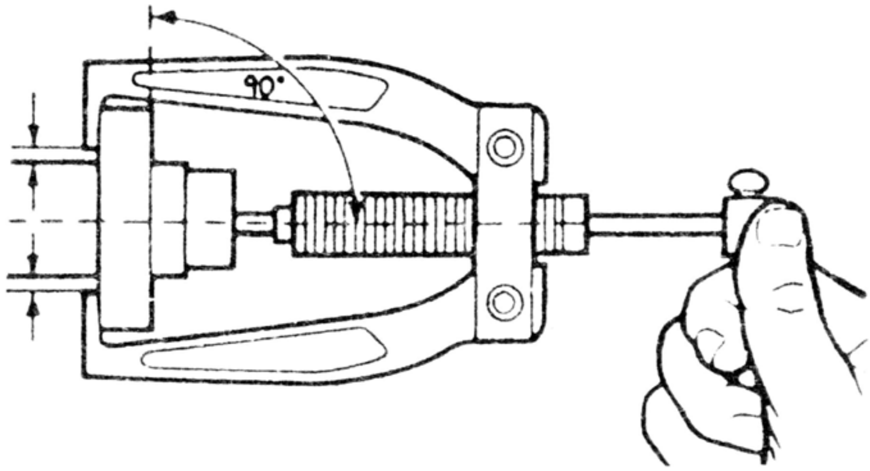


- Fretting. Corrosive fretting may occur on the outer ring and sides of a bearing which is a light interference fit on the shaft if there is a defection of the bearing arrangement during running. This could be caused by a bent shaft. The shaft should be replaced or the fault corrected before fitting a new bearing.

Removal of Bearings

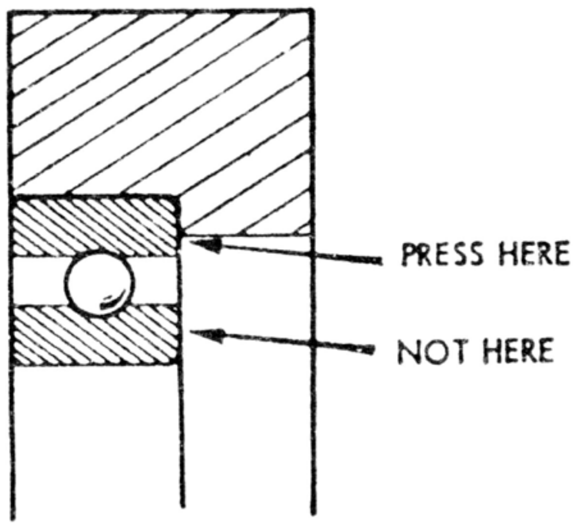
When a new bearing is to be fitted, the seatings must not be damaged, therefore:

- Oil the surfaces to prevent scratching or scouring during removal.
- Keep pullers clear of seatings.
- Keep the bearing square to the seating during removal



When the bearing is to be re-used, it must not be damaged, therefore:

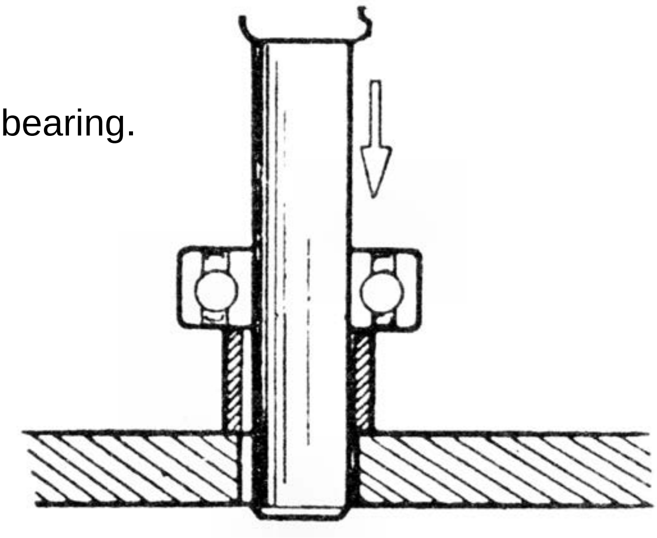
- Exert force only on the race being extracted.
- Whenever possible, remove the free race and the cage first.
- Never clamp pullers to the working surfaces of a bearing.



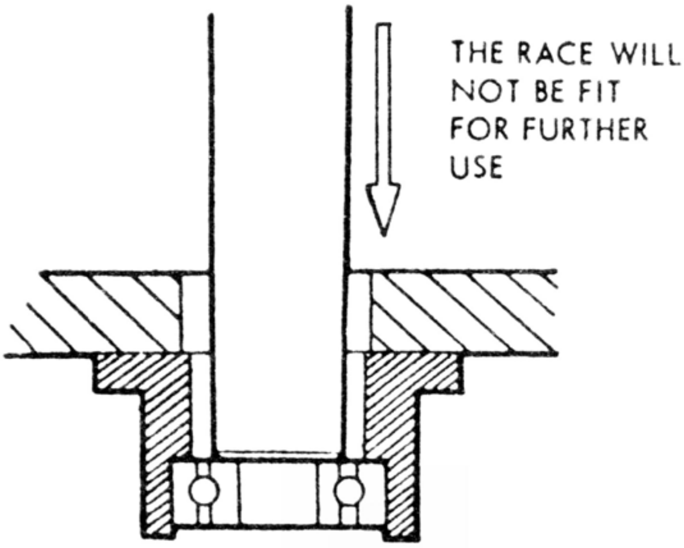
Arbor Press

Decide which is the best way to set the job on the press.

- Pressing a shaft out of a bearing.



- Pressing a bearing out of a housing. A tube must be used so that the force is applied evenly to the face.

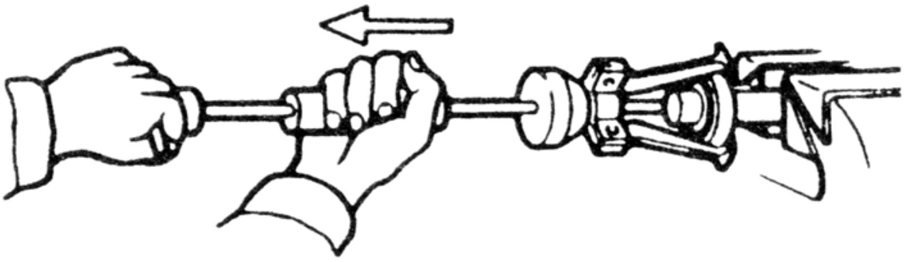


Bearing Pullers

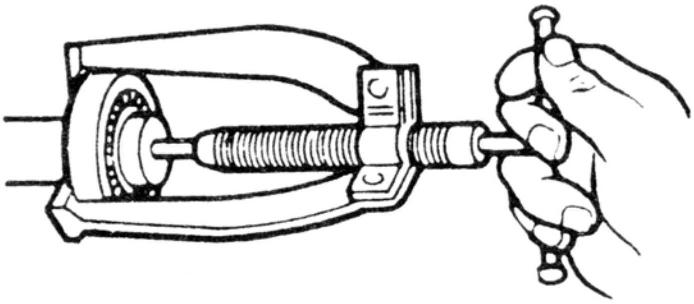
NOTE

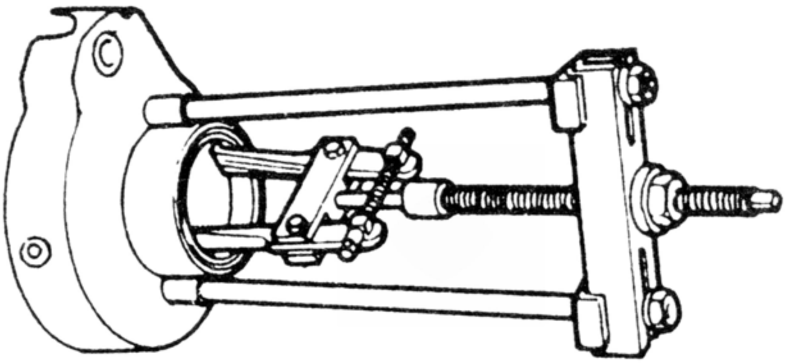
When using bearing pullers take care to keep the bearing square to the shaft.

- Select the most suitable puller:

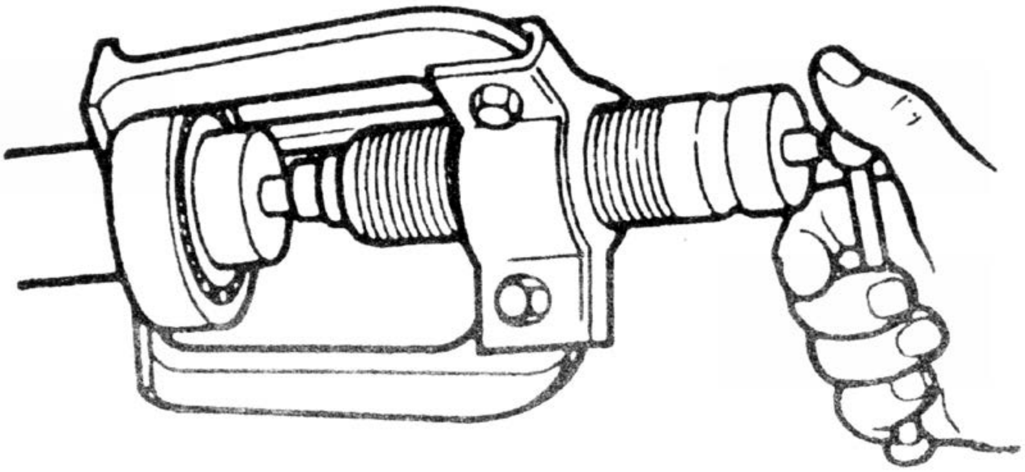


Impact pullers are only suitable for small bearings; the weight must be held when it is tapped against the stop.





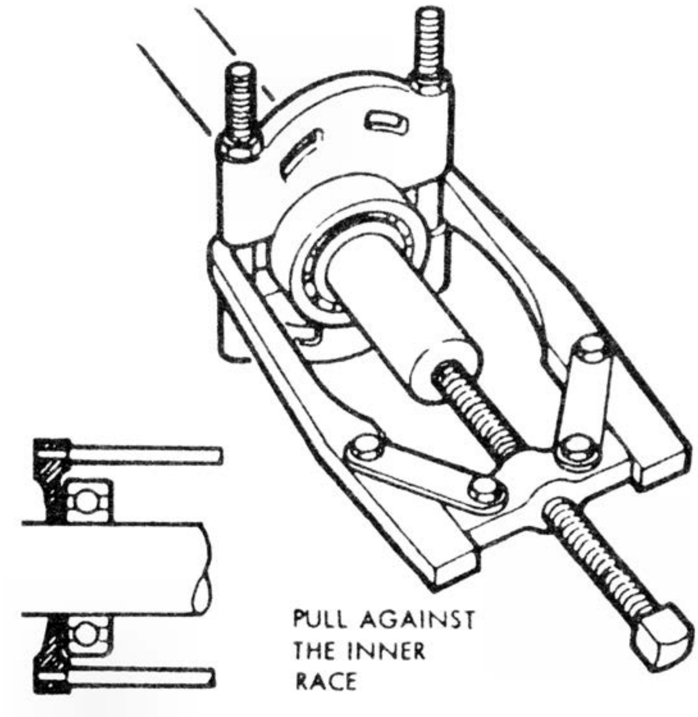
Screw pullers are suitable for most purposes; take care to keep the puller square when turning the screw.



Hydraulic pullers are to be used when a large force is required.

- Arrange the puller inside or outside the bearing as required.
- Fit the puller and tighten it to hold it in position.
- Check that the puller is square and bearing only on the correct surfaces.
- Pull the bearing slowly. Stop frequently to check that the bearing puller is square.

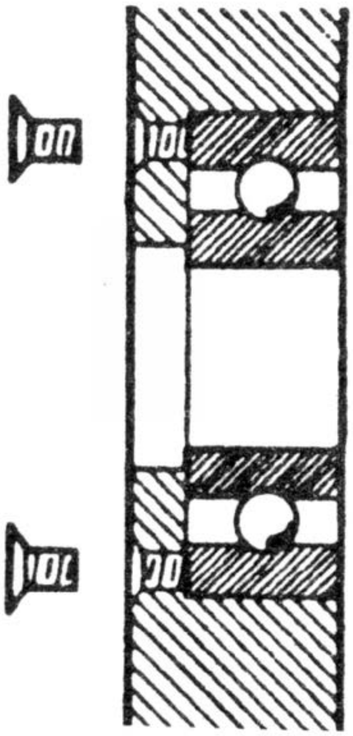
Puller Plates



When a bearing mounted on a shaft is to be re-used, a puller plate should be used so that the force is exerted against the inner race.

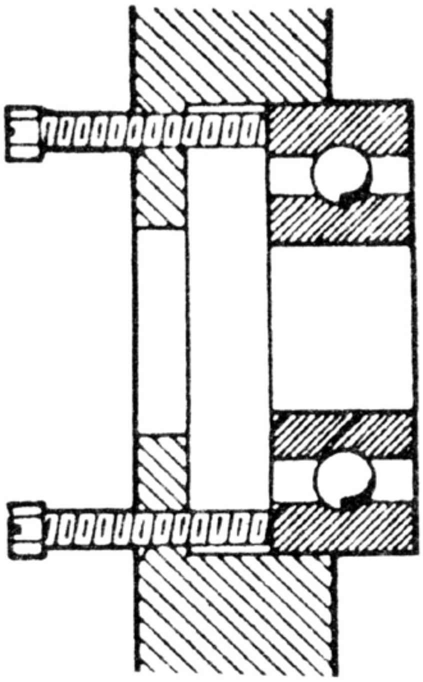
Bearing Removal Screws

Some housings have tapped and countersunk holes behind the bearing. These holes are normally fitted with short screws to prevent the threads becoming blocked with dirt.



- Remove the screws from the holes.

- Select the same number of screws that will fit the holes and are long enough to remove the bearing.
- Fit the longer screws and tighten them equally by small amounts to remove the bearing slowly from its housing. Take care to keep the bearing square to its housing.

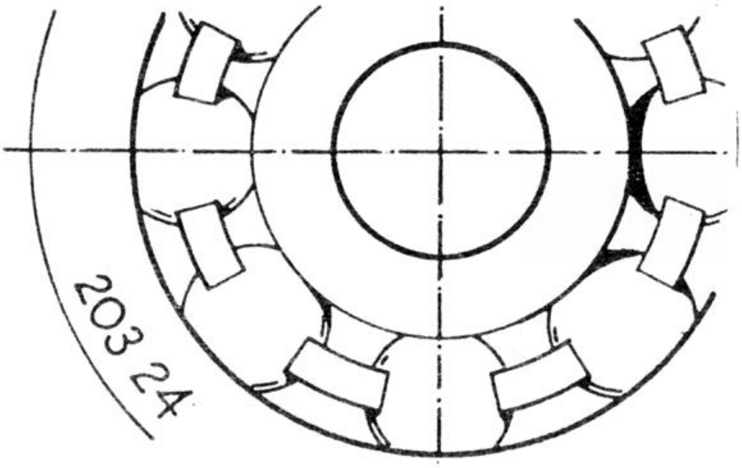


Replacement of Bearings

A replacement bearing must be identical or equivalent to the bearing it is replacing. Bearings that look identical may differ in dimensional limits, in the materials used or in heat treatment. If an identical bearing is not available an equivalent bearing may have to be selected. Equivalent bearings can be selected by reference to manufacturers' equivalent bearing lists

Bearing Assembly Number

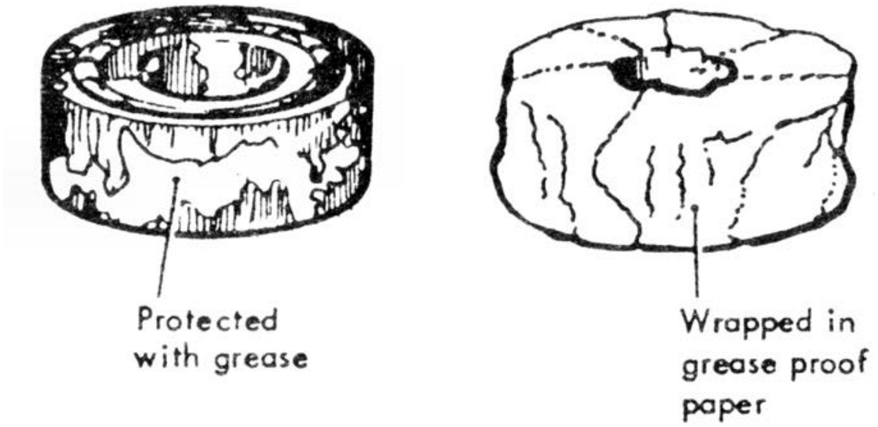
The various manufacturers of bearings have their own numbering systems. The meanings of the numbers used can be found from the manufacturers' catalogues. These numbers can signify: the dimensions of the bearing, the type of bearing e.g., ball or roller, and the maximum working temperature.



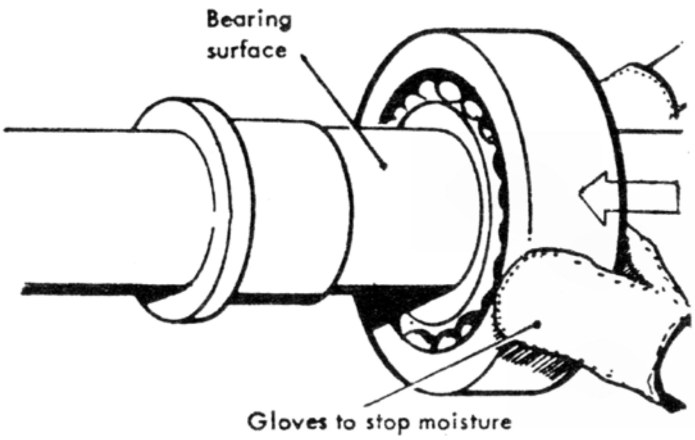
The assembly number will be found on the manufacturer's assembly drawings and is usually situated on the outer race of ball and roller bearings. Always note the assembly number of the existing bearing; details of the new bearing required can be obtained from this.

Handling and Storing Bearings

A bearing can be damaged by incorrect handling or storage. To prevent damage due to dirt, corrosion or deformation the following rules must be obeyed:



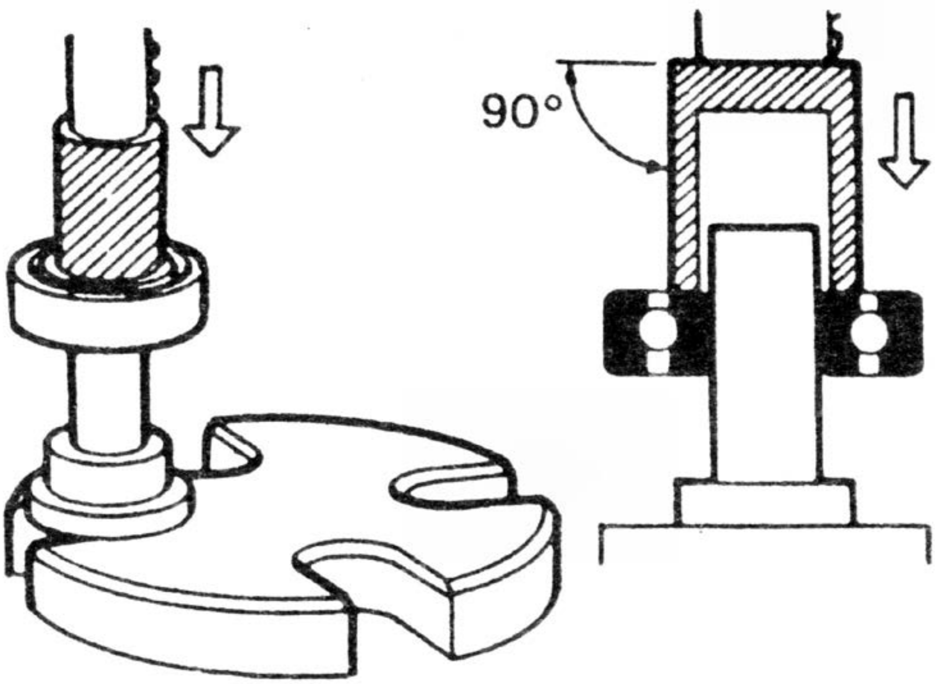
- Keep all bearings in the manufacturer's wrappings until they are required for use. This will protect them from dirt and corrosion. Bearings are protected from a film of grease or light oil and wrapped in greaseproof paper before they leave the manufacturer.
- Store bearings where they cannot be damaged when other equipment is moved



- Always handle bearings carefully, particularly after removing the manufacturer's wrapping. Pick them up and lay them down gently and deliberately. Ensure that any surface on which a bearing is placed is clean and secure. Wear suitable gloves if possible to prevent moisture from the hands being transferred to the bearing.

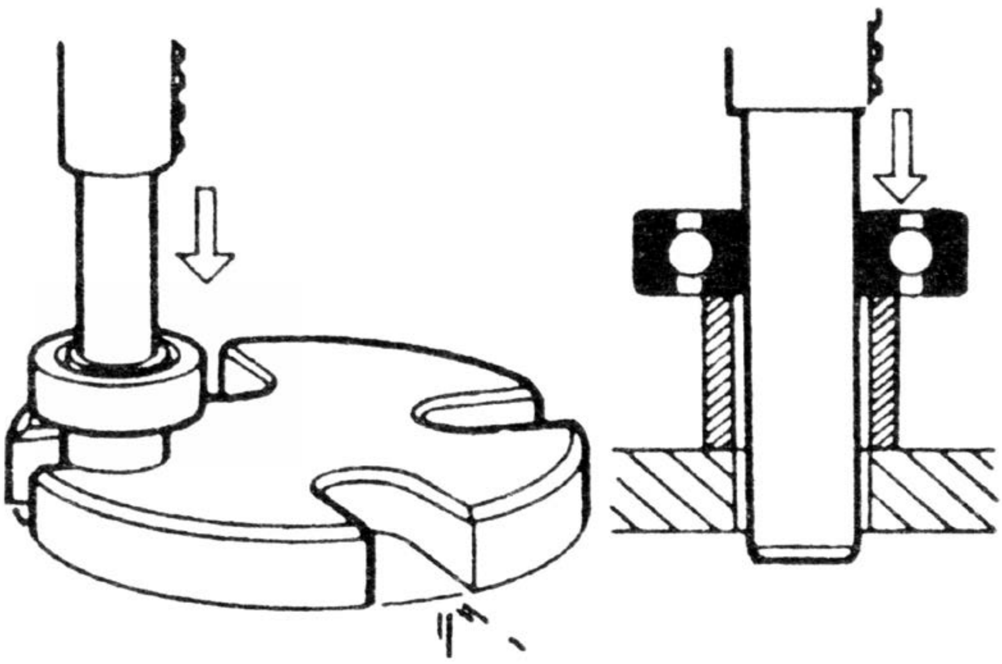
Fitting a Ball Bearing using an Arbor Press

Whenever possible, use an arbour press. This keeps the bearing square to the shaft or housing.



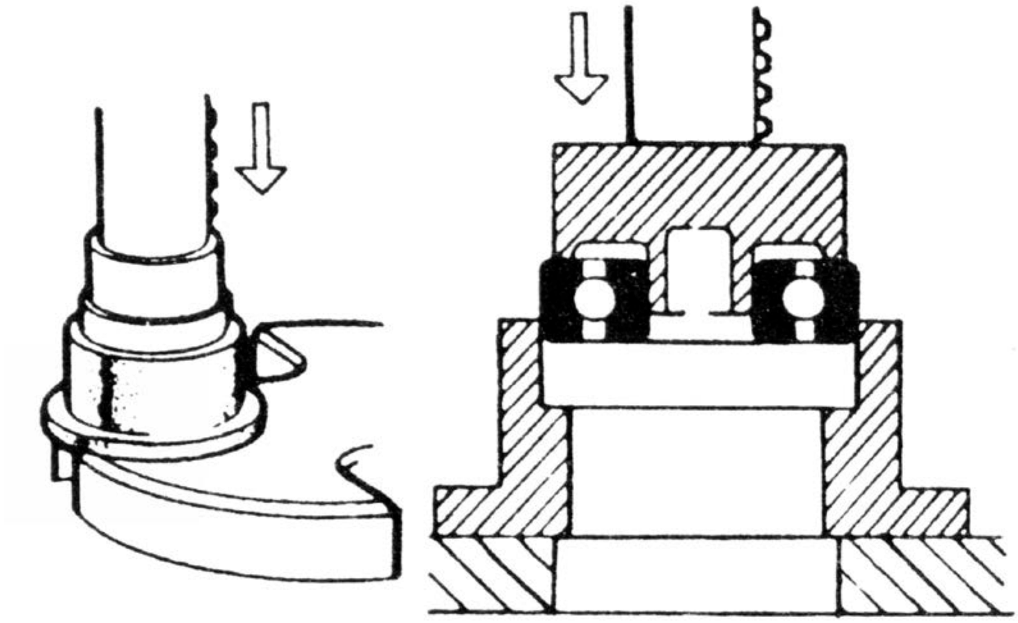
When pressing a bearing onto a shaft:

- Select a tube with an outside diameter equal to the diameter of the bearing inner race.
- Set up the shaft on the press table.
- Align the bearing over the shaft and lower the ram to just hold the tube in place.
- Check that parts are square to each other.
- Press the bearing home gently.



To press a shaft into a bearing:

- Support the bearing inner race on a tube.
- Insert the shaft into the bearing bore and lower the ram to hold it in place.
- Check that the shaft is square to the bearing bore.
- Press the shaft home gently until its shoulder abuts the bearing.



To press a bearing into a housing as follows:

- Support the housing on the press table.
- Select a tube with an outside diameter equal to the outside diameter of the bearing.
- Insert the bearing in the housing, ensuring that it is square with the housing bore.
- Place the tube on the bearing and lower the press ram to hold it in position.
- Press the bearing gently into the housing until the bottom face abuts the housing shoulder.