

# **Bearing failures and their causes**



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# Introduction

## Bearing failures and their causes

Bearings are among the most important components in the vast majority of machines and exacting demands are made upon their carrying capacity and reliability. Therefore it is quite natural that rolling bearings should have come to play such a prominent part and that over the years they have been the subject of extensive research. Indeed rolling bearing technology has developed into a particular branch of science. SKF has been well to the forefront right from the start and has long led this field

Among the benefits resulting from this research has been the ability to calculate the life of a bearing with considerable accuracy, thus making it possible to match the bearing life with the service life of the machine involved.

Unfortunately it sometimes happens that a bearing does not attain its calculated rating life. There may be many reasons for this – heavier loading than has been anticipated, inadequate or unsuitable lubrication, careless handling, ineffective sealing, or fits that are too tight, with resultant insufficient internal bearing clearance. Each of these factors produces its own particular type of damage and leaves its own special imprint on the bearing. Consequently, by examining a damaged bearing, it is possible, in the majority of cases, to form an opinion on the cause of the damage and to take the requisite action to prevent a recurrence.

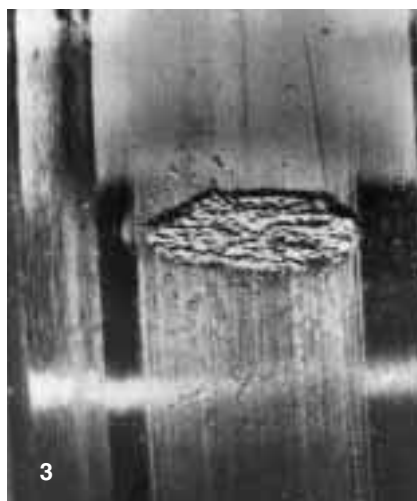
## How is bearing life defined?

Generally, a rolling bearing cannot rotate for ever. Unless operating conditions are ideal and the fatigue load limit is not reached, sooner or later material fatigue will occur. The period until the first sign of fatigue appears is a function of the number of revolutions performed by the bearing and the

magnitude of the load. Fatigue is the result of shear stresses cyclically appearing immediately below the load carrying surface. After a time these stresses cause cracks which gradually extend up to the surface. As the rolling elements pass over the cracks fragments of material break away and this is known as flaking or spalling. The flaking progressively increases in extent (figs 1 to 4) and eventually makes the bearing unserviceable.

The life of a rolling bearing is defined as the number of revolutions the bearing can perform before incipient flaking occurs. This does not mean to say that the bearing cannot be used after then. Flaking is a relatively long, drawn-out process and makes its presence known by increasing noise and vibration levels in the bearing. Therefore, as a rule, there is plenty of time to prepare for a change of bearing.

Figs 1–4 Progressive stages of flaking



# Path patterns and their interpretation

When a rolling bearing rotates under load the contacting surfaces of the rolling elements and the raceways normally become somewhat dull in appearance. This is no indication of wear in the usual sense of the word and is of no significance to the bearing life. The dull surface in an inner or outer ring raceway forms a pattern called, for the purposes of this paper, the path pattern. This pattern varies in appearance according to the rotational and loading conditions. By examining the path patterns in a dismantled bearing that has been in service, it is possible to gain a good idea of the conditions under

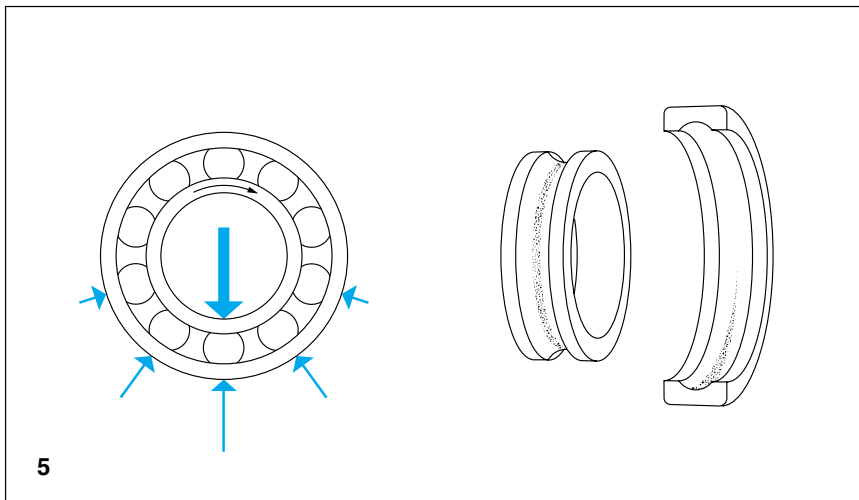
which the bearing has operated. By learning to distinguish between normal and abnormal path patterns there is every prospect of being able to assess correctly whether the bearing has run under the proper conditions.

The following series of figures illustrates normal path patterns under different rotational and loading conditions (figs 5 to 11) as well as typical patterns resulting from abnormal working conditions (figs 12 to 18).

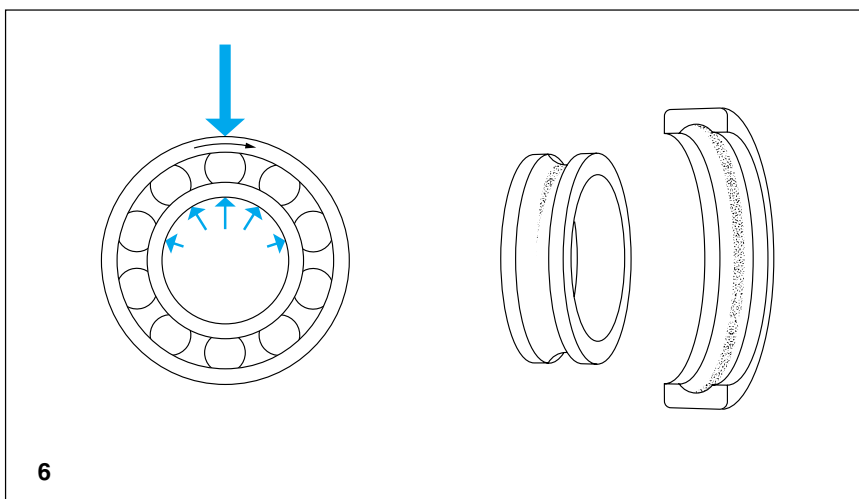
In the majority of cases the damage to the bearing originates within the confines of the path patterns and, once their significance has been learned,

the appearance and location of the patterns prove to be useful aids in diagnosing the cause of the damage.

Deep groove ball bearings and thrust ball bearings have been used for illustrative purposes as they display such characteristic path patterns. However, the figures are applicable, with some modifications, to other types of bearing as well.

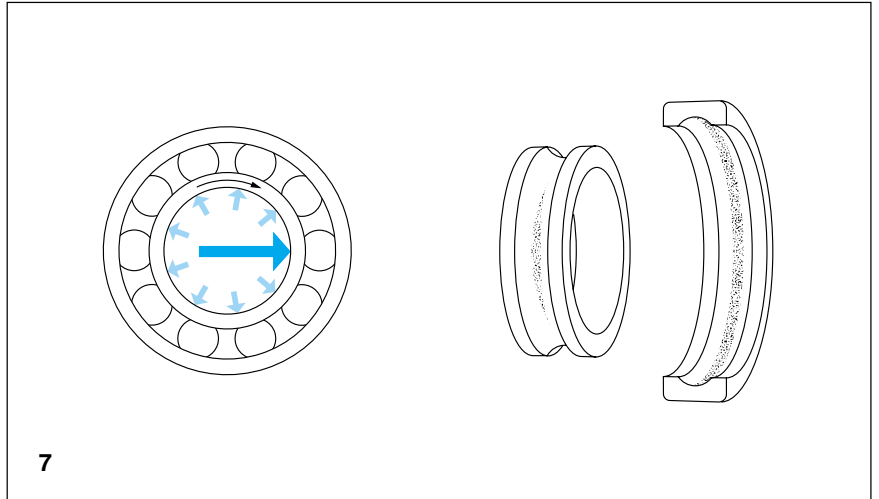


**Fig 5** Uni-directional radial load. Rotating inner ring – fixed outer ring.  
 Inner ring: path pattern uniform in width, positioned in the centre and extended around the entire circumference of the raceway  
 Outer ring: path pattern widest in the load direction and tapered off towards the ends. With normal fits and normal internal clearance, the pattern extends around slightly less than half the circumference of the raceway

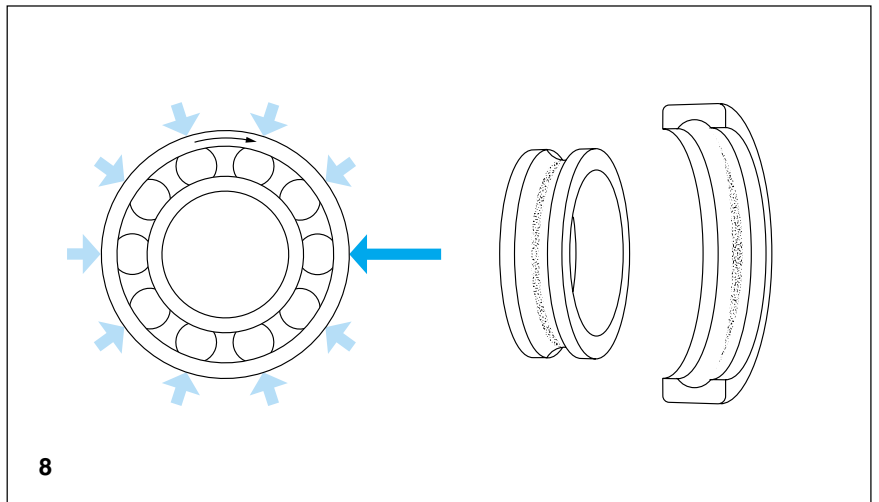


**Fig 6** Uni-directional radial load. Fixed inner ring – rotating outer ring.  
 Inner ring: path pattern widest in the load direction and tapered off towards the ends. With normal fits and normal internal clearance, the pattern extends around slightly less than half the circumference of the raceway  
 Outer ring: path pattern uniform in width, positioned in the centre and extended around the entire circumference of the raceway

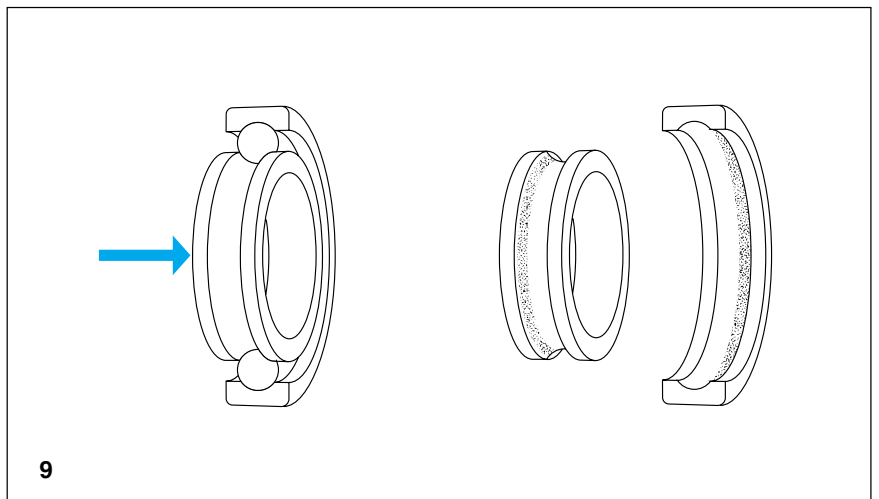
**Fig 7** Radial load rotating in phase with the inner ring. Rotating inner ring – fixed outer ring.  
 Inner ring: path pattern widest in the load direction and tapered off towards the ends. With normal fits and normal internal clearance, the pattern extends around slightly less than half the circumference of the raceway  
 Outer ring: path pattern uniform in width, positioned in the centre and extended around the entire circumference of the raceway



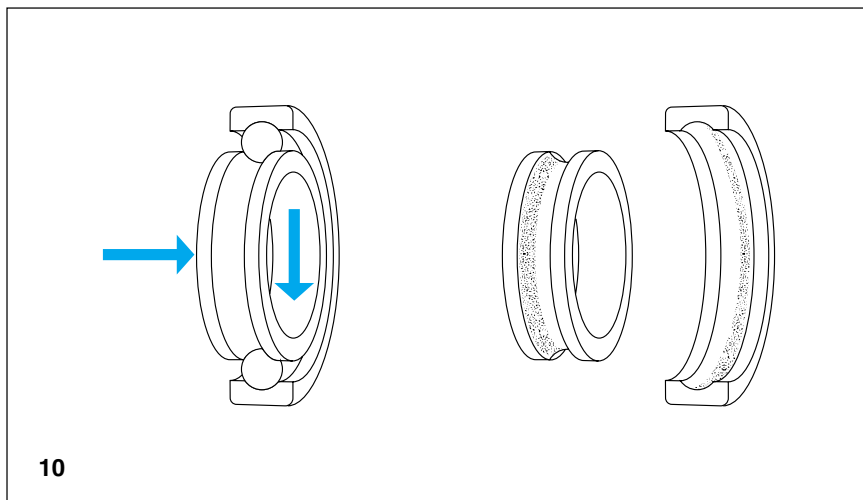
**Fig 8** Radial load rotating in phase with the outer ring. Fixed inner ring – rotating outer ring.  
 Inner ring: path pattern uniform in width, positioned in the centre and extended around the entire circumference of the raceway  
 Outer ring: path pattern widest in the load direction and tapered off towards the ends. With normal fits and normal internal clearance, the pattern extends around slightly less than half the circumference of the raceway



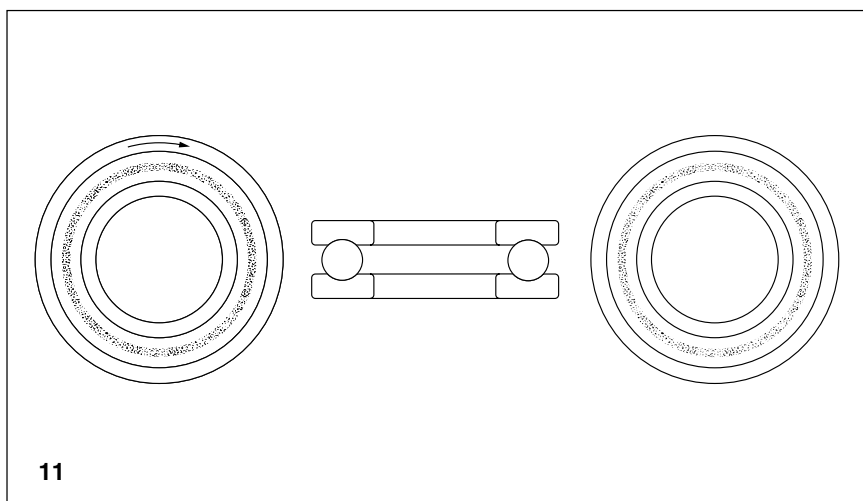
**Fig 9** Uni-directional axial load. Rotating inner or outer ring.  
 Inner and outer rings: path pattern uniform in width, extended around the entire circumference of the raceways of both rings and laterally displaced



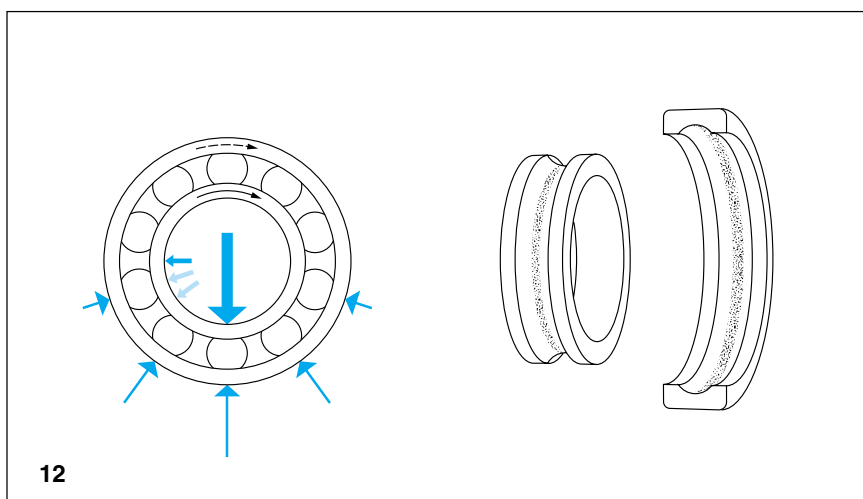
Path patterns and their interpretation



**Fig 10** Combination of uni-directional radial and axial loads. Rotating inner ring – fixed outer ring.  
 Inner ring: path pattern uniform in width, extended around the entire circumference of the raceway and laterally displaced  
 Outer ring: path pattern extended around the entire circumference of the raceway and laterally displaced. The pattern is widest in the direction of the radial loading

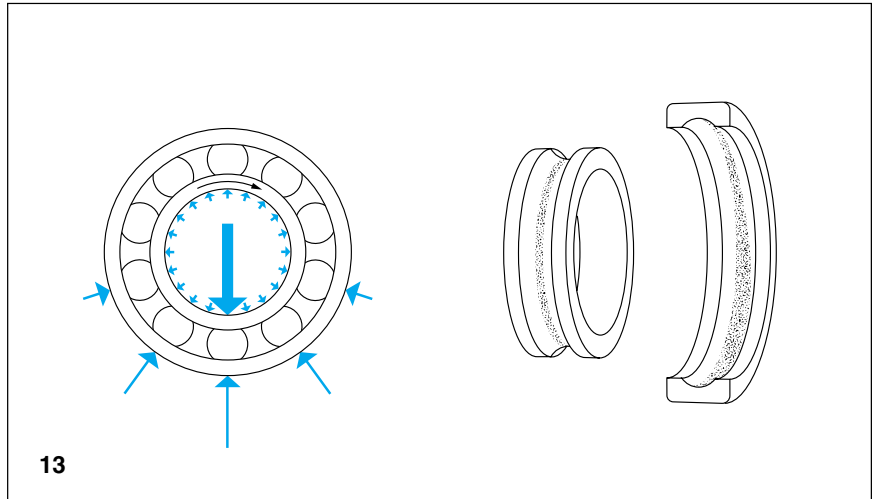


**Fig 11** Uni-directional axial load. Rotating shaft washer – fixed housing washer.  
 Shaft and housing washers: path pattern uniform in width, extended around the entire circumference of the raceways of both washers

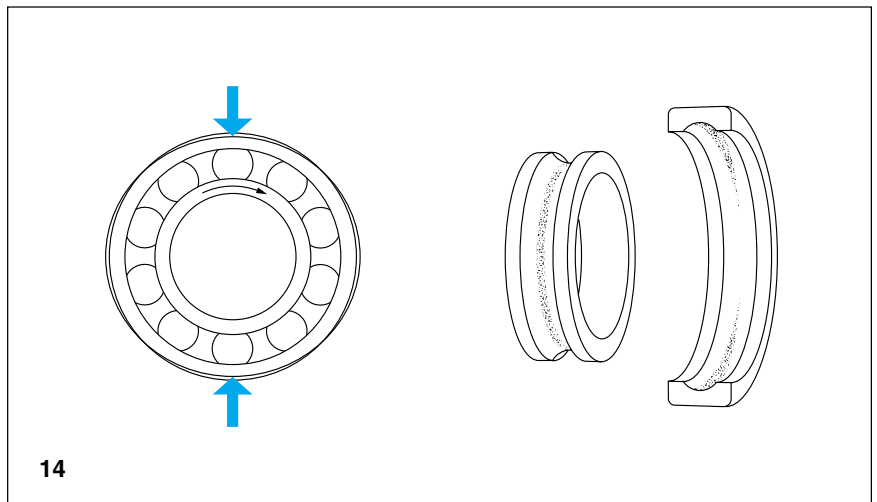


**Fig 12** Uni-directional radial load + imbalance. Rotating inner ring – creeping outer ring.  
 Inner and outer rings: path pattern uniform in width, extended around the entire circumference of the raceways of both rings

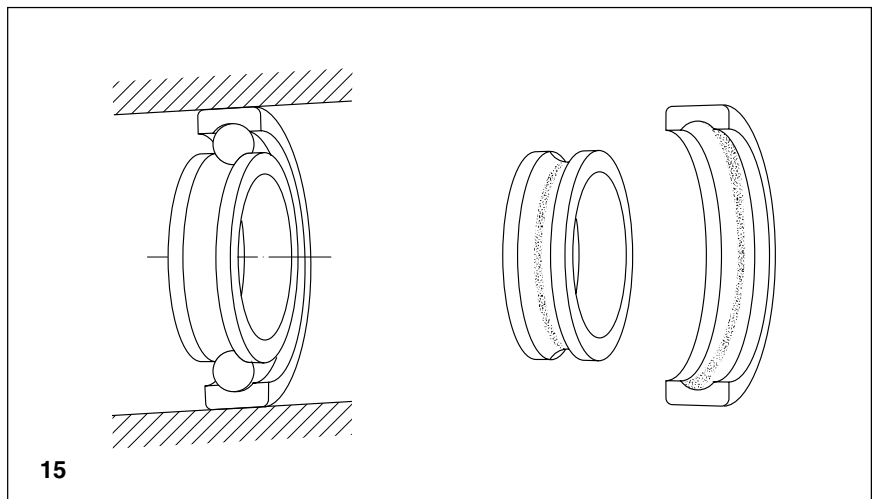
**Fig 13** Fits too tight – preloading. Uni-directional radial load. Rotating inner ring – fixed outer ring.  
 Inner ring: path pattern uniform in width, positioned in the centre and extended around the entire circumference of the raceway  
 Outer ring: path pattern positioned in the centre and extended around the entire circumference of the raceway. The pattern is widest in the direction of the radial loading

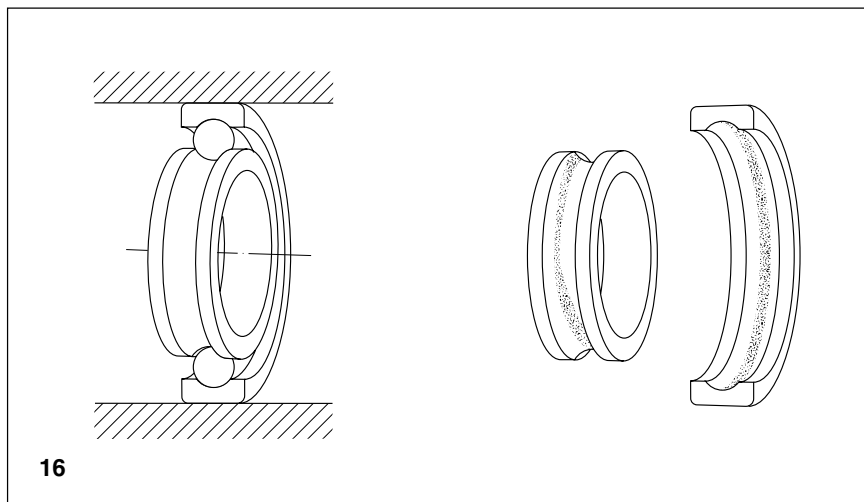


**Fig 14** Oval compression of outer ring. Rotating inner ring – fixed outer ring.  
 Inner ring: path pattern uniform in width, positioned in the centre and extended around the entire circumference of the raceway  
 Outer ring: path pattern positioned in two diametrically opposed sections of the raceway. The pattern is widest where the pinching has occurred

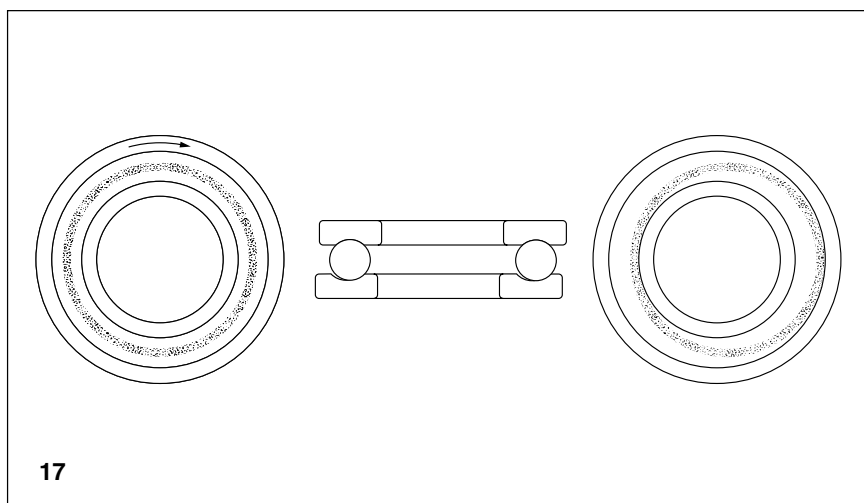


**Fig 15** Outer ring misaligned. Rotating inner ring – fixed outer ring.  
 Inner ring: path pattern uniform in width, positioned in the centre and extended around the entire circumference of the raceway  
 Outer ring: path pattern in two diametrically opposed sections, displaced diagonally in relation to each other

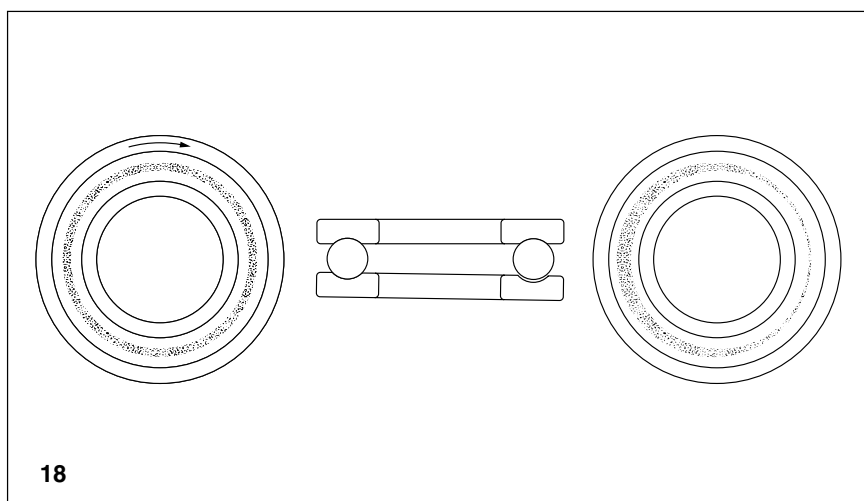




**Fig 16** Inner ring misaligned. Rotating inner ring – fixed outer ring.  
 Inner ring: path pattern in two diametrically opposed sections, displaced diagonally in relation to each other  
 Outer ring: path pattern widest in the load direction and tapered off toward the ends. The internal clearance is reduced on account of the misalignment of the inner ring; the length of the path pattern depends upon the magnitude of the internal clearance reduction



**Fig 17** Housing washer positioned eccentrically relative to shaft washer. Rotating shaft washer – fixed housing washer.  
 Shaft washer: path pattern uniform in width, extended around the entire circumference of the raceway  
 Housing washer: path pattern extended around the entire circumference of the raceway and off-centre relative to raceway



**Fig 18** Housing washer misaligned. Rotating shaft washer – fixed housing washer.  
 Shaft washer: path pattern uniform in width, extended round the entire circumference of the raceway  
 Housing washer: path pattern in the centre of the raceway but wider around part of its circumference



# Different types of bearing damage

Each of the different causes of bearing failure produces its own characteristic damage. Such damage, known as primary damage, gives rise to secondary, failure-inducing damage – flaking and cracks. Even the primary damage may necessitate scrapping the bearings on account of excessive internal clearance, vibration, noise, and so on. A failed bearing frequently displays a combination of primary and secondary damage.

The types of damage may be classified as follows:

## **Primary damage**

- Wear
- Indentations
- Smearing
- Surface distress
- Corrosion
- Electric current damage

## **Secondary damage**

- Flaking
- Cracks

**Different types of bearing damage**

**Wear**

In normal cases there is no appreciable wear in rolling bearings. Wear may, however, occur as a result of the ingress of foreign particles into the bearing or when the lubrication is unsatisfactory. Vibration in bearings which are not running also gives rise to wear.

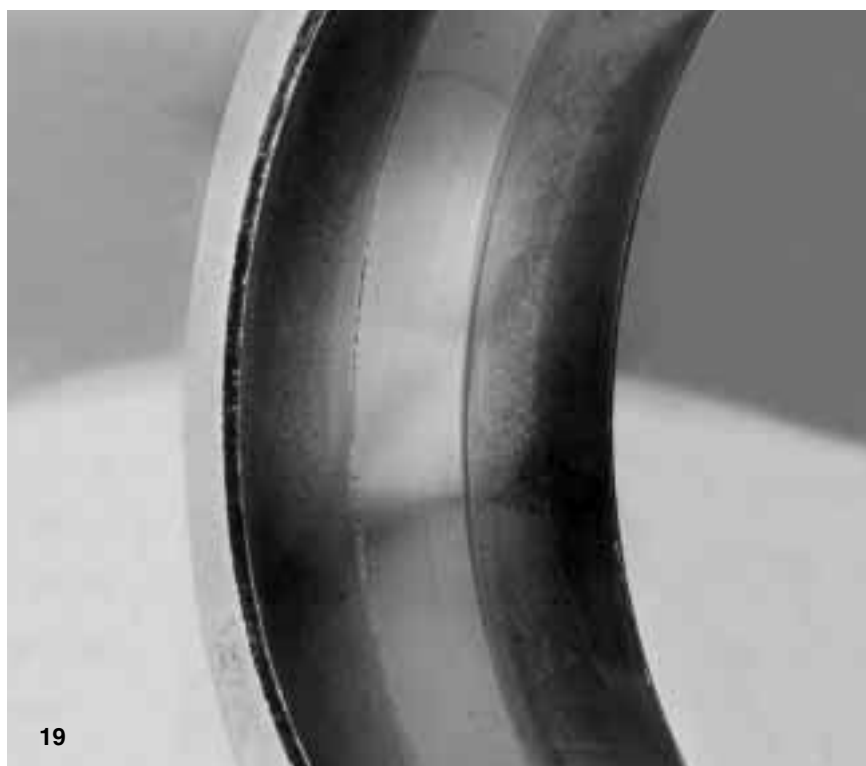
**Wear caused by abrasive particles**  
 Small, abrasive particles, such as grit or swarf that have entered the bearing by some means or other, cause wear of raceways, rolling elements and cage. The surfaces become dull to a degree that varies according to the coarseness and nature of the abrasive particles. Sometimes worn particles from brass cages become verdigrised and then give light-coloured grease a greenish hue.

The quantity of abrasive particles gradually increases as material is worn away from the running surfaces and cage. Therefore the wear becomes an accelerating process and in the end

the surfaces become worn to such an extent as to render the bearing unserviceable. However, it is not necessary to scrap bearings that are only slightly worn. They can be used again after cleaning.

The abrasive particles may have entered the bearing because the sealing arrangement was not sufficiently effective for the operating conditions involved. They may also have entered with contaminated lubricant or during the mounting operation.

Appearance	Cause	Action
Small indentations around the raceways and rolling elements. Dull, worn surfaces.	Lack of cleanliness before and during mounting operation.	Do not unpack bearing until just before it is to be mounted. Keep workshop clean and use clean tools.
Grease discoloured green.	Ineffective seals.	Check and possibly improve the sealing.
	Lubricant contaminated by worn particles from brass cage.	Always use fresh, clean lubricant. Wipe the grease nipples. Filter the oil.



**Fig 19** Outer ring of a spherical roller bearing with raceways that have been worn by abrasive particles. It is easy to feel where the dividing line goes between worn and unworn sections

### **Wear caused by inadequate lubrication**

If there is not sufficient lubricant, or if the lubricant has lost its lubricating properties, it is not possible for an oil film with sufficient carrying capacity to form. Metal to metal contact occurs between rolling elements and raceways. In its initial phase, the resultant wear has roughly the same effect as lapping. The peaks of the microscopic asperities, that remain after the production processes, are torn off and, at the same time, a certain rolling-out effect is obtained. This gives the surfaces concerned a varying degree of

mirror-like finish. At this stage surface distress can also arise, see page 23.

If the lubricant is completely used up, the temperature will rise rapidly. The hardened material then softens and the surfaces take on blue to brown hues. The temperature may even become so high as to cause the bearing to seize.

#### **Appearance**

Worn, frequently mirror-like, surfaces; at a later stage blue to brown discolouration.

#### **Cause**

Lubricant has gradually been used up or has lost its lubricating properties.

#### **Action**

Check that the lubricant reaches the bearing.  
More frequent relubrication.

**Fig 21** Outer ring of a spherical roller bearing that has not been adequately lubricated. The raceways have a mirror finish



**Fig 20** Cylindrical roller with mirror-like surface on account of lubricant starvation



## Different types of bearing damage

### Wear caused by vibration

When a bearing is not running, there is no lubricant film between the rolling elements and the raceways. The absence of lubricant film gives metal to metal contact and the vibrations produce small relative movements of rolling elements and rings. As a result of these movements, small particles break away from the surfaces and this leads to the formation of depressions in the raceways. This damage is known as false brinelling, sometimes also referred to as washboarding. Balls produce sphered cavities while rollers produce fluting.

In many cases, it is possible to discern red rust at the bottom of the depressions. This is caused by oxidation of the detached particles, which have a large area in relation to their volume, as a result of their exposure to air. There is never any visible damage to the rolling elements.

The greater the energy of vibration, the more severe the damage. The period of time and the magnitude of the bearing internal clearance also influence developments, but the frequency of the vibrations does not appear to have any significant effect.

Roller bearings have proved to be more susceptible to this type of dam-

age than ball bearings. This is considered to be because the balls can roll in every direction. Rollers, on the other hand, only roll in one direction; movement in the remaining directions takes the form of sliding. Cylindrical roller bearings are the most susceptible.

The fluting resulting from vibrations sometimes closely resembles the fluting produced by the passage of electric current. However, in the latter case the bottom of the depression is dark in colour, not bright or corroded. The damage caused by electric current is also distinguishable by the fact that the rolling elements are marked as well as the raceways.

### Appearance

Depressions in the raceways. These depressions are rectangular in roller bearings and circular in ball bearings. The bottom of these depressions may be bright or dull and oxidised.

### Cause

The bearing has been exposed to vibration while stationary.

### Action

Secure the bearing during transport by radial preloading. Provide a vibration-damping base. Where possible, use ball bearings instead of roller bearings. Employ oil bath lubrication, where possible.



Bearings with vibration damage are usually found in machines that are not in operation and are situated close to machinery producing vibrations. Examples that can be cited are transformer fans, stand-by generators and ships' auxiliary machinery. Bearings in machines transported by rail, road or sea may be subject to vibration damage too.

**Fig 22** Outer ring of taper roller bearing damaged by vibration during operation

**Fig 23** Vibration damage to the ring of cylinder roller bearing. The damage has arisen while the bearing was not running. It is evident, from the fainter fluting discernible between the pronounced depressions with corrosion at the bottom, that the ring has changed position for short periods

Where machines subject to constant vibration are concerned, it is essential that the risk of damage to the bearings be taken into consideration at the design stage. Consequently, where possible, ball bearings should be selected instead of roller bearings. The ability of ball bearings to withstand vibrations without being damaged can also be considerably improved by applying axial preloading with the aid of springs, see fig 25. An oil bath, in which all rolling elements in the load zone are immersed in the oil, has also proved to provide satisfactory protection. A vibration-damping base helps to prevent damage too.

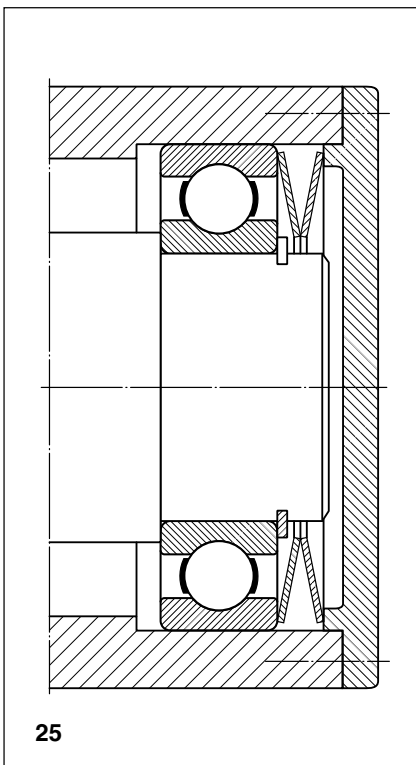
The bearings in machines that are to be transported can be protected by locking the shaft, thus preventing the small movements that have such a damaging effect on the bearings.



**Fig 24** Inner and outer ring of a cylindrical roller bearing exposed to vibration. The inner ring has changed position

**Fig 25** Spring loading a deep groove ball bearing to prevent vibration damage

**Fig 26** Outer ring of a self-aligning ball bearing damaged by vibration. The bearing has not rotated at all



## Indentations

Raceways and rolling elements may become dented if the mounting pressure is applied to the wrong ring, so that it passes through the rolling elements, or if the bearing is subjected to abnormal loading while not running. Foreign particles in the bearing also cause indentations.

### Indentations caused by faulty mounting or overloading

The distance between the dents is the same as the rolling element spacing. Ball bearings are prone to indentations if the pressure is applied in such a way that it passes through the balls during the mounting or dismounting operations. Self-aligning ball bearings are particularly susceptible to damage in such circumstances. In spherical roller bearings the damage originates as smearing (see page 17) and subsequently, if the pressure increases, develops into a dent. The same conditions apply in taper roller bearings that

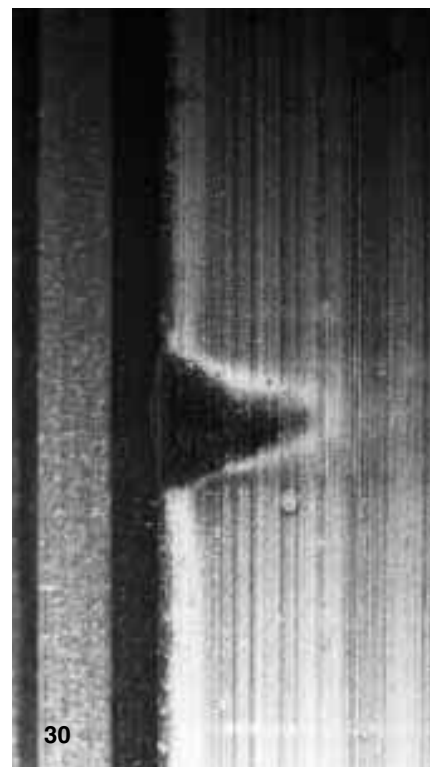
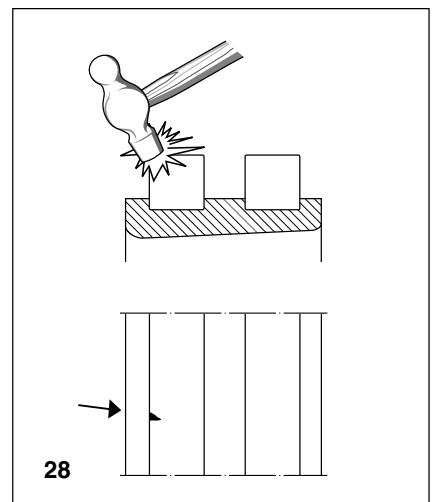
are unduly preloaded without being rotated.

Bearings that are mounted with excessively heavy interference fits, and bearings with tapered bore that are driven too far up the shaft seating or sleeve, also become dented.

Appearance	Cause	Action
Indentations in the raceways of both rings with spacing equal to the distance between the rolling elements.	Mounting pressure applied to the wrong ring.	Apply the mounting pressure to the ring with the interference fit.
	Excessively hard drive-up on tapered seating.	Follow carefully the SKF instructions concerning mounting bearings on tapered seating.
	Overloading while not running.	Avoid overloading or use bearings with higher basic static load ratings.



**Fig 27** Washer of a thrust ball bearing subjected to overloading while not running. The indentations are narrow and radially aligned, not sphered as in radial ball bearings



**Figs 28–30** An example of the results of improper handling. A roller in a double row cylindrical roller bearing has suffered impact (fig 28). A periphery camera view of the roller shows two diametrically opposed indentations (fig 29). The roller has, in turn, dented the inner ring raceway (fig 30)

## Different types of bearing damage

### Indentations caused by foreign particles

Foreign particles, such as swarf and burrs, which have gained entry into the bearing cause indentations when rolled into the raceways by the rolling elements. The particles producing the indentations need not even be hard. Thin pieces of paper and thread from cotton waste and cloth used for drying may be mentioned as instances of this. Indentations caused by these particles are in most cases small and distributed all over the raceways.

#### Appearance

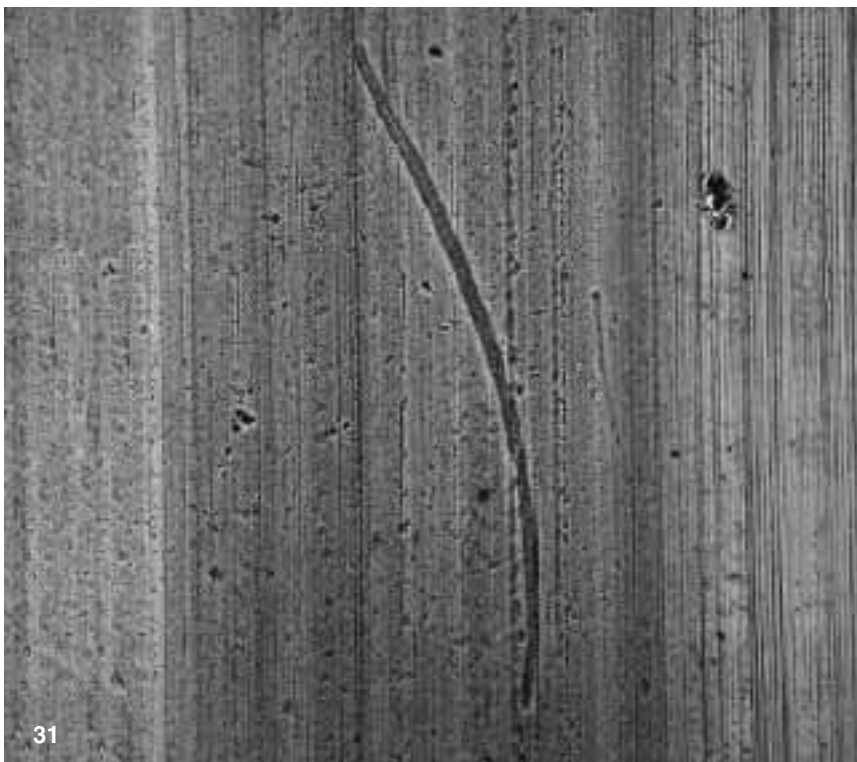
Small indentations distributed around the raceways of both rings and in the rolling elements.

#### Cause

Ingress of foreign particles into the bearing.

#### Action

Cleanliness to be observed during the mounting operation.  
Untaminated lubricant.  
Improved seals.



**Fig 31** Indentations, caused by dirt, in one of the raceways of a roller bearing – 50 × magnification



## Smearing

When two inadequately lubricated surfaces slide against each other under load, material is transferred from one surface to the other. This is known as smearing and the surfaces concerned become scored, with a “torn” appearance. When smearing occurs, the material is generally heated to such temperatures that rehardening takes place. This produces localised stress concentrations that may cause cracking or flaking.

In rolling bearings, sliding primarily occurs at the roller end-guide flange interfaces. Smearing may also arise

when the rollers are subjected to severe acceleration on their entry into the load zone. If the bearing rings rotate relative to the shaft or housing, this may also cause smearing in the bore and on the outside surface and ring faces.

In thrust ball bearings, smearing may occur if the load is too light in relation to the speed of rotation.

### Smearing of roller ends and guide flanges

In cylindrical and taper roller bearings, and in spherical roller bearings with guide flanges, smearing may occur on the guiding faces of the flanges and

the ends of the rollers. This smearing is attributable to insufficient lubricant between flanges and rollers. It occurs when a heavy axial load acts in one direction over a long period, for instance when taper roller bearings are subject to excessive preloading. In cases where the axial load changes direction, smearing is much less common as the opportunity is provided for the ingress of lubricant when the roller end is temporarily relieved of load. Such smearing can be avoided to a considerable extent by selecting a suitable lubricant.

#### Appearance

Scored and discoloured roller ends and flange faces.

#### Cause

Sliding under heavy axial loading and with inadequate lubrication.

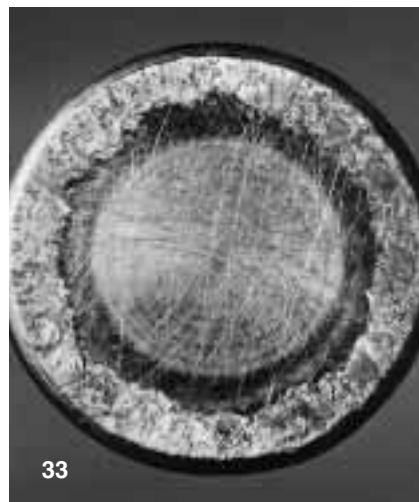
#### Action

More suitable lubricant.

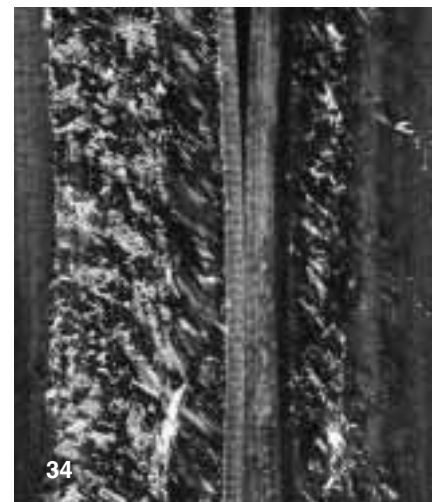
**Fig 32** Smearing on the surface of a roller from a spherical roller bearing – 100 × magnification



**Fig 33** A cylindrical roller with end smearing caused by heavy axial loading and improper lubrication



**Fig 34** Guide flange smearing attributable to the same causes as the smearing shown in fig 33



## Different types of bearing damage

### Smearing of rollers and raceways

In certain circumstances, smearing may occur on the surface of rollers and in raceways of spherical and cylindrical roller bearings. This is caused by roller rotation being retarded in the unloaded zone, where the rollers are not driven by the rings. Consequently their speed of rotation is lower than when they are in the loaded zone. The rollers are therefore subjected to rapid acceleration and the resultant sliding is so severe that it may produce smearing.

#### Appearance

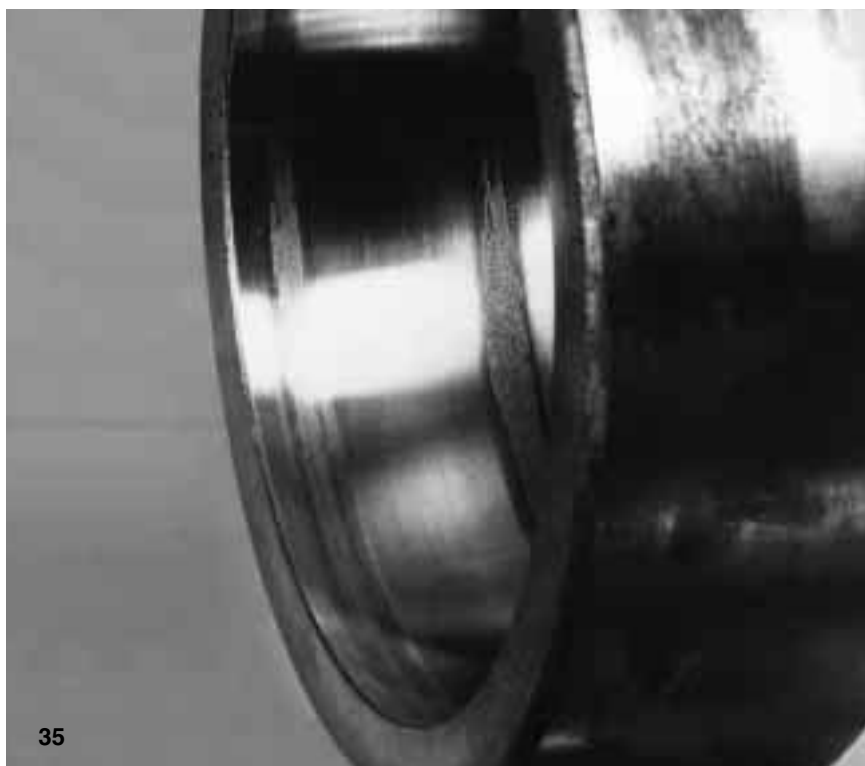
Scored and discoloured areas at the start of the load zone in raceways and on the surface of the rollers.

#### Cause

Roller acceleration on entry into the loaded zone.

#### Action

More suitable lubricant.  
Reduce bearing internal clearance.



**Fig 35** Skid smearing in both raceways of a spherical roller bearing outer ring

### Raceway smearing at intervals corresponding to the roller spacing

Far too often, when cylindrical roller bearings are being mounted, the ring with the roller and cage assembly is entered askew, without being rotated. The rollers then scratch the raceway of the other ring, causing smearing in the form of long, transverse streaks. The rollers may be smeared too. This type of damage can be avoided if the bearing is well lubricated and one of the rings is rotated. When large numbers of bearings are to be mounted it is expedient to employ a mounting ring, see fig 36. Similar damage may arise if the bearing rings are mounted with fits

that are too tight in relation to the internal clearance, so that preloading occurs.

Smear streaks may also be found in the raceways of spherical and taper roller bearings. These streaks are the result of careless handling or incorrect mounting practice. Blows or heavy pressure applied to the wrong ring, without rotating the bearing, cause the rollers to produce narrow, transverse streaks of smearing in the raceways, see fig 38.

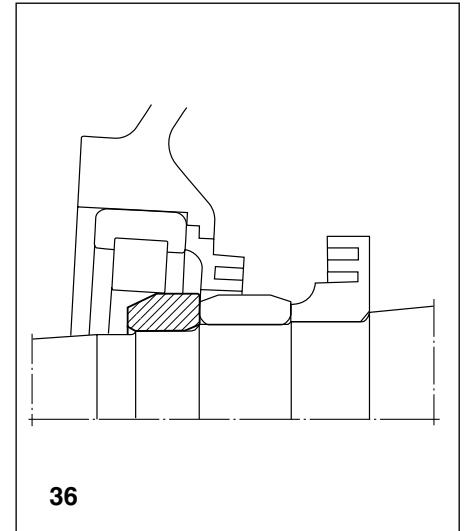


Fig 36 Mounting ring

#### Appearance

Transverse smear streaks – spaced at intervals equal to the distance between the rollers – in the raceways of cylindrical roller bearings.

Transverse smear streaks – spaced at intervals equal to the distance between the rollers – in the raceways of spherical and taper roller bearings.

#### Cause

During the mounting operation, the ring with the roller and cage assembly has been entered askew on the other ring.

Blows applied to the wrong ring or heavy preloading without rotating the bearing.

#### Action

Rotate the inner or outer ring during entry. Lubricate the surfaces well. Use a mounting ring when fitting a series of bearings.

Rotate the bearing when it is being adjusted. Apply the mounting force against the ring with the tightest fit; never allow the force to pass through the rolling elements.



Fig 37 A cylindrical roller bearing with smear streaks in the inner ring raceway and on the rollers. The smearing has been caused by the roller assembly being entered askew without being rotated

## Different types of bearing damage

**Fig 39** One of the smear streaks shown in fig 38 – 50 × magnification



**Fig 38** Outer ring raceway of a spherical roller bearing with smear streaks caused by a blow against the inner ring



### Smearing of external surfaces

Smearing may occur on the external surfaces of heavily loaded bearings. Here, the smearing is the result of movement of the bearing ring relative to its shaft or housing. Smearing of the inner ring bore, outer ring outside surface and ring faces can only be avoided if the fits are tight enough to prevent movement of the ring concerned in relation to its seating. Increasing the axial compression does not result in any improvement.

#### Appearance

Scored and discoloured ring bore or outside surface or faces.

#### Cause

Ring rotation relative to shaft or housing.

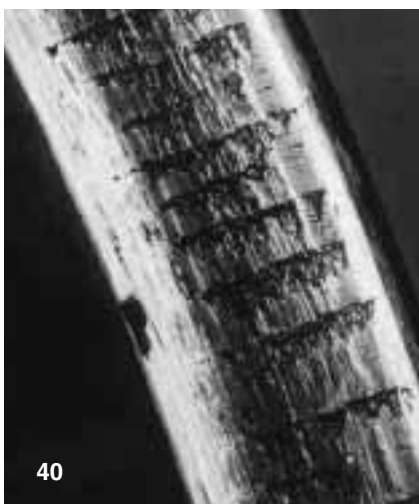
#### Action

Select heavier interference fits.

**Fig 41** Smeared outside surface of a spherical roller bearing outer ring. Material transfer has occurred from housing bore to bearing ring



**Fig 40** Smeared face of a cylindrical roller bearing inner ring



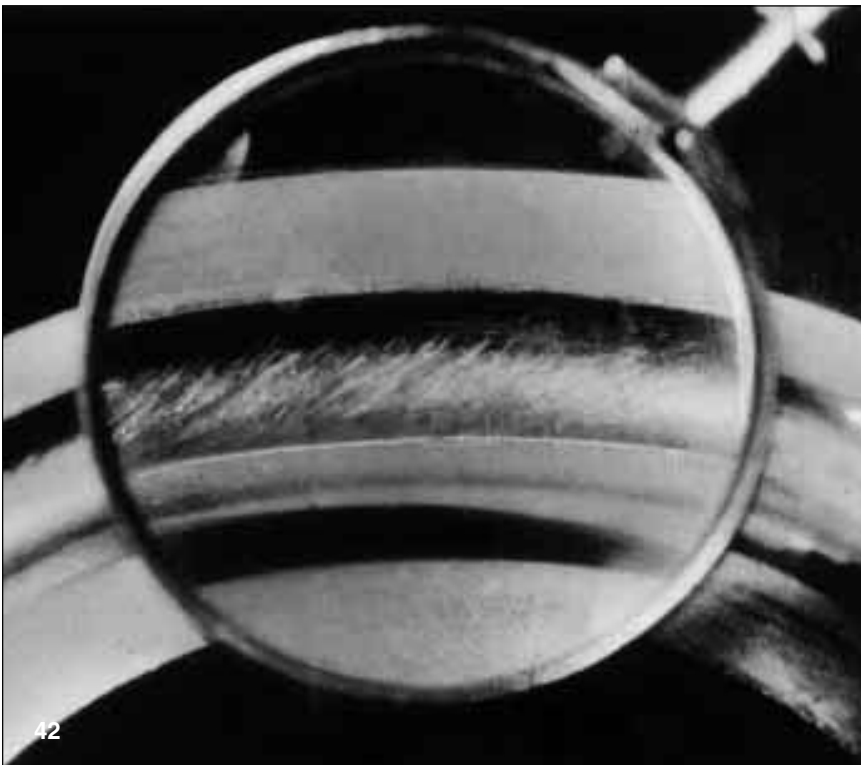
**Different types of bearing damage**

**Smearing in thrust ball bearings**

Smearing may occur in the raceways of thrust ball bearings if the rotational speed is too high in relation to the loading. The centrifugal force then impels the balls to the outer part of the shallow raceways. There the balls do not roll satisfactorily and a great deal of sliding occurs at the ball-to-raceway contacts. This leads to the formation of diagonal smear streaks in the outer part of the raceway. In the case of thrust ball bearings operating under light loads and at high speeds, such damage can be prevented by subjecting the bearings to extra loading, for instance by applying springs, see fig

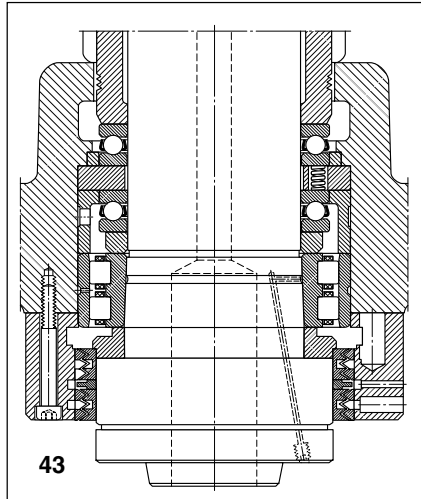
43. Details of how to calculate the minimum required axial loads are given in the SKF General Catalogue.

<b>Appearance</b>	<b>Cause</b>	<b>Action</b>
Diagonal smear streaks in the raceways.	Loading too light in relation to speed of rotation.	Preload the bearing by using springs.



**Fig 42** Thrust ball bearing raceway with smear streaks on account of the rotational speed having been too high in relation to the load

**Fig 43** Preloading thrust ball bearings by means of springs



## Surface distress

If the lubricant film between raceways and rolling elements becomes too thin, the peaks of the surface asperities will momentarily come into contact with each other. Small cracks then form in the surfaces and this is known as surface distress. These cracks must not be confused with the fatigue cracks that originate beneath the surface and lead to flaking. The surface distress cracks are microscopically small and increase very gradually to such a size that they interfere with the smooth running of the bearing. These cracks may, however, hasten the formation of

sub-surface fatigue cracks and thus shorten the life of the bearing

If the lubrication remains satisfactory throughout, i.e. the lubricant film does not become too thin because of lubricant starvation or viscosity changes induced by the rising temperature or on account of excessive loading, there is no risk of surface distress.

### Appearance

Initially the damage is not visible to the naked eye. A more advanced stage is marked by small, shallow craters with crystalline fracture surfaces.

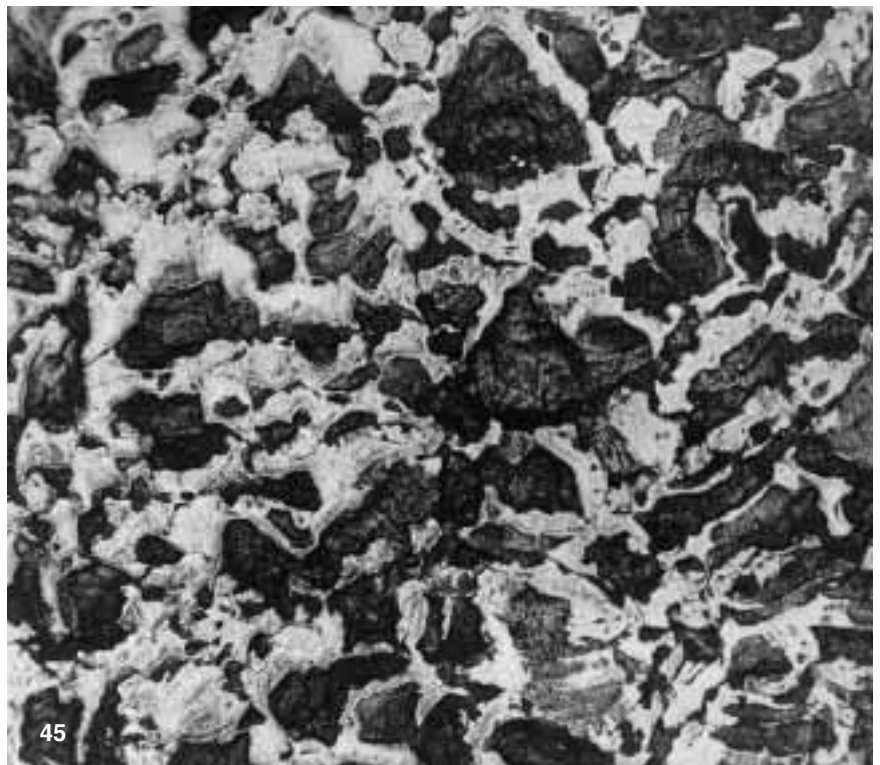
### Cause

Inadequate or improper lubrication.

### Action

Improve lubrication.

**Fig 45** The surface distress depicted in fig 45 – 100 × magnification



**Fig 44** Surface distress in the form of a band encircling a roller from a spherical roller bearing



## Corrosion

Rust will form if water or corrosive agents reach the inside of the bearing in such quantities that the lubricant cannot provide protection for the steel surfaces. This process will soon lead to deep seated rust. Another type of corrosion is fretting corrosion.

### Deep seated rust

A thin protective oxide film forms on clean steel surfaces exposed to air. However, this film is not impenetrable and if water or corrosive elements make contact with the steel surfaces, patches of etching will form. This development soon leads to deep seated rust.

Deep seated rust is a great danger to bearings since it can initiate flaking and cracks. Acid liquids corrode the steel quickly, while alkaline solutions are less dangerous. The salts that are present in fresh water constitute, together with the water, an electrolyte which causes galvanic corrosion,

known as water etching. Salt water, such as sea water, is therefore highly dangerous to bearings.

### Appearance

Greyish black streaks across the raceways, mostly coinciding with the rolling element spacing. At a later stage, pitting of raceways and other surfaces of the bearing.

### Cause

Presence of water, moisture or corrosive substances in the bearing over a long period of time.

### Action

Improve sealing.  
Use lubricant with better rust-inhibiting properties.



**Fig 46** Deep seated rust in the outer ring of a cylindrical roller bearing

**Fig 47** Extensive water etching on the inner ring of a spherical roller bearing



**Fretting corrosion**

If the thin oxide film is penetrated, oxidation will proceed deeper into the material. An instance of this is the corrosion that occurs when there is relative movement between bearing ring and shaft or housing, on account of the fit being too loose. This type of damage is called fretting corrosion and may be relatively deep in places. The relative movement may also cause small particles of material to become detached from the surface. These particles oxidise quickly when exposed to the oxygen in the atmosphere.

As a result of the fretting corrosion, the bearing rings may not be evenly

supported and this has a detrimental effect on the load distribution in the bearings. Rusted areas also act as fracture notches.

**Appearance**

Areas of rust on the outside surface of the outer ring or in the bore of the inner ring. Raceway path pattern heavily marked at corresponding positions.

**Cause**

Fit too loose.  
Shaft or housing seating with errors of form.

**Action**

Adjust seatings.



**Fig 48** Fretting corrosion on the outer ring of a spherical roller bearing



**Fig 49** Extensive fretting corrosion in the bore of a self-aligning ball bearing

## Damage caused by the passage of electric current

When an electric current passes through a bearing, i.e. proceeds from one ring to the other via the rolling elements, damage will occur. At the contact surfaces the process is similar to electric arc welding.

The material is heated to temperatures ranging from tempering to melting levels. This leads to the appearance of discoloured areas, varying in size, where the material has been tempered, re-hardened or melted. Small

craters also form where the metal has melted.

The passage of electric current frequently leads to the formation of fluting (corrugation) in bearing raceways. Rollers are also subject to fluting, while there is only dark discolouration of balls

It can be difficult to distinguish between electric current damage and vibration damage. A feature of the fluting caused by electric current is the dark bottom of the corrugations, as opposed to the bright or rusty appearance at the bottom of the vibration-induced fluting. Another distinguishing feature is the lack of damage to the rolling ele-

ments of bearings with raceway fluting caused by vibrations.

Both alternating and direct currents cause damage to bearings. Even low amperage currents are dangerous. Non-rotating bearings are much more resistant to electric current damage than bearings in rotation. The extent of the damage depends on a number of factors: current intensity, duration, bearing load, speed and lubricant.

The only way of avoiding damage of this nature is to prevent any electric current from passing through the bearing.

### Appearance

Dark brown or greyish black fluting (corrugation) or craters in raceways and rollers. Balls have dark discolouration only. Sometimes zigzag burns in ball bearings raceways.

Localised burns in raceways and on rolling elements.

### Cause

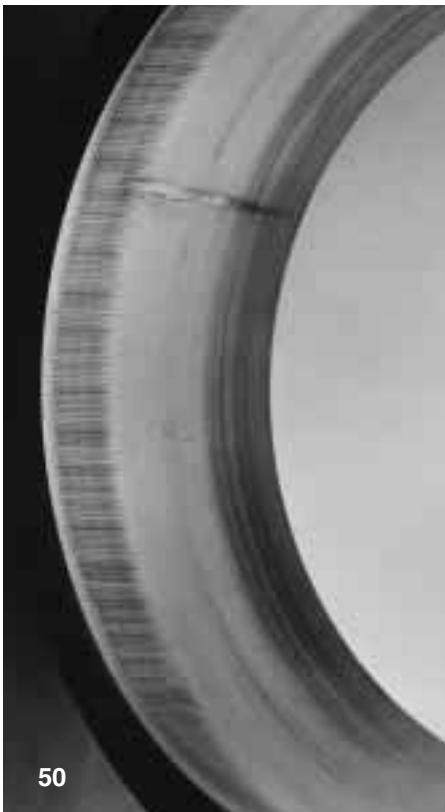
Passage of electric current through rotating bearing.

Passage of electric current through non-rotating bearing.

### Action

Re-route the current to by-pass the bearing.  
Use insulated bearings.

Re-route the current to by-pass the bearing. When welding, arrange earthing to prevent current passing through the bearing.  
Use insulated bearings.



**Fig 50** Fluting, caused by the passage of electric current, in the outer ring of a spherical roller bearing

**Fig 51** The outer ring of a self-aligning ball bearing damaged by electric current

**Fig 52** Deep groove ball bearing with electric current damage in zigzag pattern. It is assumed that burns of this configuration arise when the momentary passage of high amperage current is accompanied by axial vibration



**Fig 53** A railway axlebox bearing damaged by the passage of high amperage current while the bearing was not running



**Fig 54** Roller of a railway axlebox bearing damaged by electric current (same bearing as in fig 53)



## Flaking (spalling)

Flaking occurs as a result of normal fatigue, i.e. the bearing has reached the end of its normal life span. However, this is not the commonest cause of bearing failure. The flaking detected in bearings can generally be attributed to other factors. If the flaking is discovered at an early stage, when the damage is not too extensive, it is frequently possible to diagnose its cause and take the requisite action to prevent a recurrence of the trouble. The path pattern of the bearing may prove to be useful, see page 4.

When flaking has proceeded to a certain stage, it makes its presence known in the form of noise and vibrations, which serve as a warning that it is time to change the bearing.

The causes of premature flaking may be heavier external loading than had been anticipated, preloading on account of incorrect fits or excessive drive-up on a tapered seating, oval distortion owing to shaft or housing seating out-of-roundness, axial compression, for instance as a result of thermal expansion. Flaking may also be caused by other types of damage, such as indentations, deep seated rust, electric current damage or smearing.



**Fig 55** Flaked cone and rollers of taper roller bearing. Heavy loading and inadequate lubrication are the causes of this damage

## Flaking caused by preloading

Appearance	Cause	Action
Heavily marked path pattern in raceways of both rings.	Preloading on account of fits being too tight.	Alter the fits or select bearing with larger internal clearance.
Flaking usually in the most heavily loaded zone.	Excessive drive-up on a tapered seating.	Do not drive the bearing so far up its tapered seating. Follow carefully the instructions given by SKF.
	Single row angular contact ball bearings or taper roller bearings adjusted to give excessive preload.	Re-adjust the bearings to obtain lighter preload.
	Temperature differential between inner and outer rings too great.	Select bearing with larger internal clearance.



**Fig 56** Outer ring of a self-aligning ball bearing that has been driven too far up its tapered seating. The bearing had only performed a few revolutions when the damage was detected. Flaking would soon have occurred if the bearing had been put into service

## Different types of bearing damage

### Flaking caused by oval compression

#### Appearance

Heavily marked path pattern at two diametrically opposed sections of either bearing ring. Flaking in these sections.

#### Cause

Oval shaft or oval housing seating. The latter is a common defect in split housings and machine frames.

#### Action

Usually it is necessary to manufacture a new shaft or a new housing to remedy this defect. One expedient is to spray metal on the components and then regrind. If it is a matter of an oval shaft with the bearing mounted on a sleeve, it is possible to adjust the shaft by grinding, in certain cases.

The bore of plummer blocks mounted on an uneven base becomes oval when the base bolts are tightened.

Adjust the base.



**Fig 57** Flaking in the outer ring outer ring of spherical roller bearing that has been mounted in a housing with oval bore

## Flaking caused by axial compression

### Cause

Incorrect mounting, which results in axial loading, e.g. excessive preloading of angular contact ball bearings and taper roller bearings.

The non-locating bearing has jammed.

Axial freedom of movement has not been sufficient to accommodate the thermal expansion.

### Action

Check adjustment when mounting the bearings.

Check the fit and lubricate the surfaces.

If temperature differential between shaft and housing cannot be reduced, provide greater freedom of movement.

**Fig 58** Outer ring of a self-aligning ball bearing subjected to excessive axial loading. Flaking in the load zone



**Fig 59** Flaked inner ring of a spherical roller bearing. The extent of the flaking around one entire raceway indicates that the axial load has been very heavy in relation to the radial load



## Different types of bearing damage

### Flaking caused by misalignment

#### Appearance

Deep groove ball bearings: diagonal path pattern, severely marked at two diametrically opposed sections.  
Cylindrical roller bearings: flaking at the edge of the raceway.

#### Cause

Bearing seatings out of alignment.  
Bearing mounted on the skew.

#### Action

Rectify the seatings.  
Use mounting sleeve with parallel faces.



**Fig 60** Deep groove ball bearing outer ring that has been out of alignment with the shaft. The ball path has an oval configuration on account of the misalignment. The result is the same as with oval compression, see page 31

**Fig 61** Cylindrical roller bearing inner ring with flaking at one side of the raceway, as a result of overloading due to misalignment





## Flaking caused by indentations

### Appearance

Flaking in conjunction with indentations coinciding with the rolling element spacing.

Flaking in conjunction with small indentations.

### Cause

Indentations resulting from faulty mounting practice or overloading of the non-rotating bearing, see page 28.

Indentations made by foreign particles, see page 16.

**Fig 63** Flaking (the dark area) initiated by the adjacent indentations – 100 × magnification

**Fig 62** Various stages of flaking in the inner ring of a deep groove ball bearing. The ring has been mounted with interference fit on the shaft and blows have been directed against the outer ring, causing the mounting force to pass through the balls, which have produced the indentations



## Different types of bearing damage

### Flaking caused by smearing

#### Appearance

Flaking at the start of the load zone in raceways of roller bearings.

Flaking, coinciding with the roller spacing, in raceways of roller bearings.

#### Cause

Skid smearing, see page 18.

Transverse smearing resulting from faulty mounting practice, see page 19.



**Fig 64** Inner ring of a cylindrical roller bearing with extensive flaking caused by smearing of the kind depicted in fig 65

**Fig 65** Inner ring of a cylindrical roller bearing with smearing, at intervals corresponding to the roller spacing, caused by incorrect mounting

**Flaking caused by deep seated rust**



**Fig 66** Flaking originating from deep seated rust on the roller of a spherical roller bearing

**Appearance**

Flaking originating from rust damage.

**Cause**

Deep seated rust, see page 24.

**Fig 68** Magnification of the damage shown in fig 66

**Fig 67** Cross section through the roller depicted in fig 66, showing the way in which the fatigue crack extends beneath the surface. The fully developed flaking originated in the same manner



## Different types of bearing damage

### Flaking caused by fretting corrosion

#### Appearance

Flaking in the raceway of either the inner or outer ring. Corroded area at corresponding part of the inner bore of outside surface.

#### Cause

Fretting corrosion, see page 25.



**Fig 69** Flaking in the raceways of the outer ring of a spherical roller bearing. Corresponding area of advanced fretting corrosion on the outside surface (for this photograph the ring has been placed in front of a mirror). Development of the corrosion has been accompanied by an increase in volume that has led to deformation of the bearing ring and localised overloading. The results have been premature fatigue and flaking

**Flaking caused by fluting or craters**



**Fig 70** The outer ring of a self-aligning ball bearing with flaking caused by craters that have formed in conjunction with the passage of electric current. It is evident that the flaking has originated at the craters, from where it has spread out in both directions. Detached fragments of flaked material have in turn caused indentations and further flaking

**Appearance**

Flaking in conjunction with bright or corroded fluting or craters.

Flaking in conjunction with dark-coloured or burnt fluting or craters.

**Cause**

Wear resulting from vibrations while the bearing was not running, see page 12.

Electric current damage, see page 26.



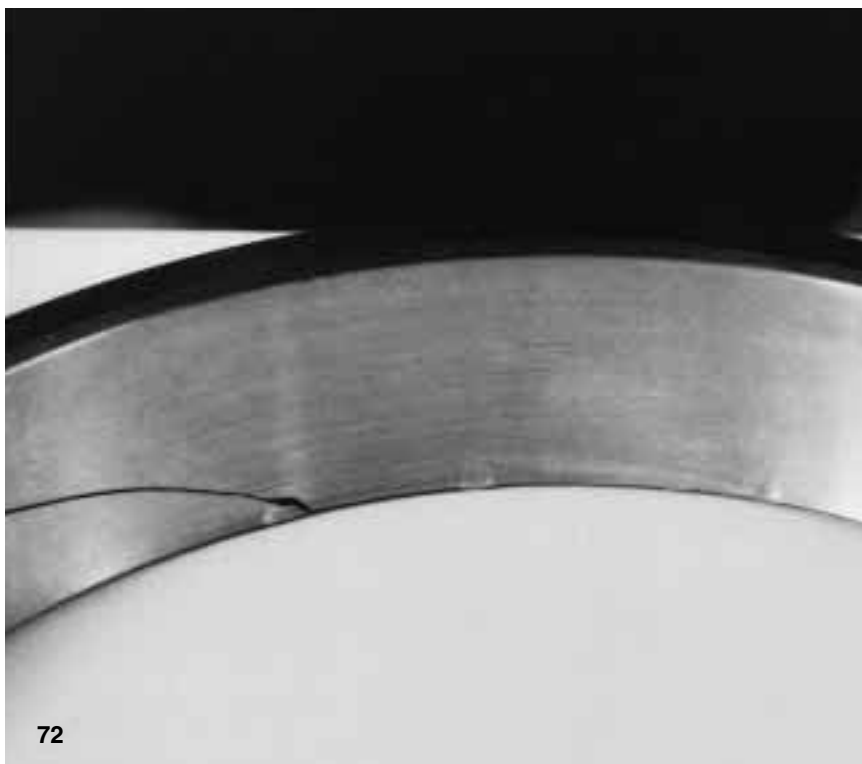
**Fig 71** Flaking in both raceways of the inner ring of a spherical roller bearing. The flaking has originated from the vibration markings

## Cracks

Cracks may form in bearing rings for various reasons. The most common cause is rough treatment when the bearings are being mounted or dismounted. Hammer blows, applied direct against the ring or via a hardened chisel, may cause fine cracks to form, with the result that pieces of the ring break off when the bearing is put into service. Excessive drive up on a tapered seating or sleeve is another cause of ring cracking. The tensile stresses, arising in the rings as a result of the excessive drive-up, produce cracks when the bearing is put into operation. The same result may be obtained when bearings are heated and then mounted on shafts manufactured to the wrong tolerances.

The smearing described in an earlier section may also produce cracks at right angles to the direction of slide. Cracks of this kind produce fractures right across the rings.

Flaking, that has occurred for some reason or other, acts as a fracture notch and may lead to cracking of the bearing ring. The same applies to fretting corrosion.



**Fig 72** Fractured outer ring of a self-aligning ball bearing. The indentations visible at the bottom edge of the ring were caused by rough treatment and the crack originated at one of these indentations

## Cracks caused by rough treatment

### Cause

Blows, with hammer or hardened chisel, have been directed against the ring when the bearing was being mounted.

### Action

Always use a soft drift or mounting sleeve. Never subject the bearing to direct hits.



**Fig 73** Cracked inner ring of a spherical roller bearing. One roller has been removed to allow the raceway of the left-hand of the photograph to be examined. The roller has then been hammered back in place, causing part of the centre flange to break away. The impacts have been transmitted via a roller in the other row and part of the outer flange has broken off too. At the same time the ring has cracked right through



**Fig 74** Inner ring of a spherical roller bearing with outer flange fracture produced by direct hammering

## Different types of bearing damage

### Cracks caused by excessive drive-up

#### Appearance

The bearing ring has cracked right through and has lost its grip on the shaft.

#### Cause

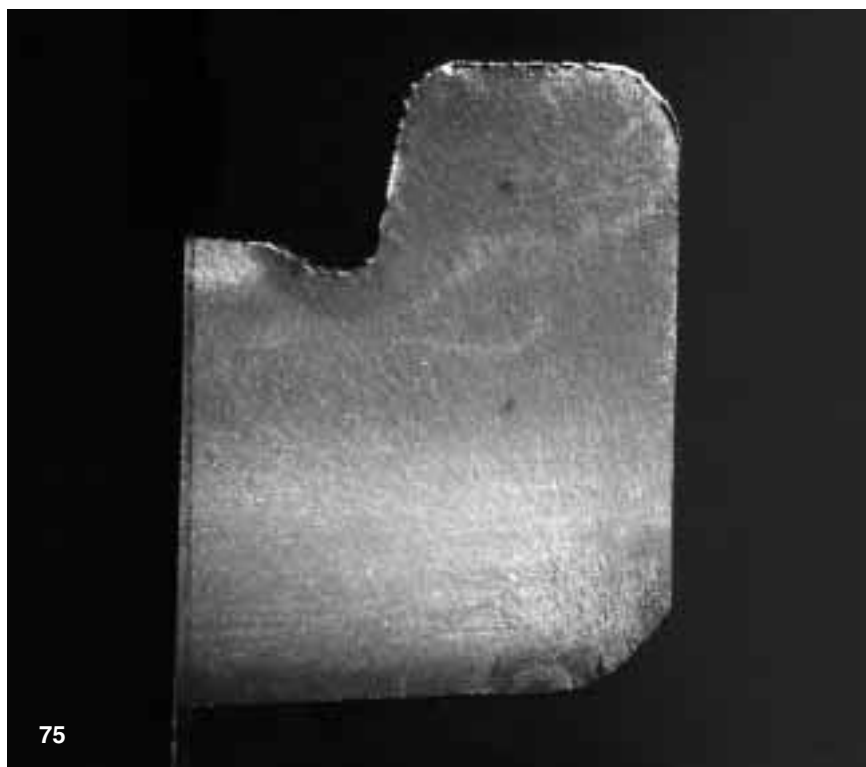
Excessive drive-up on a tapered seating or sleeve.

Interference fit on cylindrical seating too heavy.

#### Action

Follow carefully the SKF mounting instruction concerning bearings on tapered seatings.

Alter the fit.



**Fig 75** Section of the inner ring of a spherical roller bearing – 3,5 × magnification. The ring has cracked because of excessive drive-up. The fracture originated at the dark area by the bore chamfer

**Fig 76** Fractured surface of the inner ring in fig 75





## Cracks caused by smearing

### Appearance

Crack or cracks in conjunction with smearing of the bearing ring. The ring may have cracked right across. Smearing cracks generally form across the smearing.

### Cause

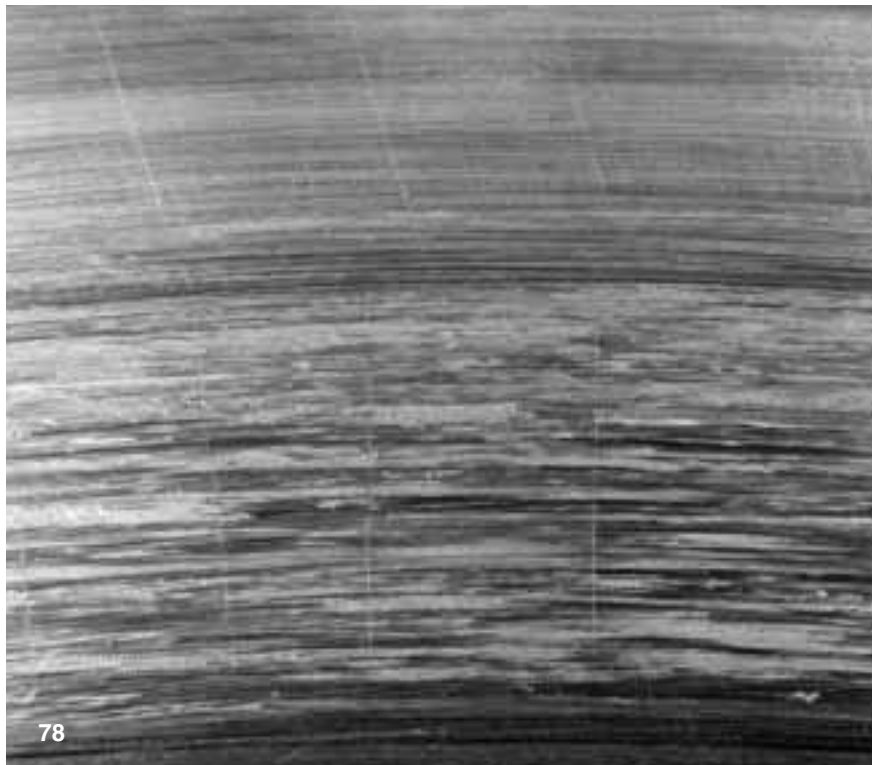
Smearing, see page 17.

**Fig 78** Smearing damage on the face of a bearing ring. Note the incipient transverse cracks

**Fig 77** Spherical roller bearing inner ring that has cracked right across following smearing of one face. The ring has been mounted to abut a spacer that has not had a sufficiently tight fit on the shaft. Consequently the spacer has rotated relative to the shaft and the bearing ring



77



78

## Different types of bearing damage

### Cracks caused by fretting corrosion

#### Appearance

Cracks, transverse in inner rings and generally longitudinal in outer rings, in conjunction with fretting corrosion.

#### Cause

Fretting corrosion, see page 25.



**Fig 79** Spherical roller bearing inner ring with fretting corrosion and a transverse crack right through the ring. The fretting corrosion has caused the cracking

**Fig 80** Longitudinal crack in a deep groove ball bearing outer ring with fretting corrosion

## Cage damage

If, on examination of a failed bearing, the cage is found to be damaged, it may in many cases prove difficult to ascertain the cause. Usually other components of the bearing are damaged too and this makes it even more difficult to discover the reason for the trouble. However, there are certain main causes of cage failure, viz. vibration, excessive speed, wear and blockage.

### Vibration

When a bearing is exposed to vibration, the forces of inertia may be so great as to cause fatigue cracks to form in the cage material after a time. Sooner or later these cracks lead to cage fracture.

### Excessive speed

If the bearing is run at speeds in excess of that for which the cage is designed, the cage is subjected to heavy forces of inertia that may lead to fractures. Frequently, where very high speeds are involved, it is possible to select bearings with cages of special design.

### Wear

Cage wear may be caused by inadequate lubrication or by abrasive par-

ticles. The idea with rolling bearings is of course to avoid sliding friction. However, where the cage is concerned, sliding cannot be eliminated in the contacts with the other components of the bearing. This explains why the cage is the first component to be affected when the lubrication becomes inadequate. The cage is always made of softer material than the other components of the bearing and consequently it wears comparatively quickly. As the cage pockets increase in size, due to wear, the rolling element guidance deteriorates and this also applies to the cage in cases where the cage is centred on the rolling elements. The resultant forces may lead to cage failure within a short space of time.

### Blockage

Fragments of flaked material or other hard particles may become wedged between the cage and a rolling element, preventing the latter from rotating round its own axis. This leads to cage failure.

### Other causes of cage damage

If the rings of a deep groove ball bearing are fitted out of alignment with each other, the path of the balls has an oval configuration. If the cage is centred on the balls, it has to change shape for every revolution it performs.

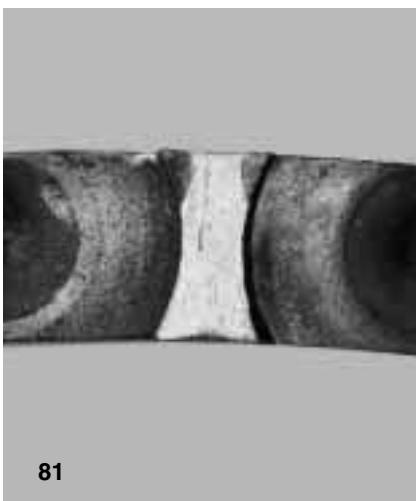
Fatigue cracks then form in the material and sooner or later they lead to fractures.

There is a similar case when a thrust ball bearing is fitted together with radial plain bearings. If clearance arises in the plain bearings, the washers of the thrust bearing become displaced in relation to each other. Then the balls do not follow their normal path and heavy stresses may arise in the cage.

Cages in bearings subject to severe acceleration and retardation, in conjunction with fluctuations in speed, are affected by forces of inertia. These give rise to considerable pressure between the contacting surfaces, with consequent heavy wear.

**Fig 82** Cage of a spherical roller bearing. Fatigue cracks have formed in the fillets

**Fig 81** Fractured surface of the cage shown in fig 82. The fatigue cracks are clearly visible



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