

# Bearing investigation

Extract from the Railway technical handbook,  
volume 1, chapter 6, page 122 to 135



## 6 Bearing investigation

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# Bearing investigation

*Roller bearings are extremely vital components in any railway application. A large number of factors need to be considered to select the appropriate bearing for an application. But, complete information is not always available. Real operating conditions might differ from the specifications. Wear and tear might change the operating conditions. Also, use of the vehicle might change over time. All of these can influence rolling bearing service life. Damage to bearings might occur earlier than foreseen. It is therefore important that timely inspections are made to determine the root cause of the problem and that actions are taken necessary to avoid recurrence of the problem.*

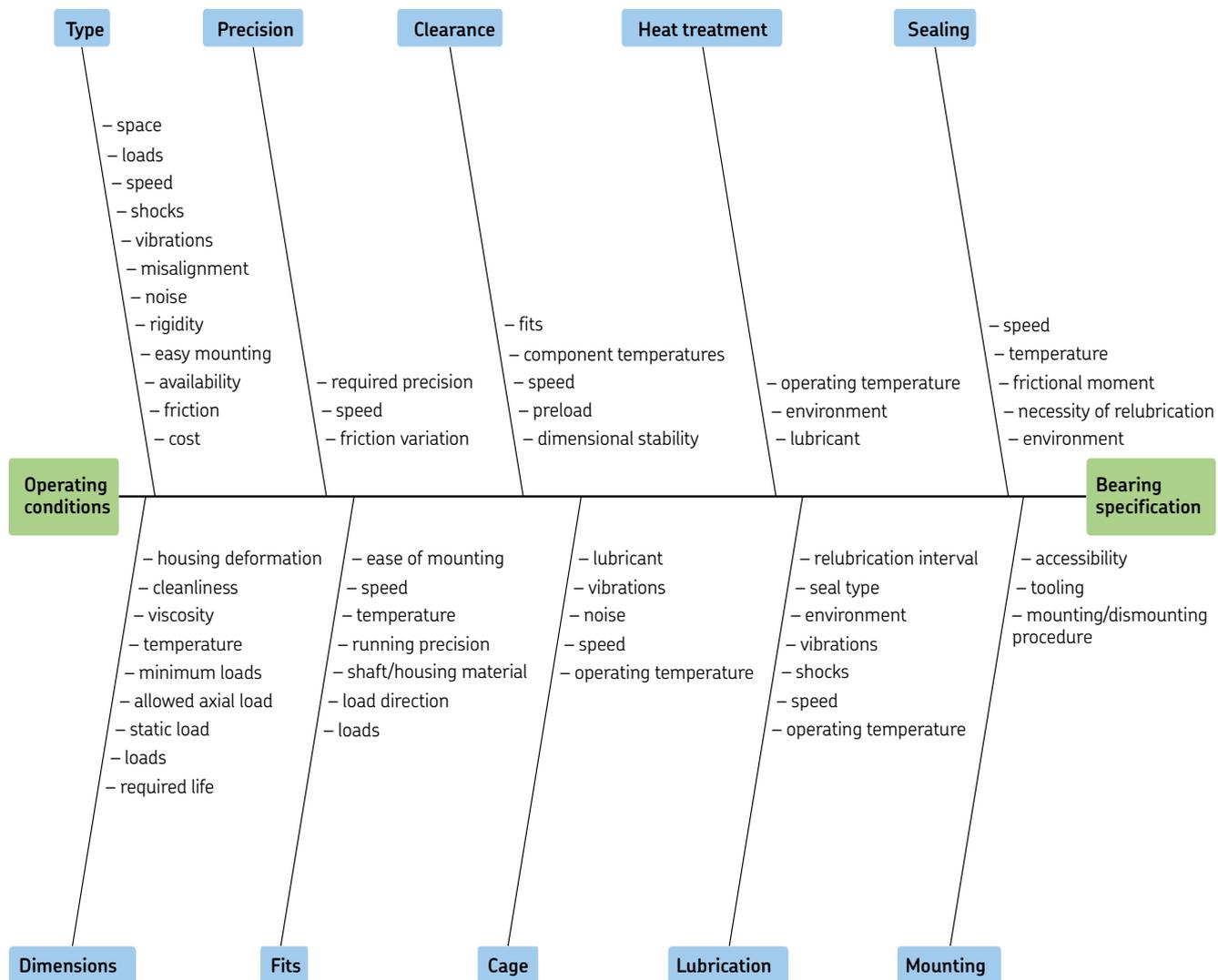
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## Considerations

Calculated bearing life is dealt with in the different chapters. However, to select the bearing final variant, a large number of factors need to be considered. The following main factors influence this selection:

- type
- dimensions
- precision
- fits
- clearance
- cage
- heat treatment
- lubrication
- sealing
- mounting/dismounting

Selecting the appropriate bearing for the application (→ **chapter 4** and **chapter 5**) is only the first step in achieving reliable equipment performance.



*A large number of operating conditions influence the bearing specification*

## Trouble in operation

If all the assumptions in the table are met, a bearing would reach its calculated life.

Unfortunately, this is quite hypothetical. There is often something that occurs that prevents “ideal” operating conditions. Bearings might get damaged and their life impaired.

Even the smallest event can have severe consequences – an example:

A Y25 axlebox can be fitted with two spherical roller bearings. There are two versions, a long axle for 20 tonnes axleload and a shorter axle for 22,5 tonnes axleload. The main difference is the width of the spacer between the bearings. During an overhaul of an axlebox for a 20 tonnes axleload, the wrong distance ring (for 22,5 tonnes axleload) was fitted. The width difference of 21 mm caused the bearings to shift on the journal and, as a result, heat was generated. Shaft fatigue occurred and finally the axle collapsed, leading to a derailment with substantial material damage. A very costly affair indeed compared to the cost of a small spacer.

It is clear that identifying the root cause of bearing damage is the next step in achieving reliable equipment performance. One of the most difficult tasks is identifying the root cause and filtering out any secondary effects that resulted from the root cause of failure.

A new bearing looks beautiful. Its components have been made to exact dimensions, often to fractions of microns. The dimensions have been checked many times during the manufacturing process. The areas that have been ground, such as the surfaces of inner and outer rings and rolling elements, look very shiny.

When examining a bearing that has run for some time, a number of changes can be observed, such as:

- dull areas on raceways and rolling elements, sometimes even very shiny
- inner ring and outer ring seats are discoloured
- cage wear
- fretting corrosion on the inner ring bore or outer ring outside diameter

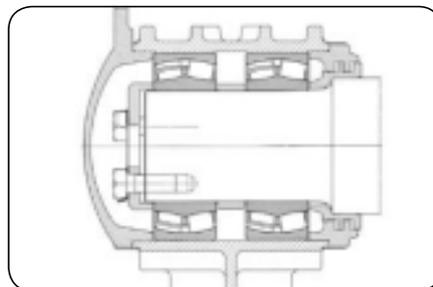
Whether a bearing shows minor wear or damage, or has failed completely, a thorough inspection can provide information about what happened to the bearing during operation. During the inspection, the key is to look for “patterns”. A pattern can be

Calculated life expectancy of any bearing is based on eight assumptions:

- 1 The bearing is the appropriate one for the application.
- 2 The bearing is of high quality and has no inherent defects.
- 3 Dimensions of parts related to the bearing, such as shaft and housing seats, are appropriate.
- 4 The bearing is mounted correctly.
- 5 The appropriate lubricant in the required quantity is always available to the bearing.
- 6 The bearing arrangement is properly protected (sealed).
- 7 The operating conditions are matched to the bearing arrangement.
- 8 Recommended maintenance is performed.



Y25 axlebox



Bearing arrangement



Axlebox after derailment (cut through)

“normal” or it can indicate a problem. The patterns found quite frequently identify the root cause of a problem.

# Bearing damage

Because of the increasing attention given to preventing bearing damage and failures from recurring, the International Organization for Standardization (ISO) has developed a methodology for classifying bearing damage and failures (ISO 15243).

This standard recognizes six primary damage/failure modes and their sub-modes related to post-manufacturing sustained damage. These are based primarily upon the features visible on rolling element contact surfaces and other functional surfaces and which identify the mechanisms involved in each type of damage/failure.

Most bearing damage can be linked back to the six main modes as well as their various sub-modes.

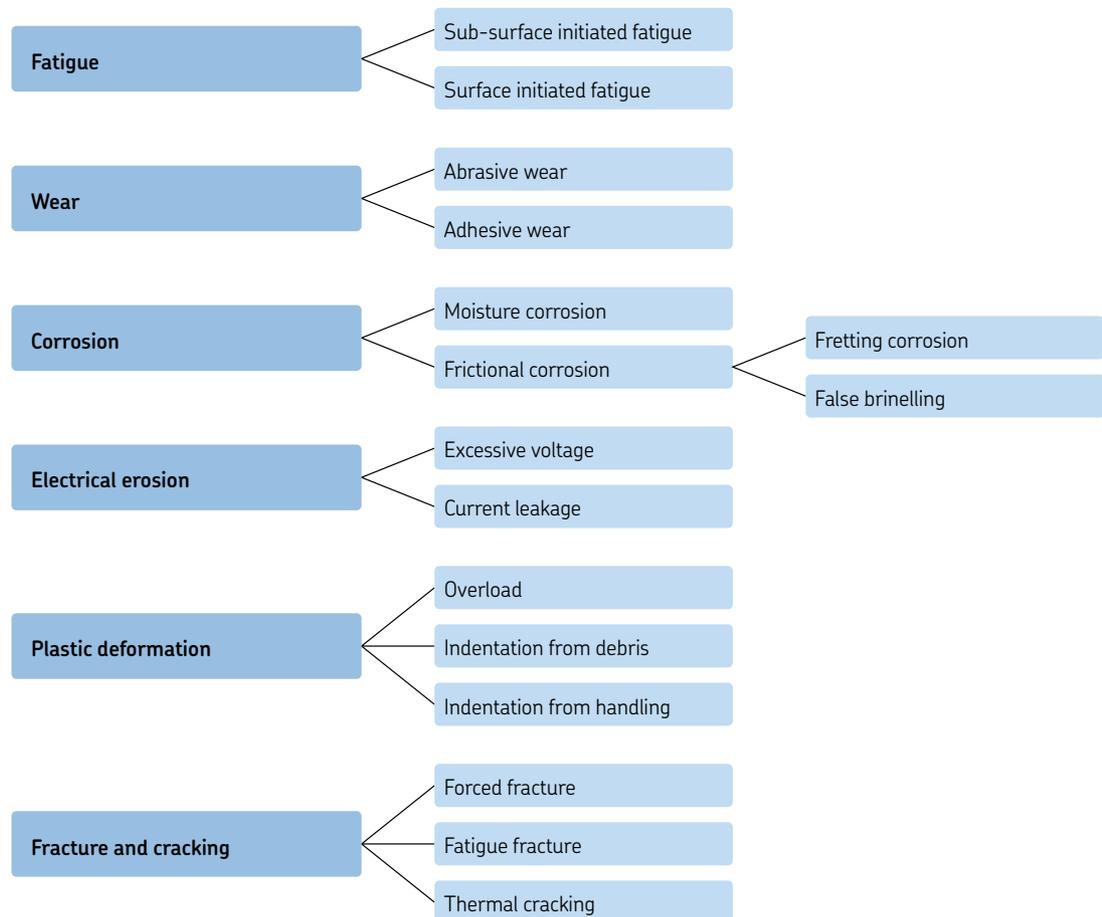
In the following pages, damage to wheelset bearings are presented. These are the most common damage modes [26]. For additional information, refer to the *SKF Maintenance handbook*.

# Damage and limits of acceptability

Damage is explained and limits of acceptability are discussed below. Wheelset bearings are very critical components. If any doubt arises on acceptability, the bearing should be scrapped.

However, the limits for acceptability of bearings used in freight wagons are less stringent compared with other applications.

For additional information, refer to the chapter *Services*, section *Remanufacturing* (→ page 192).



ISO 15243: Bearing damage classification – showing 6 primary failure modes and their sub-modes.

## Fatigue

Fatigue is a change in the material structure that is caused by the repeated stresses developed in the contacts between the rolling elements and the raceways. Fatigue is mostly manifested visibly as spalling/flaking, i.e. breaking out of material.

### Sub-surface initiated fatigue

Due to repeated stresses, material fatigue results. Structural changes occur underneath the raceway surface and micro cracks develop. When these cracks reach the surface, material breaks loose and spalls occur.

Pure sub-surface fatigue under normal operating conditions does not occur frequently, only after very long running time.

However, if operating conditions become abnormal, certain areas of the bearing might become too heavily loaded, leading to early fatigue. One common example is shaft and housing seats that are deformed, i.e. tapered, out-of-round, out-of-square, or thermally distorted. Another possibility is steel that is not clean. Impurities such as oxides weaken the material structure, leading to earlier material fatigue.

#### *Limits of acceptability<sup>1)</sup>*

Bearings with sub-surface initiated fatigue should always be scrapped.

#### *Possible action*

Check bearings seats for conformity.  
Check loading conditions.



**Sub-surface initiated fatigue in the outer ring load zone**



**Surface initiated fatigue in the outer ring of a spherical roller bearing.**  
*There is surface distress on part of the outer ring raceway. In one place spalling has already started.*

### Surface initiated fatigue

Surface initiated fatigue in general is caused by inadequate lubrication. If the lubricant supply or lubricant selection is wrong, or if the lubricant is contaminated, the contact surfaces will no longer be separated by an appropriate lubricant film. Asperities shear over each other and break off. The surface becomes plastically deformed and sometimes smoothed. Micro-spalls occur and in turn grow to larger spalls. Finally, a combination of total spalling/wear might occur around the load zone and on the rotating inner ring. Sometimes wear, corrosion, electrical erosion and plastic deformation also damage the raceway surfaces. These are dealt with separately.

#### *Limits of acceptability<sup>1)</sup>*

Bearings with surface initiated fatigue spalls should always be scrapped.

#### *Possible action*

Check lubrication conditions:

- appropriate grease
- sufficient grease
- replenishment/overhaul intervals
- adequate sealing

<sup>1)</sup> See *Damage and limits of acceptability* on **page 126**. For additional information, refer to the chapter *Services*, section *Remanufacturing* (→ **page 192**) where different standards are described.

## Wear

Wear is the progressive removal of material resulting from the interaction of the asperities of two sliding or rolling/sliding contacting surfaces during service.

### Abrasive wear

Abrasive wear is the progressive removal of material.

This type of wear occurs most of the time due to inadequate lubrication resulting mostly from the ingress of abrasive contaminant particles. Raceway material, but also rolling elements and cage material, is removed by abrasion. Most of the time, dull surfaces appear. However, some abrasive particles might act as polishing material and surfaces might become extremely shiny, all depending on the size, their hardness and in what stage.

This is an accelerating process because wear particles will further reduce the lubrication ability of the lubricant and this destroys the micro geometry of the bearings.

The cage is usually a critical part of the bearing. Rings and rolling elements are hardened to around 60 Rockwell. A sheet metal cage is usually made from unhardened soft steel. If lubrication fails, the cage might be the first component to collapse.

#### *Limits of acceptability<sup>1)</sup>*

Wear that results in a mirror finish on the bearing components might be acceptable. However, further clean conditions are needed. When wear causes ridges that can be felt with a fingernail or other blunt probes in the running surfaces of the bearing, the bearing should be scrapped.

#### *Possible action*

Implement bearings/units with polymer cages in case not already used before.

Check seals for effectiveness in stopping possible ingress of particles. Check the grease type. Analyze grease for foreign particles and their possible origin.



*Pocket wear in a steel cage*



*Smearing on the large diameter thrust face of a tapered roller*

### Adhesive wear (smearing)

Adhesive wear, just like most other lubrication-related damage, occurs between two mating surfaces. It is often a material transfer from one surface to another with friction heat, sometimes with a tempering or rehardening effect on the surface. This produces localized stress concentrations with potential spalling of the contact areas.

In railway axle bearings, this is quite rare and usually due to poor lubrication. The roller thrust face (large end) in tapered roller bearings and the corresponding thrust face on the inner ring become smeared with a characteristic torn finish as shown above.

#### *Limits of acceptability<sup>1)</sup>*

Any bearing with smearing detectable by drawing a fingernail across the damage should be scrapped.

#### *Possible action*

Check lubrication conditions:

- appropriate grease
- sufficient grease
- replenishment/overhaul intervals
- adequate sealing

<sup>1)</sup> See *Damage and limits of acceptability* on **page 126**. For additional information, refer to the chapter *Services*, section *Remanufacturing* (→ **page 192**) where different standards are described.

## Corrosion

### Moisture corrosion

Rust will form if water or corrosive agents reach the inside of the bearing in such quantities that the lubricant cannot provide adequate protection for the steel surfaces. This process will soon lead to deep-seated rust. This produces greyish black streaks across the raceways, mostly corresponding to the rolling element distance.

The risk of corrosion is highest in non-rotating bearings, such as during standstill.

Concentration of the water will be highest just aside the rolling contact. The reason is that the free water in the oil, which is heavier than the oil, will sink until it comes to a suitable gap between the roller and the raceway (capillarity).

#### *Limits of acceptability<sup>1)</sup>*

Bearing components with corrosion damage that can be felt with a finger nail should be scrapped. A stain on the surface of the bearing components might be acceptable if it can be removed by polishing with fine abrasive paper.

#### *Possible action*

Check the seal conditions and make sure to use appropriate grease.

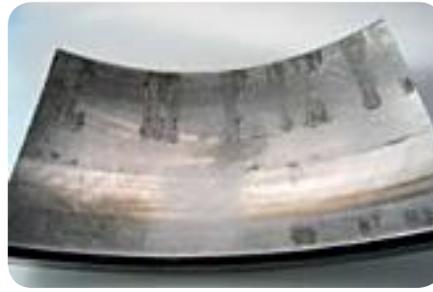
### Frictional corrosion

Frictional corrosion is a chemical reaction activated by relative micro movements between contacting surfaces under certain conditions inside a bearing. Railway axle bearings usually suffer from either fretting corrosion or wear caused by vibration which is also known as false brinelling.

### Fretting corrosion

Fretting corrosion occurs when there is a relative movement between a bearing ring and shaft or housing, because the fit is too loose, or inaccuracies are formed. The relative movement may cause small particles of material to become detached from the surface. These particles oxidize quickly when exposed to the oxygen in the atmosphere (or air trapped between the surfaces).

<sup>1)</sup> See *Damage and limits of acceptability* on page 126. For additional information, refer to the chapter *Services*, section *Remanufacturing* (→ page 192) where different standards are described.



**Rust marks on rolling element distance**  
several sets due to stop and go



**Fretting corrosion marks on the outer ring. The outer ring has a clearance fit in the housing.**  
Note that the contact marks are not even or in line, suggesting an uneven load acting on the axlebox housing.



**Fretting corrosion on a rear seal and rear inner ring. The grease is discoloured brown due to the fretting debris.**  
The SKF polymer washer eliminates this problem and extends the service life of the grease and therefore the bearing.

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. Corroded 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. The raceway path pattern could be heavily marked at corresponding positions.

This condition normally occurs on the external surfaces of the bearing outer ring with a clearance fit in its housing. It can also occur on the side faces of the inner rings where axle bending causes the parts to move microscopically in contact with each other.

#### *Limits of acceptability<sup>1)</sup>*

Fretting corrosion might be acceptable on the outside diameter of the outer ring if the bearing steel has not been worn away to a depth of more than 0,100 mm. Bearing inner rings might be reused if the fretting marks on the locating side faces are not deeper than 0,100 mm. Deep fretting marks may need to be removed by grinding if they are deeper than 0,100 mm, depending on the application.

*Possible action*

Use special anti-fretting paste on the surfaces.

Implement bearing units with a polyamide spacer between the backing ring and the inner ring side face in case not already used before (→ **page 80**).

***Vibration corrosion - false brinelling***

False brinelling occurs in rolling element-raceway contact areas due to micro-movements and/or resilience of the elastic contact under cyclic vibrations.

Depending on the intensity of the vibrations, the lubrication condition and load, a combination of corrosion and wear occurs, forming shallow depressions in the raceway.

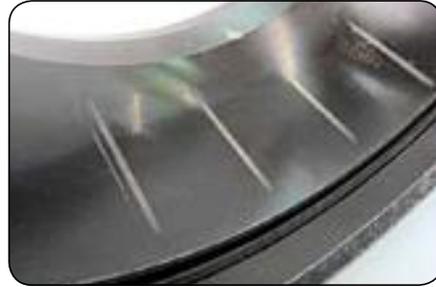
In the case of a stationary bearing, the depressions appear at rolling element pitch and can often be discoloured (reddish) or shiny (lines for roller bearings).

*Limits of acceptability<sup>1)</sup>*

If the damage to the surfaces can be felt with a fingernail, then the bearing should be scrapped. Light vibration markings on the bearing surface might be acceptable if they can be polished away with abrasive paper and/or cannot be felt by a fingernail.

*Possible action*

Avoid using vibratory equipment close to rolling stock at standstill.



***False brinelling damage in a TBU outer ring***

*Damage occurs at roller spacing and can be felt with a fingernail.*

<sup>1)</sup> See *Damage and limits of acceptability* on **page 126**. For additional information, refer to the chapter *Services*, section *Remanufacturing* (→ **page 192**) where different standards are described.

## Electrical erosion

### Excessive voltage

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 (high current density over a small contact surface).

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. Craters are formed where the material has been melted.

Appearance: Craters in raceways and rollers. Sometimes zigzag burns in ball bearing raceways. Localized burns in raceways and on rolling elements.

#### *Limits of acceptability<sup>1)</sup>*

Any bearing with craters should be scrapped.

#### *Possible action*

Make sure earth return devices (brushes) work properly (→ page 40).

When welding, make sure the earth connection is properly done.

### Current leakage

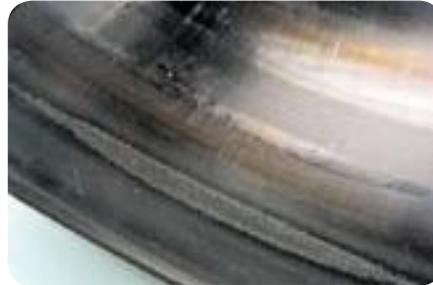
Where current flows continually through the bearing in service, even at low intensity, the raceway surfaces become heat affected and eroded as many thousands of mini-craters are formed, mostly on the surface. They are closely positioned to one another and small in diameter compared to the damage from excessive voltage. Flutes (washboarding) will develop from craters over time, where they are found on the raceways of rings and rollers.

The extent of damage depends on a number of factors: current intensity, duration, bearing load, speed and lubricant.

Also, check the grease. In addition to bearing damage, the grease close to the damage will be carbonized, eventually



**Heavy cratering on a spherical roller due to excessive voltage**



**TBU outer ring with a large area full of craters**  
The bearing should be scrapped.



**Washboarding in a TBU outer ring**  
The bearing should be scrapped.

leading to poor lubrication conditions and consequently to surface distress and spalling.

#### *Limits of acceptability<sup>1)</sup>*

Any bearing with electrical erosion (craters or washboarding) should be scrapped.

#### *Possible action*

Make sure earthing devices (brushes) work properly (→ page 40).

<sup>1)</sup> See *Damage and limits of acceptability* on page 126. For additional information, refer to the chapter *Services*, section *Remanufacturing* (→ page 192) where different standards are described.

## Plastic deformation

### Overload

Overload is caused by static or shock loads, leading to plastic deformation.

Typical root causes are incorrect mounting (force applied through the rolling elements), or blows to the cage, rings, rolling elements or seals.

#### *Limits of acceptability<sup>1)</sup>*

Any bearing with noticeable plastic deformation should be scrapped.

#### *Possible action*

Use the right tools when mounting bearings.

### Indentation from debris

Foreign particles (contaminants) that have gained entry into the bearing cavity cause indentations when rolled into the raceways by the rolling elements. This is also the case when a lubricant contains contaminant particles. The particles producing the indentations do not need to be hard. However, harder particles are more harmful.

Raised material, due to plastic deformation by heavy indentations, cause fatigue. This is caused by the load concentration on the raised rim around the indentation. When the fatigue reaches a certain level, it leads to premature spalling.

#### *Limits of acceptability<sup>1)</sup>*

Over rolled indentation damage is not acceptable if widespread throughout the bearing as shown in the photo. It might be acceptable if only slightly damaged and not present across the entire raceway.

#### *Possible action*

Check seal conditions and make sure to use appropriate and clean grease during overhaul.



**Impact during mounting or standstill**  
Plastic deformation at roller distance. Spalling is starting.



**TBU outer ring with heavy indentation damage**  
Spalling has started on one side of the raceway (top).

### Indentation by handling

Handling is sometimes critical, be it during transport, stocking, mounting or overhaul.

Inappropriate handling is characterized by localized overloading, which creates 'nicks'.

#### *Limits of acceptability<sup>1)</sup>*

Bearings with indentations from handling might be acceptable if the damage only occurs in isolated areas and not deeper than 0,05 mm into the surface of any component.

#### *Possible action*

Always treat bearings with care. Bearings can endure heavy loads, but are very sensitive to shock loads from handling.

<sup>1)</sup> See *Damage and limits of acceptability* on **page 126**. For additional information, refer to the chapter *Services*, section *Remanufacturing* (→ **page 192**) where different standards are described.

## Fractures and cracking

### Forced fracture

Forced fracture is caused by stress concentration in excess of the material tensile strength by local overloading or by over-stressing.

The most common cause is rough treatment (impact) when the bearings are being mounted or dismounted.

Use of incorrect tooling or assembling onto axle journals that have a poor shape and incorrect size can cause ring fracture.

#### *Limits of acceptability<sup>1)</sup>*

Any bearing that exhibits a fracture should be scrapped.

#### *Possible action*

Prior to mounting, make sure the journals are the correct size.

Use the correct tools. Never use a hammer on any component.

### Fatigue fracture

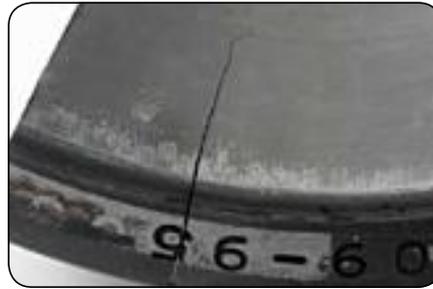
Fatigue fracture occurs when the fatigue strength is exceeded due to applied stress cycles. A crack is initiated, which will then propagate. Finally, the whole ring or cage cracks.

#### *Limits of acceptability<sup>1)</sup>*

Any bearing with fractures should be scrapped.

#### *Possible action*

Make sure the bearing seats are correct.



**Cracked inner ring**  
The bearing was fitted on an oversized journal.



**Due to heavy spalls and continuous loading, the material became fatigued and fractured all the way through.**

### Thermal cracking

Thermal cracking can occur in a bearing inner or outer ring where sliding causes high frictional heating. Cracks usually occur perpendicular to the direction of movement of the contacting surfaces. It can happen when a bearing is not correctly seated and the adjacent components, such as backing rings and end caps, are free to turn because they are not locked in position.

#### *Limits of acceptability<sup>1)</sup>*

Any bearing with a thermal crack should be scrapped.

#### *Possible action*

When mounting a TBU, make sure all components are locked correctly.

<sup>1)</sup> See *Damage and limits of acceptability* on **page 126**. For additional information, refer to the chapter *Services*, section *Remanufacturing* (→ **page 192**) where different standards are described.

## Other damage

### Discolouration

The components within a bearing or bearing unit can become discoloured. This is a sign of heat.

Be careful when analyzing the colour. Colour, to some extent, is temperature dependent, but also depends on the operating conditions (presence of air).

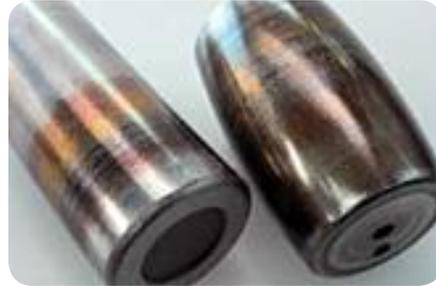
Generally, discolouration can be caused by residue from the lubricant, the additives or thickener. It could be, however, also caused by the passage of current.

Consequently, inspection by high magnification might be necessary to determine the cause of the discolouration.

#### *Limits of acceptability<sup>1)</sup>*

Lubrication stains might be acceptable if no other damage is present.

Blue discolouration caused by heat is not acceptable on any bearing component.



### **Discolouration**

*The tapered roller (left) had lubricant contamination.*

*The spherical roller (right) had passage from electric current (craters in the surface).*

<sup>1)</sup> See *Damage and limits of acceptability* on **page 126**. For additional information, refer to the chapter *Services*, section *Remanufacturing* (→ **page 192**) where different standards are described.

# Damage and failure matrix

When looking at a damaged bearing, often the damage can be classified in one of the ISO damage modes.

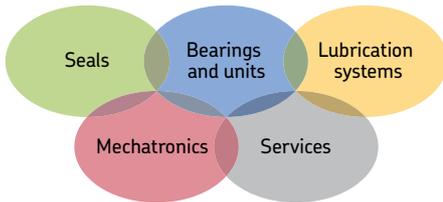
The difficulty might be to trace back this damage to its root cause.

The damage and failure matrix shown below can help.

It shows the links between the damage (sub)modes and operating conditions and whether or not one of the operating conditions might be a root cause.

Failure matrix

Possible causes			Operating conditions					Environmental factor				Lubrication				Mounting				Other									
			Overload	Overspeed	Excessive freq. of load/speed changes	Vibrations	Shaft/housing deflection	Temperature too high/low	Dust and dirt ingress	Water ingress	Electrical leakage	Wrong viscosity	(Consistency) additives selection	Lack of lubricant	Excess of lubricant	Impurities	Incorrect handling (shock loads)	Mounting procedures	Fit too tight	Fit too loose	Tilting/misalignment	Incorrect setting	Incorrect locating (clamping)	Storage	Transportation (vibration/shock)	Bearing selection	Equipment design	Manufacturing concerns	Material concerns
Failure modes with characteristics																													
Fatigue	Flaking, spalling, peeling		•				•	•				•	•	•		•	•	•		•	•		•	•	•	•	•		
	Burnishing, microcracks			•	•	•		•	•	•	•	•	•	•	•		•				•			•	•	•	•	•	
Wear	Abrasive	Excessive wear		•	•	•	•	•	•	•	•	•	•	•			•	•	•	•	•			•				•	
		Scratches, scores		•	•				•				•		•		•	•						•					•
	Adhesive	Seizing marks, smearing	•		•		•	•				•	•	•	•		•	•	•	•	•				•	•	•	•	•
		Hot runners	•	•	•		•	•				•	•	•	•		•	•	•	•	•	•			•	•	•	•	•
Corrosion	Moisture corrosion								•			•		•		•							•	•		•			
	Fretting corrosion		•		•	•	•											•	•	•	•				•	•	•		
	False brinelling				•	•							•					•						•	•	•			
Electrical erosion	Craters, fluting										•															•			
Plastic deformation	Depressions		•				•	•					•		•	•	•		•	•	•			•	•	•	•	•	•
	Debris indentation								•					•		•	•									•	•		•
	Nicks, gouges															•	•										•		
Fracture & cracking	Forced fracture		•	•			•								•	•	•		•	•	•				•	•	•	•	•
	Fatigue fracture		•	•	•	•	•											•	•	•	•					•	•	•	•
	Thermal cracking		•	•	•			•				•	•	•		•	•				•						•		•



### The Power of Knowledge Engineering

Drawing on five areas of competence and application-specific expertise amassed over more than 100 years, SKF brings innovative solutions to OEMs and production facilities in every major industry worldwide. These five competence areas include bearings and units, seals, lubrication systems, mechatronics (combining mechanics and electronics into intelligent systems), and a wide range of services, from 3-D computer modelling to advanced condition monitoring and reliability and asset management systems. A global presence provides SKF customers uniform quality standards and worldwide product availability.

## References

- [26] Kerry, M., Peterson, L., Cagnasso, R.: *An Atlas of railway axle bearing defects including guidelines on how to examine bearings and overhaul practice*. SKF (2008).

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