Smarter rail

SKF for railway maintenance

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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.

- **1. Fatigue**
  - **Subsurface-initiated fatigue**
  - **Surface initiated fatigue**
- **2. Wear**
  - **Abrasive wear**
  - **Adhesive wear**
- **3. Corrosion**
  - **Moisture corrosion**
  - **Frictional corrosion**
    - **Fretting corrosion**
    - **False brinelling**
- **4. Electrical errosion**
  - **Excessive voltage**
  - **Current leakage**
- **5. Plastic deformation**
  - **Overload**
  - **Indention from debris**
  - **Indention from handling**
- **6. Fracture and cracking**
  - **Forced fracture**
  - **Fatigue fracture**
  - **Thermal fracture**

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?

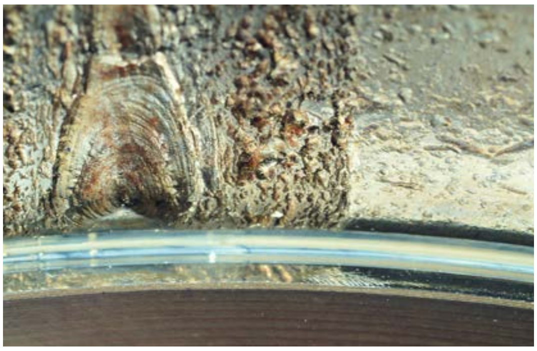
- Make sure earth return devices (brushes) work properly.
- When welding, make sure the earth connection is properly done.

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.

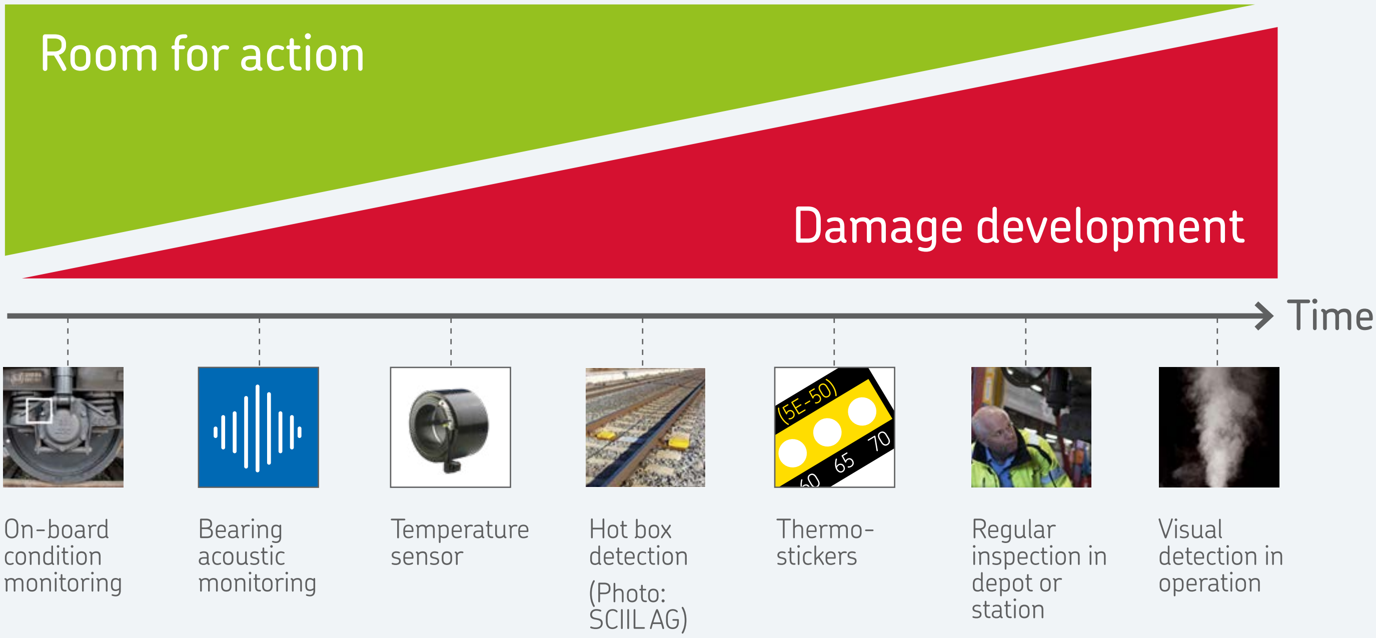
Why is the speed of detection important? Because if failure is not detected until it is obvious, the damage will have already had a direct effect on operation and will drive costs. For example, if smoke is detected while the part is in operation, the train may be able to run with reduced speed to the 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

AN UNPLANNED STOP TYPICALLY TAKES THREE TIMES LONGER TO SOLVE THAN A PLANNED ONE

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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The lubricant link

Railway bearing life? It may come down to grease!

Did you know that something as simple as grease condition can significantly affect maintenance intervals for railway cars? It's true – and the more you know about grease lubricants, the more you'll realize how complex, and how critical, correct grease selection can be.

Technology and innovation in railway components have resulted in wheels and bearings capable of delivering service life far greater than was previously possible. But, whilst bearing components have been optimized through new and better materials, innovative design engineering, bearing performance is affected primarily by the grease within the bearing.

The importance of grease

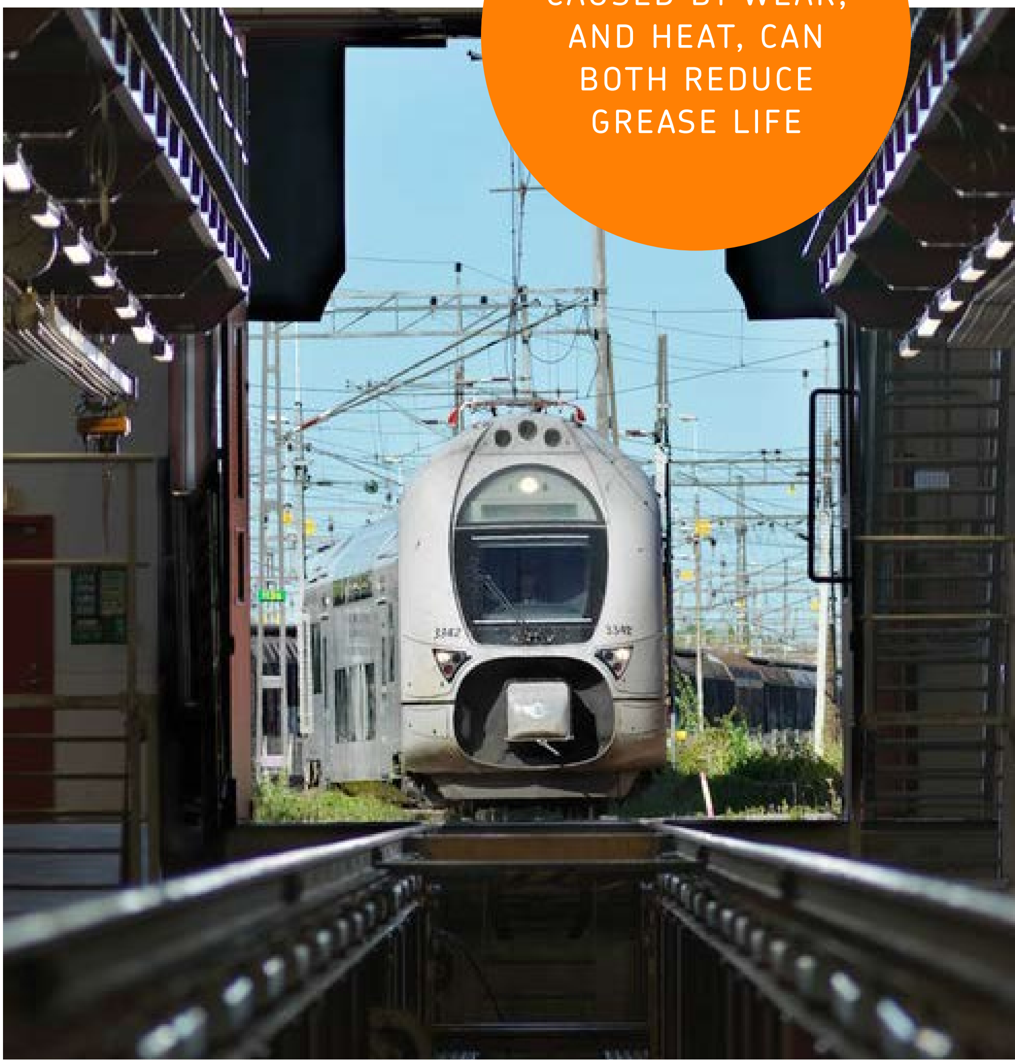
Under the weight of the railway vehicle, grease prevents metal-to-metal contact inside the bearing between the rolling elements, raceways and cage. It also protects the bearing surfaces against corrosion and helps to seal the bearing against contaminants. Railway specific grease formulations are designed to address operational and environmental challenges so that bearing performance can be optimized – and maintenance intervals can be extended. Railway bearing life? It may come down to grease!

What's affecting your grease?

Many factors can influence grease life and these include application and environmental factors such as operational temperatures, cage material and design, rotational speed, bearing size, external contamination, seal material and design, lubricant degradation and changes in chemical composition, vibration, load and the presence of electric currents.

Lubricant life can also be affected by the design of the bearing itself. Contamination caused by wear, and heat caused by friction, can both reduce grease life. Bearings designed with smoother rolling surfaces, optimized geometry and advanced, highly robust materials can significantly improve lubricant life.

CONTAMINATION CAUSED BY WEAR, AND HEAT, CAN BOTH REDUCE GREASE LIFE



Right grease. Right amount.

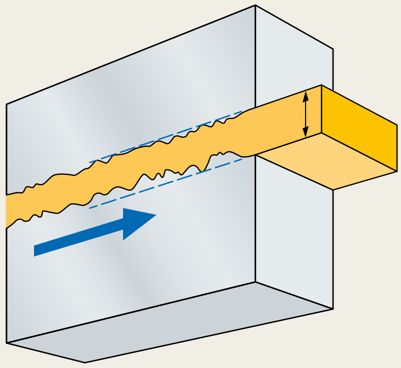
How do you choose the right grease for your application? That will depend on the operating conditions, where the primary factors considered are the load, temperature range and speeds as well as the influence of the sur-roundings. Lubricant manufacturers and railway compa-nies have invested a lot of time into developing robust products for railway applications.

- Grease consistency
- Base oil viscosity
- Mechanical stability
- Drop point (the temperature at which grease changes to a liquid)

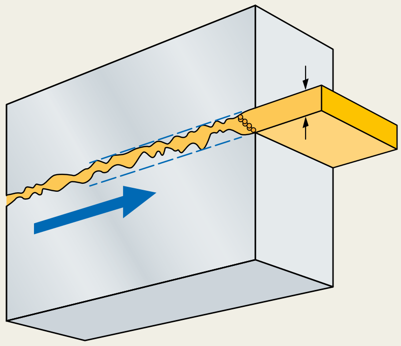
Consistency forms the basis of the grease classification, and ranges from very soft greases (000) to very hard greases number 6 correct consistency. Environmental and climate conditions should also be considered. Hard greases, for example, don't usually work well in cold climates.

The viscosity ratio of grease is another critical factor. The effectiveness of a lubricant is primarily determined by the degree of surface separation of the rolling contact surfaces. For an adequate lubricant film to form, the lubricant must have a given minimum viscosity when the application has reached its normal operating temperature.

In addition to choosing the right type of lubricant, it's also important to know how much lubricant to apply. Too much grease can cause a bearing to overheat, while too little can cause it to fail before the planned maintenance stop and reduce the effectiveness of the seals.



Full film lubrication hydrodynamic lubrication which means a complete separation of rolling contact surfaces by the lubricant film viscosity ratio $k \geq 1$



Mixed lubrication which means an incomplete separation of rolling contact surfaces by the lubricant film viscosity ratio $k < 1$

Limit your risk in lubricant selection

Sometimes, it's the small things that count – and that's obviously the case with railway bearing grease. But, "small" does not necessarily mean "simple." Selecting the right grease takes careful consideration of many factors. Done correctly, it can pay off in the cost and time savings of extended maintenance intervals. SKF can help. To learn more about how SKF is supporting railway maintenance and developing better lubricants, visit:

www.skf.com/railways.

Regreasing railway bearings: Why expertise matters.

In railway applications, the element that can have the greatest impact on bearing life may also be seen as the easiest to manage. That element is grease. But, optimizing it in regreasing operations is far more complex – and much more critical to bearing performance – than it may seem.

There's no question that railway bearings will require fresh grease at some point, because the grease life is significantly lower than the life of the bearing itself. Done correctly, delivery of a new lubricant into the bearing can help extend bearing life and optimize performance. But, it is a delicate process and there are pitfalls to avoid. Overfilling, insufficient cleanliness or the use of an incorrect grease type can significantly affect bearing performance, leading to higher costs and unplanned downtime.

Here are a few key points to keep in mind for minimizing risks.

Where and when to equip the bearing with fresh grease

The optimum time to revive a bearing by applying fresh grease is when the bearing has been removed from the railcar and sent to an expert facility for remanufacturing. This process assures that all old grease is removed from the bearing, and replaced with an amount and type of grease that is exactly in accordance with bearing manufacturer specifications. Expert remanufacturing in a dedicated facility with a controlled environment offers the best way to assure that risks are minimized.

However, while refilling the bearing with fresh grease at the time of remanufacturing is ideal. Sometimes, regreasing in the field is necessary. In the North American-field regreasing is controlled by AAR standards (the American Association of Railroads).

EXPERT REFURBISHING OFFERS THE BEST WAY TO ASSURE THAT RISKS ARE MINIMIZED

In certain applications, regreasing in the field is an option. To add grease properly to an in service bearing, it's necessary to have a dedicated highly skilled and knowledgeable staff with the correct equipment. Retain-ing staff competence in-house can increase manpower expenses and restrict staff flexibility. An alternative is to establish a maintenance partnership with a third-party expert.

Risks of field relubrication or non-expert refurbishment

Why is in-field regreasing, or refurbishment by non- expert staff, so problematic? It's because improper greasing can directly impact bearing performance and service life, increase risks and therefore costs of operation and maintenance, and decrease rail transport reliability. Common mistakes include:

Over filling

It may seem logical that, when in doubt about the correct volume of grease to add, it's better to have too much than too little. But the fact is that overfilling can cause the rotating bearing elements to begin churning the grease, resulting in energy loss and rising temperatures. This can cause a chain reaction of issues leading to bear-ing failure due to grease degradation and accelerated wear of the rolling elements.

Insufficient cleanliness

Bearing manufacturer specifications state how much grease should be used. But the bearing regreasing hole is not always easily accessible or clean and often the fresh grease must be transported to the bearing through the axlebox groove. In this case it's difficult to determine the precise amount of grease to inject, because it is hard to know how far the grease is filling the spaces inside the axlebox assembly. In cases where the grease is to be injected through the greasing nipple in the axlebox housing, the grease needs to travel a long way from the greasing pistol through the nipple, through the axlebox wall to the circumferential groove in the axlebox bore, and eventually to the bearing unit outer ring and bearing unit interior. This can introduce fretting debris into the bearing from the axlebox bore reducing grease and bearing life rather than extending it.

Risks:

Overfilling

Insufficient cleanliness

Grease distribution

Grease condition and contamination issues

Wrong grease

Grease distribution matters

Adding to the challenge is the fact that it takes time for the new grease to be redistributed in the bearing. Often, the bearing temperature rises after in service lubrication, before the grease has made its way throughout the bearing. Adding smaller amounts, more frequently, can help minimize the heating issue.

Grease condition and contamination issues

Grease condition and contamination issues are major concerns and typical issues in railway refurbishment workshops. Proper storage practices are key to assuring that grease is in optimum condition to support bearing performance. Temperature and environment, storage methods and inventory control can all affect grease quality. Of course, grease also must be kept clean as it moves from the storage container, to application tool, and into the bearing. Contaminants carried into the bearing with the grease will ultimately compromise bearing performance.

A major contamination issue when it comes to field relubrication is the risk of the grease collecting fretting corrosion. Fretting corrosion results from the loose fit of the bearing unit outer ring in the axlebox bore, a fit which is often preferred for mounting reasons. Because the outer ring can move in the axlebox bore, surface asperities, and oxidation can occur – all of which are referred to as fretting. When grease passes through the bearing unit, fretting particles can be trapped and carried along with the grease to the bearing interior.

While fretting could be reduced with the use of anti-fretting paste, this paste may not be compatible with the grease. Additionally, the paste could also be picked up by the grease, creating an additional contamination issue.

Wrong grease

All greases are not the same and cannot always be mixed inside a bearing assembly. Grease selection requires a thorough understanding of the application, the railway operating conditions, and other technical data. Choosing the right grease for your application will depend on the operating conditions, with the primary factors being the temperature range and speeds as well as the influence of the surroundings. Greases are classified by their consistency and blended to add performance enhancing charac-teristsics in a variety of areas, including:

- Grease consistency
- Base oil viscosity
- Mechanical stability
- Drop point (the temperature at which grease changes
  to a liquid),

Most importantly, it is essential to follow the manufac-turer’s recommendations.

Expertise assures performance

Considering the importance of bearing performance and the impact of railway car maintenance downtime, it’s essential that railway staff is well trained and equipped in bearing maintenance, especially in the area of field regreasing. As a strategy for minimizing costs while opti-mizing performance, skills enhancement is well worth the investment. For the most expert and reliable refurbish-ment, the task should be left to specialized refurbishment workshops.

Get smart about grease storage!

Correct grease storage is important for reliable bearing performance.

With so many factors to consider in maintaining railway bearings, how to store your grease may not be at the top of the list. But, it should be. That's because proper stor-age methods can assure that the grease you're using is in optimum condition to support bearing performance. Grease that degrades due to poor storage practices can do just the opposite – and result in more headaches and maintenance costs down the road. Here are some tips to help you get smart about grease storage.

Temperature and environment

Follow the manufacturers storage instructions

- Store grease in a cool, dry, indoor area.
- Avoid lubricant storage in extreme temperatures.
- Do not store lubricant in areas where the temperatures fluctuate significantly.
- Keep lubricants away from areas with high humidity.
- Keep grease away from direct sunlight.

Storage containers

- Keep grease in its original container, and keep it closed until needed.
- Reseal containers immediately after use.
- Store the lubricant container in a position where the bung (the plug to the container opening) can be easily accessed.

Inventory control

- Monitor the lubricate date codes, to guarantee the lubricant shelf life has not been exceeded.
- Follow a first in, first out policy, rotating the lubricants to be sure that the first lubricant into storage is the first lubricant to be pulled for use.
- Verify grease quality if stored for more than 24 months.

SKF is committed to making your job easier – and your maintenance intervals longer. To learn more about grease storage and handling for optimum railway bearing performance, visit:

www.skf.com/railways

Save money, save resources

Through bearing remanufacturing

Manufacturing, operating, maintaining and decommissioning railway vehicles are processes that can have a huge impact on the environment in terms of materials and energy consumption, pollution and waste.

Considering the number of vehicles in operation globally, and the increasing demand for rail transportation, it's essential to implement practices that can reduce this environmental impact wherever possible throughout the railway vehicle life cycle. Every decision made during this life cycle can have important implications and consequences in meeting environmental objectives.al step of the refurbishing process.

Bearings and the maintenance phase

During the maintenance phase, bearings are critical components that need to be addressed. Remanufacturing the bearings, instead of replacing them with new bearings, can significantly reduce the environmental impact from the rail vehicle life cycle.

By remanufacturing, products or components are restored to like-new condition.

The option to remanufacture the used bearings offers the possibility to reduce the number of new components to be purchased, helping in turn to save energy and raw materials, while also reducing waste and pollutants during the production process of the bearings. Additionally, it may be desirable from an economic point of view, as it is generally much cheaper to purchase a remanufactured product rather than an entirely new one.

The facts: a life cycle study

SKF has been offering wheelset bearing remanufacturing services to the railway industry for many years through our global network of state-of-the-art service centres.

In order to measure the environmental benefits of bearing remanufacturing, a study has been carried out, in which resource efficiency, waste generation and overall environmental impact for a new-manufactured bearing and a remanufactured bearing are estimated and compared thorough their life cycle. The study was performed in accordance with the ISO 14040 Life Cycle Assessment methodology. Following is an overview of that study, and details on the results.

EVERY DECISION MADE DURING THE RAILWAY VEHICLE LIFE CYCLE CAN HAVE IMPORTANT IMPLICATIONS

A life cycle perspective

Environmental profile of SKF remanufactured and new-manufactured compact tapered roller bearings

Life Cycle Assessment (LCA) is a methodological framework to assess environmental impacts associated with all the stages of a product's life from cradle to grave. These stages include raw material extraction through materials processing, manufacture, distribution, use, repair and maintenance, and disposal or recycling.

The products analysed and compared in this study were:

- the SKF new-manufactured compact tapered roller bearing
- the SKF remanufactured compact tapered roller bearing

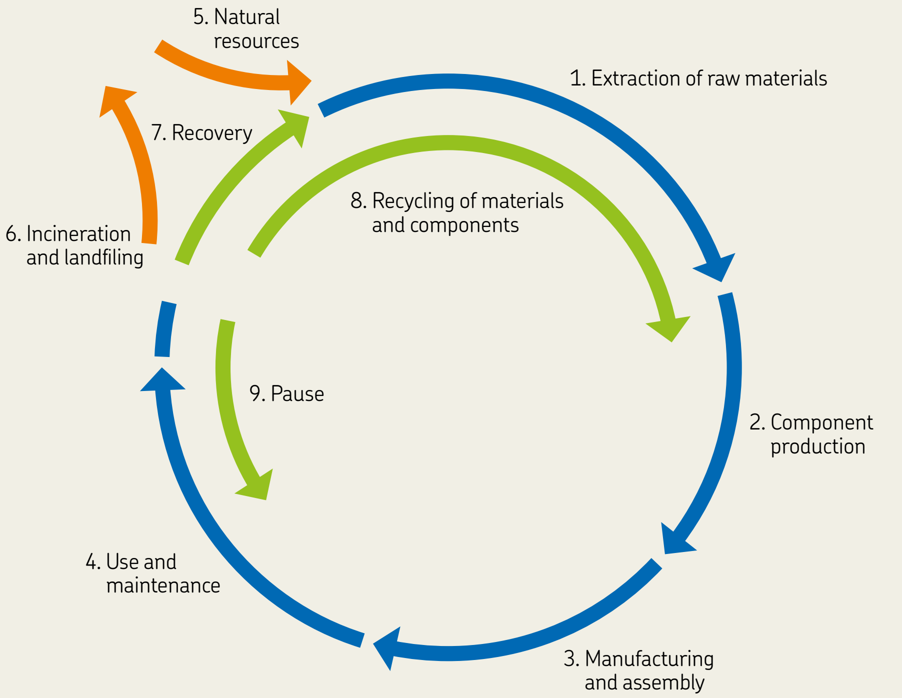
Both are wheelset bearings used on passenger rail vehicles. These bearings are one of the most important components of the vehicle, and are specially designed to run under arduous conditions and remain in service for many years.

The **new-manufactured compact tapered roller bearing** is a double-row bearing with one outer ring, and two inner rings with roller and cage assemblies. It is assembled with a spacer ring that provides the correct axial clearance, and two rubber-steel seals to ensure grease retention and protection against contamination. A backing ring correctly positions the unit axially on the journal.

The **remanufactured tapered roller bearing** composition is equal to a new-manufactured bearing. During the remanufacturing process, all components are inspected and some replaced by new ones, giving the remanufactured bearing the same properties and functionality as a new-manufactured unit.

The following chart shows the material composition of an SKF compact tapered roller bearing **(→ Diagram 1).**

Cycle model



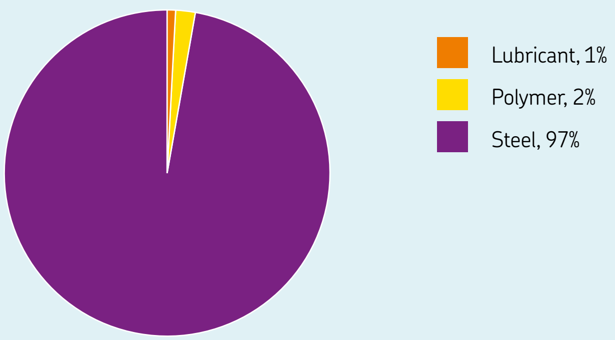
Blue
The assessment takes all stages into consideration, the extraction of raw materials (**1**), component production (**2**), manufacturing and assembly (**3**) and use-phase and maintenance (**4**).

Orange
It also considers all natural resource needed in all steps along the life-cycle (**5**) as well as how components and materials are treated at the end of life, whether incinerated or land-filled (**6**), or recovered into new raw material (**7**).

Green
The assessment of also considers the reuse of components in other application (**8**) and the remanufacturing of bearings and units which pauses the material flow and significantly extends the operating life (**9**).

Diagram 1

SKF CTBU material composition



Life cycle assessment

Resource efficiency **(diagram 2),** energy **(diagram 3),** waste generation **(diagram 4)** and six different categories of environmental impact **(diagram 5)** have all been analysed from cradle to grave. The results show that environmental impact can be reduce by 60-66%.

The analysis were based on the followingfactors:

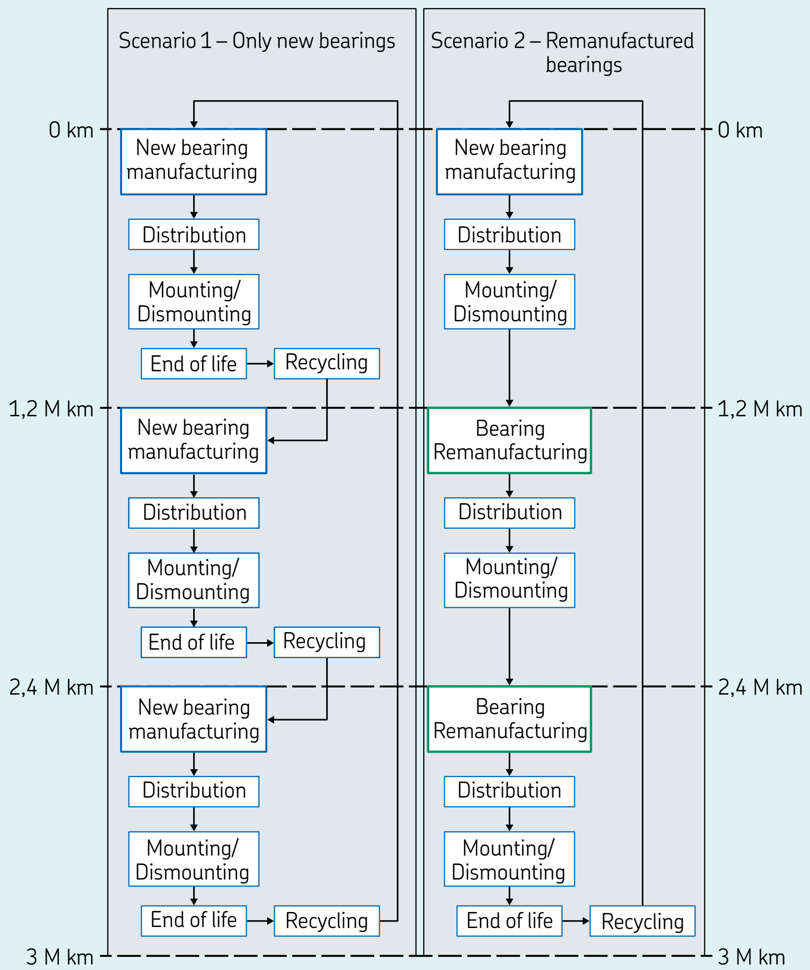
- The use of a compact tapered roller bearing on an electric passenger train for a distance of 3 000 000 km.
- The considered distance is based on the basic rating life of a bearing (L10) according to ISO 281:1990, which represents the actual bearing life before it fails.
- The bearing life depends on different factors, including lubrication condition, misalignment, etc. For this reason, the bearing needs to be maintained every 1,2 M km.

Two different scenarios were considered in the study:

Scenario 1 – new bearings:
The first scenario considered the use of only new-manufactured wheelset bearings within the defined life cycle. So, the bearing is exchanged by another new-manufactured bearing, scrapping the used one, every 1,2 M km until reaching 3 M km.

Scenario 2 – remanufactured bearings:
The second scenario considered the remanufacturing of the wheelset bearing. The bearing is reused after its remanufacturing every 1,2 M km, and the bearing is scrapped when it reaches 3 M km.

Two life cycle scenarios



The use-phase of the bearing, which would include the energy lost during the operation of the train due to the bearing friction, was not included in this study.

Energy and materials use

The results of the study allowed us to determine that 62% more resources were utilised in **Scenario 1** (new bearings), in comparison with **Scenario 2** (remanufactured bearings).

Almost 100% of the steel used in the bearing production is produced from recycled steel. This reduces the amount of non-renewable resources used in the process. A comparison of the different renewable and non-renewable resources used in the two scenarios is detailed in the following chart **(→ Diagram 2).**

The total energy used in **Scenario 1** was 63% higher than the one used in **Scenario 2.**

For both scenarios the major part of this energy was provided by non-renewable resources, which represent 95% of the total **(→ Diagram 3).**

Diagram 2

Resource use - material

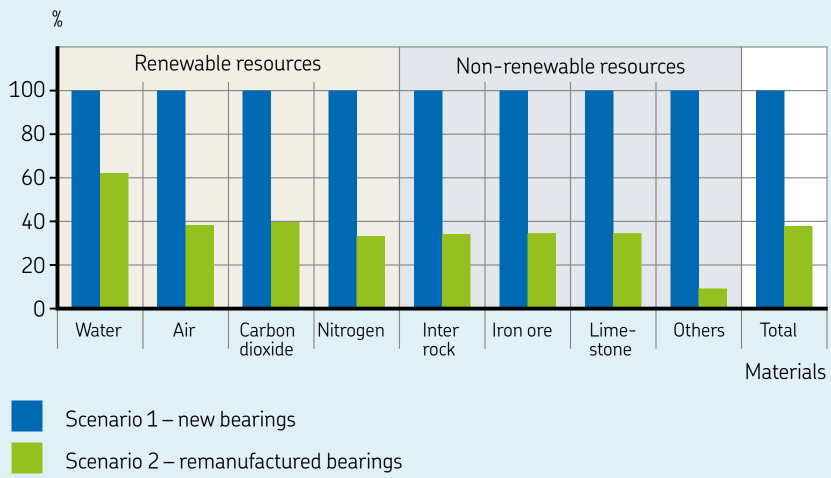
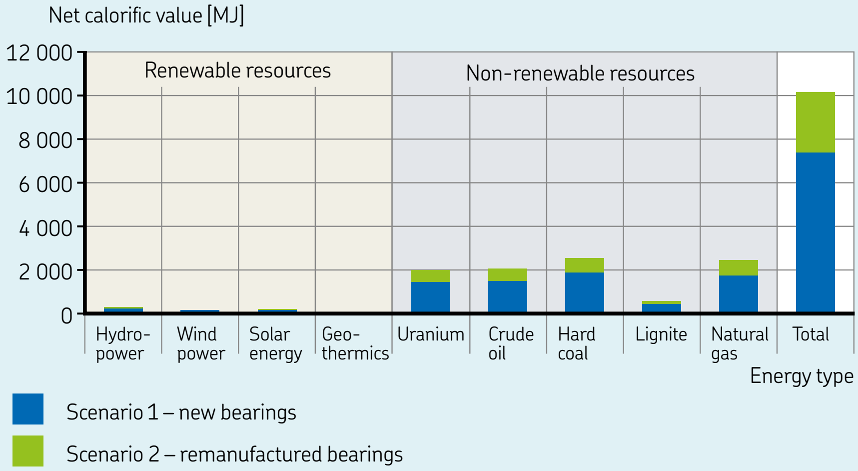


Diagram 3

Resource use - Energy [MJ]



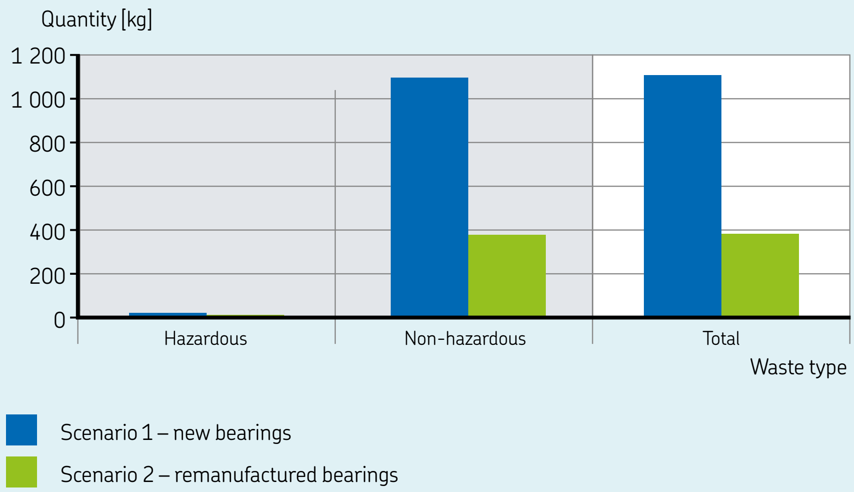
Waste generation

Scenario 1 generated 65% more waste than **Scenario 2.** Hazardous waste was negligible, representing 1% of the total generated in both scenarios.

In both scenarios, the major part of the waste was generated during the raw material extraction and processing, and the components production **(→ Diagram 4).**

Diagram 4

Waste generation



Environmental impact categories

A comparison of the different environmental impacts in both scenarios is shown in the chart below.

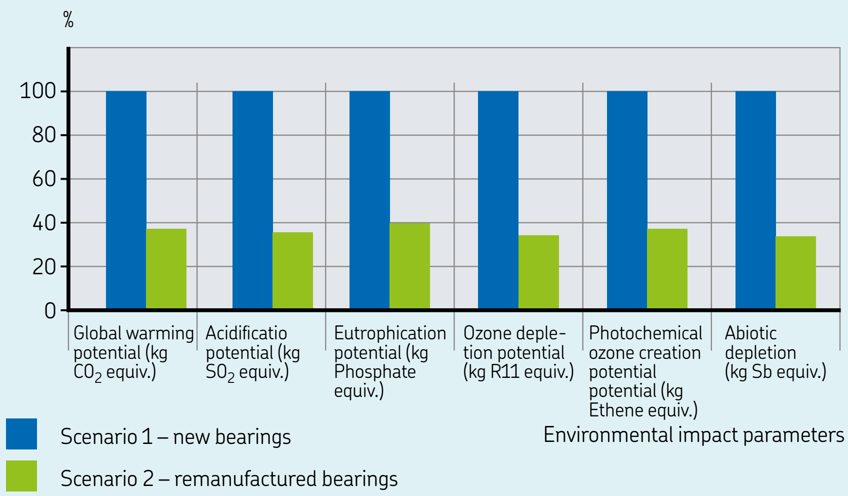
Carbon footprint - Greenhouse gas emissions (GHG) are considered to be one of the most harmful emissions due to their implication on global warming.

The results of the study showed that the total amounts of GHG emissions is 414 for **scenario 1** and 145 kg-CO2 for **scenario 2.**

These results, obtained from the CML 2001 impact assessment method, show how the carbon footprint related to the use of wheelset bearings can be significantly reduced by 63% through remanufacturing, during the life cycle of the rail vehicle **(→ Diagram 5).**

Diagram 5

Environmental impact categories (normalised results)



The positive impact of remanufacturing

Our study of the environmental benefits of new vs. remanufactured bearings is convincing. It shows that many environmental impacts can be reduced by 60% – 66% through remanufacturing. This compelling evidence can help SKF and our customers in making good decisions for the environment – and for business – during the making phase of the railway life cycle.

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Bearing remanufacturing

A delicate and critical process

Wheelset bearings are among the most safety-critical components on rail vehicles. Reliability with minimal maintenance is essential as these bearings must operate in harsh conditions, withstanding heavy loads, constant exposure to the elements, possible contamination and extremes of climate.

When bearing refurbishment is needed, the process steps must be carried out in the right way to ensure continued reliability and smooth operation. Following are key factors to keep in mind during each critical step of the refurbishing process.

Cleanliness

A clean environment during refurbishment operations is imperative. This prevents dirt and debris from entering the bearing during the assembly and re-greasing process. This contamination can lead to premature failure.

Inspection

After dismounting and cleaning, the used bearings must be inspected. The inspection should be conducted by staff trained to identify bearing damage, and certified to work on safety critical products. These qualifications include not only theoretical education but also many hours of practical experience, including shadowing experts who can demonstrate methods of identifying failure modes and possible trends. To keep up to date with the latest technologies, products and inspection methods, personnel must continue developing these competencies with additional training and education on a regular basis.

Axial clearance

Axial clearance is a critical measurement to ensure that the bearing is not exposed to premature failure. If the bearing is assembled with the incorrect clearance, problems will arise when mounting to the axle in service. It's very important to pay attention to the measurements provided in the OEM specifications and to measure carefully.

Checklist

- ☐ Ensure the environment for the remanufacturing operation is clean
- ☐ Visual inspection
- ☐ Correct axial clearance
- ☐ Grease filled in a proper way
- ☐ Seals mounted correctly
- ☐ Marked for traceability

Grease filling

Grease is necessary for optimized bearing performance. But, it is not as simple as filling the bearing with the right grease and quantity. It's essential to ensure that the grease is distributed to the right areas. Additionally, it is important that the grease filling be performed in a clean environment with the right tools, so that contamination does not enter the bearing.

Grease storage

Before filling, be sure that the grease has been stored properly. Grease condition and contamination issues are major concerns and typical issues in railway refurbishment workshops. Proper storage practices will assure that the grease is in optimum condition to support bear ing performance. Temperature and environment, storage methods and inventory control can all affect grease quality.

Correct mounting of seals

Seals must be mounted in the correct way to allow low-friction torque and to avoid unwanted contact and misalignment. Used seals should not be mounted back on the bearings. Instead, they should be replaced with new seals to ensure the correct fit and performance in the field.

Traceability

It is mandatory that all refurbished bearings are marked with the date of the refurbishment and the facility that carried out the work. The ability to trace individual bearings is the main factor in analyzing failure trends, enabling corrective actions.

Remanufacturing operations

To reduce scrap rates, remanufacturing operations such as polishing, honing and grinding of raceways can be used. Through these operations, bearings with minor defects can be repaired instead of scrapped. However, these operations require access to OEM equipment and should not be implemented by a 3rd party without support from an OEM bearing manufacturer.

Refurbishing in-house vs. outsourcing

Proper bearing refurbishment is key to the reliability of wheelset bearings – and to railway operations. If in-house staff is not qualified to follow recommended processes, it is best to outsource refurbishment operations to a partner that can guarantee the process quality required. OEMs have the sophisticated equipment and expertise needed. By taking advantage of these resources operators will be able to use refurbished bearings with confidence.

The 100/100 business model:

Helping improve spare parts management

Spare parts management is a common challenge for rail operators. The pressure for train availability is high and spare parts must be available exactly when needed to avoid unnecessary downtime. At the same time, cost pressure is increasing. Cost drivers such as space for stock keeping, and capital tied up in spare parts, must be avoided in order to keep budgets low. SKF's new 100/100 model for railway bearings offers a solution, by addressing the issues of cost control and parts availability.

The challenge: Predicting needs and costs

Having bearing refurbished costs less than a purchasing a new one. But, it's not always clear how many bearings will be suited to refurbishment, and how many may need to be scrapped and replaced with new bearings. To avoid delays, most operators will keep a number of new bearings in stock, or will order new bearings in anticipation of future needs. This creates a cost disadvantage related to space for stock keeping and tied up capital. It also creates budget planning difficulties, as exact costs cannot not be identified until bearings that have been in operation are evaluated for refurbishment or replacement.

The solution: Assuring bearing availability and fixed costs

The SKF 100/100 business model helps railway operators and maintenance partners by reducing the uncertainty, complexity and costs of spare parts management. It does so by shifting the spare parts planning and stock keeping responsibility and management from operators / maintenance partners to SKF. The model is actually very simple.
The bearings are sent for refurbishment, and no matter how many of them need to be scrapped, the operator will always get exactly the same number of bearings back. If 100 bearings are sent for refurbishment, 100 will be brought back to the operator / maintenance partner as a mix of refurbished and new. And most importantly, the price will always be the same, whether the scrap rates for a specific batch are unusually high or low. It is very much like an insurance system where the supplier takes the risk. This way the operator will avoid surprises and stock keeping uncertainty, and can rest assured that the right amount of bearings will be available at the right time within the agreed budget.

Getting started

To set up the system, SKF requires that scrap-rate statistics are gathered during a period of six months. Based on the results, the contract will be agreed. The operator or maintenance partner will know exactly what to pay during the contractual period. The contract will then be revised every six months to make sure the scrap rates are in the right range.

The 100/100 model: Inventory and cost control

To set up the system, SKF requires that scrap-rate statistics are gathered during a period of six months. Based on the results, the contract will be agreed. The operator or maintenance partner will know exactly what to pay during the contractual period. The contract will then be revised every six months to make sure the scrap rates are in the right range.

Upgrading your bearing

– an opportunity for component upgrades

Designed to save energy, improve performance and extend maintenance intervals in high speed rail applications.

The typical challenge when designing bearing seals is to balance friction and contamination exclusion. On the one hand you want to avoid friction for mainly two reasons; to save energy, and to reduce operating temperature in the bearing. Lower operating temperatures means longer grease life which has a direct correlation to maintenance needs – the longer the grease life, the longer maintenance interval. On the other hand you need to make sure that contamination is properly excluded from entering the bearing.

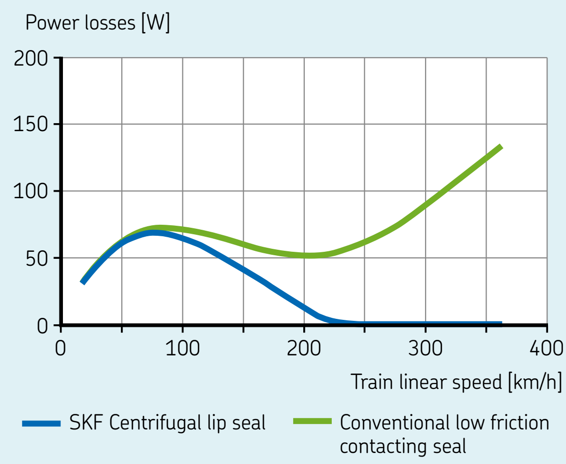
The traditional seals used in wheelset bearings today are either of a contacting lip seal design or labyrinth design. The contacting lip seal design implies that there is a lip.... This solution is effective for contamination exclusion in all speeds but has the disadvantage of creating friction torque due to the contacting surfaces. The labyrinth seal design does not have contacting surfaces and is therefore effective from a friction torque perspective but has the disadvantage of less effective contamination exclusion at lower speeds.

However, now there is a solution available that combines the pros and avoids the cons with both these designs. It is called SKF Centrifugal Lip Seal. This design is a contacting lip seal at lower speeds but turns in to a labyrinth seal at higher speeds.

"The SKF Centrifugal Lip Seal has been developed specifically to overcome the traditional sealing quandary manufacturers face with high speed train wheelset bearing units," Maurizio Martinetti, Senior Project Manager at SKF Product Development, said. "No lip contact at low speeds meant there was a risk of contamination, while contact at high speeds led to energy-consuming friction and its other associated problems, such as excessive operating temperatures and the need for frequent maintenance. However, this new seal eliminates all of these issues for consistently efficient and high performance operation."

When the vehicle is standing still or travelling at low speed, the contacting lip is closed, effectively excluding con tamination from the bearing. While the speed is increasing the pressure and the friction torque are progressively reduced and above a certain speed the lip opens and it becomes a zero friction seal, with centrifugal force preventing the ingress of pollution.

This means that the SKF Centrifugal Lip Seal allows for an optimised friction pattern throughout the operation cycle of high speed trains. As a result, the unit can operate at a low temperature and extended maintenance intervals can be realised to cut the cost of servicing and improve the reliability of the application through cleaner grease. The significantly enhanced efficiency and energy savings can also lead to a reduction in the environmental impact of high speed rail.



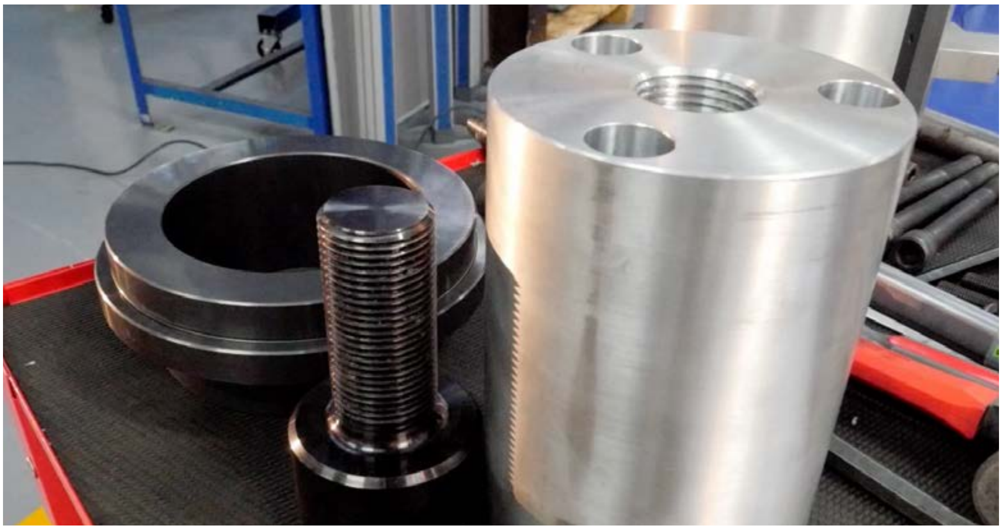
Mounting and dismounting

Handling, mounting and dismounting bearings

Dangers, damages and precautions

Railway wheelset bearings designed for railway vehicles are robust and engineered for these demanding applications. However, railway bearings can be damaged before even being put into service on the vehicle or when taken out of service for refurbishing. This can happen during transportation from the manufacturer to the customer and through incorrect handling, mounting and dismounting practices.

Generally, damage to the bearings during handling, mounting or dismounting is due to a lack of knowledge or to a lack of care in following proper procedures. Following are some of the most common issues – and steps that can be taken to prevent bearing damage.



Did you know railway bearings can be damaged before ever being put into service on a vehicle?

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1. Incorrect handling during transportation and storage

Transportation

Careless storage of pallet boxes during transportation can expose them and their bearings to moisture and dirt as well as temperature variations which leads to corrosion. Vibration during transportation could expose the bearing components to vibrations causing frictional corrosion also known as wear Rough transportation might generate impact loads forcing the rollers against the raceways and creating surface indentations. Always make sure that the packaging is strong enough to protect the bearing from impact and contamination during shipping .

Storage before mounting

During the time between delivery and mounting, the bearings must be stored in appropriate conditions. Unlike open bearings, bearing units are pre-greased by the manufacturer. This offers performance advantages for the user but it also creates the need for special attention during storage to avoid damage to the grease.

When storing bearings and especially bearing units, the storage rules mentioned in EN12080, EN12081, EN 15313 and in the Association of American Railroads manual H II must be followed. It is also recommended that you follow the instructions of the bearing manufacturer.

Common mistakes are extended storage times or incorrect storage of bearing units that have not yet been assembled on to the wheelset journals. The main problem is the keeping the grease lubricant in good condition protected from contamination and temperature variations.

Unused grease will degrade with time and oil will start to separate out from the grease. This can cause the bearing raceways to become corroded and lead to premature failure in service.

Best practices for storing bearing units prior to mounting include:

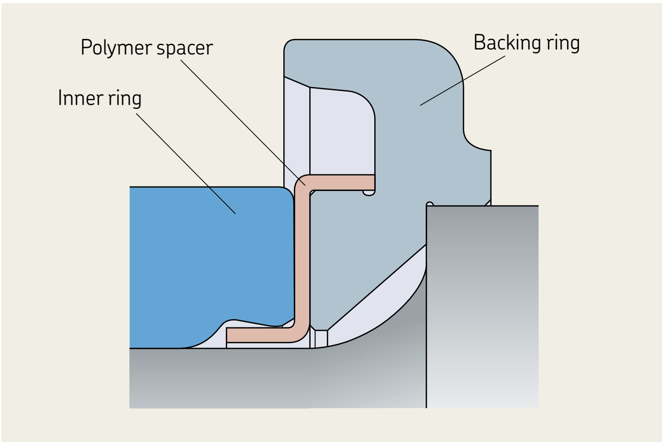
- The bearings must not be stored for more than two years.
- The bearing storage temperature should remain as constant as possible in order to avoid condensation.
- Do not store bearing units close to vibration sources.
- Handle the bearing units with care when moving them. Rough handling could generate impact loads forcing the rollers against the raceways and generating surface indentations.
- Stock rotation must be applied, first in, first out.

Handling prior to assembly

If the bearing units are delivered to wheelset workshops, they should not be unpacked from the transport packages until just before the assembly. This will help minimize the potential for damage.

When the shipping boxes are opened, the technician should make sure that the opened pallet box is not exposed to contamination. Handling individual bearing units can allow damage to the internal steel and polymer components so careful handling is important. Look for bearings fitted with an internal polymer seal which can be easily damaged during careless handling.

The parts in a bearing unit are usually kept together by either a cardboard triangle or by plastic straps which keep the parts in place. The triangle must remain in the bearing unit bore until the bearing unit is assembled on the mounting sleeve. At this point, the triangle should be removed. When removing the plastic straps, ensure the bearing unit parts are not free to fall apart.



Storing the mounted bearing unit

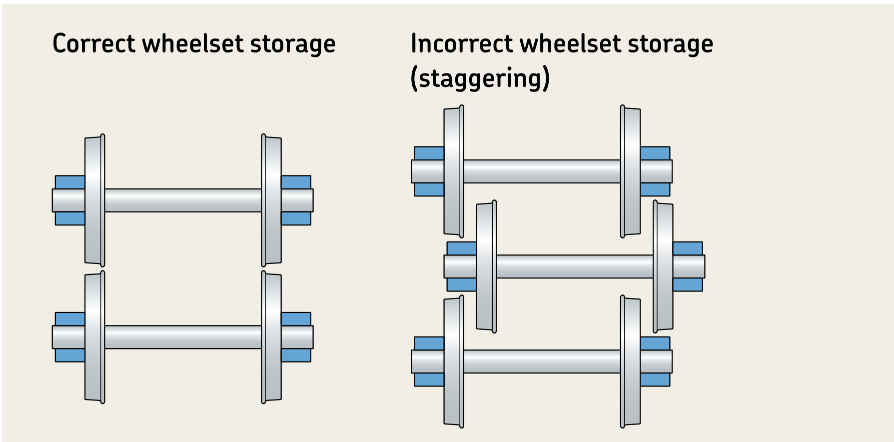
Proper storage of the bearing unit continues to be critical after the unit has been mounted on the journal. In particular, care must be taken to ensure the correct storage of wheelsets with mounted bearing units without axle boxes. As well as impact damage from adjacent wheelsets, bearings can be damaged by contamination so should be stored under cover or protected by a plastic cover.

If the wheelset is stored in an inappropriate manner, the outer ring may be damaged by the impact of the adjacent wheel. This often happens when wheelsets are placed too close together in an attempt to save storage space.

Rules for the proper length of time and method of storing bearing units mounted on wheelsets or bogies are detailed in EN12080, EN12081 and EN 15313 in AAR H II manual. Two of the most important rules to follow are:

- Wheelsets with bearing units must be put into operation no later than one year after installation.
- During the storage period of the wheelset or bogies, it is necessary to rotate the bearing periodically. This will help prevent corrosion from stand still roller raceway contact and stirs the grease filling the seals to protect the bearing. If the rotation is not done and months have gone by, it will be necessary to dismount some units and have their condition checked by the manufacturer. This inspection can determine if other bearings stored in the same condition can be used or if they may need to be sent for refurbishment because the grease has deteriorated.

Mounting a wheel set bearing.



Wheelsets with bearing units must be put into operation no later than one year after installation.

2. Incorrect mounting tools

The assembly on the journal is an important milestone in the life of the wheel set bearing. During assembling or disassembling, it is essential to use the correct measuring devices and suitable mounting tools.

Measuring before mounting

Measuring gauge

Visual inspection of the journal for damage and geometry are all essential but the most important factor is control of the journal diameter.

- The optimal gauge for manual journal diameter control is a three-point gauge calibrated to 0,001 mm or 0.001" according to the journal size.

The three-point gauge ensures that the journal's maximum diameter is measured for size and roundness. Two point measuring devices such as micrometers are not acceptable for journal measurement because it is often difficult to achieve repeatable readings between operators and roundness cannot easily be seen.

Gauge calibration

It is important to note that even when the correct type of three-point gauge is used, the gauge must be calibrated properly in order to provide an accurate measurement. The calibration should be done using a master ring certified by a certified laboratory. Verification of the master ring must be performed periodically as the dimension of this caliber can be changed by wear or, possibly, due to structural changes in the material.

Calibration tools

Tool temperature

The last important condition for successful journal checking is temperature. The axle journal, measuring gauge and master ring must be the same temperature. The best way to achieve a consistent temperature is to keep all of the mentioned parts in the same room for several hours so that their temperature is the same. Be aware that a temperature difference of only 5 °C can result in a measurement error in the order of one quarter of the tolerance of the journal daimeter! It's easy to see why storing wheelsets in the sun, or in other extremely hot or cold environments, can lead to completely wrong measurement results.

Measuring the temperature

Bearing assembly tools

When the journal has been checked, bearing assembly can start. The assembly of axle bearing units with a portable hydraulic press gives reliable mounting by keeping the components aligned during the mounting process.

A high-quality, well-designed tool will fulfill three basic conditions:

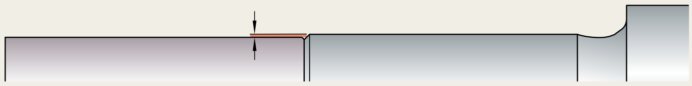
- The tool design should give a single smooth fitting action of the bearing unit from the pilot sleeve to the final position on the axle journal.

For example, if the pilot sleeve is not designed correctly with the journal, either the bearing or the axle journal can be damaged. If this happens:

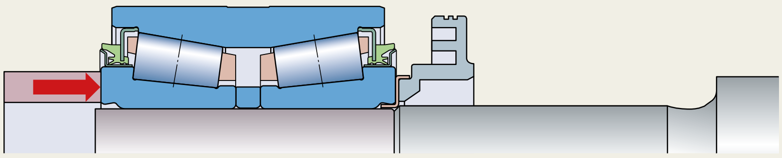
  - the journal surface will be torn by the bearing creating metal debris.
  - The bearing can become jammed on the journal.

- The tool must ensure the mounting force is transmitted only through the inner rings. Failure to observe this principle will result in the transfer of mounting force through the rolling elements, damaging the raceways.

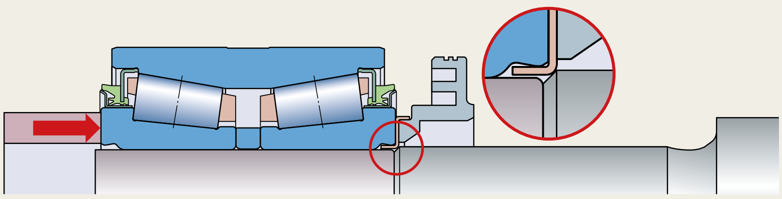
Assembly tool set.



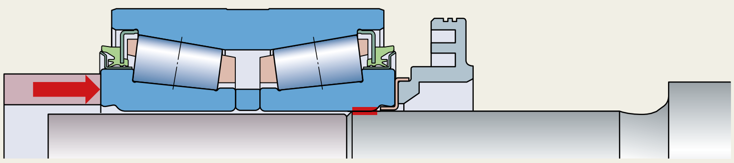
The pilot sleeve is not designed correctly or it is not mounted correctly on the journal face. Its upper part is not in line with the top of the journal.



The mounting process has been initiated.

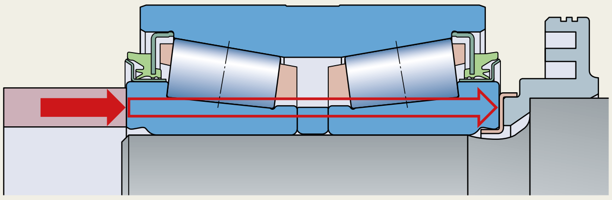


The first inner ring approaching the journal chamber cuts the journal edge.

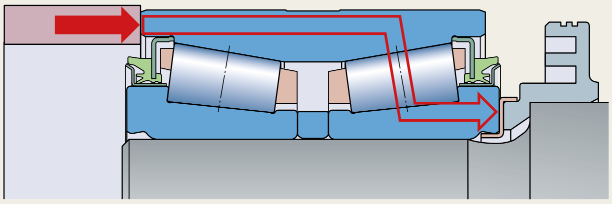


The metal chip generated by cut on the journal edge causes jamming of the inner ring on the journal with subsequent damage to the journal and the bearing unit.

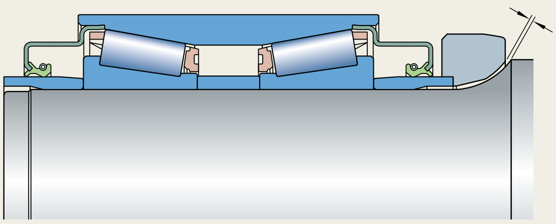
- The tool and the press must ensure that the bearing unit is pressed up to its final position on the journal against the axle shoulder. The consequences of this are explained more in detail in the following section 4.



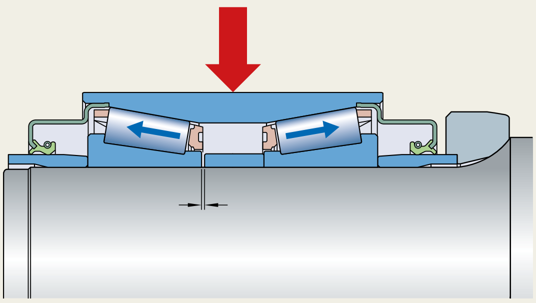
Correct



Incorrect



Due to incorrect tooling design the bearing unit is not pushed up to its final position on the journal. There is axial gap between the backing ring and the journal collar.



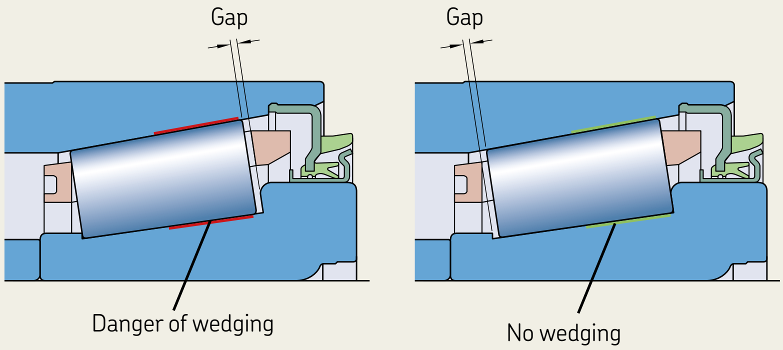
When the bearing unit is radially loaded in the application, the inboard inner ring travells towards the journal collar. And the gap appears now between the inner ring face and the central spacer.

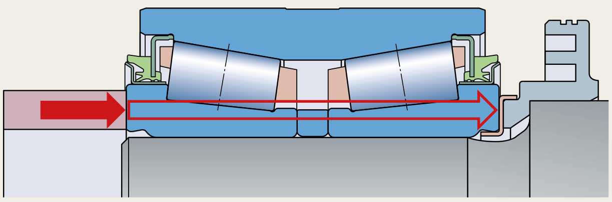
3. Failure to rotate the TBU outer ring during assembly

When assembling a tapered roller bearing unit (TBU) on a wheelset journal using a hydraulic press, the TBU outer ring must be rotated during the process. This ensures that the bearing is free to rotate at all times so clearance inside the bearing is present. If the outer ring is not rotated during the mounting procedure, there is a risk that the axel load is transmitted via the roller set and wedging can occure.

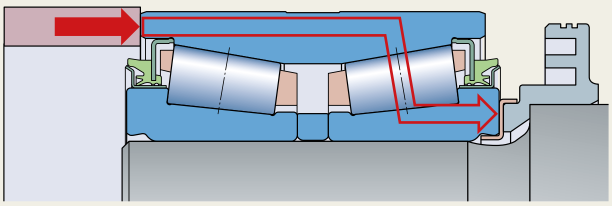
Tapered roller bearing in "silent" position (no rotation)

Tapered roller bearing rotating



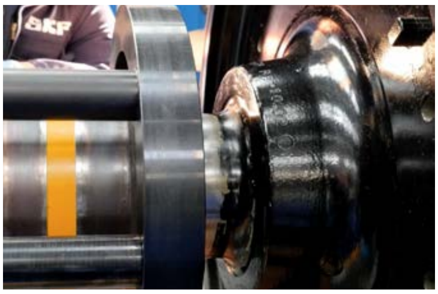


Correct



Incorrect

Mounting without outer ring rotation. In this case the left inner ring has no axial contact and the axial load is transmitted via the roller set.

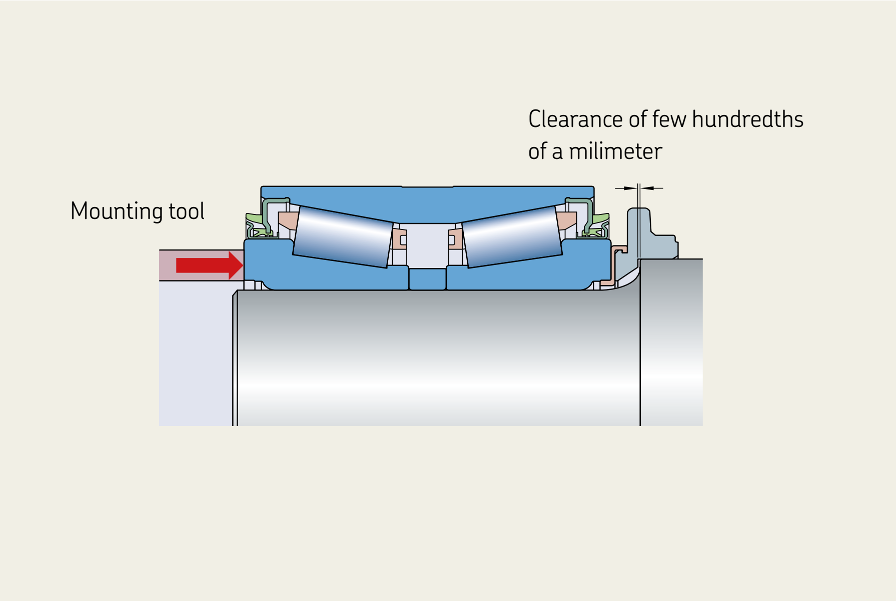


Tapered roller bearing unit outer rings must be rotated during the process.

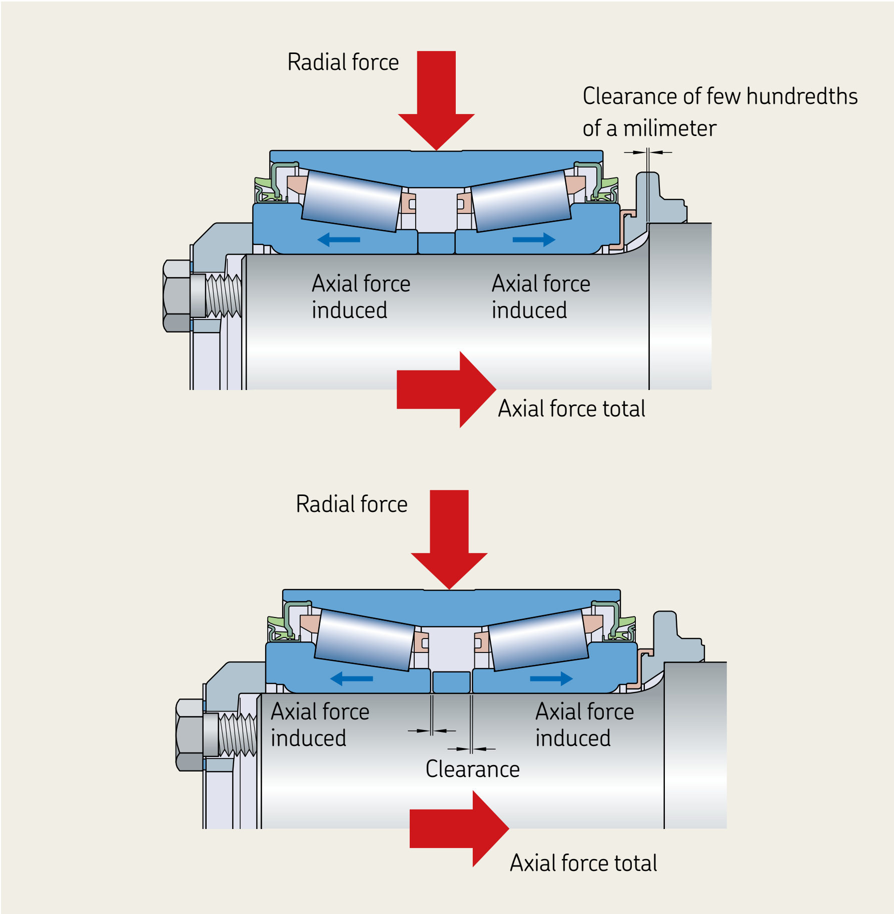
4. Omitting of TBU final seating force

Technicians know that the bearing units can be moved along the axle journals by a force lower than the final seating force specified by the manufacturer on the bearing drawing. The manufacturer's specified final seating force for the TBU bearing unit is usually twice the force needed to move the bearing along the axle. In such a situation, the following scenario may occur:

- The TBU is not mounted in its final position, being off by perhaps by only a few hundredths of a millimeter.
- When the wheel set is put into operation, the bearing unit is normally radially loaded, which naturally induces the axial forces acting on the inner rings. This force is further reinforced by the axial force generated by the bogie hunting and by the centrifugal force from passing the curves.

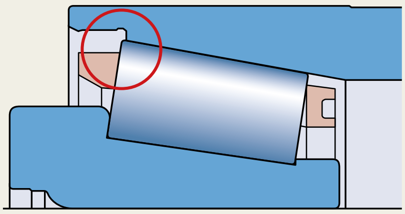


- The TBU inner ring on the end cap side is axially blocked by this end cap, so it has no problem. However, the wheel side TBU inner ring may get into trouble. If the total axial force exceeds the interference fit of the inner ring and the backing ring on the journal, the inner and labyrinth rings can move towards the wheel several hundredths of a mm previously noted. This now axially releases the TBU central spacer.
- Because the central spacer is mounted on the journal with a clearance fit, it is now free to move on the journal. The journal rotation and vibrations found in rail operations allow the bearing spacer to suffer fretting between the spacer ring and the inner ring faces. This can damage both the axle journal and grease.



Short tons vs. metric tons

The problem of non-compliance with the manufacturer's prescribed final seating force is often due to confusion with the units of measurement. American hydraulic presses use U.S. tons while European bearing manufacturers define the seating force in metric tons. The metric ton is roughly 10% higher than the U.S. ton so a technician mounting a European manufactured bearing using a U.S. hydraulic press may actually be pressing the TBU on the journal only by 90% of the prescribed final seating force. It is best practice to observe the movement of the bearing and the pressure of the mounting press together to ensure the bearing is correctly fitted against the axle shoulder.



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5. Mounting temperature

Cold mounting

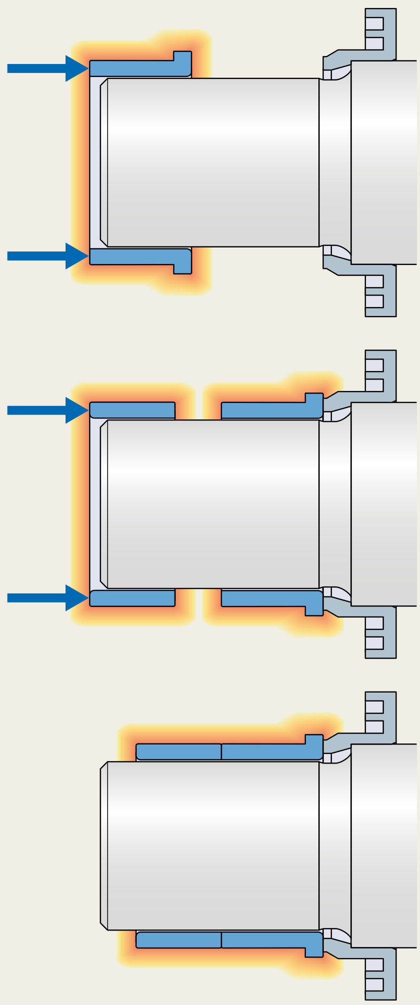
A sealed and greased tapered and cylindrical roller bearing unit must be cold mounted. This means that it must be pressed onto the journal by a hydraulic press cold without being heated to avoid damaging the grease.

Hot mounting

The correct mounting temperature is very important for hot mounting and dismounting of open bearings like cylindrical and spherical roller bearings. In order to fit the inner rings of the cylindrical or spherical roller bearing) onto the railway journal, it is necessary to heat them to a temperature about 6X higher than the temperature of the journal. The same rule applies when dismounting the inner rings from the journal using heating devices.

Hot mounting or dismounting process recommendations and precautions:

- Never heat a bearing using an open flame such as a blowtorch. Also avoid localized or uneven overheating of the rings. For hot mounting, it is best to use an induction heater which can accurately control the heating process by temperature. At the end of the heating cycle, the ring is automatically demagnetized.
- Hot oil baths have traditionally been used to heat bearing rings. This is not recommended primarily due to health, safety and environmental considerations. This method also creates the risk of bearing contamination.



Clearance of few hundredths of a milimeter

- When dismounting, an induction heater with extractor is recommended. These will heat the bearing evenly avoiding localised overheating of the bearing inner ring.
- Since the journal has a temperature of 20 °C under normal workshop conditions and the interference fit between the inner ring and the journal is about 0,070 mm, the inner ring must be heated to at least 110 °C. It is not recommended to heat the rings to more than 125 °C to avoid altering the heat treatment of the bearing rings.
- The handling of the ring heated to 110 °C requires the correct tools to align the bearing to the axle journal and avoid getting the bearing stuck in the wrong position.
- Oil should be applied to the axle journal to protect it, to stop the bearing from sticking in the wrong position and to assist with dismounting in the future.

Induction heater

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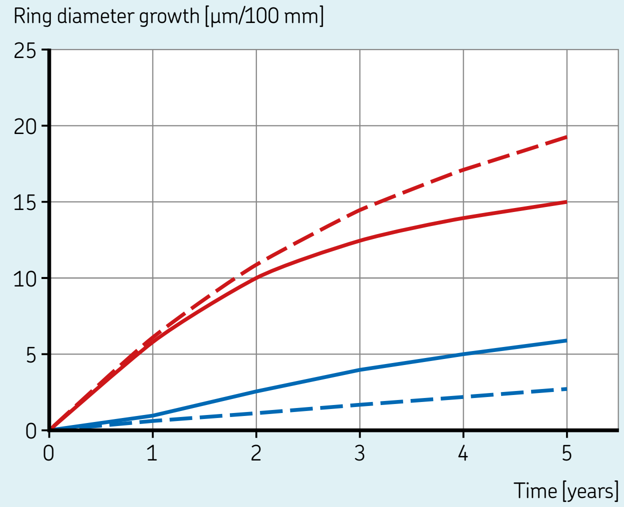
Dismounting precautions

During dismounting bearings, look for the bearing ring with an interference fit and only apply the dismounting force to that ring, usually the inner ring. This will avoid damaging the bearing during dismounting process. Bearings removed from axles should be stored wrapped in protective paper to avoid contamination and corrosion ensuring the bearings can be refurbished. Use the manufacturers original wrapping to protect and store the bearings during the dismounting and refurbishment process.

Protect your investment

Understanding and implementing best practices for bearing transportation, handling, mounting and dismounting is the best way to protect your investment, and to avoid unplanned downtime. SKF offers a broad range of assistance and support to help you take the necessary precautions to prevent bearing damage. To learn more, contact your SKF representative (cc.railways@skf.com).

Predictions compated with measured long-term stability data
Grade 3 hardened and tempered at 220 °C for 4 hours.



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