Smarter rail

Why bearings fail & How to detect bearing failures in the field

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About SKF Railway

Today, SKF solutions and services for the railway industry deliver global solutions for rail around the world.

From contributing design expertise and providing advanced axlebox bearings, to installing lubrication systems, validating reliability and safety requirements, mounting bearings and more, SKF helps increase railway vehicle safety, reliability, efficiency and service intervals

SKF offers customers unique insights into railway vehicle bogie system operations by drawing on our unmatched combination of railway bearing design and manufacturing expertise and cutting-edge condition monitoring and application knowledge.
By collecting and analyzing data throughout the operational life of the train, we're helping to enhance the next generation of railway vehicle designs in ways not previously possible.

Why bearings fail

6 primary factors

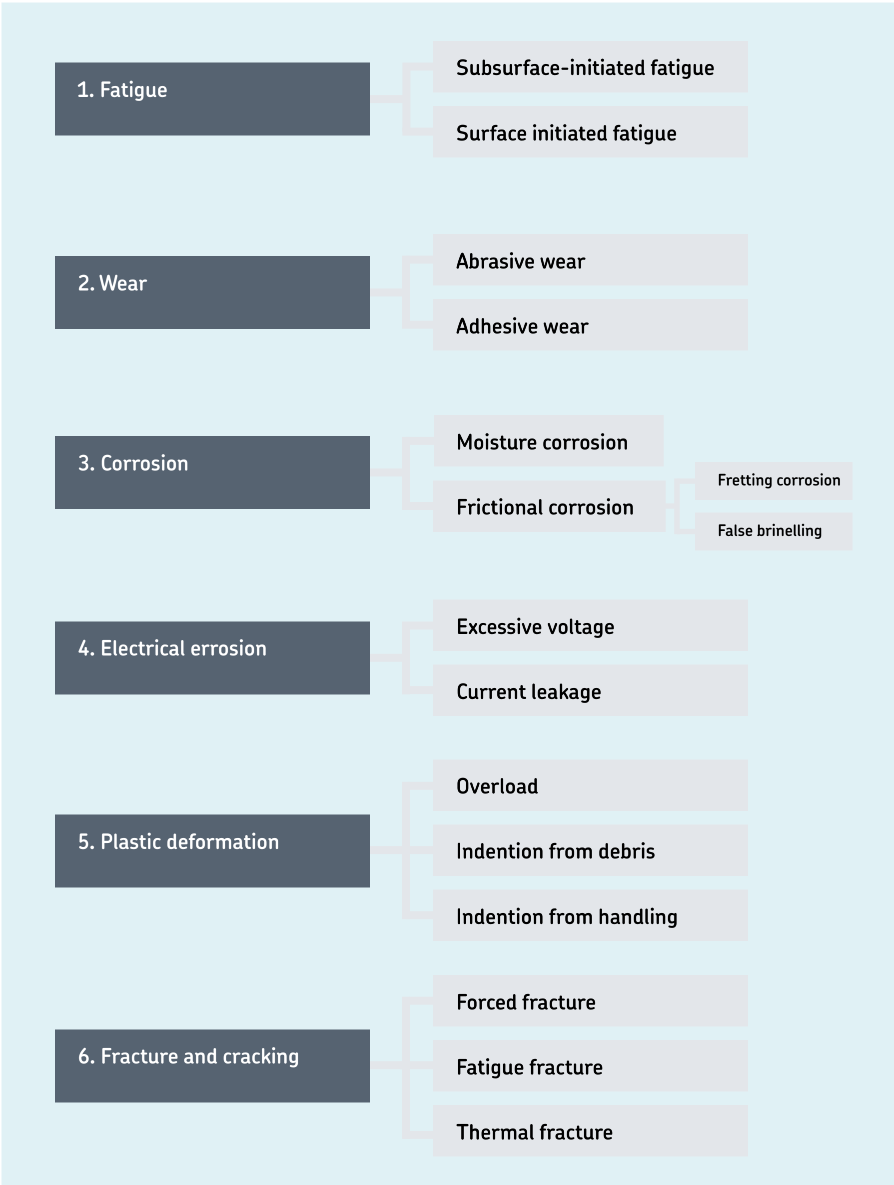
A rolling bearing is a product of precision manufacturing with clean, machined surfaces to give accurate flawless movements. The bearings components have been made to precise dimensions, often to a fraction of a millimeter and these dimensions have been checked numerous times during the manufacturing process.

However, after a period of time, the appearance and performance of the bearing can change in service due to less-than-ideal operating conditions. These conditions can result in bearing damage, reduced service life and sometimes premature bearing failure.

To prevent bearing failure, it is important to understand the most common factors affecting poor performance and how to avoid them.

The six primary bearing failure modes

There is a great deal of interest in the factors affecting bearing failures where ISO 15243 groups rolling bearing failure modes into six categories. This standard recognizes six forms of primary damage or initial failure modes corresponding to damage after manufacture.



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

1. Fatigue

Fatigue is a change in the bearing material grain structure caused by the repeated cycles of stress in normal service. Evidence of fatigue is usually visible when the rolling surfaces fracture, usually known as flaking.

There are two types of fatigue – subsurface-initiated fatigue and surface-initiated fatigue.

Subsurface-initiated fatigue

This fatigue starts underneath the raceway surface. Micro cracks can develop when structural changes occur in the material. When these cracks reach the surface, material breaks loose and spalls occur. Under normal operating conditions, pure subsurface fatigue does not occur frequently. Usually, it happens only after a very long running time.

Surface-initiated fatigue

This fatigue is on the other hand much more common. It's generally 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. Areas that are rough or uneven can shear over each other and break off. The surface becomes plastically deformed and sometimes smoothened. Micro spalls occur and, in turn, grow to larger spalls.

How to avoid it?

Lubrication condition is key.

- Make sure that the appropriate grease is being used for the bearing.
- Be sure that a sufficient amount of lubricant is used.
- Follow the bearing manufacturer's replenishment/overhaul intervals.
- Be sure that adequate sealing is used.

2. Wear

Abrasive wear

Wear (abrasive wear) is the gradual removal of material from the rolling contact surfaces during service and is primarily caused by an issue affecting the lubrication of the bearing such as contamination of the lubricant with dirt. With continued use, the bearing surfaces wear and internal clearance is altered affecting the accurate smooth running of the bearing.

How to avoid it?

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

Adhesive wear (also known as smearing)

Adhesive wear, occurs between two rolling surfaces where material is transferred between two contacting surfaces inside the bearing. Heavy loads can contribute to this form of damage, especially in bearing designs with thrust faces such as taper roller bearings. The roller thrust face (larger diameter roller end) in tapered roller bearings and the corresponding thrust face on the inner ring become smeared with a characteristic torn finish.

How to avoid it?

In railway axle bearings, adhesive wear is quite rare. When it does occur, it is usually due to poor lubrication.

- Make sure that the appropriate grease is being used for the bearing.
- Make sure the sufficient amount of grease is used.
- Follow the manufacturer's replenishment/overhaul intervals.
- Be sure that adequate sealing is used.

3. Corrosion

Moisture corrosion

Water or corrosive agents inside of the bearing will result in the formation of surface corrosion known as rust. If the quantity of water or corrosive agents is large, the lubricant cannot provide adequate protection for the bearing surfaces which then soon leads to deep-seated rust.

How to avoid it?

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

Frictional corrosion

Frictional corrosion occurs in two forms: fretting and vibration corrosion.

Fretting corrosion

Fretting corrosion occurs when there is a microscopic relative movement between a bearing rings and shaft or housing because a clearance fit is present. The relative movement causes small particles from the surface finish to become rubbed of each surface. These particles oxidize when exposed to the oxygen in the atmosphere turning to a rust colour hence the term fretting corrosion. It usually appears between the outer diameter of the outer ring and the bearing housing in railway applications.

How to avoid it?

- 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.

Vibration corrosion (known as false brinelling)

Vibration corrosion is actually better known and easier to understand as wear caused by vibration. When subject to vibration whilst stationery, the clearance inside the bearing between components allows the components to vibrate against each other which in extreme cases can create significant erosion of the contacting surfaces. The term false brinelling comes from the appearance which looks similar to that made by the Brinel hardness test where a ball is pressed into a surface to measure its hardness.

How to avoid it?

- Avoid using vibratory equipment close to rolling stock at standstill.

4. Electrical erosion

Excessive voltage

When an electric current passes through a steel bearing, damage to the contacting surfaces will occur even at very low levels as the electricity travels to earth. On the contacting surfaces, a process is similar to electric arc welding occurs when the bearing surfaces are momentarily welded together. As the bearing continues to rotate, the weld is broken leaving characteristic pits in the bearing rolling surfaces. Permanent damage will have been made to the metal structure leading to subsurface flaking with continued running.

How to avoid it?

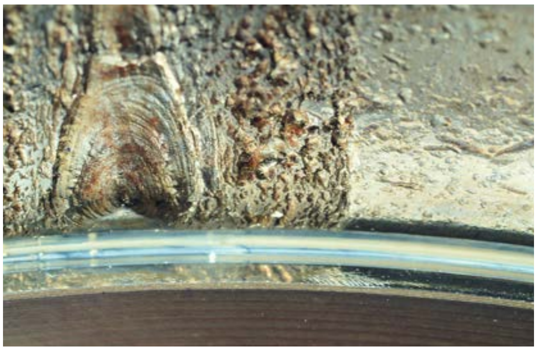
- Make sure earth return devices (brushes) work properly.
- When welding, make sure the earth connection is properly done.

Current leakage

When current flows continually through the bearing in service, even at low intensity, the raceway surfaces become eroded as many thousands of microscopic pits or craters are form on the rolling surfaces. In extreme cases, electric current erosion appears as flutes burnt into the rolling surfaces and is also known as washboard damage because of its appearance. Flaking of the surfaces will follow leading to catastrophic bearing failure.

How to avoid it?

- Make sure earth return devices (brushes) work properly.



5. Plastic deformation

Overload

Overload is caused by static or shock loads, leading to plastic deformation or indentations. Typical causes are incorrect mounting techniques (force applied through the rolling elements and rings) or a heavy impact at very low bearing rotational speed.

How to avoid it?

- Use the right tools when mounting bearings.

Indentation from debris

Particles of contamination can cause indentations in the rolling contacting surfaces if the bearing can roll over the debris. The particles producing the indentations do not need to be hard. Contaminants also absorb the oil in the lubricant which can lead to premature bearing failure.

How to avoid it?

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

Indentation by handling

Handling rolling bearings correctly during storage, transportation and assembly is critical to keep the components in good condition. Always use the correct tooling to handle bearing components and take care when transporting and storing bearings to avoid contamination and corrosion. Shock loads during mounting or overhaul from inappropriate handling techniques can cause damage to the rolling surfaces which may be felt and heard when the bearing rotates.

6. Fractures and cracking

Forced fracture

As well as shock loads, forced fracture is commonly caused by trying to install bearings into housings or onto shafts with a poor shape or incorrect dimensions. Use of incorrect tooling or assembling onto axle journals that have a poor shape and incorrect size can cause ring fracture.

How to avoid it?

- 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 cyclic bending for example if the bearing rings are not adequately supported and subject to bending forces in service. A crack is initiated which will then propagate until the crack grows through the ring.

How to avoid it?

- Make sure the bearing seats are correct.

Thermal cracking

Thermal cracking can occur in a bearing ring where friction from sliding causes heat. Cracks occur in the contacting surfaces and 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.

How to avoid it?

- When mounting a tapered roller bearing unit (TBU), make sure all components are locked correctly.

Other damages

Blue discolouration

The components within a bearing or bearing unit can become discoloured blue and this is usually a sign of heat damage. Heat discolouration usually occurs all over the bearing even in places where there is no contact between surfaces such as roller ends.

Brown discolouration

Generally, brown discolouration is caused by residue left on the running surfaces from ingredients in the lubricant and can be due to heat too. A thorough examination of a discoloured bearing by an expert is necessary to confirm the cause of discolouration to avoid scrapping serviceable bearings.

If you want to know more about bearing failures in general or if you would like to diagnose a specific bearing damage to find the root cause, SKF application engineers are available to support (cc.railways@skf.com). SKF knowledge is also captured in publication EN 14219 where descriptions and pictures of each form of failure mode is documented for a deeper understanding of this subject. A table also assists in finding out what factors influence bearing performance and failure so that SKF customers can achieve ever increasing performance from SKF products.

How to detect bearing failures in the field

SKF's railway customers tell us that an unplanned stop and delay can have a monetary impact in the range of tens of thousands of EUR. They also say that an unplanned stop typically takes three times longer to solve than a planned one, creating a significant impact on train availability.

Maintaining time schedules can also be critical to the bottom line. On-time service can help a rail line's reputation. Delays, however, can have the opposite effect. Income can be impacted as customers seek other providers, while operating expenses can increase due to penalties and costs for corrective actions.

Today bearing manufacturers decide how far or for how long a bearing can run before it should be removed for service. But, sometimes maintenance planning can be a challenge for operators, and bearings are not serviced exactly when recommended by the manufacturer. Adding to this, despite a full focus on reliability, in a large population of bearings there is statistically always a risk of failure-prone outliers.

To avoid unplanned stops, reliable performance is an absolute must. Systems that aid in monitoring bearing performance and preventing unplanned downtime are essential.

Why early detection matters

Technology has evolved over the last decade, and there are many systems available to support operators in detecting potential issues. The systems vary in sophistication, but generally, the more sophisticated the system, the faster the error is detected.

Why is the speed of detection important? Because if failure is not detected until it is obvious, the damage will have already had a direct effect on operation and will drive costs. For example, if smoke is detected while the part is in operation, the train may be able to run with reduced speed to the closest station. But, often, the train may need to be stopped and travelers evacuated. Repairing the problem might require additional lead times if spare parts are not available.

With more sophisticated condition monitoring systems, issues can be detected and addressed before they have caused problems in the field. Also, early detection raises the likelihood that the bearing can be repaired or refurbished, reducing scrap rates.

The most advanced of available technologies incorporates a detection system that uses smart algorithms to distinguish anomalies in vibration pattern. These

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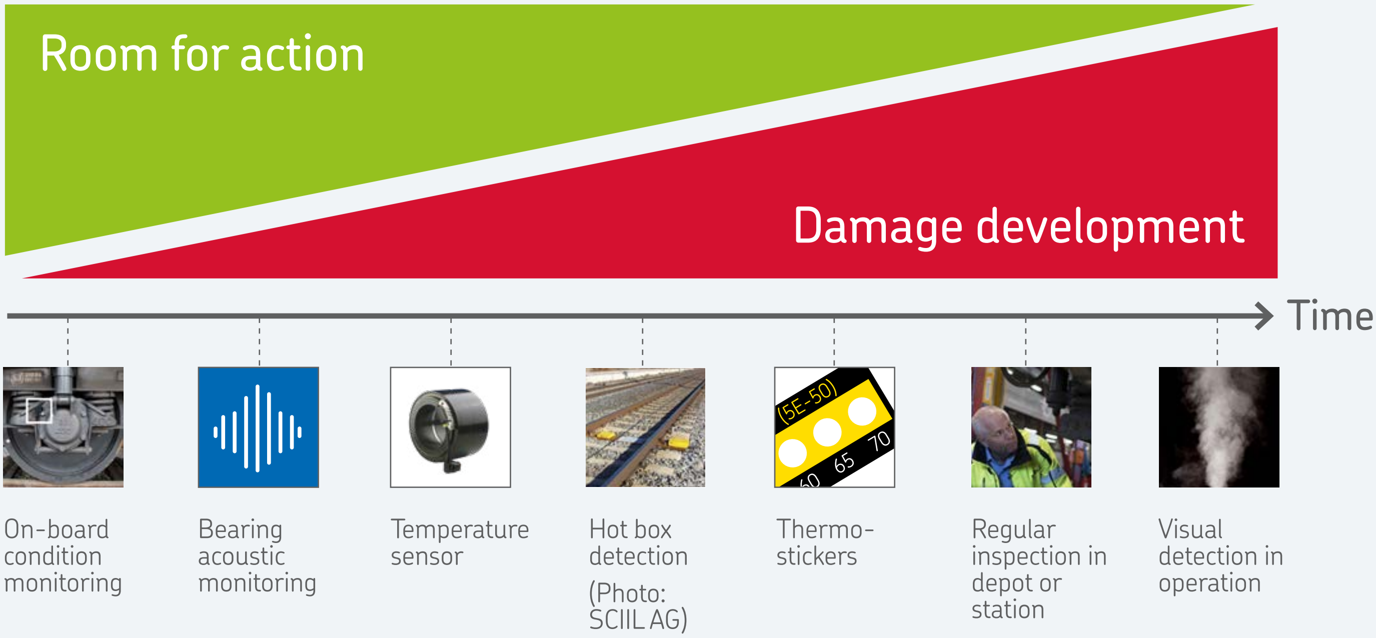
Failure detection systems



anomalies can indicate if damage is developing, what type of damage it is, and by when it needs to be fixed – adding a dimension of flexibility to maintenance planning. This is helpful, because while the maintenance intervals given by bearing manufacturers are strict, operator maintenance capacities are often limited. Maintenance capacity may not be available, for example, if the workshop is occupied by another, more urgent, issue. The most sophisticated monitoring systems can help the operator know if it is possible to run the vehicle for longer than the prescribed maintenance interval.

Available systems

The figure above depicts a range of available systems, ranging from the most basic visual detection during vehicle operation, to the most advanced onboard systems that detect anomalies before they develop into failures.

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