160202b

Millwright

Anti-Friction Bearing Removal and Installation

Bearings and Seals

Second Period

Table of Contents

Anti-Friction Bearing Removal and Installation

Rationale

Why is it important for you to learn this skill?

Since all machinery has bearings of various kinds, many of which are anti-friction bearings, it is essential that you be able to replace bearings efficiently and correctly. This skill obviously requires knowledge of removal and installation techniques. It is also essential to know how to ensure the correct fit of the bearing to the shaft and to the housing.

Outcome

When you have completed this module you will be able to:

Describe the replacement of anti-friction bearings.

Objectives

1. Describe the various procedures used to remove anti-friction bearings.
2. Determine the correct shaft and housing sizes required to provide the correct fit to the anti-friction bearing.
3. Describe the preparations required before mounting anti-friction bearings.
4. Describe the drive or press-on methods of mounting anti-friction bearings.
5. Describe the oil injection and hydraulic nut methods of mounting anti-friction bearings.
6. Describe the various hot mounting procedures used to install anti-friction bearings.
7. Describe the procedures for setting internal clearances in anti-friction bearings.

Introduction

In order to replace a bearing efficiently and correctly, a certain amount of planning is required. This in turn requires knowledge of removal and installation techniques as well as of the tools and equipment needed to do the job. In addition, you must know how to select the correct fit using bearing fit charts. All of this is necessary in order to prevent premature bearing failure.

NOTE
Although bearing bore sizes are specified in millimetres, the fit tables providing dimensions and clearances, etc. are in inch measurements.

Objective One

When you have completed this objective, you will be able to:

Describe the various procedures used to remove anti-friction bearings.

Non-Destructive Removal Methods

Non-destructive removal methods are used so that the bearing can be reused. In preparation for removal, it is good practice to remove any deposits or burrs from the shaft over which the bearing is to be pulled to avoid any extra interference and damage.

Cooling and Heating

Cooling

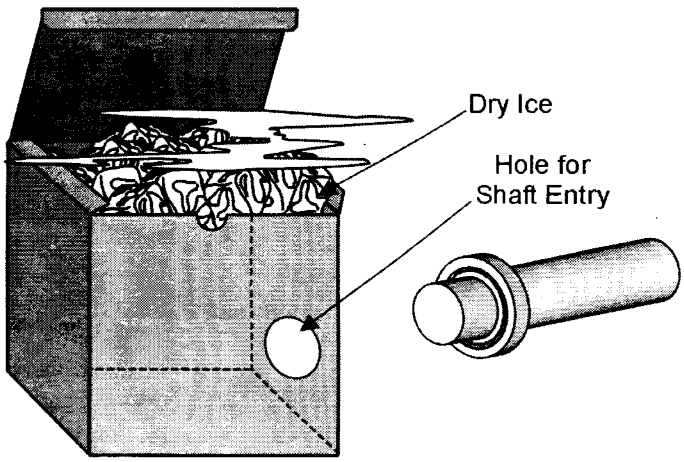


Figure 1 - Cooling using dry ice.

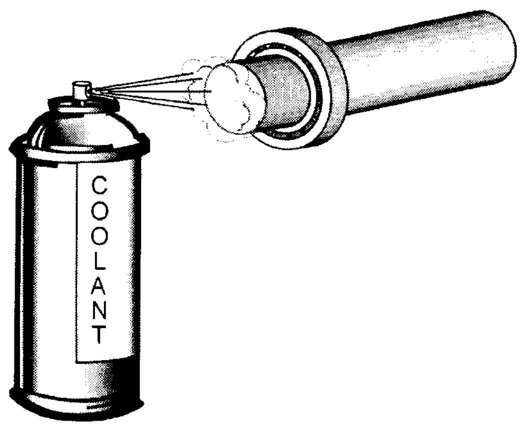


Figure 2 - Cooling using liquid nitrogen or other commercial coolant.

Since the inner ring of a bearing is often not accessible for a suitable method of heating, a coolant can be applied to reduce the diameter of the shaft, as shown in Figure 1 and Figure 2. As the shaft is being cooled, a steady pull should be applied to the bearing if possible so that it can be removed before it begins to shrink due to contact with the shaft.

NOTES

NOTE
When you use a coolant, be careful not to apply it to the part that you are applying force to. Parts become extremely brittle when chilled with dry ice or liquid nitrogen.

DANGER
Always wear clean protective gloves while working with coolants such as dry ice or liquid nitrogen. These coolants can cause severe frostbite and permanently damage skin tissues.

Heating

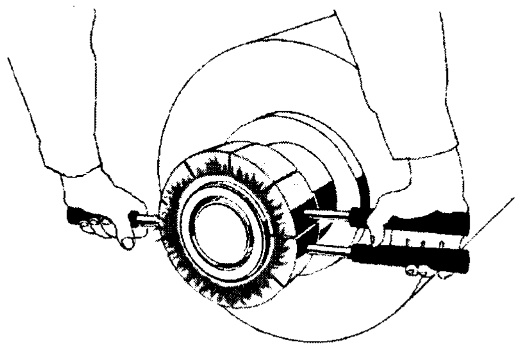


Figure 3 - Inner ring removal using an aluminum heating ring. (Courtesy SKF Canada Limited)

Since we are considering non-destructive removal methods we must avoid the use of a flame directly on the bearing. The flame could cause uneven heating and consequent distortion of the inner and outer rings, as well as oxidation of the rollers and the raceways.

Figure 3 shows the use of an aluminum heating ring to evenly expand the inner ring. When using this method, you should coat the bearing ring with high-temperature oil that is oxidation-resistant. This will protect the raceway. Alternatively, an adjustable ring-style induction heater can be used.

The use of a heating ring obviously requires removal of the outer ring and rolling elements. For this reason this method is limited to cylindrical roller bearings with separable roller and cage assemblies.

Oil Injection

Removal from a Cylindrical Bearing Seat

The oil injection method requires that the shaft is pre-drilled with ducts as shown in Figure 4 and a hydraulic fitting installed in the end of the shaft. A puller will be required to remove the bearing. However, this method offers the following advantages.

- No heat is required, which ensures that the bearing is not distorted or oxidized.
- Since the bearing is separated from the shaft by a film of oil, very little force is required to remove the bearing.
- The film of oil ensures no abrasion damage to the bearing or to.the shaft during removal.

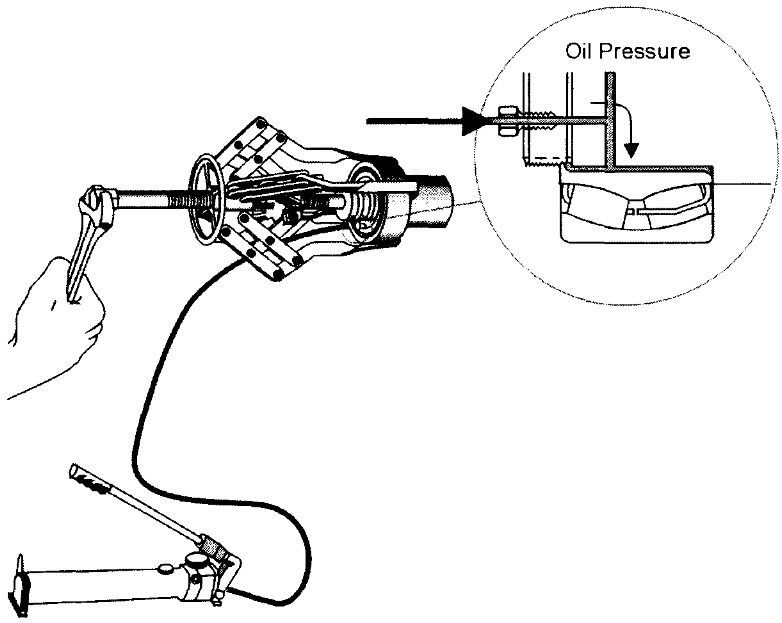


Figure 4 - Removal using oil injection. (Courtesy SKF Canada Limited)

Removal from a Tapered Bearing Seat

Removal from a tapered seat, as shown in Figure 5, requires the same oil ducts used with the cylindrical seat, but there are two important differences:

1. No puller is required since there is an axial component to the hydraulic force due to the taper. This will push the bearing off as soon as it expands away from the taper.
2. It is very important to leave the bearing retaining nut close to the bearing to prevent the bearing from being ejected at high speed.

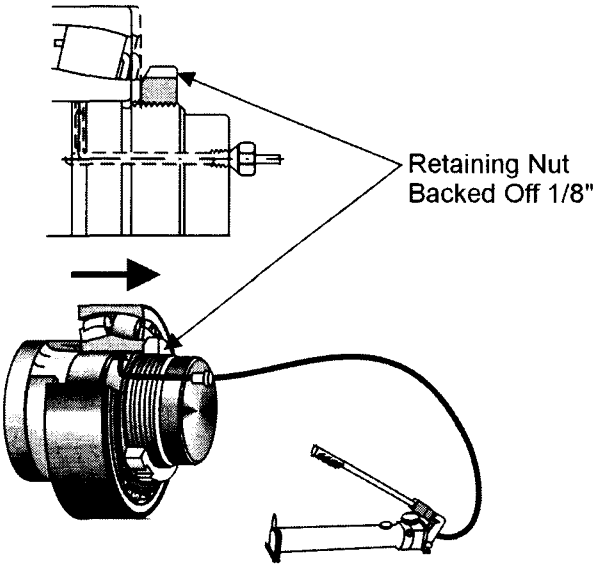


Figure 5 - Removal from a tapered seat using oil injection. (Courtesy SKF Canada Limited)

DANGER
The bearing will break away from the taper very suddenly when the oil is pumped into the shaft under pressure. To avoid severe injury or damage, the retaining nut must be left on the shaft near the bearing to prevent the bearing from being ejected at high speed.

NOTE
The tapered seat may either be a tapered shaft or a tapered adapter sleeve on a cylindrical shaft as shown in Figure 5. In the case of the tapered adapter sleeve, the removal procedure is exactly the same as with the tapered shaft since the sleeve is drilled with oil ducts.

NOTES

Hydraulic Methods

Hydraulic methods of removal would include the use of a hydraulic nut, a hydraulic jack or a hydraulic press. The use of hydraulics provides greater force than mechanical methods.

Removal with a Hydraulic Nut from a Tapered Withdrawal Sleeve

Figure 6 shows a hydraulic nut that consists of a nut fitted with a ring-shaped hydraulic piston. When the nut is screwed onto the removal sleeve and hydraulic fluid is pumped into the nut, the piston extends and pushes against the bearing. This pulls the sleeve to which the nut is attached out from under the bearing.

On larger bearings, oil ducts as shown in the sleeve in Figure 6 will facilitate the removal as described in the previous topic titled *Oil Injection.*

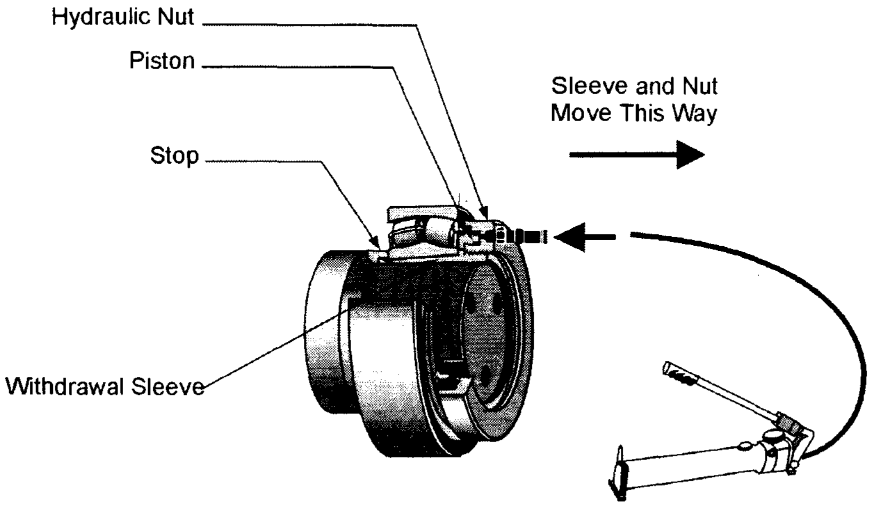


Figure 6 - Removal with a hydraulic nut from a withdrawal sleeve. (Courtesy SKF Canada Limited)

NOTE
The difference between the removal sleeve shown in Figure 6 and the adapter sleeve in Figure 5 is that the adapter sleeve has a thread on the small end of the taper, which is used to install and retain the bearing. The removal sleeve has the thread on the large end of the taper, which is used to remove the bearing.

Removal Using a Hydraulic Jack

As shown in Figure 6, a hydraulic nut can be used to remove a bearing from a tapered removal sleeve. However, if the bearing is mounted on a cylindrical seat, a hydraulic press or a hydraulic ram would be required for hydraulic removal.

Figure 7 shows the use of a hydraulic jack to pull a bearing. This is necessary on medium-sized bearings mounted on shafts that are either too long to fit in a press or are still in the machine. The following points should be observed when using this removal method.

- If at all possible, use a bearing splitter behind the bearing (Figure 7).
- Ensure that the splitter is adjusted so that it does not contact the shaft and damage the bearing seat as the bearing is being removed.
- If the end of the shaft is threaded, use a smooth soft piece of metal to protect the end of the shaft.

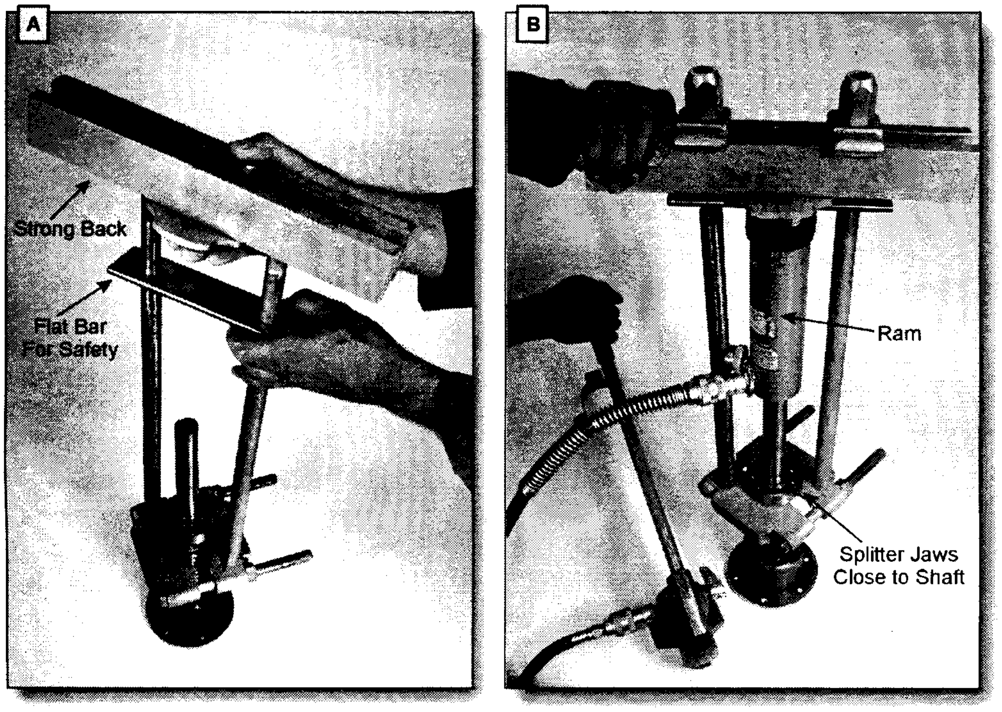


Figure 7 - Removal using a hydraulic jack.

DANGER
• Very large forces can be generated while pulling a bearing. If there is a flaw in the bearing, the bearing may explode under pressure or the tie rods connected to the strong back may spread and the ram may fly out. • When you set up the pulling equipment, adjust the strong back so that it is at right angles to the axis of the shaft and ensure that the ram is carefully centred on the shaft. • To prevent the rods from spreading and the ram from coming out of the strong back, drill holes in a piece of flat bar and install it over the tie rods between the ran and the strong back (Figure 7). • When applying hydraulic pressure, stand at the end of the shaft opposite to the end that the puller is on.

Removal Using a Hydraulic Press

When pressing a bearing out of a shaft as shown in Figure 8, the following points should be observed.

- Make sure that any retaining ring, collar, key or anything that would obstruct the removal of the bearing is removed.
- Ensure that the bearing is supported as close to the shaft as possible. Ideally the supporting surface (support plates in Figure 8) should bear against the inner ring of the bearing. A bearing splitter is ideal for this purpose.
- Support the shaft and bearing assembly so that there is enough space under the lower end of the shaft to let it drop free of the bearing. Also, provide wooden blocking so that the shaft will only drop the few inches necessary for the bearing seat to pass down through the bearing.
- Always make sure that the support beams of the press are fully supported by the pins through the frame uprights!

CAUTION
Never attempt to press with the beam hanging by the lifting cables.

- To prevent damage to the end of the shaft, place a soft metal spacer between the ram and the shaft. The spacer should be slightly smaller than the shaft diameter if it has to enter the bearing bore. It should be as short as possible and its end surfaces should be flat, smooth, free of burrs and at right angles to its axis.
- Apply a small amount of hydraulic pressure to the spacer and then check that the ram, the spacer and the shaft are all in a straight line.
- Close the safety cage around the press, stand to one side and begin to apply hydraulic pressure to push the shaft down through the bearing.

DANGER
High stresses are developed while pressing a shaft through a bearing. There is potential for the spacer between the ram and the shaft to fly out or the bearing to explode if there are any internal flaws. This could cause serious injury or death! Therefore, be sure to close the safety cage around the press.

CAUTION
Presses provide very large forces that are capable of damaging components if there is anything that interferes with the parts being pushed apart. Therefore, always proceed with caution when you attempt to press an assembly apart. If you have any doubt that something is interfering, release the pressure and check carefully for any problems.

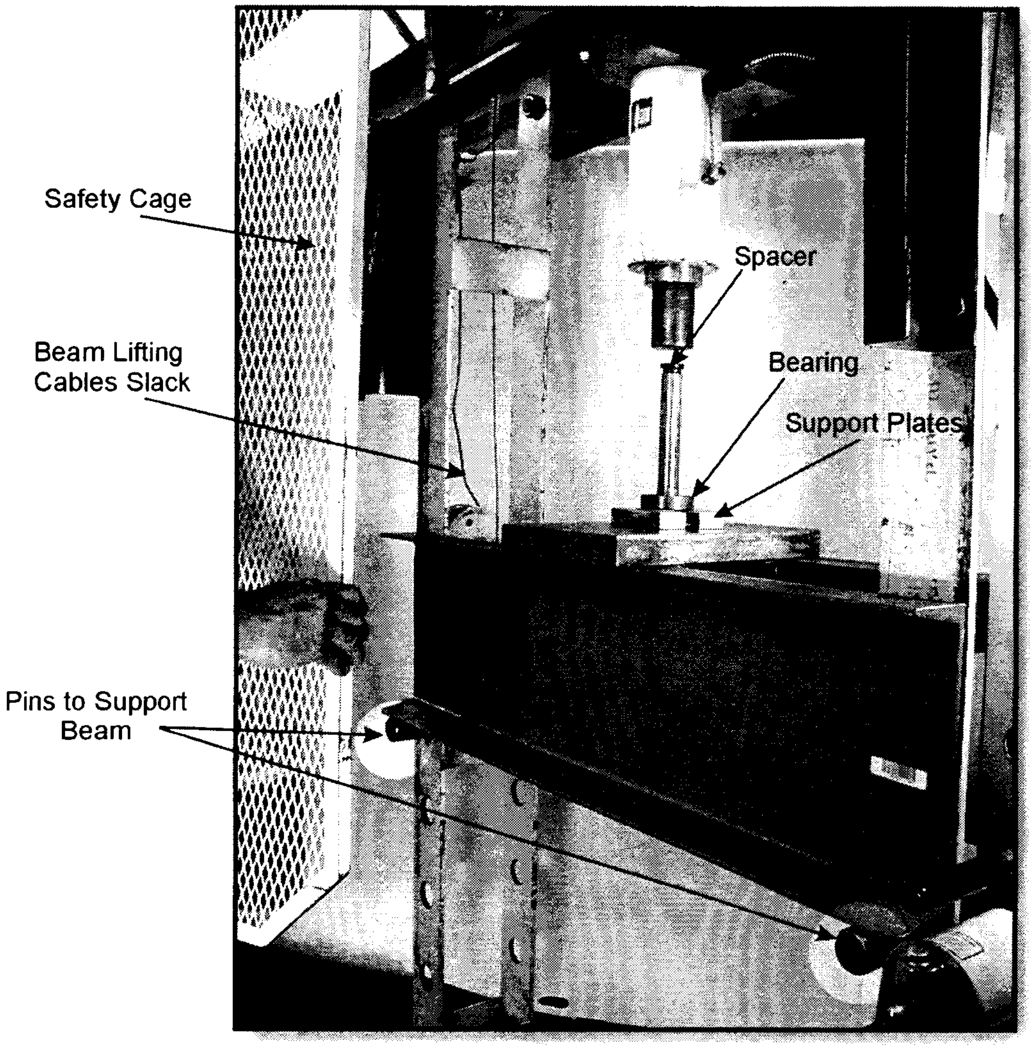


Figure 8 - Removal in a hydraulic press.

Mechanical Methods

Pullers

The type of puller that you use will depend on the type of bearing and on how it is mounted. The following is a brief description of the features of each of the pullers shown in Figure 9. The most secure and effective puller is the bearing splitter (Figure 9B). It cannot slip off the bearing and also pulls on the inner ring, which avoids distortion to the bearing.

- A two, three or four-jaw puller (Figure 9A) is sometimes necessary when there is not enough space for a splitter. In this case the pulling force is applied to a few small areas on the outer ring, which can cause distortion of the bearing.
- This method should not be used on larger bearings if the bearing is to be reused. Smaller bearings (approximately 4 inches) can be pulled by their outer rings without damage. This is done by rotating the bearing and the puller jaws while holding the screw stationary.
- Rotating the jaws and the bearing while holding the screw stationary not only reduces distortion on the bearing but also makes the pulling much easier.

- Some sort of shaft protection should be used to protect the shaft centre when using a puller.

DANGER
Never pull on the outer ring of a self-aligning ball bearing; it may explode under tension!

NOTE
When using these pullers to remove larger bearings, the job can be made easier and faster by using an air or electric impact wrench on the puller screw.

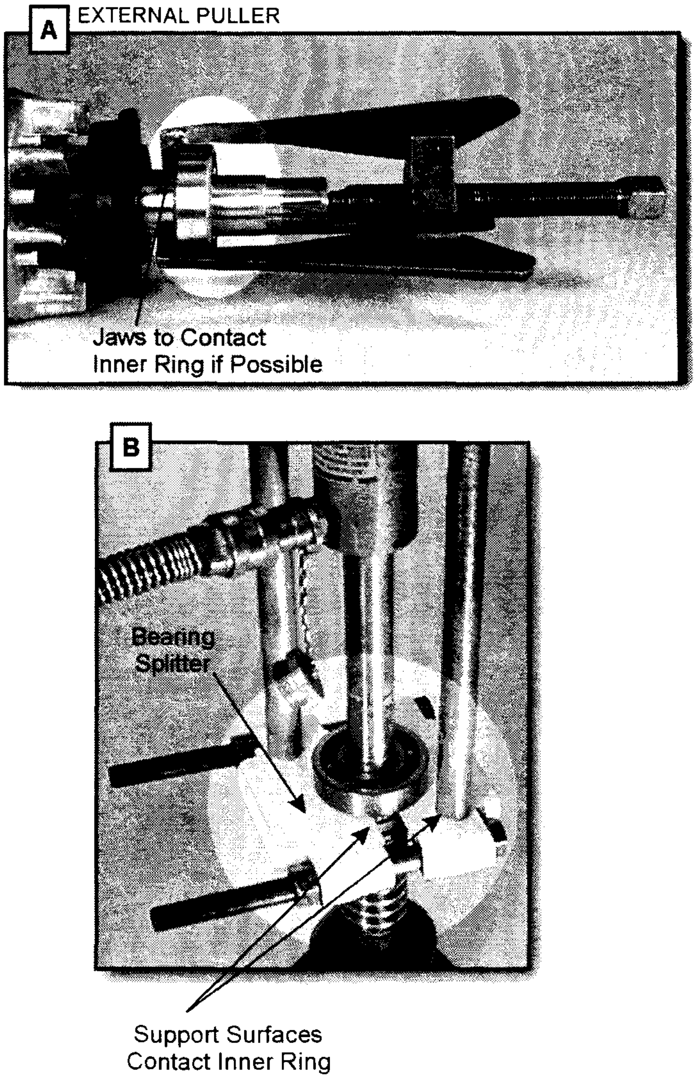


Figure 9 - Bearing pullers.

Arbor Press

An arbor press is often more convenient for removing small bearings than a hydraulic press (Figure 10).

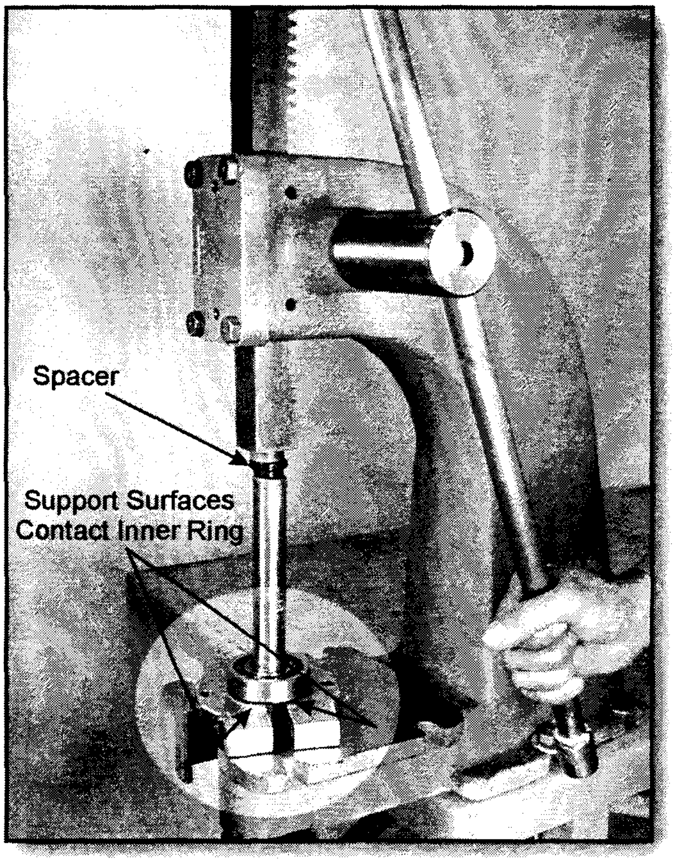


Figure 10 - Arbor press.

Drive

It is often convenient and safe to remove small bearings without damage using a hammer and a suitable sleeve (Figure 11) if the following points are observed.

- Select a sleeve with an inside diameter that is smaller than the outside diameter of the bearing inner ring.
- The sleeve, or at least the surface of the sleeve that contacts the bearing, should be made of a material that will not work-harden and flake. Brass is very bad for work-hardening and flaking and will usually damage and contaminate the bearing. At the same time, the material must not be harder than the bearing ring or it will damage the bearing.
- The ends of the sleeve should be free of burrs, smooth and at right angles to the axis.
- The sleeve should be clean inside and out.
- The hammer should be in safe condition, meaning that it should be clean, the handle must be secure and the head must have its surface ground smooth if it is work-hardened.

Occasionally, the inner ring is only accessible to a punch. In this case, the following points must be observed.

- Great care should be taken not to contact the cage or the rolling elements with the punch.
- The punch should be of mild steel and not brass so that it will not flake and contaminate the bearing.
- The punch should also be ground so that the ends are flat and free of burrs or any work-hardening on the surface.
- As the bearing begins to move off the shaft, be very careful not to damage the seat by allowing the punch to contact it.

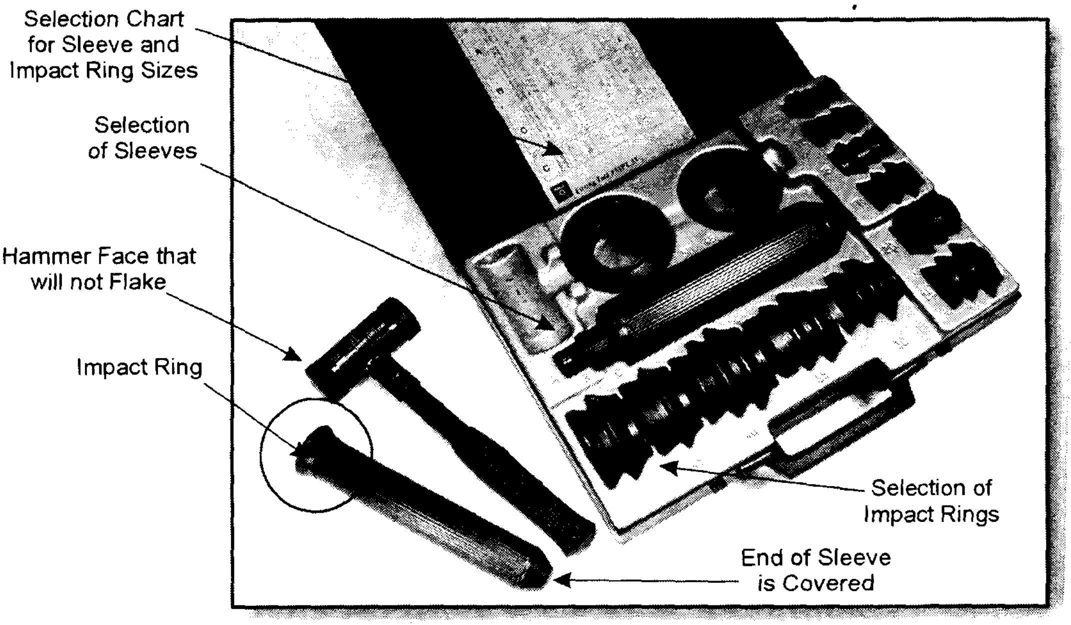


Figure 11 - Drive sleeves. (Courtesy SKF Canada Limited)

Destructive Removal Methods

Cut with a Grinder

Figure 12 shows a bearing that has had the outer ring and roller assembly cut off with a disc grinder to leave the inner ring exposed. The inner ring is then simply cut at two places, 180 degrees apart, using a grinder. This method is sometimes the fastest and mos convenient removal method if the bearing has seized to the shaft or the correct puller assembly is not available.

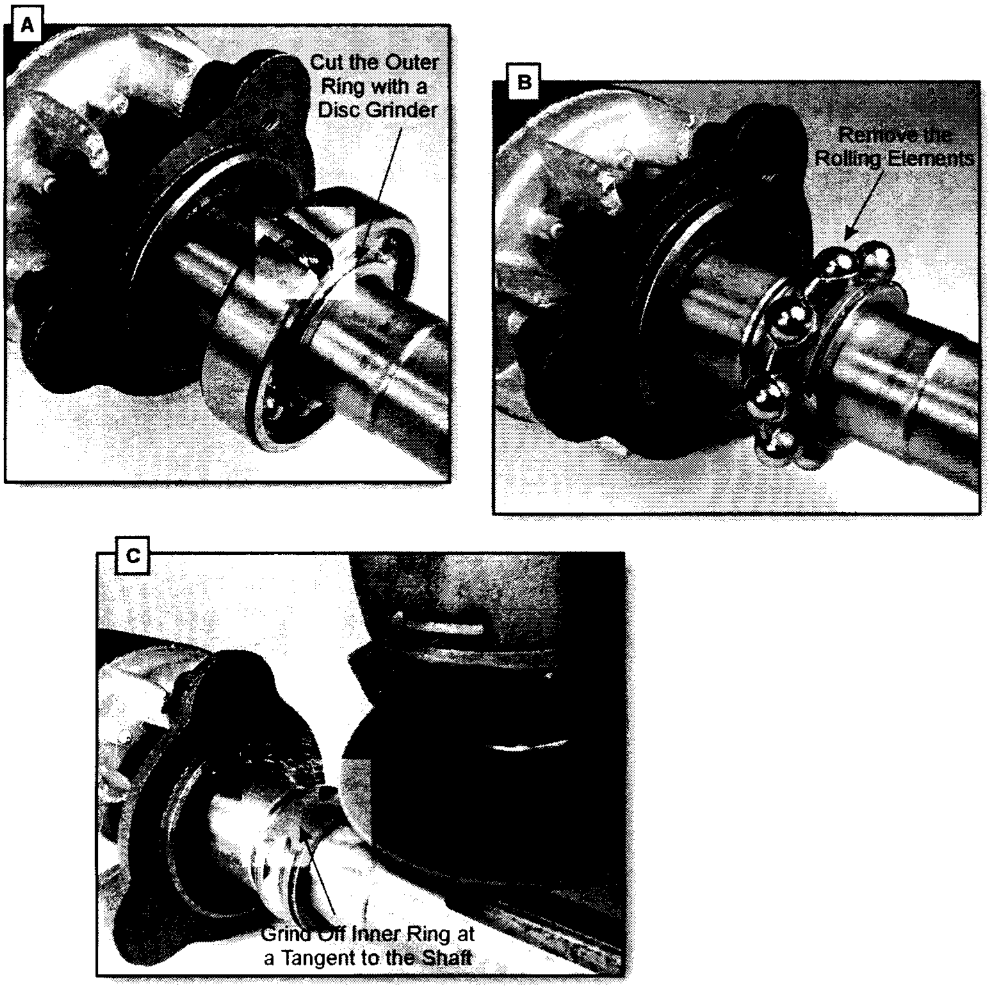


Figure 12 - Cutting a bearing off with a grinder.

CAUTION
1. Be very careful not to cut quite through to the shaft to avoid unnecessary damage to the bearing seat. The ring can usually be split with a sharp blow of a hammer on a chisel applied to the side of the cut. 2. If the shaft is heated too much on one side, it may tend to bend and stay bent.

DANGER
This operation is potentially dangerous and should be used only as a last resort! If the ring has a tight interference fit, it will be under considerable tension and can fly apart when it has been cut through. **When grinding:** • always wear safety glasses and a face shield and • ensure that sparks do not contact other people, other assemblies or any combustibles **When using a hammer and chisel**: • always wear eye protection and • ensure that other personnel are not exposed to flying metal when the ring is being split from the shaft.

Cut with a Torch

The method shown in Figure 13 should only be used when the correct bearing puller is not available or cannot be improvised or when the bearing and shaft can not be removed from the housing. This method requires some skill and care with the torch to avoid unnecessary damage to the shaft, the housing or other parts of the machine. It is good technique to point the flame at a tangent to the ring that you are cutting and to shave the metal off a bit at a time instead of cutting straight in towards the shaft. This method does, however, have the advantage that it is relatively fast and does not require much equipment.

Figure 13 - Burning out a bearing.

DANGER
• Have the proper fire extinguisher and a fire watch on hand. • Remove as much grease and oil from the bearing and the machine as is practical. • Remove all combustibles from around the machine. • Wear gloves and ensure that your skin is adequately protected against burning grease or oil that can blow back at you.

Drive

Figure 14 shows a fast convenient method of removal if the bearing is not salvageable. This method is not usually successful when the shaft diameter is over two inches. As with other destructive methods, this "hammer and bang" technique is used when pullers are not available or the time to use them is not warranted since the bearing is not going to be salvaged. Although a sleeve is more effective for removal, if it is not available a hammer and punch can be used. In this case care must be taken not to contact the shaft with the punch, in order to avoid damage to the shaft.

DANGER
Wear eye protection against flying metal fragments when you use a hammer and punch. This is especially important on bearing removal where the bearing could suddenly shatter.

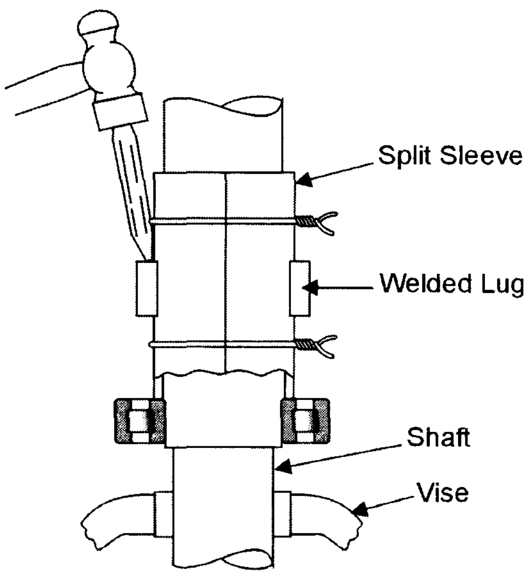


Figure 14 - Drive method of removal.

Weld

Figure 15 shows two situations in which it is necessary to remove the bearing by welding. In Figure 15A, there is no access for puller jaws behind the outer bearing ring. By applying a substantial weld in a zigzag pattern all the way around the raceway, the ring will be forced to contract when the weld cools and the ring can then be easily extracted.

In Figure 15B, there is no place to hook the puller jaws to the bearing. This is because either there are no jaws available to go between the rolling elements and hook onto a ring or there is insufficient space to insert the jaws. In this case, welding nuts to the ring is a fast convenient way to provide attachment points for a puller.

CAUTION
When you weld on a bearing that is still mounted, be careful not to get any weld onto the shaft, housing or on any other part of the machine.

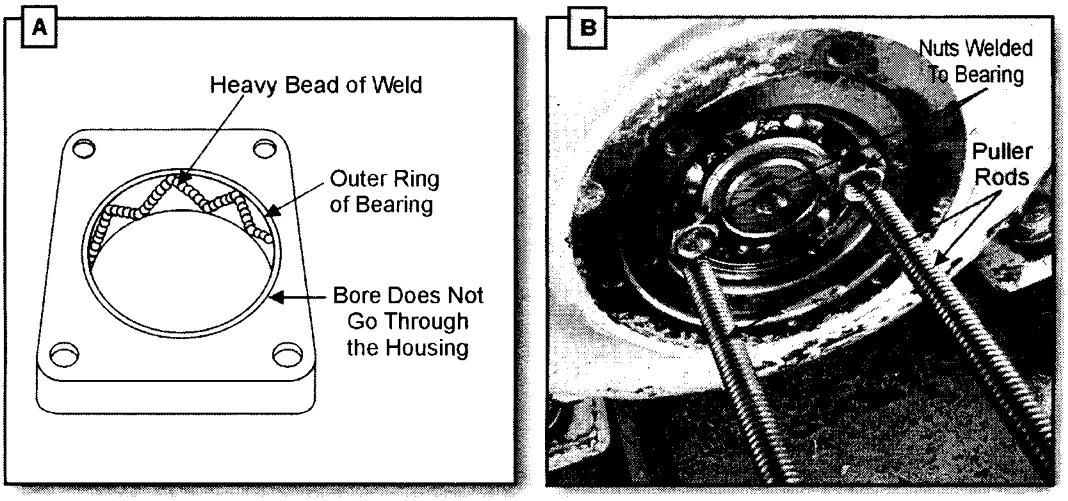


Figure 15 - Removal by welding.

Pullers

Internal Puller

The internal four-jaw puller is required when the shaft and bearing assembly cannot be removed from the housing. In this case the only way to pull on the inner ring is to insert the jaws between the rolling elements. These pullers come with a large selection of jaws specially designed to attach to the inner ring.

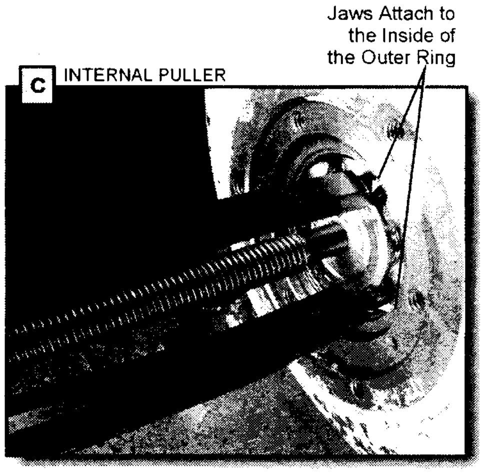


Figure 16 - Internal four-jaw puller. (Courtesy SKF Canada Limited)

Collet-Style Puller

The collet-style puller is the most practical way to remove caged needle bearings from a blind housing. A common example would be hydraulic gear pumps.

In Figure 17, you can see that the collet puller is a fast convenient way to remove a small bearing that is not easily accessible with a regular jaw puller.

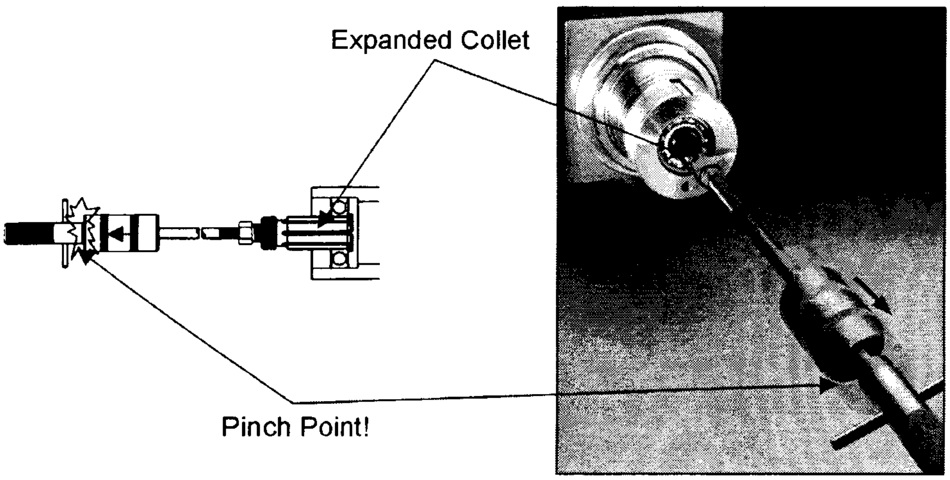


Figure 17 – Collet-style puller. (Courtesy SKF Canada Limited)

NOTES

CAUTION
Although it is faster to set up than a puller or hydraulics, the collet-style puller may cause impact damage to ball bearings.

DANGER
Be careful to keep the side of your hand out of the pinch point between the slide and the stop of the slide hammer!

Objective One Exercise

1. What is the reason for using a non-destructive method to remove a bearing?

2. How should the shaft be prepared before you attempt to remove a bearing?

3. How can a bearing be removed without damage when it is not practical to heat it?

4. What personal safety protection should you wear when you work with coolants?

5. What are three advantages of using oil injection to help remove a bearing?

6. Is a puller required to remove a bearing from a tapered seat if oil injection is used?

7. What safety precaution is necessary when you use oil injection to remove a bearing from a tapered seat?

8. What are three safety precautions to observe when you use hydraulic pressure on a bearing puller?

9. What safety protection should be used to protect against flying metal when you use a hydraulic press to remove a bearing?

10. When you press a shaft out of a bearing, what part of the bearing must be supported to avoid damage to the bearing?

11. How can you remove a smaller bearing without damage if you have to attach the puller to the outer ring?

12. Why is brass a bad material to use for sleeves or punches that are to be used for bearing removal?

13. What are four destructive methods for removing a bearing?

14. When you split a bearing from a shaft, what hazard should you guard against?

15. What are four safety precautions that you should observe when you use a cutting torch to remove a bearing?

Objective One Exercise Answers

1. So the bearing can be reused.
2. Remove any deposits and burrs.
3. Shrink the shaft with dry ice, aerosol coolant spray or liquid nitrogen.
4. Clean gloves.
5. No heat is required, very little force is required to remove the bearing and no abrasive damage occurs to the shaft during removal.
6. No.
7. Locate the bearing retaining nut close to the bearing before you inject the oil.
8. Keep the ram centred and the strong back at right angles to the shaft.
   Ensure that the puller rods are restrained from spreading and flying out.
   Stand at the end of the shaft opposite the puller.
9. Close the safety cage around the press when pressure is being applied.
10. The inner ring.
11. Rotate the bearing and the puller jaws while holding the screw stationary.
12. It work-hardens and flakes into the bearing.
13. Cut with a grinder,
    Cut with a torch.
    Drive off with a hammer and punch.
    Weld nuts to the bearing and attach a puller.
14. Flying metal.
15. Have the proper fire extinguisher and a fire watch on hand.
    Remove as much grease and oil from the bearing and machine as is practical
    Remove all combustibles from around the machine.
    Wear gloves and ensure that your skin is adequately protected against burning grease or oil that can blow back at you.

NOTES

Objective Two

When you have completed this objective, you will be able to:

Determine the correct shaft and housing sizes required to provide the correct fit to the anti-friction bearing.

The Importance of Getting the Correct Fit

In the past, getting the correct fit for an anti-friction bearing was often a hit-and-miss procedure. Fitting a bearing was done by feel instead of by specifications from the internationally accepted fit tables. Afterwards, when the bearing ran "a bit warm" the theory was that "the bearing is just wearing in." Later when the bearing failed, the failure was commonly blamed on a "bad bearing," on lack of lubrication or on too much lubricant.

The fact is that how tightly or loosely a bearing is fitted in its mount, directly affects its performance and the length of its life. The correct fit (specified in the fit tables) will ensure the following.

- That the rings do not spin or creep on their seats. For example, if the inner ring on an electric motor is 0.0005in. loose, it will creep 1.69 miles/month.
- That skidding of the rolling elements on the raceways is minimized.
- That the inner ring is not tight enough to crack from hoop stress.
- That the rolling elements do not bind between the rings. A 6210 bearing with normal clearance has 0.0002 to 0.0009 inches of clearance between the balls and the raceways.
- That the required axial clearance or preload is present.

Tolerances and Fits

Since getting the correct fit for a bearing requires the use of tables that give you tolerances, allowances and fits, you should be clear about what these terms mean.

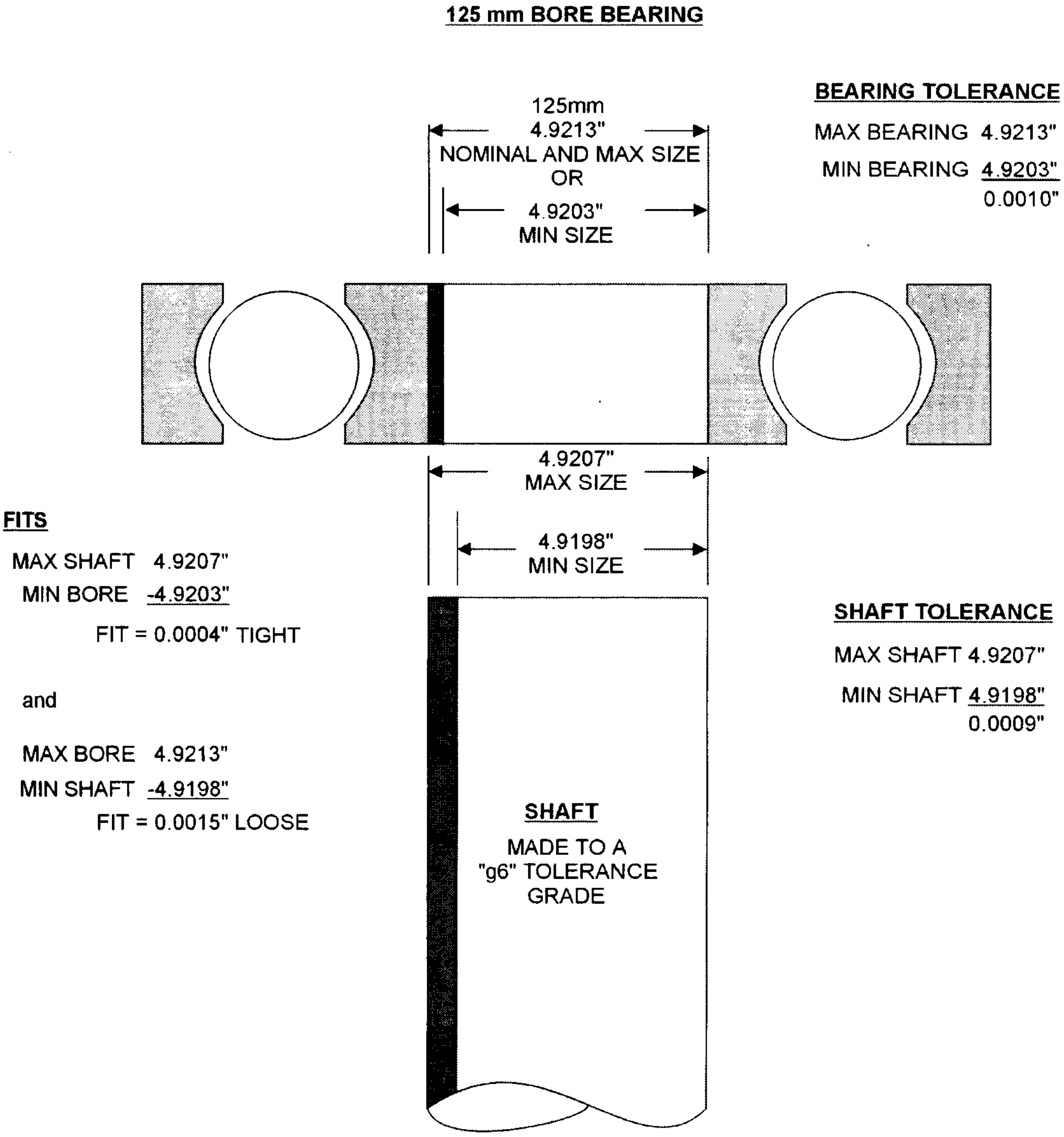


Figure 18 - Tolerance and fit.

Definition of Tolerance

The tolerance for any dimension is the total permissible variation in its size.

For example, when you look at a bearing fit table, you will find that the bore diameter of a 125 mm (4.9213 inches) bearing can be from a minimum of 4.9203 inches to a maximum of 4.9213 inches (Figure 18). The **difference** between these two size limits is 0.001 inches.

This **difference** in sizes is called the tolerance.

NOTES

Definition of a Fit

Fit is the term used for the range of permissible tightness or looseness of mating parts.

For example, in a table of recommended fits, if a "g6" fit was recommended for a 125 mm bearing, you would find that in the g6 fit column, the fit would be listed as 15L to 4T.

This means that the fit is from 0.0015 clearance to 0004 interference as shown in Figure 18.

Types of Fits

The following are three types of fits:

- A *clearance* fit (Figure 19A) means that the shaft is always smaller than the bearing bore or that the outside diameter of the bearing is always smaller than the housing bore.
- A *transition* fit (Figure 19B) means that the shaft and bore sizes will be such that the combination of their tolerances may produce a tight fit, a loose fit or sometimes they will be the same size.
- An *interference* fit (Figure 19C) means that the shaft will always be larger than the bearing bore or the outside diameter of the bearing will be larger than the housing bore.

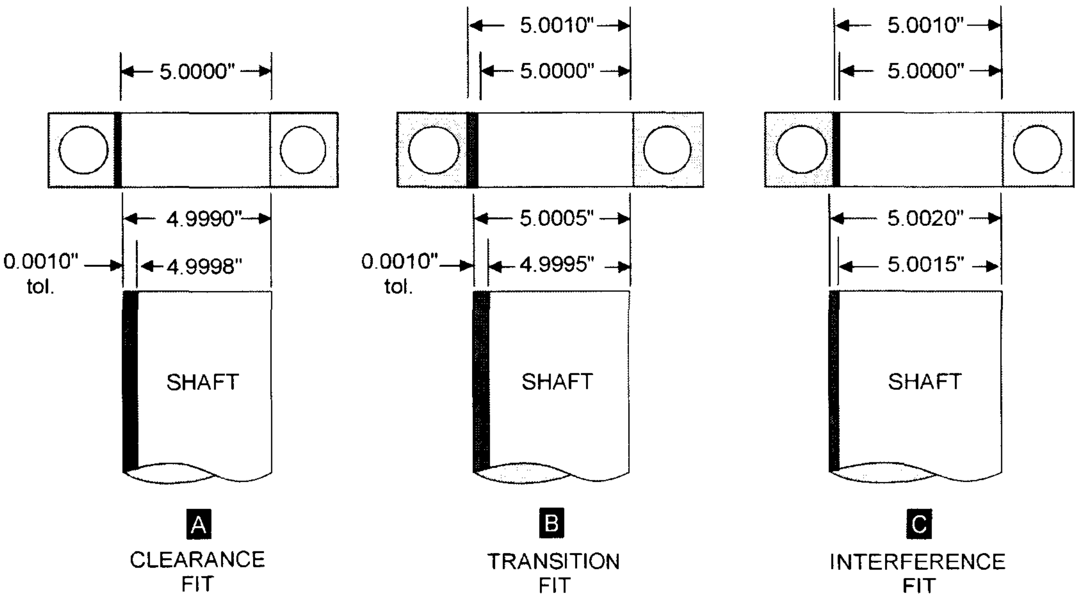


Figure 19 - Types of fits.

Tolerance Codes

When you look up the recommended shaft sizes in Bearing Fit Table 3 or the recommended housing bore sizes in Table 4 (tables shown in later pages), you will find these sizes listed under various tolerance codes. The code has the following two pieces of information:

1. The number in the codes is an ISO grade to indicate the size of the tolerance. In other words, the grade indicates how much variation in size would be allowed for that grade number. If you look at the codes shown on the diagram in Figure 20, you will see that an h8 tolerance permits a larger variation in size than a h6 or a g6 tolerance.
2. The letter in the tolerance code has the following three pieces of information.
   - If it is an uppercase letter, it indicates the tolerance for a hole size (in this case the housing bore).
   - If it is a lowercase letter, it indicates the tolerance on the shaft.
   - The letter also tells us the tolerance position. In the diagram in Figure 20 you will see how some tolerances give a clearance fit and some give an interference fit, while others will be a transition fit. This is described as the tolerance position.

Although you will not use the diagram in Figure 20 to look up the shaft and housing sizes, it does tell you at a glance how big the tolerance is and what type of a fit you can expect.

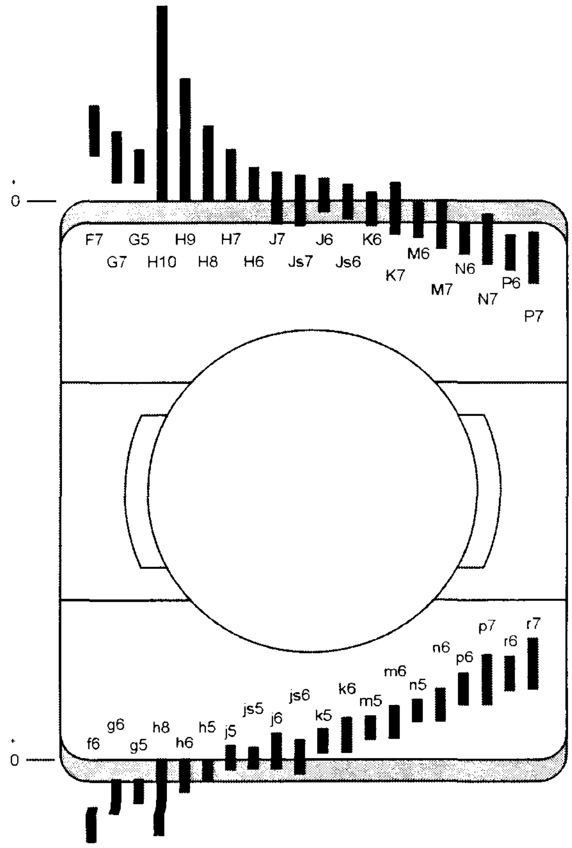


Figure 20 - Tolerance position diagram. (Courtesy SKF Canada Limited)

NOTES

Fit Tables

Table 1: Fits for Solid Steel Shafts					
Radial Bearings with Cylindrical Bore					
Conditions	**Examples**	**Shaft Diameter, mm Ball bearings**	**Cylindrical Needle (1) and taper roller**	**Spherical roller bearings**	**Tolerance**
Rotating inner ring load or direction of load indeterminate					
Light and variable loads (P ≦ 0.06 C)	Conveyors, lightly loaded gearbox bearings	(18) to 100	≦40	–	j6
		(100) to 140	(40) to 100	–	k6
Normal & heavy loads (P > 0.06)	Bearings applications generally, electric motors, turbines, pumps, internal combustion engines, gearing, woodworking machines	≦ 18	–	–	j5
		(18) to 100	≦40	≦40	k5(k6)[2])
		(100) to 140	(40) to 100	(40) to 65	m5(m6)[2])
		(140) to 200	(100) to 140	(65) to 100	m6
		(200) to 280	(140) to 200	(100) to 140	n6
		–	(200) to 400	(140) to 280	p6
		–	–	(280) to 500	r6[3])
		–	–	> 500	r7[3])
Very heavy loads and shock loads with difficult working conditions (P > 0.12 C)	Axleboxes for heavy railway vehicles, traction motors, rolling mills	–	(50) to 140	(50) to 100	n6[3])
		–	(140) to 200	(100) to 140	p6[3])
		–	> 200	> 140	r6[3])
High demands on running accuracy with light loads (P ≦ 0.12 C)	Machine tools	≦ 18	–	–	h5[4])
		(18 to 100)	40		j5[4])
		(100) to 200	(40) to 140	–	k5[4])
		–	(140) to 200	–	m5[5])
Stationary inner ring load					
Easy axial displacement of inner ring on shaft desirable	Wheels on non-rotating axles				g6[5])
Easy axial displacement of inner ring on shaft unnecessary	Tension pulleys, rope sheaves				h6
Axial loads only					
Bearing applications of all kinds		≦ 250	≦ 250	≦ 250	j6
		> 250	> 250	> 250	js6

Table 1 continued: Fits for Solid Steel Shafts					
Thrust Bearings – Shafts and Housings					
Conditions	**Shaft Tolerances**		**Housing Tolerances**		
	Shaft diameter, mm	**Toler-ance**	**Housing bore**	**Tolerances**	**Remarks**
Axial loads only					
Thrust ball bearings	all	h6	all	H8	For less accurate bearing arrangements, there can be a radial housing clearance of up to 0.001 x D
Cylindrical roller thrust bearings	all	h6(h8)	all	H7(H9)	
Cylindrical roller and cage thrust assemblies	all	h8	all	H10	
Radial and axial loads / Spherical roller thrust bearings					
Stationary load on shaft washer	≦ 250	j6	all	H7	Housing washers fitted with radial housing clearance of up to 0.001 x D
	> 250	js6			
Rotating load on shaft washer or direction of loading indeterminate	≦ 200	k6	all	M7	
	(200) to 400	m6			
	> 400	n6			

1. Applies to needle roller bearings with inner ring; fits for needle roller bearings without inner ring will be found in the SKF catalogue Needle for Roller Bearings.
2. The tolerances in brackets are generally used for taper roller bearings and single row angular contact ball bearings. They can also be used for other types of bearing where speeds are moderate and the effect on bearing internal clearance variation is not significant.
3. Bearings with radial internal clearance greater than normal may be necessary.
4. For high precision bearings other recommendations apply; see SKF catalogue Precision Bearings.
5. Tolerance f6 can be selected for large bearings to ensure easy displacement.

Table 1 - Fits for solid steel shafts. (Courtesy SKF Canada Limited)

NOTES

Table 2: Fits for Cast Iron and Steel Housings

Radial Bearings – Solid Housings

Conditions	Examples	Tolerance	Displacement of outer ring
Rotating outer ring load			
Heavy loads on bearings in thin walled housings, heavy shock loads (P > 0. 12 C)	Roller bearing wheel hubs	P7	Cannot be displaced
Normal and heavy loads (P > 0. 06 C)	Ball bearing wheel hubs, big-end bearings, crane travelling wheels	N7	Cannot be displaced
Light and variable loads (P ≦ 0. 06 C)	Conveyor rollers, rope sheaves, belt tension pulleys	M7	Cannot be displaced
Direction of load indeterminate			
Heavy shock loads	Electric traction motors	M7	Cannot be displaced
Normal and heavy loads (P > 0. 06 C), axial displacement of outer ring unnecessary	Electric motors, pumps, crankshaft bearings	K7	Cannot be displaced as a rule
Accurate or silent running [1]			
	Roller bearings for machine tool work spindles	K6[1)]	Cannot be displaced as a rule
	Ball bearings for grinding spindles, small electric motors	J6[2)]	Can be displaced
	Small electric motors	H6	Can easily be displaced
Radial Bearings – Split or Solid Housings			
Direction of load indeterminate			
Light and normal loads (P ≦ 0. 12 C) axial displacement of outer ring desirable	Medium-sized electrical machines, pumps, crankshaft bearings	J7	Can be displaced as a rule
Stationary outer ring load			
Loads of all kinds	General engineering, railway axleboxes	H7[3)]	Can be displaced
Light and normal loads (P ≦ 0, 12 C) with simple working conditions	General engineering	H8	Can be displaced
Heat conduction through shaft	Drying cylinders, large electrical machines with spherical roller bearings	G7[4)]	Can be displaced

1. For high precision bearings other recommendations apply, see SKF catalogue "Precision Bearings".
2. When easy displacement required use H6 instead of J6.
3. For large bearings (D > 250 mm) and temperature differences between outer ring and housing > 10° C (18°F), G7 should be used instead of H7.
4. For large bearings (D > 250 mm) and temperature differences between outer ring and housing 10° C (18°F), F7 should be used instead of G7.

Table 2 – Fits for cast iron and steel housings. (Courtesy SKF Canada Limited)

Table 3 • Shaft Bearing - Seat Diameters (in inches)

Bearing Bore Diameter			g6			h6			h5			j5			j6			k5			k6		
mm	Inches		Shaft Dia.		Fit in 0.0001"	Shaft Dia.		Fit in 0.0001"	Shaft Dia.		Fit in 0.0001"	Shaft Dia.		Fit in 0.0001"	Shaft Dia.		Fit in 0.0001"	Shaft Dia.		Fit in 0.0001"	Shaft Dia.		Fit in 0.0001"
	Max.	Min.	Max.	Min.		Max.	Min.		Max.	Min.		Max.	Min.		Max.	Min.		Max.	Min.		Max.	Min.	
4	0.1575	0.1572	0.1573	0.1570	5L 1T	0.1575	0.1572	3L 3T	0.1575	0.1573	2L 3T	0.1576	0.1574	1L 4T	0.1577	0.1574	1L 5T	0.1577	0.1575	0T 5T	0.1579	0.1575	0T 7T
5	0.1969	0.1966	0.1967	0.1964		0.1969	0.1966		0.1969	0.1967		0.1970	0.1968		0.1971	0.1968		0.1971	0.1969		0.1973	0.7969	
6	0.2362	0.2359	0.2360	0.2357		0.2362	0.2359		0.2362	0.2360		0.2363	0.2361		0.2364	0.2361		0.2364	0.2362		0.2366	0.2362	
7	0.2756	0.2753	0.2754	0.2750	6L 1T	0.2756	0.2752	4L 3T	0.2756	0.2754	2L 3T	0.2758	0.2755	1L 5T	0.2759	0.2755	1L 6T	0.2759	0.2756	0T 6T	0.2760	0.2756	0T 7T
8	0.3150	0.3147	0.3148	0.3144		0.3150	0.3146		0.3150	0.3148		0.3152	0.3149		0.3153	0.3149		0.3153	0.3150		0.3154	0.3150	
9	0.3543	0.3540	0.3541	0.3537		0.3543	0.3539		0.3543	0.3541		0.3545	0.3542		0.3546	0.3542		0.3546	0.3543		0.3547	0.3543	
10	0.3937	0.3934	0.3935	0.3931		0.3937	0.3933		0.3937	0.3935		0.3939	0.3936		0.3940	0.3936		0.3940	0.3937		0.3941	0.3937	
12	0.4724	0.4721	0.4722	0.4717	7L 1T	0.4724	0.4720	4L 3T	0.4724	0.4721	3L 3T	0.4726	0.4723	1L 5T	0.4727	0.4723	1L 6T	0.4728	0.4724	0T 7T	0.4729	0.4724	0T 8T
15	0.5906	0.5903	0.5904	0.5899		0.5906	0.5902		0.5906	0.5903		0.5908	0.5905		0.5909	0.5905		0.5910	0.5906		0.5911	0.5906	
17	0.6693	0.6690	0.6691	0.6686		0.6693	0.6689		0.6693	0.6690		0.6695	0.6692		0.6696	0.6692		0.6697	0.6693		0.6698	0.6693	
20	0.7874	0.7870	0.7871	0.7866	8L 1T	0.7874	0.7869	5L 4T	0.7874	0.7870	4L 4T	0.7876	0.7872	2L 6T	0.7878	0.7872	2L 8T	0.7878	0.7875	1T 8T	0.7880	0.7875	1T 10T
25	0.9843	0.9839	0.9840	0.9835		0.9843	0.9838		0.9843	0.9839		0.9845	0.9841		0.9847	0.9841		0.9847	0.9844		0.9849	0.9844	
30	1.1811	1.1807	1.1808	1.1803		1.1811	1.1806		1.1811	1.1807		1.1813	1.1809		1.1815	1.1809		1.1815	1.1812		1.1817	1.1812	
35	1.3780	1.3775	1.3776	1.3770	10L 1T	1.3780	1.3774	6L 5T	1.3780	1.3776	4L 5T	1.3782	1.3778	2L 7T	1.3784	1.3778	2L 9T	1.3785	1.3781	1T 10T	1.3787	1.3781	1T 12T
40	1.5748	1.5743	1.5744	1.5738		1.5748	1.5742		1.5748	1.5744		1.5750	1.5746		1.5752	1.5746		1.5753	1.5749		1.5755	1.5749	
45	1.7717	1.7712	1.7713	1.7707		1.7717	1.7711		1.7717	1.7713		1.7719	1.7715		1.7721	1.7715		1.7722	1.7718		1.7724	1.7718	
50	1.9685	1.9680	1.9681	1.9675		1.9685	1.9679		1.9685	1.9681		1.9687	1.9683		1.9689	1.9683		1.9690	1.9686		1.9692	1.9686	
55	2.1654	2.1648	2.1650	2.1643	11L 2T	2.1654	2.1647	7L 6T	2.1654	2.1649	5L 6T	2.1656	2.1651	3L 8T	2.1659	2.1651	3L 11T	2.1660	2.1655	1T 12T	2.1662	2.1655	1T 14T
60	2.3622	2.3616	2.3618	2.3611		2.3622	2.3615		2.3622	2.3617		2.3624	2.3619		2.3627	2.3619		2.3628	2.3623		2.3630	2.3623	
65	2.5591	2.5585	2.5587	2.5580		2.5591	2.5584		2.5591	2.5586		2.5593	2.5588		2.5596	2.5588		2.5597	2.5592		2.5599	2.5592	
70	2.7559	2.7553	2.7555	2.7548		2.7559	2.7552		2.7559	2.7554		2.7561	2.7556		2.7564	2.7556		2.7565	2.7560		2.7567	2.7560	
75	2.9528	2.9522	2.9524	2.9517		2.9528	2.9521		2.9528	2.9523		2.9530	2.9525		2.9533	2.9525		2.9534	2.9529		2.9536	2.9529	
80	3.1496	3.1490	3.1492	3.1485		3.1496	3.1489		3.1496	3.1491		3.1498	3.1493		3.1501	3.1493		3.1502	3.1497		3.1504	3.1497	

Table 3 - Shaft bearing seat diameters. (Courtesy SKF Canada Limited)

NOTES

Bearing Outside Diameter			H8			H7			H6			J6			J7			K6			K7			M6		
mm	Inches		Housing Bore		Fit in 0.0000"	Housing Bore		Fit in 0.0000"	Housing Bore		Fit in 0.0000"	Housing Bore		Fit in 0.0000"	Housing Bore		Fit in 0.0000"	Housing Bore		Fit in 0.0000"	Housing Bore		Fit in 0.0000"	Housing Bore		Fit in 0.0000"
	Max.	Min.	Min.	Max.		Min.	Max.		Min.	Max.		Min.	Max.		Min.	Max.		Min.	Max.		Min.	Max.		Min.	Max.	
16	0.6299	0.6296	0.6299	0.6310	14L 0	0.6299	0.6306	10L 0	0.6299	0.6303	7L 0	0.6297	0.6301	5L 2T	0.6296	0.6303	7L 3T	0.6295	0.6300	4L 4T	0.6294	0.6301	5L 5T	0.6293	0.6297	1L 6T
19	0.7480	0.7476	0.7480	0.8674		0.7480	0.7488		0.7480	0.7485		0.7478	0.7483		0.7476	0.7485		0.7476	0.7481		0.7474	0.7482		0.7473	0.77478	
22	0.8661	0.8657	0.8661	0.8674		0.8661	0.8669		0.8661	0.8666		0.8659	0.8664		0.8657	0.8666		0.8657	0.8662		0.8655	0.8663		0.8654	0.8659	
24	0.9449	0.9445	0.9449	0.9462	17L	0.9449	0.9457	12L	0.9449	0.9454	9L	0.9447	0.9452	7L	0.9445	0.9454	9L	0.9445	0.9450	5L	0.9443	0.9451	6L	0.9442	0.9447	2L
26	1.0236	1.0232	1.0236	1.0249	0	1.0236	1.0244	0	1.0236	1.0241	0	1.0234	1.0239	2T	1.0232	1.0241	4T	1.0232	1.0237	4T	1.0230	1.0238	6T	1.0229	1.0234	7T
28	1.1024	1.1020	1.1024	1.1037		1.1024	1.1032		1.1024	1.1029		1.1022	1.1027		1.1020	1.1029		1.1020	1.1025		1.1018	1.1026		1.1017	1.1022	
30	1.1811	1.1807	1.1811	1.1824		1.1811	1.1819		1.1811	1.1816		1.1809	1.1814		1.1807	1.1816		1.1807	1.1812		1.1805	1.1813		1.1804	1.1809	
32	1.2598	1.2594	1.2598	1.2613		1.2598	1.2608		1.2598	1.2604		1.2596	1.2602		1.2594	1.2604		1.2593	1.2599		1.2591	1.2601		1.2590	1.2596	
35	1.3780	1.3776	1.3780	1.3795		1.3780	1.3790		1.3780	1.3786		1.3778	1.3784		1.3776	1.3786		1.3775	1.3781		1.3773	1.3783		1.3772	1.3778	
37	1.4567	1.4563	1.4567	1.4582	19L	1.4567	1.4577	14L	1.4567	1.4573	10L	1.4565	1.4571	8L	1.4563	1.4573	10L	1.4562	1.4568	5L	1.4560	1.4570	7L	1.4559	1.4565	2L
40	1.5748	1.5744	1.5748	1.5763	0	1.5748	1.5758	0	1.5748	1.5754	0	1.5746	1.5752	2T	1.5744	1.5754	4T	1.5743	1.5749	5T	1.5741	1.5751	7T	1.5740	1.5746	8T
42	1.6535	1.6531	1.6535	1.6550		1.6535	1.6545		1.6535	1.6541		1.6533	1.6539		1.6531	1.6541		1.6530	1.6536		1.6528	1.6538		1.6527	1.6533	
47	1.8504	1.8500	1.8504	1.8519		1.8504	1.8514		1.8504	1.8510		1.8502	1.8508		1.8500	1.8510		1.8549	1.8505		1.8497	1.8507		1.8496	1.8502	
52	2.0472	2.0467	2.0472	2.0490		2.0472	2.0484		2.0472	2.0479		2.0474	2.0477		2.0467	2.0479		2.0466	2.0474		2.0464	2.0476		2.0463	2.0470	
55	2.1654	2.1649	2.1654	2.1672		2.1654	2.1666		2.1654	2.1661		2.1652	2.1659		2.1649	2.1661		2.1648	2.1656		2.1646	2.1658		2.1645	2.1652	
62	2.4409	2.4404	2.4409	2.4427	23L 0	2.4409	2.4421	17L 0	2.4409	2.4416	12L 0	2.4407	2.4414	10L 2T	2.4404	2.4416	12L 5T	2.4403	2.4411	7L 6T	2.4401	2.4413	9L 8T	2.4400	2.4407	3L 9T
72	2.8346	2.8341	2.8346	2.8364		2.8346	2.8358		2.8346	2.8353		2.8344	2.8351		2.8341	2.8353		2.8340	2.8348		2.8338	2.8350		2.8337	2.8344	
80	3.1496	3.1491	3.1496	3.1514		3.1496	3.1508		3.1496	3.1503		3.1494	3.1501		3.1491	3.1503		3.1490	3.1498		3.1488	3.1500		3.1487	3.1494	
85	3.3465	3.3459	3.3465	3.3486		3.3465	3.3479		3.3465	3.3474		3.3463	3.3471		3.3460	3.3474		3.3458	3.3467		3.3455	3.3469		3.3454	3.3463	
90	3.5433	3.5427	3.5433	3.5454		3.5433	3.5447		3.5433	3.5442		3.5431	3.5439		3.5428	3.5442		3.5426	3.5435		3.5423	3.5437		3.5422	3.5431	
100	3.9370	3.9364	3.9370	3.9391	27L	3.9370	3.9384	20L	3.9370	3.9379	15L	3.9368	3.9376	12L	3.9365	3.9379	15L	3.9363	3.9372	8L	3.9360	3.9374	10L	3.9359	3.9368	4L
110	4.3307	4.3301	4.3307	4.3328	0	4.3307	4.3321	0	4.3307	4.3316	0	4.3305	4.3313	2T	4.3302	4.3316	5T	4.3300	4.3309	7T	4.3297	4.3311	10T	4.3296	4.3305	11T
115	4.5276	4.5270	4.5276	4.5297		4.5276	4.5290		4.5276	4.5285		4.5274	4.5282		4.5271	4.5285		4.5269	4.5278		4.5266	4.5280		4.5265	4.5274	
120	4.7244	4.7238	4.7244	4.7265		4.7244	4.7258		4.2744	4.7253		4.7242	4.7250		4.7239	4.7253		4.7237	4.7246		4.7234	4.7248		4.7233	4.7242	

Table 4 • Housing Bearing - Seat Diameters (in inches)

Table 4 – Housing bearing seat diameters. (Courtesy SKF Canada Limited)

The preceding tables give fits (in inch dimensions) for all the standard **metric** bearing sizes. These fits have been agreed on by industry worldwide. All bearing manufacturer: use these as the standard fit for bearings to give maximum performance. Deviations fro these fits will occur only in exceptional operating conditions.

These fit tables are available from any bearing manufacturer or bearing sales outlet. When they are included in a bearing catalogue, they are usually located in the back section after the product information.

NOTE
If you are fitting inch series bearings, you must obtain a fit table written specifically for inch series bearings from the manufacturer. This is because inch series bearings are all made to plus tolerances and AFBMA standards, whereas metric bearings are made to minus tolerances and ISO standards.

Information Required to Interpret Fit Tables

When interpreting the fit tables, the following information is required:

- type of ring loading,
- operating conditions and
- bearing type and size.

Types of Ring Loading

In Figure 21A, a rotating load is shown. It can occur in the following situations.

- When the load is stationary and the ring that it acts on is rotating; e.g., on the outer ring of the bearings inside a conveyor roll.
- When the ring is stationary and the load rotates; e.g., on the **inner** ring of the connecting rod bearings in a roller bearing crank assembly.

An interference fit will be required on the ring with the rotating load.

In Figure 21B, a stationary load is shown. It can occur in the following situations.

- When the load and the ring that it acts on are both stationary; e.g., a bearing supporting the weight of the rotor in an electric motor.
- When the load and the ring both rotate together; e.g., on the **outer** ring of the bearings on a roller bearing crank.

A ring subject to a stationary load will have a looser fit than for the rotating ring load unless the direction of the load varies.

In Figure 21C, an indeterminate load is shown. It occurs when the direction of the load might reverse at any time (for example, the load on bearings for vibrating screens). This situation requires an interference or a transition fit on both rings.

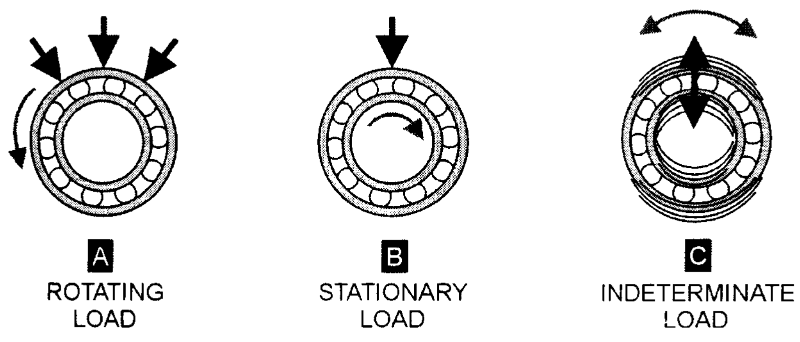


Figure 21 - Types of load. (Courtesy SKF Canada Limited)

Operating Conditions

The tables give examples of some typical operating conditions. If the exact condition for a particular application is not listed, you would pick the closest example.

Bearing Type and Size

The tolerance code for a particular application or operating condition will vary depending on the type and size of the bearing being used. Therefore, the type and size of the bearings being installed must be determined before the correct fit can be obtained from the fit tables.

How to find the Correct Fit

To become familiar with how to find the correct fit from the preceding fit tables, consider the example of a matched pair of 7210 single row angular contact ball bearings to be installed in a pump. This will involve looking up two fits:

- the shaft fit and
- the housing fit.

The Shaft Fit

1. Carefully measure the bearing seat on the shaft. Use a vernier micrometer that reads to 0.0001 inch. Take three sets of readings around the circumference at three locations along the axis. This is to check for out-of-round and taper.
2. Specify the type of ring load (rotating inner ring, stationary inner ring or axial). The bearing is mounted on a pump shaft. Therefore, it will be a rotating inner ring load (for more information on this see "Types of Ring Loading" above). This heading appears in the upper part of Table 1.
3. In the *Radial bearings with cylindrical bore* section of Table 1, find the bearing application for pumps in the *Examples* column.
4. Look in the *Ball bearings* column to the right and find the shaft diameter range into which the 7210 bearing falls. From the last two digits in the bearing code you can see that the nominal size is 50 mm and so would fall in the range (18) to 100 mm.
5. Then, look straight across to the *Tolerance* column and find the tolerance symbol. In this case, you will see the symbol k5(k6)[2]. The 2 directs you to footnote 2 at the bottom of the next page of Table 1, which tells you to use the symbols in brackets for tapered roller and single row angular contact bearings. Because this is an angular contact bearing you would select the k6 tolerance symbol to get the fit for this bearing.
6. Turn to Table 3 and locate the nominal size of the 7210 bearing in the left-hand column, i.e., 50 mm.
7. Look to the right straight across to the k6 column to find the maximum and minimum shaft diameters (1.9692 and 1.9686). This would tell you that the maximum allowable shaft diameter is 1.9692 inches and the minimum is 1.9686 inches.
8. Finally, look to the *Fit* column immediately to the right and read the fit, 1T 12T. You will see from the top of the column that the fits are given in units of 0.0001 inch. Therefore, the fit would be in the range of 0.0001 inch tight to 0.0012 inch tight (interference fit).

By comparing the measurements of the housing bore with the maximum and minimum housing dimensions found in Table 4, you can determine if the pump housing is within specification.

NOTE
When you check the housing fit, always make sure that you use the table with tolerance symbols in uppercase letters and then use the outside diameter to locate your bearing in the left hand column.

Objective Two Exercise

1. What are four ways in which the correct fit helps to extend the bearing life?

2. What is the tolerance code for a pump shaft to be fitted to a pair of 50 mm bore single row angular contact ball bearings that will have rotating inner ring loads? (Use Table 1)

3. What are the recommended shaft sizes for the bearing in question 2? (Use Table 3)

4. What is the recommended range of fits for the bearing in question 2? (Use Table 3 and give your answer in decimals of an inch.)

5. What is the tolerance code for the housing of the pump in question 2 if the outer ring has an indeterminate load and its outside diameter is 90 mm? (Use Table 2)

6. What are the recommended housing bore sizes for the bearing in question 2? (Use Table 4)

7. What is the recommended range of housing fits for the bearing in question 2? (Use Table 4 and give your answer in decimals of an inch.)

Objective Two Exercise Answers

1. The correct fit ensures that:
    - the rings do not spin on their seats
    - that skidding of the rolling elements is minimized
    - that the rolling elements do not bind
    - that the required preload or clearance is present
2. k6
3. 1.9692 in. to 1.9686 in.
4. 0.0001 in. tight to 0.0012 in. tight
5. K7
6. 3.5423 in. to 3.5437 in.
7. 0.0010 in. loose to 0.0010 in. tight.

Objective Three

When you have completed this objective, you will be able to:

Describe the preparations required before mounting anti-friction bearings.

Preparation

Proper preparation is essential to ensure efficient installation of a bearing and to ensure that no damage is done to the bearing. The following steps should be taken regardless of the installation method used.

1. Clean the machine and the bearing assembly.
2. Inspect the bearing assembly for damage; if damage is found, try to determine the cause.
3. Do a final cleanup of the assembly area.
4. Organize the tools and equipment and ensure that they are clean and in good condition.

Cleanup of the Machine and Bearing Assembly

Solvent Baths

- A solvent bath for general use should be used for the initial cleanup.
- A bath of clean solvent should be reserved for the final cleaning.

Housing Cleanup

- Thoroughly clean the machine, paying particular attention to the inside of the housing. It is critical to the life of the bearing that all traces of abrasive particles (even silt) are flushed and wiped from the bearing cavity.
- The bearing cavity and surrounding surfaces are clean enough when a white rag moistened with solvent remains white after wiping these areas.
- If abrasives still appear after thorough flushing and wiping, you may have to coat the porous surface of the inside of the bearing housing with a paint that is compatible with the lubricant. This will ensure that no further abrasives migrate into the lubricant and then into the bearings.

Shaft Cleanup

- Clean the shaft to bare metal. In doing this, be careful to keep abrasives (from bead blasting or from emery cloth) off the bearing seats and the seal mounting surfaces. It is important not to alter the diameters of these surfaces since these diameters determine the fit of the bearing.
- Carefully remove any burrs with an oilstone.
- Polish the seal contact surfaces and bearing seats on the shaft and in the housing.

DANGER
• Solvents can harm the skin or cause allergic reactions. Therefore, wear rubber gloves when using solvents. • Use compressed air carefully. Compressed air can cause particles, solvents and gases to penetrate through your skin and into your bloodstream. This may lead to gangrene and amputation or death! Therefore, always wear eye protection and cover exposed skin. Direct the air stream so that the flying particles do not contact others or yourself. • Never spin a bearing with compressed air, especially when holding it with your fingers through the inner race. The air will remove the lubricant while the bearing spins at high speed. If it locks up and spins on your fingers you may be injured or possibly drop the bearing.

NOTE
It is important not to reduce the diameter of a bearing seat, as this will destroy the specified fit. Therefore, when you clean up a bearing seat, use only emery cloth to remove the deposits to bare metal and then use crocus cloth to polish the seat.

Inspection

Inspection of the shaft, housing and bearings has the following two benefits.

- You can determine which parts have to be replaced or repaired.
- You can find clues as to what caused the failure (if any). In this way you can determine how to avoid another failure. There can be very large costs in downtime from putting faulty equipment back in service.

NOTE
Before you begin the inspection, it is good trade practice to do a cleanup of the assembly area to avoid dirt and damage that might interfere with accurate measurements.

Housing Inspection

- Look for cracks in the housing.
- Look for dents or nicks and burrs in the housing bore.
- Look for corrosion damage on the housing bore.
- Look for grooves or marks made from the outer bearing ring having spun in the bore.
- If the bore is damaged, it must be sleeved or the housing discarded.

- If the bore does not have any visible damage, carefully measure the bore using telescoping gauges or an inside micrometer in conjunction with an outside vernier micrometer to an accuracy of 0.0001in.. Take the measurements at three positions in the middle of the bearing seat to check for out-of-round, then repeat these measurements at the inside and outside ends of the bore to check for taper. Be sure to record your readings.

Shaft Inspection

- First check the shaft for straightness by setting it up in a lathe or on V blocks and using a dial indicator. If it is bent, it must either be accurately straightened to within the manufacturer's specifications in the area of the bearings, seals and hubs or be discarded.
- If the shaft is not bent, inspect the keyway and hub mounting surface for wear and damage.
- Inspect the seal seating surfaces for damage or grooves.
- Inspect the bearing seats for dents, nicks, burrs, corrosion and marks or grooves from the inner bearing ring having spun on the shaft.
- If the hub, seal and bearing seats are undamaged, measure each of these areas carefully with a vernier micrometer to check for out-of-round and taper.

Bearing Inspection

- Inspect the seating surfaces of the outer and inner rings for marks indicating that they have spun in the housing or on the shaft.
- Inspect for corrosion on the seating surfaces of the rings.
- Inspect the rings for cracks.
- Inspect the cage and rolling elements for damage from corrosion.
- Inspect the rolling elements and raceways for dents from impacts or other causes.
- Inspect the surfaces of the rolling elements for varnish (lubricant oxidized onto these surfaces by high temperatures).
- Look for tracks from electric arcing inside the bearing. These will appear as axial lines corresponding to each rolling element inside the raceways.
- Look for discolouration from overheating.
- Look for surfaces that are no longer shiny on the raceways or on the rolling elements. This could be caused by contamination or normal fatigue (causing flaking or pitting) if the bearing has been in service for a number of years.

Final Cleanup and Preparation of the Assembly Area

A final thorough cleanup of the assembly area as well as the shaft and housing should cover the following details.

- The area should be isolated from any grinding, filing, welding or machining operations.
- The area should be well-lit.
- The area should be as free as possible from dirt and corrosives.
- The bench top should be cleared and cleaned thoroughly.
- The vise should be thoroughly wiped down to remove any emery dust or abrasives from filing.
- The bench top should be covered with clean rags to protect accurately machined surfaces from dirt or damage.

NOTE
It is extremely important to avoid contamination of the bearings. To ensure this, you should always take the following precautions. • Always cover the housing, the shaft and any partly assembled bearings with clean, lint-free rags or plastic when you are not working on them. It especially important to cover these items whenever you have to leave them for any reason! • Always leave the bearings wrapped in their original package until you are ready to install them.

Organize the Tools and Equipment

The following points for organizing the tools can help with the efficiency of the job:

1. Decide on the method of mounting that is appropriate for the type of bearing, the size of the bearing assembly and the equipment that you have available.
2. Collect the equipment and clean it thoroughly.
3. Grind off all work-hardened surfaces from punches, hammers, sleeves and other equipment that will be used for installation.
4. Remove all burrs from sleeves or spacers that may be used to install the bearing. Also, ensure that all surfaces that contact the bearing are smooth and clean.
5. Clean all metal particles from the tools and the work area!

Objective Three Exercise

1. How is compressed air dangerous when you use it during the cleaning of an assembly?

2. What should you do to the bearing assembly after it has been cleaned?

3. How can you tell when the housing is clean enough?

4. After you have removed any deposits or corrosion from the bearing seat, why should you **not** use emery cloth on the bare metal surface?

5. What are two benefits of inspecting the shaft or the housing?

6. What must be done if a bearing seat in a housing is found to be grooved, tapered or out-of-round?

7. What three areas on the shaft must be checked?

8. To protect against contamination, what should you do to the housing after you have thoroughly cleaned it?

9. What should you always do to an exposed bearing assembly if you have to leave it for any reason?

NOTES

Objective Three Exercise Answers

1. Compressed air can cause particles of dirt, solvent and gases to penetrate the skin and go into the bloodstream. This may lead to gangrene.
2. Inspect it for damage and try to determine the cause of failure.
3. When a white rag moistened with solvent remains white after wiping the housing.
4. To avoid reducing the diameter of the seat and thus destroying the fit.
5. You can determine which parts have to be replaced and you can find clues as to the cause of the failure, so that future failures can be avoided.
6. It must be sleeved or replaced.
7. The area of the hub and keyway, the seal seat and the bearing seat.
8. Cover it completely with plastic.
9. Cover it with clean, lint-free rags or plastic.

NOTES

Objective Four

When you have completed this objective, you will be able to:

Describe the drive or press-on methods of mounting anti-friction bearings.

Cold Mounting Methods

When to Cold Mount

Cold mounting can be accomplished without damage to the bearing in the following situations:

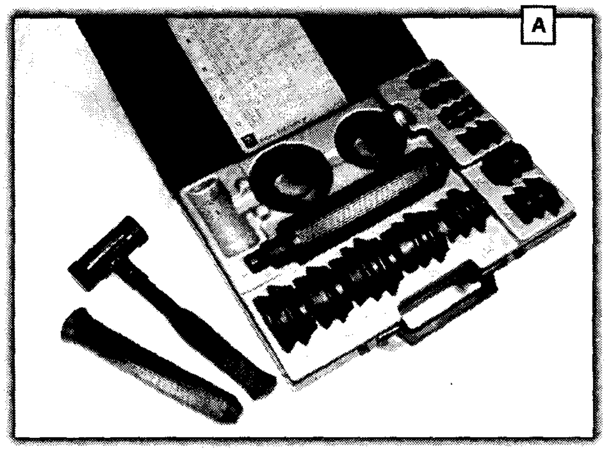
- on the bearing ring with the stationary load since this will be a light interference or a clearance fit. In most cases, this will be the outer ring.
- on small bearings (1½-inch bores or less) with cylindrical bores,
- on bearings under 100 mm with tapered bores, Installation is best done with the locknut.
- on bearings over 100 mm with tapered bores. Using a hydraulic nut or a nut equipped with jacking bolts will make it much easier to push the bearing up the taper.

NOTE
1. In most cold mounting methods, force must be applied to the bearing. To avoid damage to the bearing, never apply force through the rolling elements by pushing on the ring that has the looser fit. Always push on the ring or rings being fitted. 2. If the bearing must be installed on the shaft and in the housing at the same time, always push on both rings together. 3. Never apply hammer blows directly to a bearing. Always use a clean mandrel or sleeve of the correct size.

Small Non Separable Bearings with Cylindrical Bores

The drive method shown in Figure 23 is the most practical for small cylindrical bearings (a sleeve kit is shown in Figure 22A). Some points to note about this method are as follows.

- Clean the shaft and lightly oil the bearing seat.
- Always ensure that the sleeve is very clean on the inside and outside to avoid dislodged dirt from entering the bearing when it is being driven.
- Always keep the sleeve free of burrs.
- Never use a sleeve material such as brass that can flake under impact.
- Use a clean hammer or preferably a dead blow hammer that won't cause the sleeve to flake or splinter.
- If practical, use one of the presses in Figure 22 to install the bearing without applying any impact force.
- If the housing is bored for a clearance fit, clean and lightly oil the bore and slide the bearing assembly into place.
- If the bearing is a tight fit in the housing as well as on the shaft, use an impact ring on the end of the sleeve to contact both bearing rings (Figure 23).



Courtesy SKF
Canada Limited

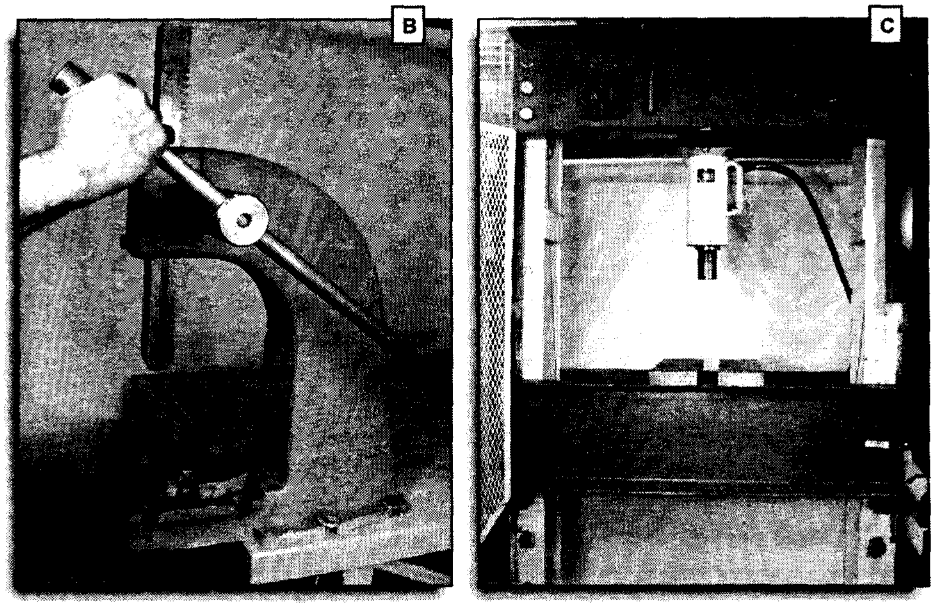


Figure 22 - Sleeve kit, arbor press and hydraulic press.

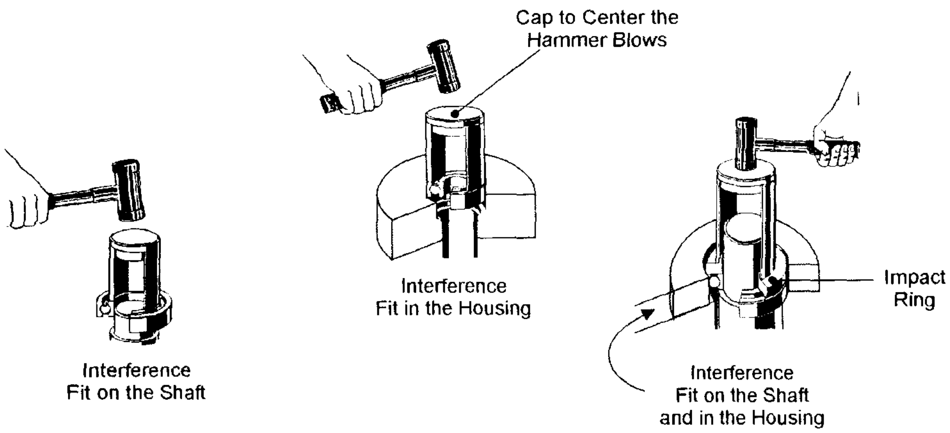


Figure 23 - Tools for driving a bearing on a shaft.
(Courtesy SKF Canada Limited)

Small Separable Cylindrical Bore Bearings

Separable bearings can be installed in three steps:

1. Cut a small chamfer on the housing bore and thoroughly clean the housing.
2. Clean and oil the shaft and press the inner ring on.
3. Oil the outer ring and the rollers and push the assembly into the housing using a guide sleeve (Figure 24).

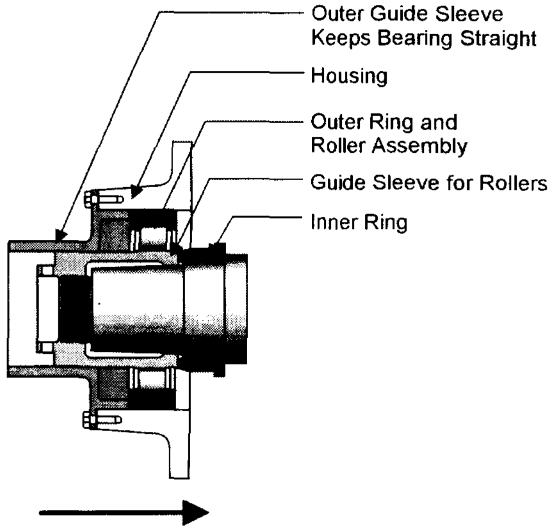


Figure 24 – Using a guide sleeve to install a separable bearing. (Courtesy SKF Canada Limited)

Needle Bearings

Figure 25 shows a needle bearing being installed into a housing using a guide mandrel. This bearing has a very thin wall on its cup, which can easily be crushed or distorted during installation. The use of an accurately sized mandrel ensures that the bearing is internally supported against crushing and also aligned with the housing bore to prevent distortion.

Be sure to slightly chamfer the bore. Then, lightly oil the bore and the rollers before installing. The oil on the bore will reduce the force required to push the cup in and the oil on the rollers will protect them from scratches when they contact the mandrel.

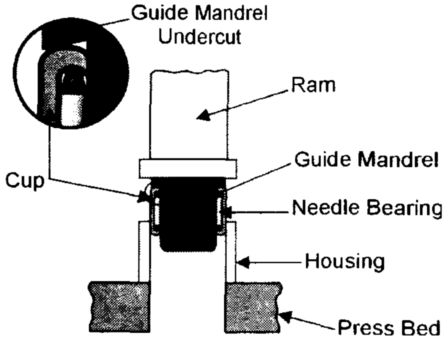


Figure 25 - Needle bearing installed with a guide mandrel.

Installing the Cup for a Tapered Roller Bearing Assembly

In Figure 26A, a small cup is being installed using a hammer and a mandrel. If convenient a press can be used, but in many situations, it is more practical to use a hammer to install small bearings. Usually the biggest problem that you will have will be to get the cup started straight in the housing. The following steps should be followed:

1. Make sure there is a very small chamfer on the bore and that the bore is smooth and free of burrs.
2. Thoroughly clean and lightly oil the bore.
3. Select a piece of round stock or a sleeve from a sleeve kit that is slightly smaller than the bore and will seat securely on the narrow rim of the cup.
4. Make sure that the round stock is smooth, clean and free of burrs.
5. Start the bearing into the bore as squarely as possible, using the hammer and round stock.
6. If the bearing is crooked when it is just being started, then tap on its high side using the round stock and hammer to straighten it. If it persists in being misaligned, do **not** drive it any further, as this can damage the bore. Carefully remove the cup, check the bore for damage or burrs or metal particles and start the cup again.
7. The cup should be driven until you feel from the hammer blows that it is solidly seated on the abutment surface in the housing. Check that it is seated by trying a 0.001-inch feeler gauge all around the abutment surface on the housing. There should not be a gap.
8. Clean and lightly oil the cup before you install the cone assembly.

Figure 26B shows a large cup being installed. The same steps and precautions should be followed as with the small cup. However, you will find that it is more difficult to get the large cup started straight. The use of a press may make it easier to start it straight and to overcome the resistance on the larger mating surfaces. If the cup does begin to start crookedly, **do not** be tempted to force it further. Carefully remove the cup and check the bore for burrs, etc., before attempting to reinstall it.

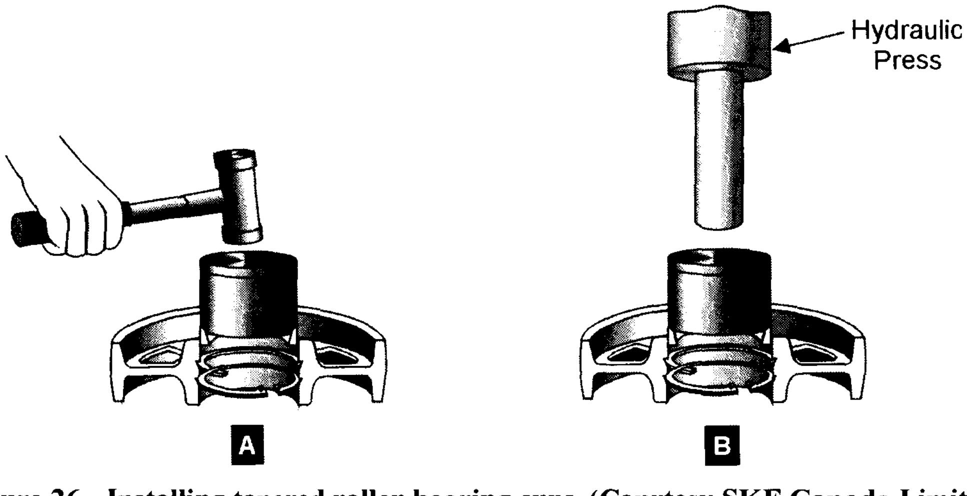


Figure 26 - Installing tapered roller bearing cups. (Courtesy SKF Canada Limited)

NOTE
Expanding the bore by heating does not help very much for cup installation.

Ball Bearings with Split Inner Rings

Figure 27 shows how to mount a four-point contact ball bearing with a split inner ring. This method applies to all other bearings with split inner rings. Perform the installation in the following three steps.

1. Install the inner half of the ring first.
2. Install the outer ring with the ball and cage assembly.
3. Install the outer half of the inner ring.

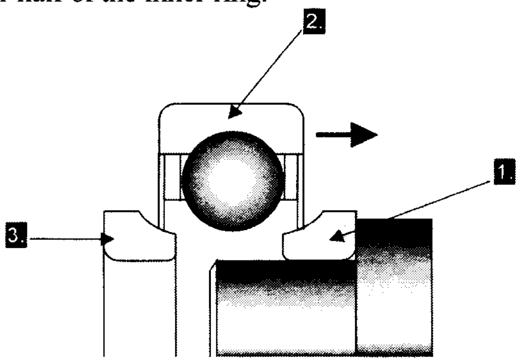


Figure 27 - Installing four-point contact bearings. (Courtesy SKF Canada Limited)

Mounting Small Tapered Bore Bearings

To prevent spinning or moving of the inner race of an anti-friction bearing, we use a tapered adapter sleeve.

When you mount a bearing on a tapered adapter sleeve, make the following two settings

1. The internal clearance in the bearing.
2. The axial position of the bearing on the shaft.

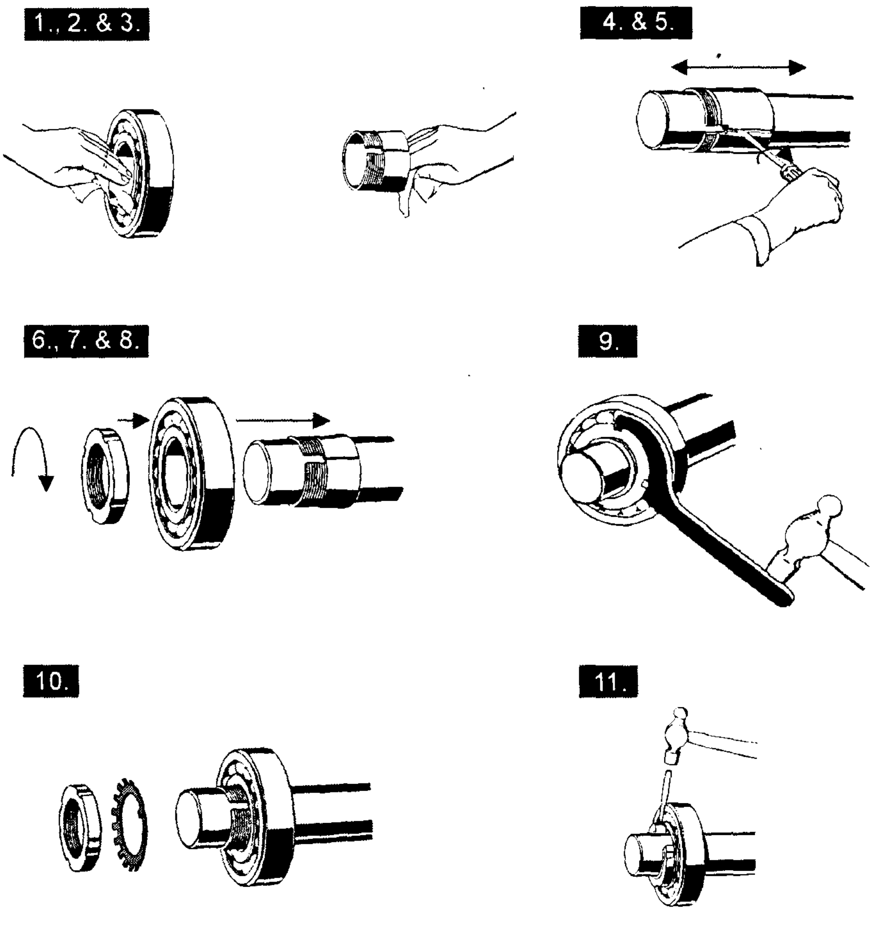


Figure 28 - Mounting a small tapered bore bearing.
(Courtesy SKF Canada Limited)

The steps to set the internal clearance will be described in Objective 7, while the step mount and position the bearing are as follows (the numbers in Figure 28 correspond t the points below).

1. Clean the shaft and adapter sleeve and inspect for damage.
2. Remove burrs from the sleeve and shaft with an oilstone, being careful not t stone the smooth (undamaged) areas.
3. Any sign of a groove or ridge around the sleeve indicates a worn taper. In th case, the sleeve should be replaced since it will no longer match the taper on bearing bore.

4. After you are sure that the shaft and sleeve are in good condition, wedge the sleeve slightly open, if necessary and slide it onto the shaft **dry** (no oil) to the approximate final axial position.
5. Lightly oil the outside of the sleeve and wipe off any excess oil.
6. Firmly seat the bearing on the taper.
7. **Without** the tab washer, assemble the locknut loosely on the sleeve so that the bevelled side of the nut faces the bearing.
8. Position the sleeve and bearing assembly to the required bearing location. To do this you will have to allow for the distance that the bearing will move up the taper when you tighten it to set the clearance.
9. Tighten the locknut to push the bearing up the taper until its internal clearance has been reduced to the recommended value. The procedure for setting the internal clearance will be covered under objective 7.
10. After the internal clearance has been set, remove the locknut, install the tab washer so that the tabs bend away from the bearing and reinstall the nut with the bevelled side towards the bearing.
11. Seat the nut firmly against the washer using a hook spanner and a light rap with a hammer. Then, bend a tab from the tab washer into a notch in the locknut.

General Installation Notes

- In step 9, the locknut was used to push the bearing up the taper to expand the inner ring in order to reduce the internal clearance to the required amount. It is considered good trade practice to do this without the washer in place. This is to avoid breaking off the tab that fits into the slot in the shaft.
- In step 9, if it is not possible to install the nut without the washer, then take care to lubricate the contacting faces of the nut and washer.
- In steps 9 to 11, it is important to have the bevelled side of the nut and washer towards the bearing so that the tabs on the washer and the wide side of the nut do not touch the cage or rolling elements.
- The tab that is used to lock the nut receives virtually no force from the nut. It only prevents the nut from loosening due to vibration. Therefore, do not hammer it down tightly against the bottom of the notch in the nut, as this will only make it hard to remove.

NOTES

Objective Four Exercise

1. Which ring must you push on when you install a bearing with an interference fit on a shaft?

2. Which ring(s) must you push on when you have to install a bearing on a shaft and in a housing at the same time?

3. What method is preferable to driving a bearing on with a hammer?

4. Why is a guide sleeve used to install the roller assembly of a separable bearing?

5. How can needle bearings with pressed steel cups be installed without crushing?

6. Are tapered bearing cups usually hot mounted or cold mounted?

7. On a tapered bore bearing assembly, should the bevelled side of the locknut face towards the bearing or away from the bearing?

Objective Four Exercise Answers

1. On the inner ring.
2. Both inner and outer rings.
3. Preferable to push a bearing on with a press.
4. To ensure that the rollers are aligned to avoid scoring the raceways.
5. Insert an accurately sized guide mandrel.
6. Cold mounted.
7. Bevel to face towards the bearing.

Objective Five

When you have completed this objective, you will be able to:

Describe the oil injection and hydraulic nut methods of mounting anti-friction bearings.

Mounting with Oil Injection and Hydraulic Nut

On bearings with bore sizes larger than 50 mm, a hydraulic nut can be used to push the bearing onto a taper. Another alternative is to use oil injection between the shaft and the bearing bore to expand the bearing and then push it into position using a locknut or a hydraulic nut.

These methods provide two main advantages over other methods.

1. They make it easier to precisely position the bearing to provide the specified internal clearance.
2. They avoid the use of heat, which is often not convenient to apply.

In Figure 29, both the hydraulic nut and the set-up for oil injection are shown. The procedure for using these methods is as follows:

Hydraulic Nut

1. Clean the shaft and adapter sleeve and inspect for damage. A grooved sleeve indicates a worn taper and it must be replaced.
2. Remove burrs from the sleeve with an oilstone, being careful not to stone the smooth areas.
3. Wipe the shaft and the inside of the sleeve dry, then install the sleeve.
4. Lightly oil the outside of the sleeve and then wipe off the excess oil.
5. Make sure that the piston on the hydraulic nut is retracted after it has been connected to the pump.
6. Screw the hydraulic nut up to the bearing.
7. Operate the pump to push the bearing up the taper.
8. Follow the procedure for setting the internal clearance as described in objective
9. Remove the hydraulic nut by releasing the pressure on the pump and unscrew t nut.
10. Install the locknut and tab washer so that the tabs on the washer bend away fro the bearing and the bevelled side of the nut faces the bearing.
11. Seat the nut firmly against the bearing with a light blow from a hammer on an impact spanner or on a piece of key stock, then bend a washer tab into a slot in the locknut.

Oil Injection

1. Complete steps 1 to 4 above.
2. Thread either the hydraulic nut or the locknut without the washer (bevelled ed towards the bearing) up to the bearing and apply some force to the bearing.
3. Using the hydraulic injection pump apply hydraulic pressure under the bearing expand the inner ring.
4. Using the hydraulic nut or the locknut set the internal clearance as described in objective 7.
5. Remove the hydraulic nut or locknut.
6. Follow steps 10 and 11 above.

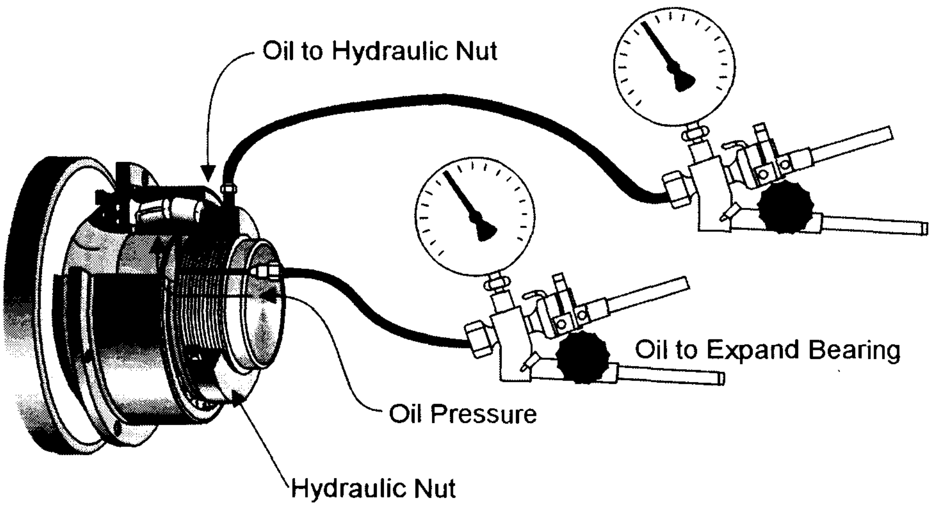


Figure 29 - Mounting with a hydraulic nut and oil injection. (Courtesy SKF Canada Limited)

CAUTION
To avoid damaging the locknut, it is best to use a hook spanner to tighten the locknut instead of a hardened steel punch or chisel. If a hook spanner is not available, mild steel key stock may be used.

Objective Five Exercise

1. What are the two main advantages of the oil injection and hydraulic nut method of mounting a bearing on a tapered seat?

2. When should the tapered sleeve be replaced?

Objective Five Exercise Answers

1. Easy to precision mount to specified clearances and avoids the use of heat.
2. If it is grooved (indicating a worn taper).

Objective Six

When you have completed this objective, you will be able to:

Describe the various hot mounting procedures used to install anti-friction bearings.

Hot Mounting Methods

When to Hot Mount

Hot mounting usually involves heating a bearing to about 80 degrees C above the shaft temperature to expand its bore in order to mount it with an interference fit.

Hot mounting is used in the following situations.

- Although hot mounting can be accomplished on all sizes of bearings, it is most practical for bore sizes over 20 mm when the cold mounting methods just described are not practical or the cold mounting equipment is not available.
- When the outer ring is a tight fit to the housing, the housing must be heated to expand its bore.
- When a bearing must be hot mounted to the shaft and installed in the housing at the same time, the housing must be heated while the bearing is being heated.

Preparations

The preparations for hot mounting are described in Objective 3 as well as some addition procedures. The following are the preparations specific to hot mounting:

1. Clean the machine and bearing assembly.
2. Inspect the shaft, housing and old bearings for damage and try to determine the cause of failure.
3. Do a final cleanup of the assembly area and the shaft and housing.
4. Organize the tools and equipment and make sure that they are clean and in gooc condition.
5. Have a clean pair of gloves or clean, lint-free rags on hand to handle hot bearings.
6. Set up the appropriate heating equipment.
7. Have on hand some means of accurately monitoring the temperature of the bearing (usually a pyrometer or a wax tempo stick).
8. Have a fire extinguisher on hand if a flame is to be used.
9. Take time to organize everything in the most convenient way possible for installing the bearings.
10. Arrange lifting gear if necessary for bearings too heavy to lift easily by hand.

Heating Methods

The heating method that you choose will depend mainly on the size of the bearing and the equipment that you have available. Figure 30, Figure 31, Figure 32 and Figure 33 show various heating methods.

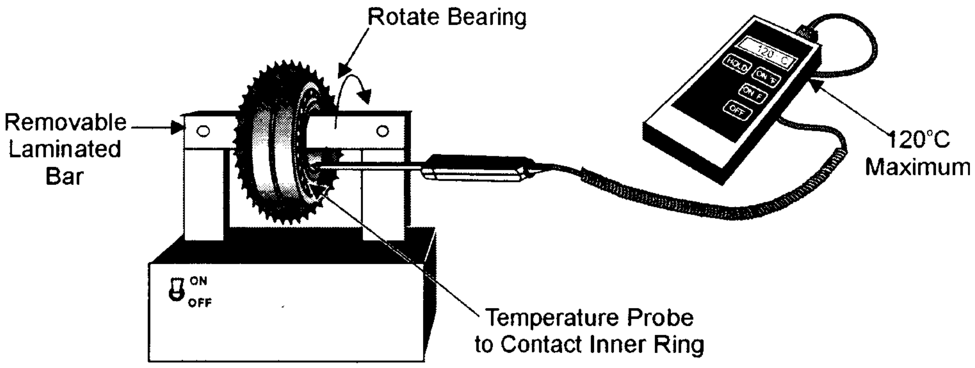


Figure 30 - Induction heating. (Courtesy SKF Canada Limited)

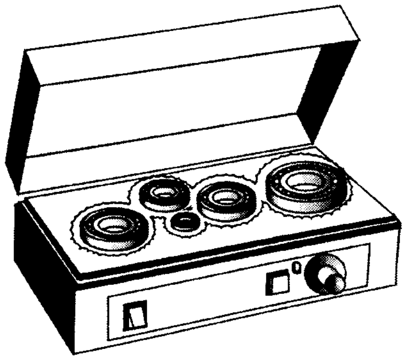


Figure 31 - Using a heating cabinet. (Courtesy SKF Canada Limited)

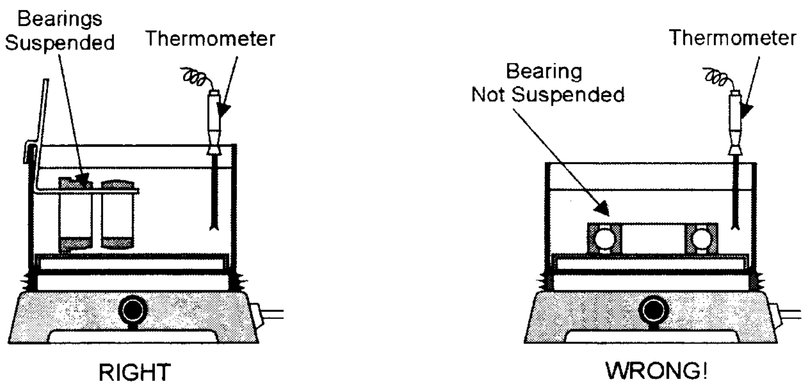


Figure 32 - Oil bath heating. (Courtesy SKF Canada Limited)

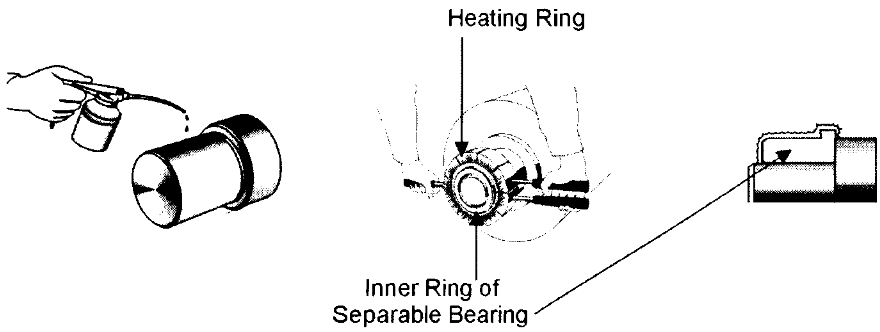


Figure 33 - Using a heating ring. (Courtesy SKF Canada Limited)

Heating Bearings.

Consider the following points when heating bearings.

1. Never apply an open flame directly on a bearing. This can damage the bearing b leaving oxidation deposits on the raceways and rolling elements. It can also distort the bearing through uneven heating and damage the grain structure.
2. Never heat a bearing above 120°C (248°F). Higher temperatures will permanently alter the shape of the bearing rings since standard bearings are not stabilized for temperatures over 120°C.
3. Never heat a sealed bearing above 80°C (175°F) as the seal lip will be damaged
4. Always use a pyrometer or a wax tempo stick to monitor the bearing temperatu as you heat it.
5. If you use an oil bath, you must make sure that new, clean, high-temperature oil is used. **Do not use oil that has been used for cooling hot metal!**

Mounting Cylindrical Bore Bearings

Procedure

1. Lightly oil the shaft.
2. Heat the bearing almost to 120°C (80°C if the bearing is sealed).
3. Using clean protective gloves, carefully install the hot bearing. Do not rush, bu slide the bearing onto its seat in one continuous movement until it is pressed against the shoulder.
4. Hold the hot bearing firmly against the shoulder until it cools enough to grip th shaft.
5. Cover the bearing until it has cooled.
6. Use a 0.001-inch feeler to check that there is no gap between the bearing and th shoulder.
7. Thoroughly coat the rolling elements with the recommended lubricant.
8. Install the locknut and tab washer against the bearing and bend a tab into a notc in the nut to secure it against vibration.
9. Lightly oil the housing bore.
10. If the shaft and bearing assembly cannot be easily handled, use lifting equipme to accurately guide it into the housing bores.
11. Carefully guide the shaft and bearing assembly into the housing. Since the fit t the housing will be a close clearance fit, you may have to wiggle the shaft if it gets stuck. Do not use a hammer for installation!
12. If the housing has an interference fit to the bearing or even a transition fit, you will have to heat the housing before you attempt to install the bearing.
13. Perform the internal clearance checks as described in objective 7.

NOTE
Sometimes you will have to install a bearing to a shaft and housing simultaneously. This will cause a problem because, when you heat the bearing to install it on the shaft, the outer ring will expand and remove the clearance fit to the housing. Therefore, you will have to arrange to heat the housing at the same time as you heat the bearing.

Hot Mounting Tapered Bore Bearings

The hot mounting method is used on large taper bore bearings (bores over 100 mm) when hydraulic or oil injection methods are not available. However, if possible, have the shaft drilled and grooved for oil injection, as this will make removal much easier (Figure 34).

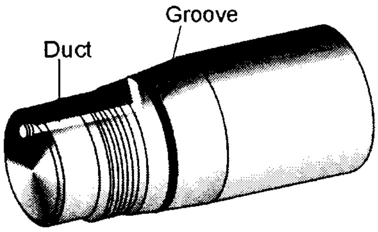


Figure 34 - Oil injection ducts for easy removal. (Courtesy SKF Canada Limited)

The procedure for hot mounting a tapered bore bearing is the same as described for cold mounting, except that no force is required to move the bearing up the taper. This presents the problem of how to position the hot bearing on the taper to arrive at the correct clearance after the bearing has cooled.

To hot mount a tapered bore bearing, follow these steps.

1. Make sure that the tapered seating surface is clean and in good condition.
2. Oil the taper lightly and wipe off any excess oil.
3. Push the cold bearing up the taper until it is firmly seated.
4. Measure from the inner ring to the shoulder (Figure 35A).
5. Look up the axial drive-up distance in a drive-up table and subtract this amount from the distance that you measured, to establish the final position of the bearing on the taper. Then, measure and mark this position on the shaft (Figure 35A).
6. If the shaft does not have a shoulder, you can establish a clear reference mark for the final position by measuring the axial drive-up distance from the initial position of the bearing after it has been firmly seated (Figure 35B).
7. If the shaft has an abutment, then you can make and install a spacer to stop the bearing at the right position (Figure 35C).
8. Heat the bearing to 120°C and carefully slide it to the position that you have marked on the shaft or to the spacer that you have installed.
9. After the bearing has cooled, check the internal clearance as described in Objective Seven.

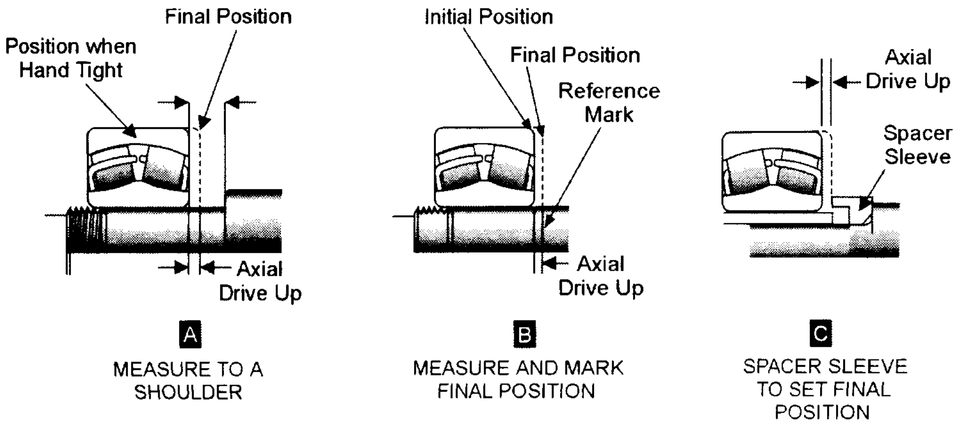


Figure 35 - Hot mounting a tapered bore bearing. (Courtesy SKF Canada Limited)

NOTES

Objective Six Exercise

1. What heating method should you never use on a bearing?

2. What is the maximum temperature that you can heat most standard unsealed bearing without damage?

3. What is the maximum temperature that you can heat a sealed bearing without damaging the seal?

4. What are four recommended methods of heating a bearing?

5. What are two recommended ways of monitoring the bearing temperature while it is being heated?

6. How is a hot mounted bearing with a tapered bore positioned correctly on the taper'

Objective Six Exercise Answers

1. A flame directly on the bearing.
2. 120°C.
3. 80°C.
4. Induction heating, heating cabinet, oil bath, heating ring.
5. Use a pyrometer or a wax tempilstik.
6. Fit the cold bearing firmly on the taper and mark the specified drive-up distance from the bearing onto the shaft or sleeve.

NOTES

Objective Seven

When you have completed this objective, you will be able to:

Describe the procedures for setting internal clearances in anti-friction bearings.

Internal Clearance

Definition

The internal clearance in a bearing is the total amount of clearance between the rolling elements and the raceway when one bearing ring is pushed as far away from the other ring as possible (Figure 36).

How Internal Clearance is Measured

Internal clearance can be determined by measuring the distance that one ring can be moved with respect to the other ring.

- This can be done with a dial indicator set against the ring that is being moved while holding the other stationary.
- This is called a lift check and is normally used to make an approximate check on the clearance after the bearing has been installed.
- An accurate measure of internal clearance using this method can only be obtained using precision jigs specially made for lab measurements.

On roller bearings, the internal clearance can be measured with a feeler gauge between the unloaded rolling element and the raceway.

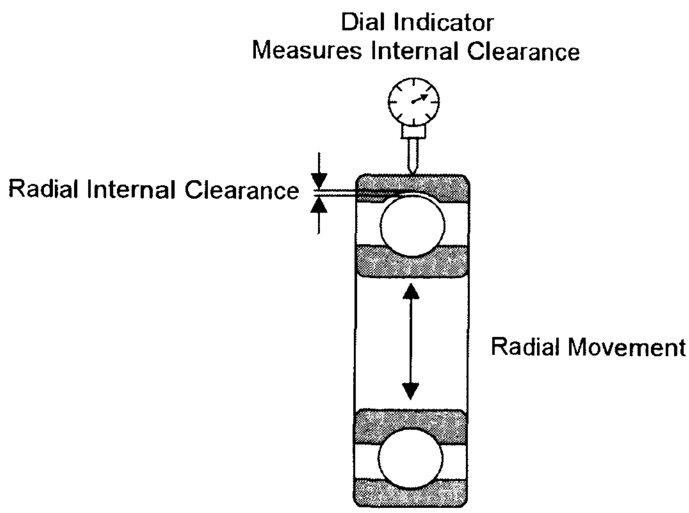


Figure 36 - Internal clearance. (Courtesy SKF Canada Limited)

Types of Internal Clearance

Axial Internal Clearance

Axial internal clearance is the clearance between the rolling elements and the raceway when one ring is moved away from the other in the axial direction (Figure 37B). It can be determined by measuring the amount of axial movement of one ring with respect to the other.

Radial Internal Clearance

Radial internal clearance is the clearance between the rolling elements and the race when one ring is moved away from the other ring in a radial direction (Figure 37A). It is determined by measuring ring movement under lab conditions.

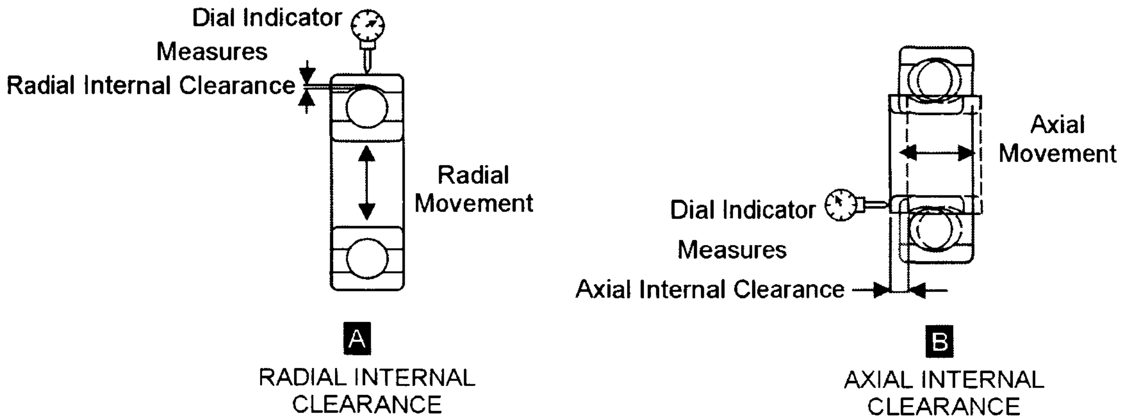


Figure 37 - Axial and radial internal clearance. (Courtesy SKF Canada Limited)

Initial Clearance

Initial clearance is the internal clearance (either axial or radial) in a bearing before it is mounted.

This initial clearance is built into non-separable bearings by the manufacturer and is standardized worldwide for each type and size of bearing. There are 6 common classes of radial clearance and 3 classes of axial clearance for each of these bearings.

These radial clearances are designated in the suffix of the bearing number. The 6 classes of radial clearance are:

- C1, which is the smallest clearance,
- C2, which is smaller than normal clearance but greater than C1,
- Normal clearance, which is the clearance in standard bearings and has no designation,
- C3, which is greater than normal clearance,
- C4, which is greater than C3 and
- C5, which is greater than C4.

Another clearance that is used in spherical roller bearings manufactured in Europe is designated as C3P and falls between C3 and C4.

Axial internal clearance is classified according to ISO standards in the following 3 classes:

- axial clearance that is less than normal,
- normal axial internal clearance and
- axial internal clearance that is greater than normal.

These axial clearance classes are used for bearings that take mainly axial loads. You would most commonly see these designations on single row angular contact bearings. Although the designation for these axial clearances appears in the suffix of the bearing number, each manufacturer has its own code. Be sure to check the code in the manufacturer's catalogue and check the code on the bearing to see if it is the bearing that was specified.

The reason for manufacturing bearings with these various clearances is to accommodate the following situations.

- The C3, C4 and C5 radial clearances are greater than normal. All of these clearances can accommodate greater reductions in clearance when the operating temperature of the inner ring is much higher than the outer ring.
- The C3, C4 andC5 radial clearances also accommodate tight fits on both the housing and the shaft.
- The C1 and C2 radial clearances are used where radial deflection of the shaft must be minimized. This is described as "close radial guidance" and is necessary on precision machine tool spindles.
- The C1 and C2 radial clearances cannot be used where the temperature is higher on the inner ring than on the outer ring. Therefore, some means of cooling is often required for these bearings.

Residual Clearance

Residual clearance is the internal clearance (radial or axial) in a bearing after it has been mounted.

Running Clearance

Running clearance is the internal clearance (radial or axial) in a bearing when it is running at its operating temperature. It is an extremely small clearance (only a few microns).

Preload

You should be aware of the following points about preload.

1. Preload is not a clearance. It is the load that the rolling elements are under before any external load is applied.
2. Preload is normally an axial load on the rolling elements.
3. Preload is expressed in pounds force or Newtons.
4. Preload is set by using spacers or shims to push one ring axially against the rolling elements.
5. Preload is also affected by the shaft and housing fits.
6. The three ISO classes of preload are:
   - lighter than normal preload,
   - normal preload and
   - heavier than normal preload.
7. The designations are not standardized for preload.
8. Preload is applied when the operating load is too light to make the rolling elements roll properly. It ensures that the rolling elements have enough traction to roll and track properly.
9. Preload is also applied to reduce radial deflection of the shaft and make a stiffer assembly.

Setting Internal Clearances on Spherical Roller Bearings

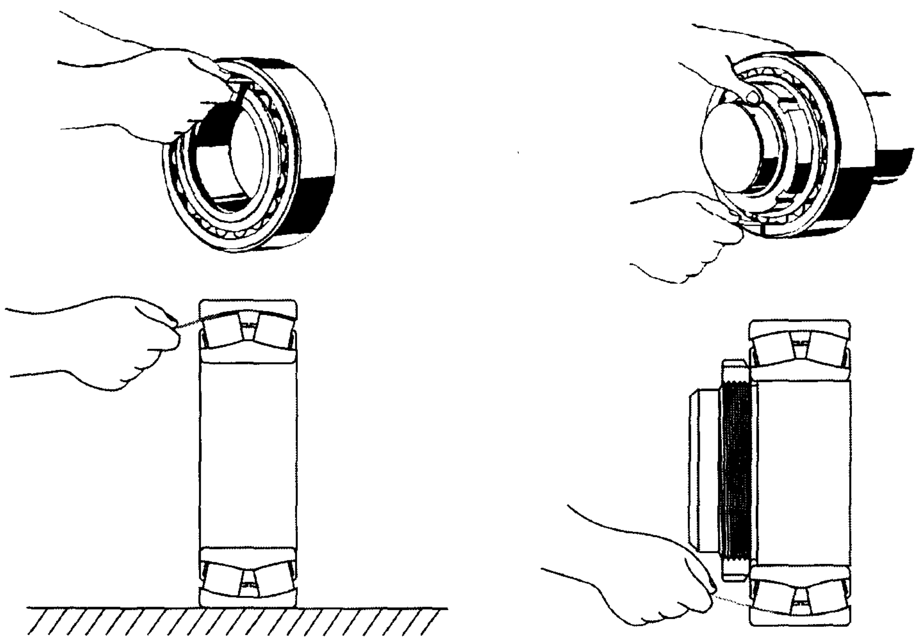
Cylindrical Bore Spherical Roller Bearings

In Figure 38, you can see that the tightness of the shaft and housing fits determines how much the internal clearance is reduced from its initial clearance before mounting. The reduction in clearance is often used in tables for setting spherical roller bearings although the residual clearance is also listed and should be your final check.

The clearance in a spherical roller bearing is commonly checked with a feeler gauge as shown in Figure 38. The procedure is as follows.

1. Stand the bearing on a clean work surface and rotate the inner ring several times while keeping the rings from tilting. This is done to make sure that the rollers are centralized in the raceways.
2. Use a feeler gauge thinner than the initial clearance given in the tables and check that it will slide freely all the way over the roller next to the top roller. This roller is selected because it is considered to be the unloaded roller.
3. Try increasingly thick feelers until there is a slight resistance when you withdraw the blade. This will be the initial clearance.
4. Repeat this measurement on the unloaded roller on the opposite side of the bearing and record the average of these two measurements, being careful to keep the rings from moving.
5. After the bearing has been mounted (see Objectives 4, 5 and 6 for mounting methods), repeat steps 1 to 3 except that the unloaded roller may be at the bottom if the bearing is hanging freely from the shaft. However, if the bearing is supporting the weight of the shaft, the unloaded roller that you will measure will be at the top.
6. Subtract the reading when mounted from the reading before mounting to get the reduction in clearance.

7. Check your reduction in clearance against the recommended reduction in the tables.
8. Check your measurement of the residual clearance against the recommended values in the table.



Initial Clearance   Residual Clearance

Figure 38 - The internal clearance on a cylindrical bore spherical roller bearin

Tapered Bore Bearings

Internal clearance is set in a tapered bore bearing by forcing the bearing up the taper o shaft for a predetermined distance. This predetermined distance can be obtained from bearing tables.

There are two methods of checking how far the bearing has been pushed up the taper. They are:

- using the tightening angle and
- using a dial indicator.

NOTE
There are two standard tapers, 1:12 and 1:30. The 1:12 taper ratio is designated "K" and is used for most taper bore bearings. The 1:30 taper ratio is designated "K30" and is used on the 240 and 241 wide series spherical roller bearings. Make sure that the taper on the bearing bore matches the taper on the shaft. These designations are found in the suffix of the bearing number.

The three methods of setting the starting point from which the drive up is measured are:

- Seat the bearing firmly by hand.
- Use a peeler gauge to check for clearance reduction.
- Use a pressure gauge in conjunction with a hydraulic nut.

Seat by Hand and Use the Tightening Angle to Measure Drive-Up

The tightening angle method shown in Figure 39 is useful for setting bearings that are difficult to check with a feeler gauge. This is often the case on small bearings or on double row self-aligning ball bearings. The tightening angle method is performed as follows:

- seat the bearing firmly on the taper,
- turn the nut the amount indicated in the following table.

Bearing Bore (mm)	Turning Angle (Degrees)	Turning Distance
up to 50 mm	70	between ⅛ and ¼ turn
55 mm to 65 mm	90	¼ turn
70 mm and over	120	⅓ turn

- remove the nut, install the tab washer and bend the lock tab into a notch in the nut.

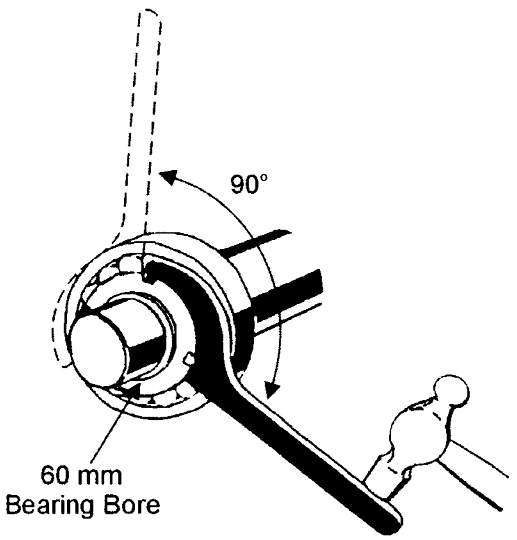


Figure 39 - Measuring drive-up using tightening angle. (Courtesy SKF Canada Limited)

NOTES

NOTE

- This method is somewhat inaccurate because the exact starting point for the drive-up can vary considerably depending on how firmly you seat the bearing on the taper at the beginning of the installation. The accuracy of the turning angle is less critical, since a 10 degree error in the turning angle will produce only a very small change in the clearance.
- The turning angle table is for double row self-aligning ball bearings only.
- For spherical roller bearings, you will have to calculate the angle based on how far the nut will advance in one turn (by using threads per inch or thread pitch) and knowing that 0.015 in. advance axially will reduce the radial clearance by 0.001 in. for a 12:1 taper.
- For CARB bearings, there is a different table of turning angles.

Mounting of Spherical Roller Bearings with Tapered Bore

Bearing bore diameter d		Reduction in radial internal clearance		Axial drive-up s[1] Taper 1:12 on diameter		Taper 1:30 on diameter		Minimum permissible residual clearance[2] after mounting bearings with initial clearance		
over	incl.	min	max	min	max	min	max	normal	C3	C4
mm		in		In				in		
161	180	0.0030	0.0045	0.050	0.070	0.130	0.165	0.0024	0.0040	0.0060
181	200	0.0035	0.0050	0.055	0.080	0.140	0.195	0.0028	0.0040	0.0065
201	225	0.0039	0.0055	0.060	0.085	0.155	0.215	0.0030	0.0045	0.0070
226	250	0.0045	0.006	0.065	0.095	0.165	0.235	0.0035	0.0050	0.0080
251	280	0.0045	0.0065	0.075	0.105	0.185	0.265	0.0040	0.0055	0.0085
281	315	0.0050	0.0075	0.080	0.120	0.195	0.295	0.0043	0.0060	0.0095

1) Valid for solid steel shafts only. Larger axial displacements are necessary for hollow shafts depending on the wall thickness; see also section "Fits for hollow shafts," page 122, SKF General Catalogue 4000.

2) The residual clearance must be checked in cases where the initial radial internal clearance is in the lower half of the tolerance range and where large temperature differentials between the bearing rings can arise in operation. The residual clearance must not be less than the minimum values quoted above.

Table 5 - Axial drive-up. (Courtesy SKF Canada Limited)

Seat by Feeler Gauge and Use a Dial Indicator to Measure Drive-Up

In Figure 40, a dial indicator is set against the inner ring so that you can watch the amount of drive-up as you push the bearing up the taper. The procedure for using the drive-up distance to set the clearance is as follows.

1. Make sure that the shaft and the sleeve are clean and in good condition.
2. Install the sleeve on the shaft dry and then lightly oil the outer surface. Wipe off any excess oil.
3. Seat the sleeve firmly on the taper and install the locknut or, if possible, a hydraulic nut.
4. Measure initial clearance of the bearing with a feeler gauge. (Figure 38)
5. Begin driving the bearing up the taper using the nut, until the internal clearance just begins to pinch the feeler.
6. Zero the dial indicator (since you have now established an accurate starting point to measure the drive-up distance).
7. Look up the axial drive-up distance in Table 5.
8. Using the nut, drive the bearing up the taper until the dial reading matches the minimum drive-up distance given in the axial drive-up table.
9. Measure the residual clearance with a feeler gauge. By subtracting this clearance from the initial clearance that you measured, you can get the amount of reduction in clearance. Check this amount against the range in the table.
10. Check the residual clearance that you measured against the minimum residual clearance in the table. When you look up the residual clearance, make sure that you look in the correct column for your bearing (Normal, C3 or C4).
11. If the residual clearance is still too great, then continue to drive the bearing up the taper until you reach the minimum residual clearance in the table. **Do not exceed this minimum value.**

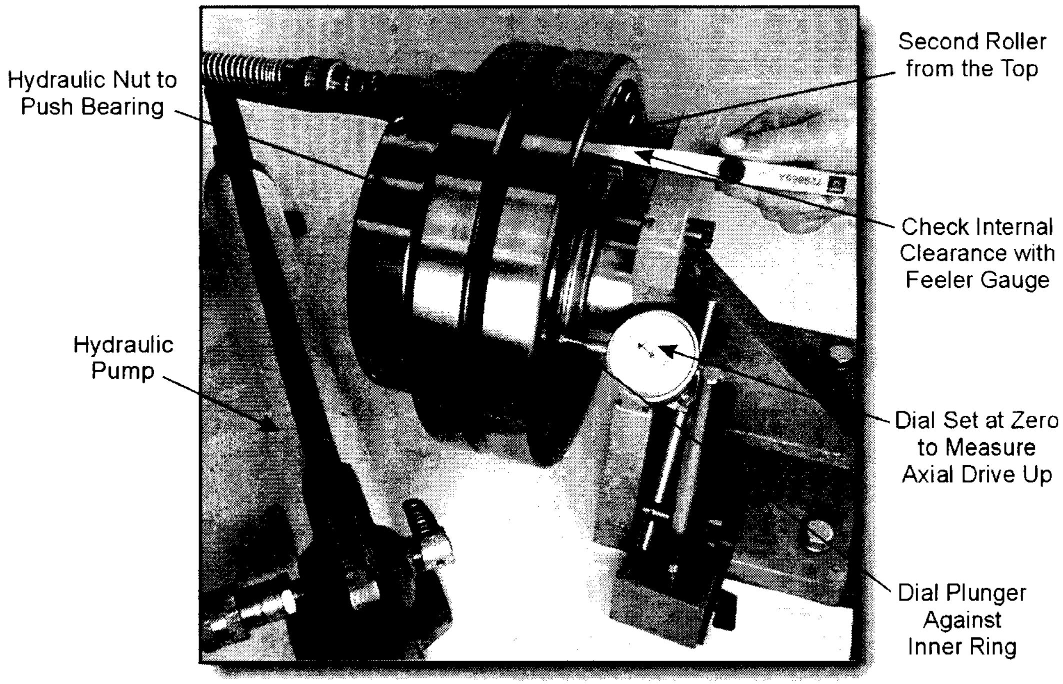


Figure 40 - Measuring drive-up using a dial indicator.

NOTE
A narrow-style feeler gauge is best for getting a more accurate measurement of the internal clearance on spherical roller bearings (see Figure 42).

Seat by Hydraulic Pressure and Use a Dial Indicator to Measure Drive-Up

An alternative and more accurate method is to use the SKF tables for the starting pressur for drive-up (see Figure 41 and Table 6). This gives a very accurate starting point for measuring the drive-up distance and the most accurate setting of the residual clearance.

The pressure method requires a pressure gauge calibrated in 0.1 MPa's and an SKF "HMVE" hydraulic nut matched to the SKF SRB table (Table 6). For convenience and accuracy, this nut is drilled to accommodate the mounting of a dial indicator.

NOTE
The starting position pressures given in Table 6 apply only to spherical roller bearings and only when using the SKF HMV E-nut (hydraulic nut). Different tables are available for the starting position pressures for CARB bearings.

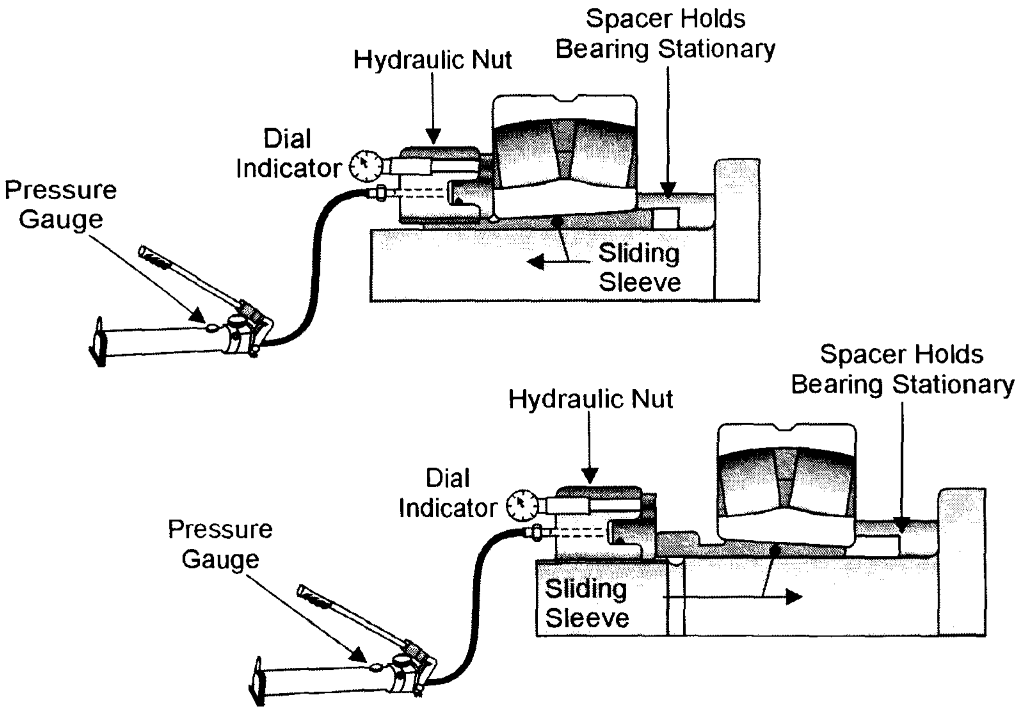


Figure 41 - Starting pressure method of drive-up. (Courtesy SKF Canada Limited)

The SRB Drive-up Method				
Pressure and axial drive-up tables				
	Starting Position		Final Position	
Bearing designation	Hydraulic pressure* MPa		Radial clearance reduction from zero position (mm)	Axial drive-up from starting position (s_s mm)
	1	2		
22222 EK	1,7	2,9	0,050	0,65
22224 CCK/W33	1,9	3,3	0,054	0,70
22224 EK	1,8	3,1	0,054	0,70
22226 CCK/W33	2,1	3,6	0,059	0,75
22226 EK	2,0	3,3	0,059	0,74
22228 CCK/W33	2,3	4,0	0,063	0,80
22230 CCK/W33	2,5	4,3	0,068	0,85
22232 CCK/W33	2,6	4,4	0,072	0,91
22234 CCK/W33	2,8	4,7	0,077	0,97

* = Values given valid for HMV E-nut size = Bearing size

1 = Should be applied when one surface slides during mounting, surface lightly oiled.

2 = should be applied when two surfaces slide during mounting, surface lightly oiled.

Table 6 - Starting pressure. (Courtesy SKF Canada Limited)

The procedure for the starting method is as follows.

1. Follow steps 1 and 2 as described in the dial and feeler gauge method.
2. Install an SKF "HMVE" nut with a dial indicator and attach a pump equipped with a pressure gauge calibrated in 0.01 Mpa's.
3. Pump the hydraulic nut to the starting pressure indicated in the SRB pressure and drive-up table for the bearing being installed.
4. Zero the dial and then pump the hydraulic nut until the dial indicates the axial drive-up given in the table for the bearing.

This drive-up distance will result in a more dependable and accurate setting of the internal clearance than would be achieved using the feeler gauge method.

Figure 42 - Feeler gauge for spherical roller bearings. (Courtesy SKF Canada Limited)

Setting Internal Clearances on Self-Aligning Ball Bearings

After you have used the turning angle to set the clearance on a double row self-aligning ball bearing, you should be aware of the following points.

- It will take surprisingly little force to arrive at the correct tightness according to the turning angle. Many of these bearings have failed because of overtightening when the turning angle was not used.
- There is a commonly used rule of thumb that "the correct clearance is indicated by a slight drag when the outer ring is swivelled" (as shown in Figure 43). This check on clearance will work for bearings with **normal** initial clearance **only.** Self-aligning ball bearings are commonly used in the pillow blocks on fans that move hot gases. Since they tend to run at higher temperatures than normal, they are often specified with a C3 clearance (i.e., greater than normal). If they are tightened until there is a slight drag, the inner ring will be overstressed and may crack. The running clearance will also be lost when the bearing is at operating temperature.

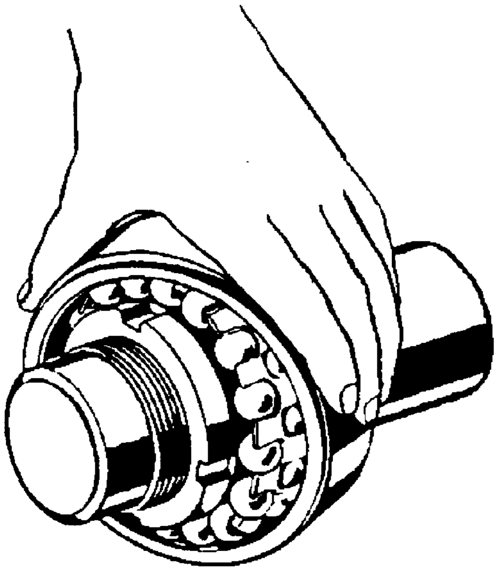


Figure 43 - Checking the internal clearance on a self-aligning ball bearing ***only for bearings with normal clearance.*** **(Courtesy SKF Canada Limited)**

Setting Internal Clearances on Angular Contact Ball Bearings

It should be noted that single row angular contact ball bearings can only support thrust in one direction. Therefore, they are mounted in pairs in either a back-to-back or face-to-face arrangement. In this way they can handle reversing loads.

The following points should be noted about the internal clearance settings on paired single row angular contact ball bearings.

- The internal clearance is predetermined in the manufacture of the bearing.
- The paired bearings must be pushed solidly together to achieve this clearance.
- After hot mounting, they may contract as they cool and leave a small gap between the bearings, resulting in too much clearance. For this reason, a feeler gauge should be used to check for any gap between the bearings or the shoulder after the bearing has cooled.

- A final check on the residual clearance can be made by an axial check as shown in Figure 44

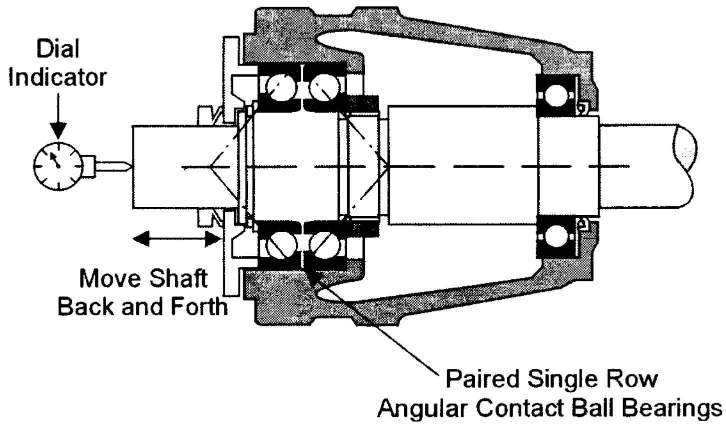


Figure 44 - Checking the clearance on a pair of single row angular contact ball bearings. (Courtesy SKF Canada Limited)

NOTE
Only the universally matched series can be mounted against each other without shims. Look for the axial clearance or preload designation in the bearing suffix. Most commonly, this will be CB, i.e., normal clearance. These universal series bearings are the most popular since you can mount them in any arrangement that is required and they will automatically have the clearance or preload indicated in the suffix.

Setting Internal Clearances on Tapered Roller Bearings

Tapered Roller Bearing Clearance is Adjusted and Measured Axially

Note the following points in reference to Figure 45.

- The tapered rollers are mounted at separate locations so that the wide side of each cup is supported against a housing shoulder.
- With this arrangement, the clearance is set on both bearings simultaneously by adjusting the locknut against the cone of the bearing on the left.
- Also, you will notice that in this "back to back" arrangement you will have to move the cone axially with the lock nut in order to adjust the clearance.
- When you adjust the axial clearance, you also adjust the radial clearance at the same time.
- Axial clearance is easier to measure accurately on a tapered roller assembly so this is normally done instead of measuring the radial clearance.

Adjusting Procedure

1. Set a dial indicator against one end of the shaft assembly as shown in Figure 45.
2. Push the shaft axially in one direction as far as it will go and zero the dial.
3. Push the shaft axially back in the opposite direction as far as it will go and read the axial clearance on the dial.

4. Adjust the nut a small amount and repeat steps 2 and 3 to check the clearance again.
5. Proceed with these gradual adjustments and clearance checks after each move until you have achieved the required clearance.
6. If the clearance is reduced too much, the shaft will have to be pressed out through the cones slightly and the adjusting procedure repeated.

Since the cones will have an interference fit on the shaft, the whole adjusting procedure can be controlled much more easily if oil injection is used as shown in Figure 45.

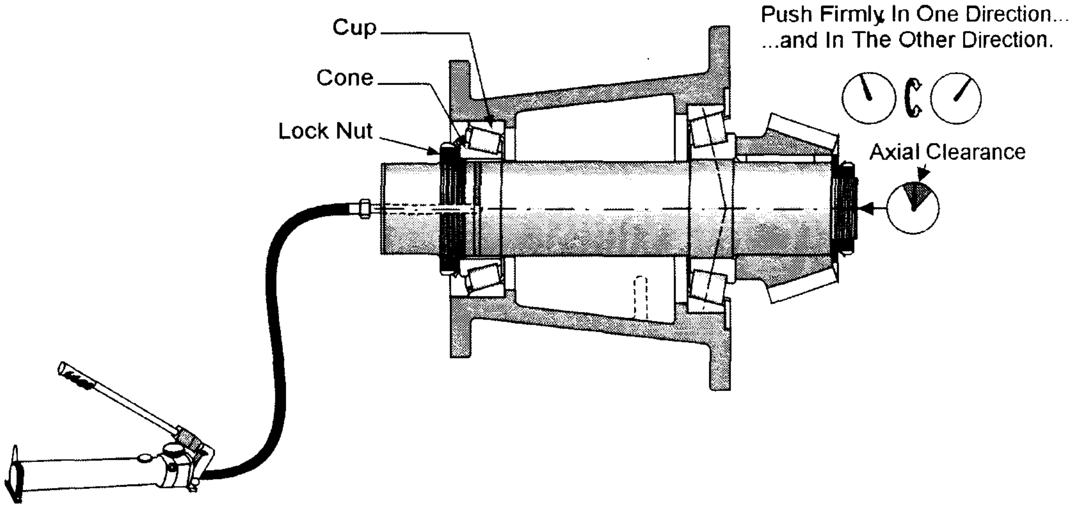


Figure 45 - Oil injection and dial indicator to adjust tapered roller bearings. (Courtesy SKF Canada Limited)

Because single row tapered roller bearings can only support thrust in one direction, they are mounted in pairs that face in opposite directions (either face-to-face or back-to-back as shown in Figure 46). This arrangement allows a pair of single row tapered roller bearings to handle reversing thrust loads.

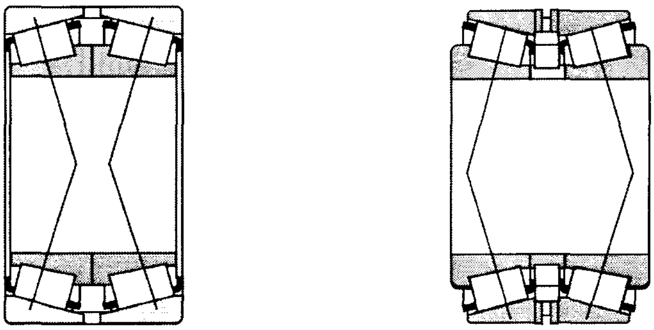


Figure 46 - Face-to-face and back-to-back arrangements for paired single row tapered roller bearings. (Courtesy SKF Canada Limited)

NOTES

Adjustment Procedure

1. Assemble the bearings loosely using a dummy shaft with a clearance fit to the inner rings and a telescoping sleeve as a spacer. See Figure 48.
2. Carefully adjust the clearance by small amounts as described in the procedure for the arrangement shown in Figure 45.
3. When the specified clearance has been accurately set, carefully slide the cone assembly that is next to the locknut from the shaft.
4. Accurately measure the sleeve.
5. Add 0.001 in. to the measurement in step 4 and precision grind a permanent sleeve to this dimension.
6. Install the sleeve and bearing assembly using the dummy shaft and make a final clearance check.
7. If the axial clearance is correct, the bearings can be assembled on the proper shaft.

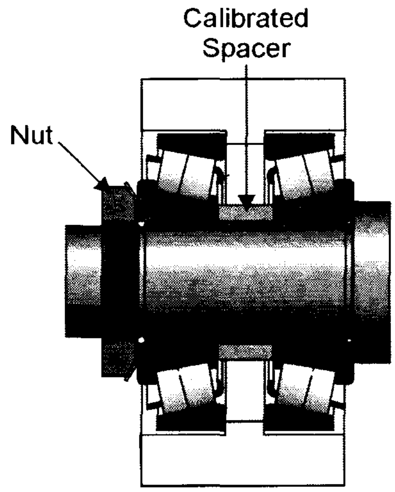


Figure 48 - Adjustment by nut and telescoping sleeve.
(Courtesy SKF Canada Limited)

NOTES

Objective Seven Exercise

1. What is meant by axial internal clearance?

2. What is meant by radial internal clearance?

3. What is meant by initial clearance?

4. How are larger than normal radial internal clearances designated?

5. How are smaller than normal radial internal clearances designated?

6. How is each of the following axial internal clearances designated: Smaller than normal clearance? Normal clearance? Greater than normal clearance?

7. What is meant by residual clearance?

8. What does running clearance mean?

9. What is meant by preload?

10. Is preload usually adjusted axially or radially?

11. By what means is preload usually adjusted?

12. Do shaft and housing fits affect preload?

13. What are two reasons for applying preload to a bearing assembly?

14. When you measure the internal clearance in a spherical roller bearing with a feeler gauge, from which roller should you measure the clearance?

15. How do you set the internal clearance on a bearing with a tapered bore?

NOTES

16. What are four ways to determine that you have the correct internal clearance when mounting a tapered bore bearing?

17. What are the two common taper ratios used on tapered bore bearings?

18. How can the starting point be accurately determined for measuring the axial drive-up on a taper?

19. How is the residual internal clearance usually checked on a double row deep groove ball bearing?

20. How can you check the residual internal clearance in a pair of single row angular contact ball bearings and paired single row tapered roller bearings?

Objective Seven Exercise Answers

1. The clearance between the rolling elements and the raceway when one ring is moved axially away from the other.
2. The clearance between the rolling elements and the raceway when one ring is moved radially away from the other.
3. Initial clearance is the internal clearance before mounting.
4. C3,C4,C5.
5. C1 and C2.
6. CA is smaller than normal, CB is normal and CC is greater than normal.
7. Residual internal clearance is the clearance after mounting.
8. Running clearance is the clearance during operation.
9. Preload is the load on the rolling elements before any external load is applied.
10. Axially.
11. Spacers or shims.
12. Yes.
13. To ensure that the rolling elements have enough traction to roll and track properly when they are lightly loaded.
14. The unloaded roller.
15. By pushing it up the tapered seat until the internal clearance is reduced to its specified amount when checked with a feeler gauge.
16. Tightening angle, dial indicator arranged to measure axial movement, feeler gauge and dial indicator to measure radial movement.
17. 1:12 and 1:30.
18. From a starting pressure chart.
19. By swivelling the outer ring to check for a slight resistance.
20. By measuring axial movement with a dial indicator.

Self-Test

1. What is the reason for using a non-destructive method to remove a bearing?
2. In what situation would you use cooling to remove a bearing?
3. What safety precaution should you take when you use a coolant to remove a bearing
4. What are three advantages of using oil injection to remove a bearing?
5. What safety precaution should you take when you use oil injection to remove a bearing from a tapered seat?
6. When you press or pull a bearing from a shaft, which ring should you support or pul on?
7. What type of puller can be used to remove a needle bearing assembly from a blind hole?
8. What are two ways to remove a tapered roller bearing cup from a blind hole?
9. What is the recommended shaft fit for a deep groove ball bearing to be used in an electric motor operating under normal to heavy loads if its bore is 120 mm? (Give tl fit in decimals of an inch).
10. How much axial drive-up should you use to install a 160 mm bore spherical roller bearing having a 1:12 tapered bore and a C3 internal clearance?
11. To what accuracy should you measure when you check a bearing fit?
12. What is the maximum temperature needed to heat most standard bearings for hot mounting?
13. When you cold mount a bearing on a shaft, on which ring should you push?
14. Why should you not use a brass sleeve or drift to drive a small bearing?

15. How should you check the clearance on a pair of single row angular contact ball bearings or a pair of single row tapered roller bearings after mounting? What class of axial internal clearance would you recommend for a bearing on a shaft that is hot and in a housing that is at ambient temperature?

16. If a face-to-face arrangement is used to mount tapered roller bearings, would you set the clearance using the locknut on the shaft or with shims between the cover and the cup?

NOTES

Self-Test Answers

1. So that it can be reused.
2. When the inner ring is not accessible for heating without a flame.
3. Wear clean gloves.
4. No heat is required, little force is required and there is no abrasion on the shaft during removal.
5. Install the locknut close to the bearing before you apply pressure.
6. The inner ring.
7. A collet style puller.
8. Cut the cup carefully with a grinder or run a heavy bead of weld in a wavy pattern around the surface of the cup.
9. 5T to 19T (0.0005 in. tight to 0.0019in. tight)
10. 0.047 in. to 0.063 in.
11. 0.0001 in.
12. 120 degrees Celsius.
13. The inner ring.
14. Brass will work-harden and flake.
15. Use a dial indicator to measure axial movement of the shaft when cold.
16. Shims between the cover and the cup.

Glossary

AFBMA Anti-Friction Bearing Manufacturers Association. This is an American organization that sets bearing standards.

Cone The inner ring of a tapered roller bearing assembly. It usually comes with the cage and rollers assembled to it.

Creep The slow turning of a bearing ring on the shaft or in the housing. Creep indicates that the fit is too loose.

Cup The outer ring of a tapered roller bearing.

Hoop stress The stress in a ring due to over-stretching.

ISO International Standards Organization. This is an international organization that establishes standards of all kinds for industry. Most metric bearings are made to ISO standards.

Micron A millionth of a metre or 0.001 millimetres.

Pyrometer A high-temperature thermometer that uses a thermocouple to measure temperature.

Tempilstik A commonly used brand of temperature stick that consists of a wax crayon with a specific melting point.

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