# Bearing damage classification

## Elearning course transcript

### Welcome

Welcome to this course, which looks at bearing damage classification, according to the international standard ISO 15243

### Special notes for iPad users

For iPad users the course plays in the “Articulate mobile player app”, available free from the App store.
The app’s library offers a download option for offline learning, but please note:

- If you wish to be able to print your course completion certificate, then you need to be on-line when you take the test

### Learning objectives

Understanding the root causes of bearing damage not only helps to ensure reliable bearing operation, but can also avoid costly downtime. While most bearings perform extremely well in their particular application, a bearing failure can have expensive consequences. Bearing failure modes are defined according to an ISO classification.
Classifying the damage in the right way helps to understand what has happened, to find the root cause and identify solutions to prevent recurrence of the problem. Armed with this information, it is possible to make sure that a bearing can perform flawlessly in its particular role. The ISO classification helps to improve communication and avoid misunderstandings.

### Let’s get started

So let’s get started. Please begin by selecting one of the lessons tabs above.

## Damage vs Failure

### Getting started

We’ll begin by talking about what we mean by the term “bearing damage”.

### Cause and effect

Note that the terms "failure" and "damage" are not synonymous. An item (e.g. a bearing) may suffer damage and yet continue to function, while failure means that the bearing can no longer assure it's designed function. Damage is typically an effect resulting from a cause, or perhaps from multiple causes.
The root cause is a cause that is at the root of an effect. Hence elimination of the root cause will lead to the elimination of the defect or problem.

### Predictive maintenance

The wide adoption of condition monitoring has enabled plant operators to detect bearing deterioration at an early stage, and to replace bearings before failure, thereby avoiding costly unscheduled downtime.
But bearing damage analysis still has a part to play here. If the root cause of the bearing’s problem is not identified then it’s likely that, sooner or later, the monitoring system will be flagging up a recurrence of the same problem.

## Proactive maintenance

Root cause failure analysis should be a embedded as a routine part of maintenance processes, and is an essential component of any Proactive Reliability Maintenance (PRM) program.

Root Cause Failure Analysis (RCFA) is a structured investigation that aims to identify the true cause of a problem, the cause-effect relationships, and the actions necessary to prevent its repetition.

Bearing damage analysis is therefore an important component of root cause failure analysis .

A full discussion of root cause analysis is outside the scope of this course, but such studies should be performed on all critical problems.

To prevent the problem from recurring, the root cause(s) should be eliminated. It is essential to know cause-effect relationships to prevent problems from recurring. The output of an RCFA study is in the form of recommended actions.

Improvement activities resulting from RCFA studies may include not only machine design improvements, but also targeted training for operations or maintenance staff, and /or provision of specialist equipment for monitoring / maintenance of relevant machinery.

## Factors influencing bearing service life:

Generally speaking, bearings in an application have a calculated rating life. The bearing's ability to achieve or exceed that rating life depends on a number of factors. Use the tabs on this page to explore further.

- Only bearings manufactured to the highest quality standards can provide a robust and long service life.
- Stocking bearings correctly is an important aspect of proper storage. Avoid overstocking and using the "first in, first out" approach will help make sure that "fresh" bearings are on the shelf. This is particularly important for bearings containing seals or shields, as they are lubricated at the factory and the grease has a limited shelf life. Also keep in mind that with rapid changes in manufacturing technology, bearings made today have a much longer built-in life than bearings made 10 or 15 years ago.
- It's obviously important that the bearings used are appropriate for the application and its operational conditions.
- Bearings will only function properly if mounted correctly. Improper mounting techniques can easily damage bearings, causing premature failure.
- Different operating conditions require different lubricants and relubrication intervals. Therefore, it is important to not only apply the right lubricant, but to also apply the right amount, at the right time, using the right method.
- The purpose of a seal is to keep lubricants in and contaminants out of the bearing. Premature bearing failure could result if the application is not sealed adequately. If any one of these factors is weak, bearing service life can be compromised. If they are all strong, long bearing service life can be expected.

## Bearing failures

### SKF experience

The percentage of bearings that actually fail in service is very small. In fact most bearings (some 90%) outlive the the equipment to which they are fitted.

Of the bearings that do fail, SKF experience suggests that generally speaking:

- 1/3 fail due to fatigue
- 1/3 fail due to lubrication problems
- 1/6 fail due to contamination
- 1/6 fail for other reasons (such as improper handling and mounting)

Note that these figures do vary, depending on the industrial segment. In the Pulp and Paper industry, for example, a major cause of bearing damage is contamination and inadequate lubrication, not fatigue.

However, a failed or damaged bearing is rarely the *root* cause of a machine failure.

When a damaged or failed bearing is considered to be a factor in a machinery problem, then it's important to find the root cause of the damage. Based on those findings corrective actions can be taken to prevent a recurrence of the problem.

## The standard

### ISO 15243: 2004

In this lesson we'll take a look at the standard. We'll consider the situations to which it is applicable.
Then we'll look at examples of each failure mode.

### Bearing failure modes

Much work has been done by the members of ISO Technical Committee TC4 to define the different failure modes and to classify them as shown here. This has resulted in ISO 15243, published in 2004. When looking at bearing failures, in total six main failure modes can be observed, which can be further classified into a number of sub modes.

### Three key assumptions

It's important to understand the situations that the standard is applicable to.
The standard applies to:

1. Damage that occurs during service (as soon as a bearing has left the factory)
2. Characteristic forms of change in appearance that can be attributed to particular causes
3. Visible features (including enlargement tools, such as microscopes).

(Click the corresponding headers on this page, for more information.)

Damage that occurs prior to service is not classified in the ISO standard. (Service is considered to be "as soon as the bearing leaves the factory.")
"Consideration is restricted to characteristic forms of change in appearance and failure, which have a well-defined appearance and which can be attributed to particular causes
with a high degree of certainty".
"Characteristic" means that the described damage is typical rather than atypical. Extreme, unlikely cases (e.g. hollow rolling elements) are therefore not classified.
"Well defined appearance": it should be remembered that in many real world cases, one type of damage is overlaid on top of another, as the machine failure progresses. Different damage types can be difficult to separate and identify.
The standard offers classification by VISIBLE FEATURES. Other testing methods for damages, such as magnetic particle inspection, or metallurgical analysis which typically is a destructive analysis method, are not considered.
The features of particular interest for explaining changes and failures are described. The various forms are illustrated with photographs and diagrams, and the most frequent 14 causes are indicated.

### Standardisation of descriptive terms

The ISO standard also lists synonyms for many standard terms. For example, the ISO Classification "Adhesive Wear" is also known as "smearing" or "galling". One of the advantages of using the ISO classification is the standardization of descriptive terms. This provides data gatherers everywhere the ability to understand and compare bearing damages using a "common language."
Eventually, as more damages are described, organizations can use the collected data to make better conclusions about the types and frequencies of damage types.

### Explore failure modes

Now spend some time exploring the different failure modes.
Click on the "information" icons to view real examples of each failure mode.

### Subsurface fatigue

When a bearing fails due to subsurface fatigue and if it's monitored carefully one will typically see only a small spalled area. If the bearing continues to run, then the area will become bigger and more areas may develop as well.

Subsurface initiated fatigue is deterioration of the material. It is caused by cyclic stresses just underneath the raceway surface and ultimately results in decay of the material. Cracks are initiated and propagate underneath the surface, and when they come to the surface, spalling occurs.

### Surface initiated fatigue

Surface initiated fatigue results from inadequate lubrication conditions. The role of the lubricant is to build up an oil film that separates the moving parts. Under poor lubrication conditions, for example due to contamination or wrong viscosity, metal-to-metal contact occurs. The surface asperities (peaks) shear over each other which results in shear stresses at the surface. Due to material fatigue, small cracks and subsequently microspalling will occur. Initially, there might be a shiny surface, because the surface roughness is reduced, but the process continues, and the surface becomes dull and breaks up more and more.

### Abrasive wear

Abrasive wear is due to abrasive particles in the lubricant. These can be contaminant particles coming from the outside or inside – for example, wear particles from gears. The abrasive particles wear out the surfaces of the raceways (fig. 6) and rolling elements. This normally results in dull surfaces. However, if the abrasive particles are very fine and hard, such as cement dust, a polishing effect might occur and mirror-like surfaces appear. Often, inadequate (or absence of) sealing arrangements result in contaminants entering the bearing cavity. A lubricant analysis might reveal the origin of the contamination, which can help in finding the solution for the problem.

### Adhesive wear

Adhesive wear occurs mainly in contact surfaces subjected to light loads, poor lubrication conditions and with important speed differences, resulting in sliding of the rolling elements.
One example is the passage of a rolling element from the unloaded zone into the loaded zone. The rolling element can lose speed in the unloaded zone and accelerate when returning into the loaded zone. This can result in breakthrough of the lubrication film, sliding, heat development and possibly material transfer from the rolling element to the raceway or vice versa. In an early stage the appearance is shiny surfaces, but quickly it turns into a dull surface with (more or less) smeared material.
Moisture corrosion
Moisture corrosion can cause serious bearing damage. In contrast to other damage processes, corrosion can happen fast and penetrate deep into the material. Corrosion occurs in the presence of water, corrosive liquids or moisture. Also high humidity in the air and touching raceways with fingers can lead to this type of corrosion. It’s therefore important to have good protection. Corrosion often happens during standstills and is then visible by corrosion marks at rolling element distance. Deep-seated rust leads to early bearing damage.

### Fretting corrosion

Fretting corrosion can be very harmful. The root cause for its occurrence is micro-movements between two loaded surfaces typically in fits. Mostly, this frictional corrosion occurs between the bearing outside diameter and housing and / or between the bearing bore and shaft. The micro-movements are mainly caused by the cyclic loads when rolling elements are passing by. Inadequate fits, shaft bending and/or imperfections in the contact surfaces can be the cause and/or accelerate the occurrence. Air can come into the unprotected surfaces and accelerate the progression of corrosion. The formed iron oxide has a larger volume than pure steel. This can develop material growth and high stresses, even to the bearing raceway and can lead to premature subsurface fatigue. Fretting corrosion can easily lead to ring cracking.

### False brinelling

False brinelling occurs in rolling element / raceway contact areas due to micro movements and resilience of the elastic contact under cyclic vibrations. Since it occurs when the loaded bearing makes rather small oscillatory movements or is stationary, the damage appears at rolling element pitch. Depending on the intensity of the vibrations, the lubrication condition and load, a combination of corrosion and wear occurs, forming shallow depressions in the raceways. Normally, the vibration results in local removal of the (protective) lubricant, metal-to-metal contact, oxidation and abrasive wear. The appearance is usually dull, often discoloured reddish due to oxidation of the wear particles. Occasionally the depressions can be shiny, most likely due to lubricant still present and consequently no abrasive wear occurring. False brinelling damage results in spherical cavities for ball bearings, lines for roller bearings.

## Excessive voltage

Damage from excessive voltage can happen when an electrical current passes through a bearing, i.e., proceeds from one ring to the other via the rolling elements. 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 (varying approximately from 0.1 mm to 0.5 mm) are formed where the material has melted.

## Current leakage

Damage from current leakage results from stray electric currents that pass through a bearing, often caused by frequency variations. The main visual damage is flutes, also called washboard pattern. These flutes have the shape of the contact ellipse in ball bearings and contact lines in roller bearings. Rollers also show flutes, while balls are dark grey discoloured. Compared to the excessive voltage damage, here the current passes via a larger area. In consequence, the current intensity is smaller, and the damaging temperature is lower. Therefore, the main visual damage is a tempering effect, i.e., a softening of the steel. However, looking at the damage with high magnification often shows that there are craters present, as well, on micro scale.

## Plastic deformation from overload

Overload results from static or shock loads and leads to plastic deformation. This can be recognized by depressions at rolling element distance. Often, wrong mounting procedures are at the base of the problem, i.e., applying the mounting force to the wrong ring and thereby producing a shock load over the rolling elements.

## Indentation from debris

Indentation from debris results from foreign particles (contaminants) that have gained entry into the bearing and which are rolled into the raceways by the rolling element. The size and shape of the dents depend on the nature of the particles. The raceway geometry at the dent is destroyed and lubrication is impaired. Stresses arise at the surface and fatigue leads to premature spalling of the surface.

## Indentation by handling

Indentation from handling can occur when bearing surfaces are gouged by hard, sharp objects. Also, bearings must always be handled with care. Although made of highest quality steel, localized overloads, e.g., from dropping a bearing, might dent the surfaces and make the bearing unserviceable.

## Forced fracture

Forced fracture is caused by stress concentration in excess of the material tensile strength by local overloading or by over-stressing. There are two common causes:

1. One is rough treatment (impact) when a bearing is being mounted or dismounted. For example hammer blows applied to a hardened chisel directly against the ring may cause the formation of fine cracks with the result that pieces of the ring break off when the bearing is put into service.
2. Forced fracture can also result from excessive drive-up on a tapered seat or sleeve. The resulting tensile stresses (hoop stresses) arising in the rings produce cracks when the bearing is put into operation.

## Fatigue fracture

Fatigue fracture starts when the fatigue strength is exceeded under bending. A crack is initiated that will then propagate. Finally, the whole ring or cage cracks. Fatigue fracture can occur when a tight fit has been used, leading to high hoop stresses. Then, the combined Hertzian and hoop stresses can lead to premature fatigue and through cracking of the ring.

## Thermal cracking

Thermal cracking can occur when two surfaces slide heavily against each other. The frictional heat that is developed causes cracks, generally at right angles to the sliding direction.

# Conclusion

We'll round the course off by considering some maintenance tips for improving bearing life. We'll also consider where you might go from here, to learn more about bearing damage analysis.

## Maintenance tips

By applying some basic maintenance rules, bearing life can often be extended.

- A bearing is made to take a certain load, to rotate at a certain speed, etc.
- Do not put too heavy (or too low) a load on a bearing or rotate it too quickly. There is a large choice of bearings. It is important to select the one that fits the application. Make sure the right tolerances and fits are applied.
- Where applicable, make sure alignment is within appropriate limits.
- A clean environment during the mounting process provides a good start for long bearing service life.
- Always use the appropriate tools during mounting or dismounting. Inappropriate tools might lead to early bearing damage.
- Make sure that the right sealing solution has been chosen and that it works effectively.
- Efficient lubrication is of utmost importance. Too little, too much or inadequate lubrication can result in early bearing damage. Make sure the right lubricant is applied, at the right time and in the right quantity.

## Instructor-led hands-on training from SKF

SKF's course "WE204 Root cause bearing damage analysis" is based on the ISO 15243 standard , using audio-visuals, lectures, and hands-on training. it includes discussion opportunities with SKF instructors, who are practicing reliability professionals with experience and know how. They know the theory of what they teach and how to apply it in your working environment.

Discussions include initial damage and failure causes, failure streams and visible conditions at the time of bearing removal.
During the course you will analyze actual bearings from a variety of distress, damage and failure conditions, using our methodology to determine the root cause of the failure mechanism.
For more details about this course please contact your local SKF representative.

# End-of-course test

At the end of the course there is a test.
You must be online when you take the test if you want to be able to print your course completion certificate. (If you're viewing the course offline on an iPad then you can still take the test to check what you've learned, but you won't be able to print the course completion certificate)