9 Maintenance

Maintenance

Machine efficiency

*The most common way to express machine efficiency is the overall machine efficiency (OME) percentage (→ **fig 1**). OME is normally 65–95%.*

Paper mills and machine builders are paying a lot of attention to the OME percentage, but also to paper speed, as total production is the result of OME, trim width and paper speed.

Aims of maintenance

Maintenance certainly has some influence on paper quality and web breaks, but the major aim of maintenance is to keep the machine running without any disturbances. An unplanned stop does not reduce the need for planned stops. During a planned stop, many other problems can be dealt with at the same time. Unplanned stops are just some extra hours taken of the the production capacity.

Measure of overall machine efficiency (OME)

Fig. 1

$$\% \text{ OME} = (\text{uptime}) \times (\text{saleable product}) \times 100\%$$

Where

$$\text{Uptime} = \frac{\text{annual hours the machine produces paper}}{\text{annual available hours*}}$$

$$\text{Saleable product} = \frac{\text{saleable tonnage}}{\text{produced tonnage}}$$

Source: TAPPI 0404-47 (1997)

* Excludes scheduled stops over 24 hours as well as holidays.

Maintenance philosophies

Reactive maintenance

In the not so distant past, the paper industry's approach to maintenance was "fix it when it breaks". Even today, some mills still use this approach. With this type of maintenance, known as reactive or "run to failure", action is not taken until a problem results in machine failure. The failure often causes costly secondary damage along with unplanned downtime and excessive maintenance costs.

Very often the failures continue to occur, since often no real analysis of the reason for the failure is performed and therefore no corrective actions are taken.

Preventive maintenance

Preventive maintenance implies that a machine, or parts of a machine, is overhauled on a regular basis regardless of the condition of the parts. The schedule is based on experience, which means that some problem areas get more service than others. While preferable to reactive maintenance, preventive maintenance is costly because of excessive planned downtime from unnecessary overhauls and the cost of replacing efficiently operating parts along with worn parts. Preventive maintenance leads to fewer unplanned machine stops than reactive maintenance (→ **fig. 2**).

As with reactive maintenance, the failures continue to occur, since often no real analysis is done of the reason for the failure and therefore no corrective actions are taken.

Predictive maintenance

Predictive maintenance is the process of determining the condition of machinery while in operation. This is possible by using vibration and lubrication analysis. This allows correction of problem components prior to failure. Predictive maintenance not only helps plant personnel reduce the risk of catastrophic failure, but also enables them to order parts in advance, schedule manpower and plan other repairs during the downtime.

Many paper mills, with efficient predictive maintenance, have no unplanned stops caused by bearing problems.

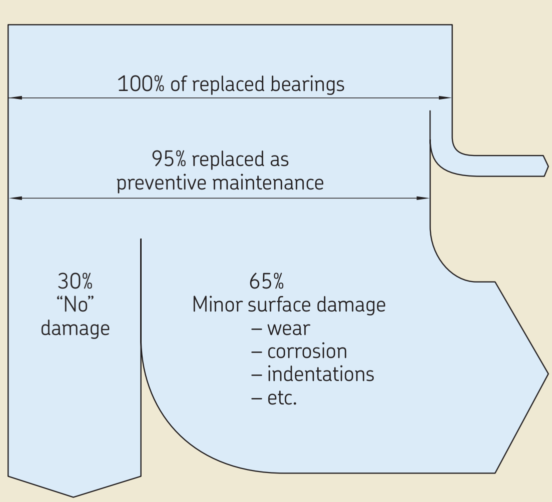
Root cause analysis is often not performed.

Proactive maintenance

Proactive maintenance is a further development of the predictive method. When a failure is detected, the reason for the failure is always analyzed and corrective actions are taken. This continuous improvement of the process, focusing on the weakest link in the chain, makes it possible to eliminate unplanned stops and to have longer time between the planned stops and shorter stops than before. The small improvements eventually make it possible to increase the production speed or load when needed.

The main difference between the maintenance philosophies can be seen in (→ **fig. 3** and **diagram 1**).

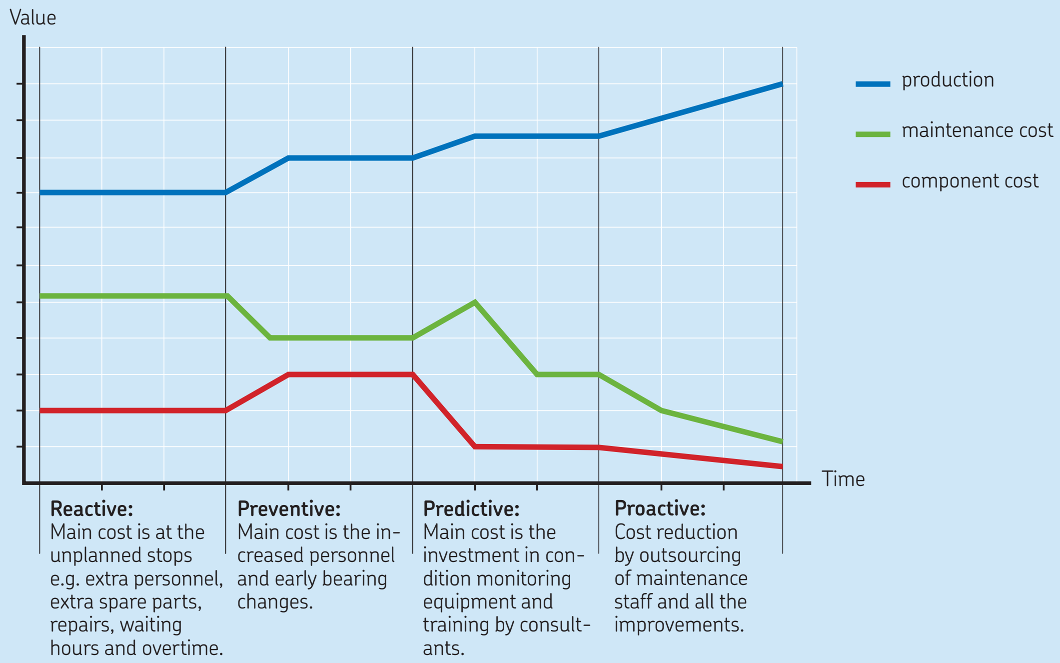
Fig. 2



Failures in Swedish paper machines, estimated 1990

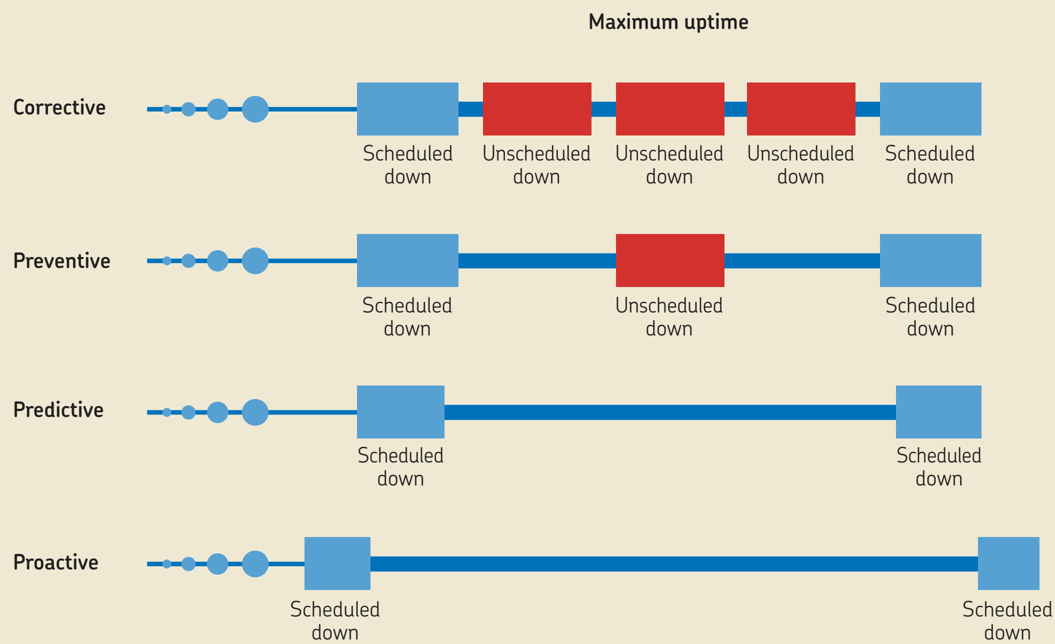
Development of production and cost relative to maintenance practices

Diagram 1



Maximum uptime versus different maintenance philosophies

Fig. 3



Services and products supplied by SKF

Over the years, the SKF's programme, Trouble-Free Operation (TFO), has extended bearing service life and increased productivity for bearing users by providing a full menu of bearing-related products and services. The original TFO programme focused on education, with most of the work performed by the mill's personnel. It also included services such as on-site trouble-shooting, application engineering support, bearing failure analysis and bearing rework services.

In recent years, it has been a clear trend in many industries to outsource non-core maintenance to the component suppliers to reduce total maintenance costs. This is also the case for paper mills. An increasing number of mills want the suppliers of machine elements like bearings, electrical motors, fans, pumps etc. to take over the responsibility for these products.

In response to this trend, SKF has combined its long experience with bearings in the paper industry with advanced capabilities in manufacturing and research to help customers increase productivity.

For example, SKF now offers performance-based contracts, with a guarantee of downtime reduction or uptime increase. The foundation for the contract is SKF's proactive reliability maintenance process, a systematic method to benchmark machine efficiency and implement corrective actions that decrease total life cycle cost. It involves predictive maintenance, root cause failure analysis, corrective actions and ongoing operational service measured according to key performance indicators.

Furthermore, SKF can offer services like shaft alignment, lubricant analysis, condition monitoring, bearing remanufacturing, etc.

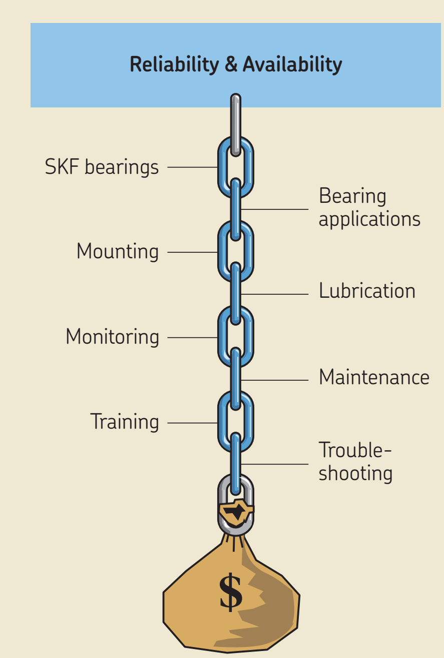
At SKF, we have also put together the industry's most comprehensive range of products for minimizing bearing failure. Among the products are mounting and dismounting tools (→ **pages 6–7**), condition monitoring equipment (→ **pages 13–16**) and grease (→ *Chapter 7*, *Lubrication*, **pages 8–12**). Some of these products and services are shown in the chain (→ **fig 5**). This chain illustrates the connection between machine reliability/availability and profitability. Remember that no chain is stronger than its weakest link!

Fig. 4

Mounting of CARB toroidal roller on a Yankee cylinder using the SKF Drive-up Method

Increased profitability through products and services supplied by SKF

Fig. 5



Rebuild front side of drying and Yankee cylinders to a CARB toroidal roller bearing arrangement

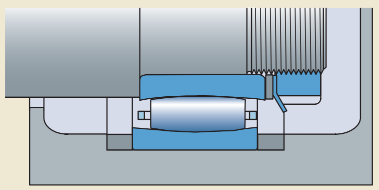
To obtain all the benefits of a CARB toroidal roller bearing arrangement, SKF normally recommends the use of SKF housings for CARB toroidal roller bearings when rebuilding existing machines. Reworking existing housings can be as expensive as a new housing.

After many years in operation, the bearing seatings of drying cylinder housings may have extensive fretting corrosion and be worn or oval. Therefore, in some cases, the housing bore has to be reworked. When converting from a rocker housing, a reworked housing will not be as stable as a new one.

As CARB toroidal roller bearings follow the ISO standard for dimensions, bearing C 3152 has the same boundary dimensions as spherical roller bearing 23152 or cylindrical roller bearing N 3152. If the existing housings are inspected with good results, they may in many cases, perhaps somewhat modified, be used for CARB toroidal roller bearings when converting from other bearing types. If too many modifications are required, the total cost for a rebuild can be as high as an investment in new housings.

When a rocker housing is modified to a fixed housing, it must be locked in all directions. This can be achieved by modifying the housing according to **fig 6**, depending on the design of the original housing.

Fig. 7



Axially located outer ring of CARB toroidal roller bearing

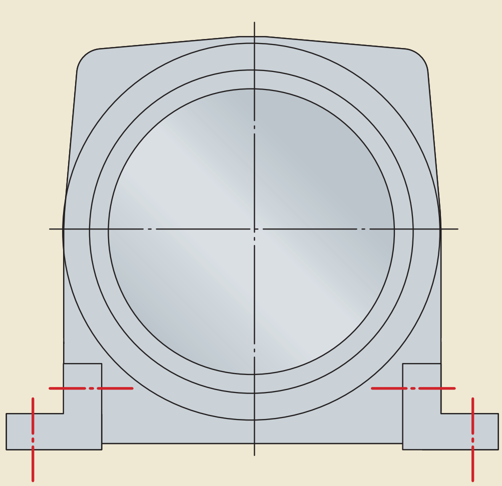
When rebuilding from spherical roller bearings with an axially free outer ring, distance rings have to be used in order to axially locate the outer ring of the CARB toroidal roller bearing (→ **fig. 7**).

When the existing bearing is lubricated from the side (→ **fig. 8**), it can be replaced by a CARB bearing without any changes related to the lubrication.

If the existing bearing is lubricated through the outer ring (→ **fig. 13** and **14**, *Chapter* 4, *Dryer section*, **page 9**) the housing lubrication design must be changed when converting to CARB toroidal roller bearing. One way is to displace the oil inlet to the outer side of the bearing for the SKF standard housings incorporating a CARB toroidal roller bearing. However, this requires modifications in order to ensure that no oil drains out without passing through the bearing. In some existing housings, the diameter of the oil channels connecting the two sides of the bearing is small and should be enlarged to make a high oil flow possible.

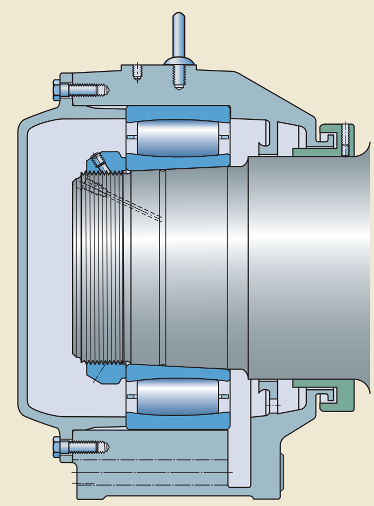
Modified rocker housing

Fig. 6



A CARB toroidal roller bearing lubricated from the side

Fig. 8



The other alternative is to displace the oil inlet to the inner side of the bearing and plug the oil channels connecting the two sides. Note that this modification may influence the drainage capacity of the housing.

When rebuilding to a CARB toroidal roller bearing arrangement, please contact SKF in order to optimize the bearing arrangement for bearing function and total cost.

SKF can offer a complete package for rebuilding existing housings to fixed housings incorporating CARB toroidal roller bearing. This includes:

- modification of existing housing
- CARB toroidal roller bearing
- mounting service

Mounting and dismounting

The paper industry has always led the way by adopting the innovative mounting and dismounting methods developed by SKF. For modern bearing arrangements, the SKF Oil Injection Method has become the industry standard. SKF offers a complete range of tools for efficient bearing installation and removal including:

- oil pumps and oil injectors
- hydraulic nuts HMV .. E
- pullers
- heaters

In order to facilitate mounting and dismounting, most bearings in paper machines are fitted on tapered seatings. The use of adapter sleeves and withdrawal sleeves used to be widespread, but the practice of mounting bearings directly on tapered journal seatings is becoming more and more common. Running accuracy is improved and the cost of the sleeves is saved.

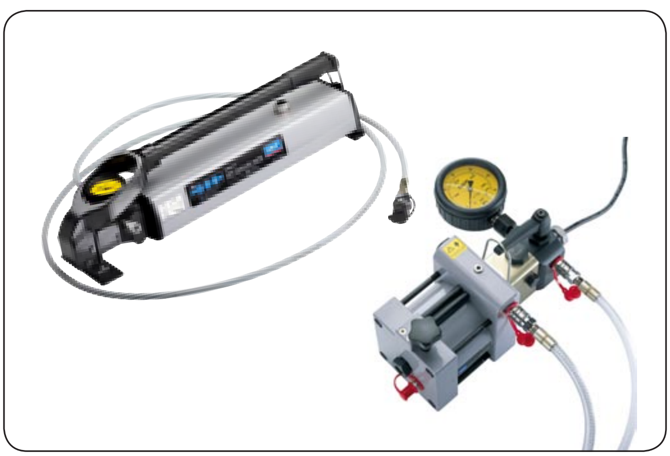
SKF Drive-up Method

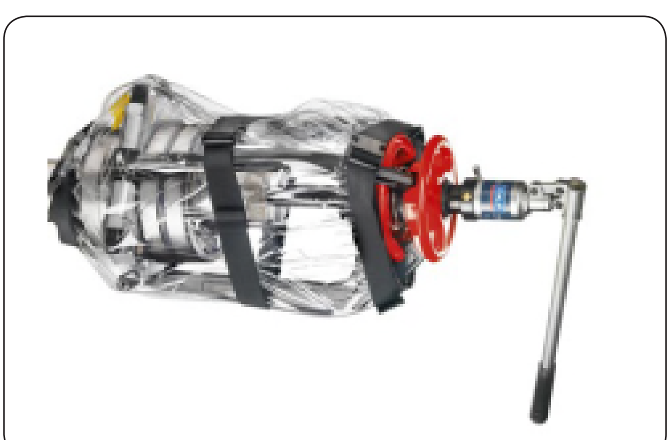
When mounting CARB toroidal roller and spherical roller bearings with a tapered bore, the SKF Drive-up Method is a more precise and less subjective method than measuring the clearance reduction with feeler gauges. Furthermore, this method saves time.

Therefore, SKF strongly recommends the use of this method for mounting and dismounting large bearings, for example, on drying cylinders, suction rolls and press rolls. This method is preferable for small bearings as well. Especially for CARB toroidal roller bearings, the feeler gauge method is difficult to apply.

Top:* *Examples of SKF hydraulic pumps

Bottom:* *Example of SKF pullers: *SKF EasyPull hydraulic puller kit*





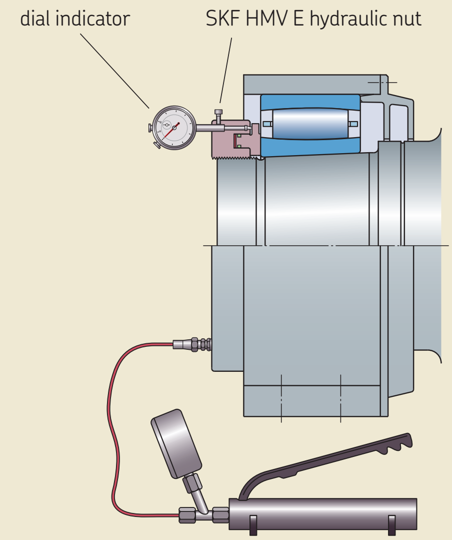
Example of SKF heaters: *SKF induction heater TIH 100m*

SKF can supply suitable tools (→ **fig. 9**) and mounting instructions for general applications as well as specific applications like drying and Yankee cylinders. It is easy to make the calculations required using the SKF Drive-up Method. At skf.com/mount, simply choose the bearing designation, seating type, method and required internal clearance reduction and the calculations are made automatically.

SKF can also supply the software program “SKF Drive-up” making it possible to do your own calculations. Note that the drive-up values obtained are only valid for SKF bearings. For more information, please contact your local SKF sales unit.

A typical printout from the program is shown on **page 11**.

Fig. 9



SKF hydraulic pump 729124 SRB (for nuts ≤ HMV 54 E)
SKF hydraulic pump TMJL 100 SRB (for nuts ≤ HMV 92 E)
SKF hydraulic pump TMJL 50 SRB (for nuts ≤ HMV 200 E)

The equipment for accurate drive-up

Sufficient clearance reduction

A radial clearance reduction – Δ_r – of around 0,0005 × d, where d is the bearing bore diameter, in paper machine applications is sufficient to prevent the inner ring from working loose. Considerable measuring uncertainty with feeler gauges is the reason for the wide tolerance range given in the *SKF General Catalogue*. Note that a bearing mounted to the mean value, using feeler gauges, according to the *SKF General Catalogue*, gets somewhat greater clearance reduction than 0,0005 × d.

Special situations

Sometimes the bearings are mounted with even greater clearance reduction than recommended in the *SKF General Catalogue*. Common reasons are:

- hollow shafts with very large bore, e.g. suction rolls
- heavy loads (very few cases in paper machines)
- experiences from equal or similar applications

One disadvantage with increased clearance reduction is an increased risk of a fractured

Top:
Tools for SKF Drive-up Method

Bottom:
SKF hydraulic nuts HMV .. E series

SKF pressure gauges and dial indicators

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inner ring. Therefore, the following guidelines should be applied for most unheated applications:

- the clearance reduction Δ_r for SKF standard spherical roller bearings should not exceed 0,0007 × d
- the clearance reduction Δ_r for SKF spherical roller bearings with case hardened inner rings (suffix HA3) should not exceed 0,0009 × d

If a greater clearance reduction than normal is chosen, do not forget to check if a bearing with greater clearance than Normal (C3, C4 ...) is needed in order to avoid preload during operation. For heated shafts – like drying cylinders – greater clearance than normal is always needed.

Starting position

In order to obtain reliable drive-up measurements, the influence of form errors must be reduced to negligible proportions. This can be done by driving the bearing up, passing the indeterminate zero position to a starting position that corresponds to a certain small initial interference (→ **fig. 10**). Above this initial interference, reduction in the radial internal clearance may be regarded as being directly proportional to the axial drive-up.

Note that pressurized oil must not be injected to the mating surfaces before the starting position is reached!

Axial drive-up from the starting position

The axial drive-up is best monitored by a dial indicator connected to an HMV .. E nut.

If pressurized oil has been injected to the mating surfaces during the drive-up, wait a few minutes before releasing the hydraulic nut pressure so that the oil can drain from the surfaces.

Interference reduction due to smoothing

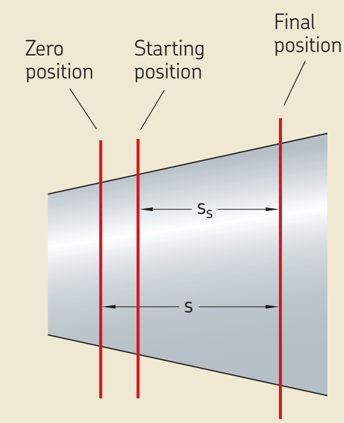
Smoothing is a particularly important consideration for smaller bearings.

The drive-up values given in tables supplied by SKF include an interference compensation for smoothing, valid for one sliding surface, new SKF components and shaft surface roughness R_a = 1,6 µm.

If the mating surfaces are worn, e.g. the bearing has been mounted several times before and/or two sliding surfaces, the interference reduction due to smoothing is different. A calculation is then recommended.

For large size bearings, the influence of smoothing is negligible in most cases. Only if the shaft surface is very rough, then compensation has to be considered.

Fig. 10



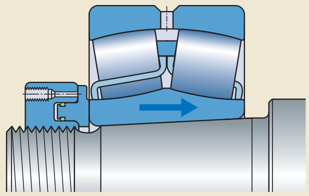
SKF Drive-up Method: *Zero/starting/final position*

Mounting on solid shafts

1. Ensure that the bearing size is equal to the HMV .. E nut size. Otherwise, the pressure listed in the tables supplied by SKF must be adjusted.
2. Determine whether one or two surfaces slide during drive-up (→ **figs. 11, 12, 13** and **14**)
   (→ **fig. 11**), one sliding surface
   (→ **fig. 12**), one sliding surface
   (→ **fig. 13**), two sliding surfaces
   (→ **fig. 14**), two sliding surfaces
3. Lightly oil all mating surfaces with thin oil, e.g. SKF LHMF 300, and carefully put the bearing on the shaft.
4. Drive the bearing up to the starting position (→ **fig. 10**) by applying the HMV .. E nut pressure listed in the tables. Monitor the pressure by the gauge on the selected pump.
   SKF hydraulic pump 729124 SRB is suitable for hydraulic nuts ≤ HMV 54E. SKF TMJL 100 SRB is suitable for hydraulic nuts ≤ HMV 92E, while TMJL 50 SRB is suitable for nuts ≤ HMV 200E.
   As an alternative, the SKF pressure gauge TMJG 100D can be screwed directly into the hydraulic nut.
5. Drive the bearing up the taper the required distance s_s (→ **fig. 10**). The axial drive-up is best monitored by a dial indicator. The SKF hydraulic nut HMV .. E is prepared for dial indicators.

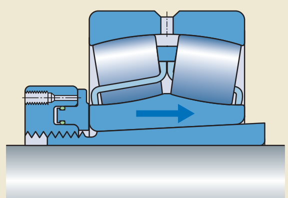
Bearing mounted directly on a tapered shaft:
One sliding surface

Fig. 11



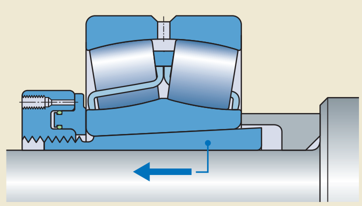
Bearing mounted on an adapter sleeve on a smooth shaft:
One sliding surface

Fig. 12



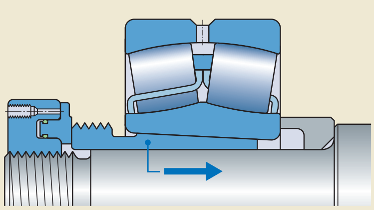
Bearing mounted on an adapter sleeve on a stepped shaft:
Two sliding surfaces

Fig. 13



Bearing mounted on a withdrawal sleeve on a stepped shaft:
Two sliding surfaces

Fig. 14



Mounting on drying cylinders

When mounting spherical roller bearings and CARB toroidal roller bearing on drying cylinder journals, the use of the SKF Drive-up Method is strongly recommended. This is a more precise and less subjective method than measuring clearance reduction with feeler gauges. Suitable tools are shown in **fig. 9**, **page 7**.

SKF spherical roller bearings

1 Lightly oil the mating surfaces with a thin oil (for example SKF LHMF 300).
2 Carefully position the bearing in the housing and on the shaft.
3a For housings bolted to the frame (or frame housings): Check that all rollers are unloaded, i.e. the shaft must be centred in the housing during the drive-up.
3b For housings disconnected from the frame: Lift the shaft with bearing and housing about 5 mm and check that the housing is free to move axially.
4 Drive the inner ring up to the starting position (→ **fig. 10**). Do not use the SKF Oil Injection Method in this case.
5 Drive the inner ring up the taper the required distance s_s (→ **fig. 10**) ±5% (wait a few minutes before releasing the hydraulic nut).
6 If the housing has been disconnected, bolt it to the frame again.
7 Check the housing alignment, e.g. shaft centred relative to the inner cover.
8a For front side housings bolted to frame: Check the axial position of the housing.
8b For front side housings on rockers: Check the position of rockers and base plate.
9 If necessary, adjust the position of the housing/rockers/base plate.

CARB toroidal roller bearings

1 Lightly oil the mating surfaces with a thin oil (for example SKF LHMF 300).
2 Carefully position the bearing in the housing and on the shaft.
3a For housings bolted to a frame: Check that all rollers are free to move throughout the drive-up process.
3b For housings disconnected from the frame: Lift the shaft with bearing and housing about 5 mm and check that the housing is free to move axially.
4 Drive the inner ring up to the starting position (→ **fig. 10**). Do not use the SKF Oil Injection Method in this case.

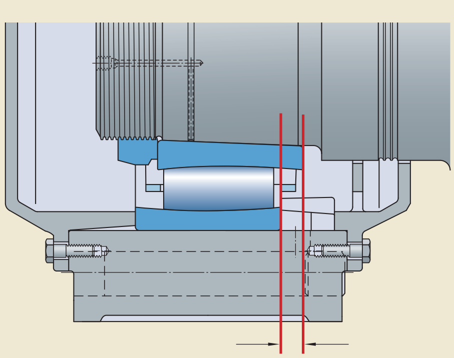
5 Drive the inner ring up the taper the required distance s_s (→ **fig. 10, page 8**) ±5% (wait a few minutes before releasing the hydraulic nut).
6 If the housing has been disconnected, bolt it to the frame again.
7 Check the housing alignment, e.g. shaft centred relative to the inner cover.
8 Check that the axial displacement of the inner ring (relative to outer ring) is within specified values.
9 If necessary, adjust the position of the housing.

Initial axial displacement of housings incorporating CARB toroidal roller bearing for heated cylinders

SKF experience shows that the thermal elongation of drying cylinders is about one millimetre per metre cylinder length at a steam temperature of 150 °C. To compensate for this elongation, it is possible to displace the housing outwards from the cylinder (→ **fig. 15**). To achieve an equal or higher safety margin against preload for spherical roller bearings with C4 clearance, the axial mounting positions shown in **table 1** are recommended (valid for a cold machine).

Initial displacement can be used to increase the available axial clearance for cylinder expansion

Fig. 15



Housing displacement for heated cylinders

Table 1

Cylinder length over	incl.	Steam temperature heading	Initial axial displacement
m		°C	mm
0	4	<160	0–1
0	4	160–200	2–4
4	7	<160	2–4
4	7	160–200	4–6
7	11	<160	4–6
7	11	160–200	6–8

Example of SKF Drive-up calculation: Bearing 23152 CCK/W33 mounted directly on a tapered shaft

SKF Drive-up

2002-05-09

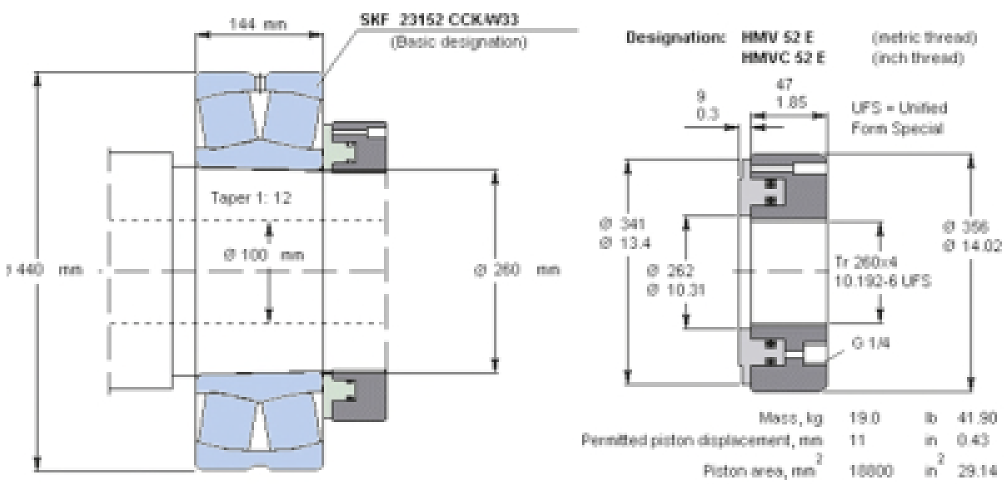
Every care has been taken to ensure the accuracy of the information in this system but no liability can be accepted by SKF for any errors or omissions.
NB! This method applies only for current generation SKF bearings.

Input

Mounting	Bearing directly on shaft, one sliding surface
Number of previous mountings	3 (of same bearing on the same shaft and sleeve)
Required clearence reduction, mm	0.130
Shaft material	Steel E = 210 000 N/mm² ν = 0.3

Results

Force to starting position		54051	N
		12152	lbf
Pump pressure to starting position using	**HMV 52 E**	2.88	MPa
	HMVC 52 E	417	psi
Drive-up distance from starting position		1.618	mm
		0.064	inch



Suitable tools

Hydraulic nut	SKF HMV .. E	
Hydraulic pump with special pressure gauge	SKF 729124 SRB	for nuts ≤ HMV 54 E
	SKF TMJL 100 SRB	for nuts ≤ HMV 92 E
	SKF TMJL 50 SRB	for nuts ≤ HMV 200 E
Dial indicator	SKF TMCD 5 P or SKF TMCD 10 R	

Mounting procedure

1. Lightly oil all mating surfaces with a thin oil, e.g. SKF LHMF 300.
2. Drive the bearing up to the starting position by applying correct pump pressure or force.
3. Drive the bearing up on the taper the required distance while measuring the axial movement of the HMV .. E piston.

Complete bearing designation ....
Machine no.: ....
Position: ....
Mounted by: ....
Date: ....

SKF Drive-up Method

SKF

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Dismounting

In most cases, drying cylinder bearings are mounted in non-split housings and dismounted without disconnection of the housing from the frame. The shaft is then to be centred in the housing (i.e. all rollers in the bearing are to be unloaded) during dismounting.

First, the bearing inner ring is released from the tapered shaft by the use of the SKF Oil Injection Method. The distance between the inner ring side-face and nut must be about twice the drive-up distance. If the distance is longer, there is a risk of raceway damage.

When the inner ring is released, the bearing is to be dismounted from the housing.

It is often difficult to dismount a bearing from a non-split housing. The reasons are that it is difficult to apply an axial dismounting force by hand and that sometimes the outer ring tends to stick in the housing, especially if fretting corrosion has occurred.

For spherical roller bearings the easiest way is to lift the shaft slightly, pull out the bearing and housing and, when they are outside the machine, press out the bearing.

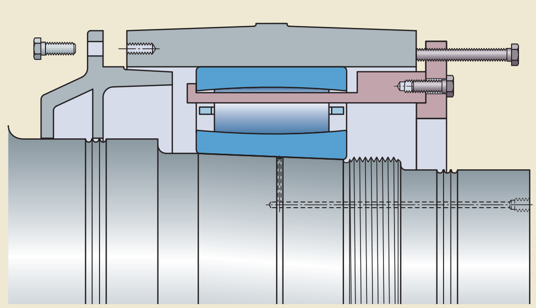
For spherical roller bearings mounted in the machine frame, special tools or methods may be needed.

As the dismounting force on a CARB toroidal roller bearing must be applied on the outer ring, the use of an extractor as shown in **fig. 16** is strongly recommended. The use of the extractor is possible due to the design of the CARB toroidal roller bearing with more space between rollers, cage and outer ring compared with a spherical roller bearing.

For more information about dismounting tools, please contact SKF. Please also contact SKF if you want mounting and dismounting services to be provided. Your local SKF company can offer the resources as well as the equipment to provide proper installation and cost savings by reducing the risk of secondary damage caused by improper handling of the bearings.

Extractor for easy dismounting of CARB toroidal roller bearings

Fig. 16



Condition monitoring

The aim of the condition monitoring system is to measure the condition of "wear" components and other functions that influence machine reliability. The advantage of condition monitoring using vibration analysis is that it acts as an early warning system. Early warning of machinery problems provide time for corrective actions and for planning maintenance actions, including bearing replacement.

Here are examples of components and systems that are measured:

- bearings
- felts
- gearboxes
- electric motors
- roll covers

Here are examples of "wear" components that are manually inspected instead of monitored:

- seals
- doctor blades

Multi-parameter monitoring

Developed jointly by SKF Condition Monitoring and the SKF Engineering & Research Centre in the Netherlands, multi-parameter monitoring is the most comprehensive, reliable and accurate approach to machinery monitoring and analysis. Collecting and analyzing multiple measurement parameters greatly increases the capability to accurately and readily identify bearing faults and other machinery problems.

By measuring a number of machinery parameters – from vibration acceleration, velocity and displacement to process parameters like speed, temperature, current, pressure and flow – users gain essential insights into a machine's condition. Advanced analysis techniques, like Acceleration Enveloping, enable analysts to take the guesswork out of maintenance by supplying the information needed to take action toward preventing unscheduled downtime

Vibration

Traditional low frequency vibration monitoring continues to be an essential in identifying problematic machinery conditions. Generally, malfunctions that cause vibration and loss of machine efficiency ultimately result in damage to the machine or its components. While low frequency vibration analysis can be an effective indicator of bearing damage, it is not typically the earliest indicator of a bearing problem.

Acceleration enveloping

For early detection of impulsive machine faults, enveloping techniques are very effective. Enveloping enhances repetitive signals caused by the pulses emanating from a damaged bearing, for example. In the early stages, these types of bearing flaws generate signals that may go undetected amid general machine vibration "noise." The use of envelope detection makes it possible to pinpoint not only the problem bearing or gearbox, but also the specific bearing or gear component with the fault. This is the same technique that SKF has used in its own factories since the 1970s to check bearing quality.

Operator tools

Economical, easy-to-use, handheld instruments provide a quick and basic indication of problem areas.

The SKF Machine Condition Advisor is a pocket-sized, go anywhere measurement device that provides an overall "velocity" vibration reading and automatically compares it to pre-programmed International Organization for Standardization (ISO) guidelines. An "alert" or "danger" alarm displays when the measurement exceeds those guidelines. Simultaneously an "enveloped acceleration" measurement is taken and compared to established bearing vibration guidelines to verify conformity or indicate potential bearing damage. The SKF Machine Condition Advisor also measures temperature using an infrared sensor to indicate uncharacteristic heat.

SKF Machine Condition Advisor

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SKF Machine Condition Detector

SKF Microlog Analyzer AX Series

SKF Microlog Analyzer GX series

SKF Microlog Inspector and SKF Wireless Machine Condition Detector

The hand-held product range also features the SKF Machine Condition Detector, which is a hand-held probe that collects and compares operating data to provide advance warning of costly machine problems. Red, yellow and green lights indicate machine status instantly for assessment of bearing and lubrication problems.

Portable data collection

Portable data collectors, like the SKF Microlog Inspector and Wireless Machine Condition Detector, are rugged high-performance portable computers that replace paper inspection trails by documenting inspections with accurate, consistent, and actionable information. The SKF Microlog Series Analyzers take route-based data collection and stand-alone analysis to a new level with the large screen four-channel AX Series. Modular flexibility and high performance data collection make the SKF Microlog Series a complete portable vibration analysis package when used with SKF @ptitude Monitoring Suite software.

Continuous monitoring

On-line monitoring for round-the-clock bearing and machinery analysis offers significant advantages in a paper-making environment. With the SKF Multilog On-line Systems IMx, DMx, and WMx, permanently installed sensors collect data from hard-to-reach or more critical machine sections, providing continuous monitoring and eliminating the need for manual or walk-around data collection.

The SKF Multilog On-line System IMx is the new standard for on-line monitoring of paper machines. It comes in two versions; IMx-S for field installation (includes industrial housing) or IMx-T for mounting in a 19" instrument cabinet. Its modular design enables it to be used for other areas (e.g., pulp mill). Together with SKF @ptitude Analyst and Observer software, which are part of the SKF @ptitude Monitoring Suite, the SKF Multilog IMx provides a complete system for early fault detection and prevention, automatic recognition to be able to correct existing or impending conditions and advanced condition-based maintenance to improve machine reliability, availability and performance.

The SKF Multilog On-line System DMx provides distributed vibration based machinery protection and condition monitoring in a single device, for use in both conventional and hazardous areas. The SKF Multilog DMx offers a 4-channel vibration monitoring solution that for the first time enables the requirements of critical machinery monitoring, from transducer to dynamic data processing, to be fulfilled by an intrinsically safe device (e.g. for use on critical equipment in the mill's power house). The SKF Multilog DMx provides two distinct vibration monitoring capabilities in the same module:

- Machine protection measurements, in compliance with the API 670 standard, to react to a vibration alarm that may signify a looming catastrophic failure.
- Condition monitoring measurements to be used by sophisticated software to predict a potential catastrophic failure.

The SKF Multilog On-line System WMx is a compact, eight-channel, field mounted monitoring device that communicates using industry standard 802.11b/g wireless networking. It collects acceleration, velocity, displacement, temperature and bearing condition data and automatically uploads it for viewing, alarm evaluation, and analysis in SKF @ptitude software.

SKF Multilog On-line System IMx-S

SKF Multilog On-line System DMx

SKF Multilog On-line System WMx

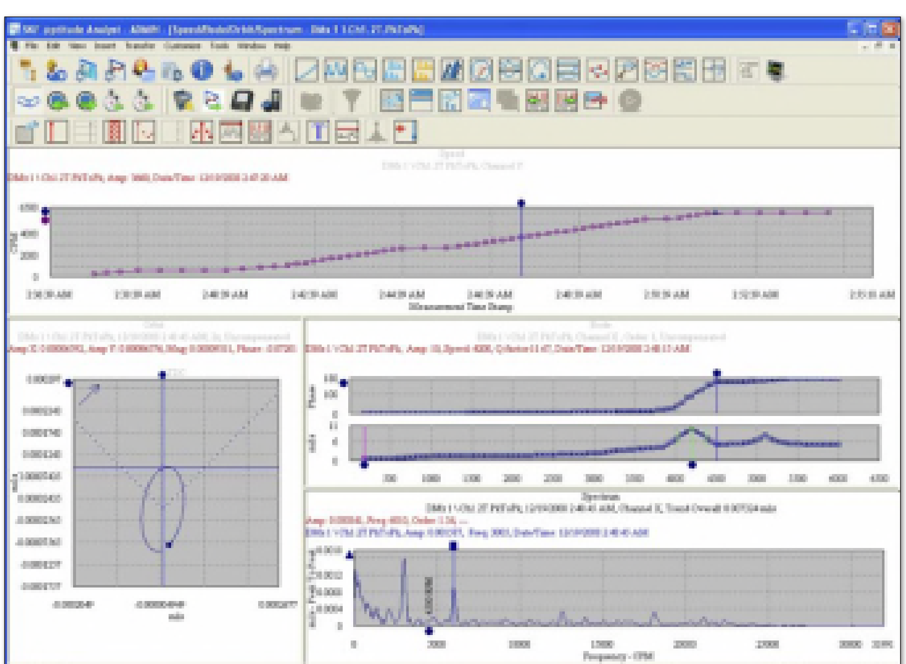
SKF @ptitude Analyst

SKF @ptitude Analyst is a comprehensive software solution with powerful diagnostic and analytical capabilities. SKF @ptitude Analyst provides fast, efficient and reliable storage, analysis and retrieval of complex machine information and makes the information accessible throughout your organization. Its advantages are:

- One software program to manage machinery condition data from portable and on-line devices
- One installation with limitless expansion capabilities
- Easy to learn and use for novice or experienced users
- Interconnectivity with other software programs and systems
- Easy personalization for individual users

When you select SKF @ptitude Analyst, you are immediately equipped to integrate and analyze data from the full range of SKF data collection devices. This enterprise-wide software platform enables operations, maintenance and reliability staff to view the integrated data and communicates the information to each department in a customized format to meet individual user needs. SKF @ptitude Analyst can incorporate data from other sources such as OPC servers and seamlessly interface to your SAP, Computerized Maintenance Management System (CMMS), Enterprise Resource Planning (ERP) or other information management systems.

SKF @ptitude Analyst's integrated platform forms the hub to share information, foster teamwork, and facilitate consistent and reliable decision-making across functional departments. The addition of SKF @ptitude Decision Support automates reliability maintenance decision-making by identifying probable faults with an asset or process, then prescribing appropriate action.



SKF @ptitude Analyst software

Standstill precautions

Despite the use of water extractors, many oil lubrication systems have small quantities of free water, especially in the forming and press section. Grease lubricated bearings may also have free water in the lubricant.

The highest risk of water ingress probably occurs during high-pressure cleaning of machine frames, wires and felts. Free water in the lubricant, especially water mixed with cleaning chemicals, will rapidly start a corrosion process on bearing surfaces when the machine is at a standstill. There are some different ways of avoiding such corrosion:

- Never direct the high pressure spray nozzle towards the sealing gap.
- Keep the water outside the bearing by more efficient seals.
- With oil lubrication, remove the free water by using more efficient water extractors.
- Replace the contaminated lubricant (grease or oil in a bath) with fresh and clean lubricant.

The last alternative is the most commonly used method for grease lubricated bearings. Fresh grease is injected just before closing down while bearings are still rotating.

The most common method with oil lubrication is to remove the water by increasing extractor capacity before closing down, e.g. using a portable vacuum extractor. In some circulating oil systems, it is even possible to let the oil continue to circulate during standstill, which is of course an advantage.

If the machine is closed down for some time, you should perform oil analysis to determine water content. Oil circulation should not be stopped if the water content is above 200 ppm. When oil circulation is stopped, a rust inhibiting agent should be sprayed on the bearings. SKF recommends SKF LHRP 2 which provides long term indoor and outdoor protection to ferrous and non-ferrous surfaces. This product deposits a slightly greasy, thixotropic film. The SKF LHRP 2 is compatible with mineral oils and PAO or PAO/ester oils which are commonly used in paper machines. It is not compatible with polyglycol oils that are often used in industrial gearboxes. For other types of oil, please contact SKF.

SKF Anti Corrosive LHRP 2

How to store spare bearings

Unused bearings

Unused bearings should be stored in their original SKF packaging in an indoor low humidity storage area.

The storage area should:
– be clean
– be dry
– be free from air flow
– have air conditioning if the relative humidity in the area is >60% (peak at 65% accepted)
– be free from vibration
– have a constant temperature. Max temperature fluctuation: 3 °C/48 hours.

Table 2

Recommended maximum storage time (from the packing date)[1)]

Relative air humidity	Temperature	Storage time
%	°C	years
60	20–25	10
75	20–25	5
75	35–40	3
Uncontrolled tropical conditions		1

[1)] Recommendation is valid for open bearings only. For lubricated (sealed) bearings, recommended time is 3 years maximum.

Table 2 gives recommended maximum storage times.

Used bearings

Paper mills have a number of spare rolls in their roll store. Some of these rolls, like suction, press and calender rolls, are regularly reground and replaced in the machine, while others are only stored for security reasons. The latter type of rolls can be stored for a long time.

Before taking out a roll from the machine, it is normally high pressure cleaned. The roll is then stored, often for several weeks, before regrinding. During this period, there is a great risk of corrosion if water is present in the housing.

When the roll has been taken out from the machine, SKF's recommendations should be followed. However, SKF's experience is that this is often not done before the regrinding, thus resulting in bearing corrosion. Therefore, to be on the safe side, grease lubricated bearings should be regreased during rotation, after the cleaning procedure, just before the machine is stopped. Note that the grease quantity must be large enough to press out all contaminated grease. If the cleaning of the rolls takes place outside the machine, it is important to cover the seals so no water can enter through the seals. For oil lubricated bearings the housing should be flushed with fresh, clean oil with very good anti-corrosion properties. If possible, spray an anti-corrosion agent such as SKF LHRP 2 on the bearing. SKF LHRP 2 is compatible with mineral oils and PAO or PAO/ester oils which are commonly used in paper machines.

Bearing storage

For bearings that are going to be stored for a lengthy period, SKF recommends the following:

- In the case of grease lubricated bearings, dismount the bearing housings and remove all old grease from the bearings and the housings.
- If possible, dismount the bearings from the journals.
- Wash the bearings with a very thin clean oil.
- Inspect the bearings to ascertain whether or not they can be used for further service in the machine.
- Remount the bearings and the housings.
- Lubricate and protect the bearings against corrosion. This can be done with the same lubricant that is used in the machine.
- If possible, place the roll in a store where it is supported by the bearings and subjected to perpetual rotation.

- Bearings that are to be stored under static conditions, either dismounted or on the journals, must be protected against corrosion. Grease lubricated bearings can be packed with fresh grease with good anticorrosion properties, oil lubricated bearings can be protected with a rust inhibiting e.g. SKF LHRP 2. Up to one year's protection can be obtained. Thereafter, preservation needs to be repeated. The SKF LHRP 2 is compatible with mineral oils and PAO or PAO/ester oils which are commonly used in paper machines, thus the bearings do not need to be cleaned. For other types of oil, please contact SKF.

How to avoid transport damage

The best and only fully safe way to avoid bearing damage is to transport the bearing in its original packaging and only unpack the bearing at the final destination.

When installed bearings are transported, the rollers should either be preloaded or completely free to move. When the rollers are preloaded, there is usually no risk of sliding and smearing. However, during transportation under bad conditions, small movements sometimes occur causing false brinelling.

Since the rolling element weight is relatively small, the contact load in a bearing with free rollers is usually not large enough to cause smearing even if the rollers are sliding in the bearing. However, during transportation under bad conditions, the rolling element weight might be enough to cause smearing.

The best way to reduce the risk of damage in installed spherical roller bearings is to axially preload one of the roller rows. The axial preloading should be around 10% of the C value. In the bearing, the rollers in one of the rows will be preloaded and the rollers in the other row completely free to move. This method cannot be used for CARB toroidal roller bearings because of the very small contact angle for these bearings. With preloading, there would be a risk of indentations. For CARB toroidal roller bearings, SKF recommends transportation with all rolling elements free to move. This is achieved by positioning the housing so that the radial internal clearance is the same in all positions of the bearing.

Failure modes

Most bearing damage in modern paper machines consists of minor surface damage as a result of inadequate lubrication and/or contamination or improper handling during mounting or dismounting. However, corrosion during standstill is perhaps the most common problem today. Other reasons for bearing damage are vibration marks and passage of electric current.

One bearing may be subjected to several failure modes at the same time, though these modes are in different stages of development. This is illustrated by the following examples of failure modes.

Normal fatigue

When a rolling bearing is rotating and is loaded to a certain level, it is subjected to a phenomenon called fatigue. This occurs when a rolling body creates high, alternating stresses beneath the raceway surface. The most dangerous stresses are the shear stresses which change direction during every passage of a rolling element. If sufficiently high, these stresses cause a crack to form below the raceway surface (→ **fig. 17**). With the passage of time, this crack grows until eventually the material above the crack breaks away.

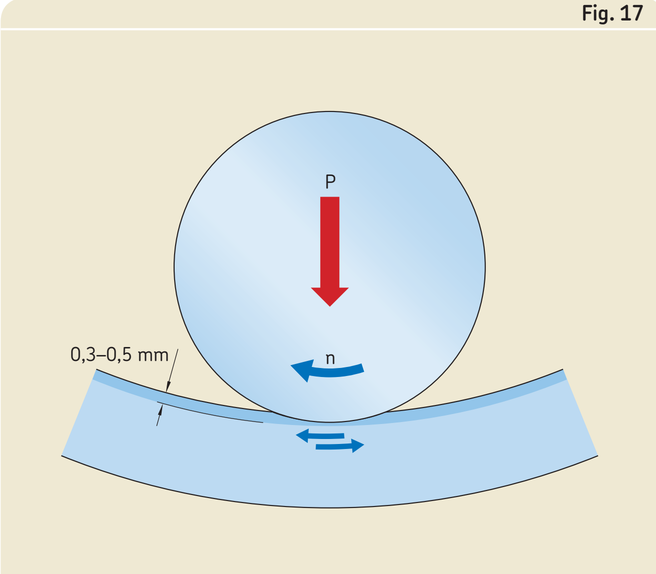
Normally, paper machine bearings are selected on a basis of life calculation using the well-known ISO equation for basic rating life. By definition, 90% of the bearings will reach the calculated life before the first sign of normal fatigue occurs.

Fig. 18 shows an early stage of spalling in a drying cylinder bearing. Note that the size of the spall at this early stage is only a few millimetres. Note too that this bearing has been running with adequate lubrication. The aim for all bearing applications is that the bearings should not be damaged before normal fatigue develops. Unfortunately, it is rare for paper machine bearings to run until normal fatigue occurs.

Bearings might be damaged due to a number of reasons and fail prematurely, meaning that the service life of the bearing is shorter than the calculated life. Research by SKF shows that water also has a major influence on the bearing service life. The SKF recommendation is that water content in the lubricant should not exceed 200 ppm (0,02%). According to laboratory tests, water content of 0,1–0,5% halves the bearing service life.

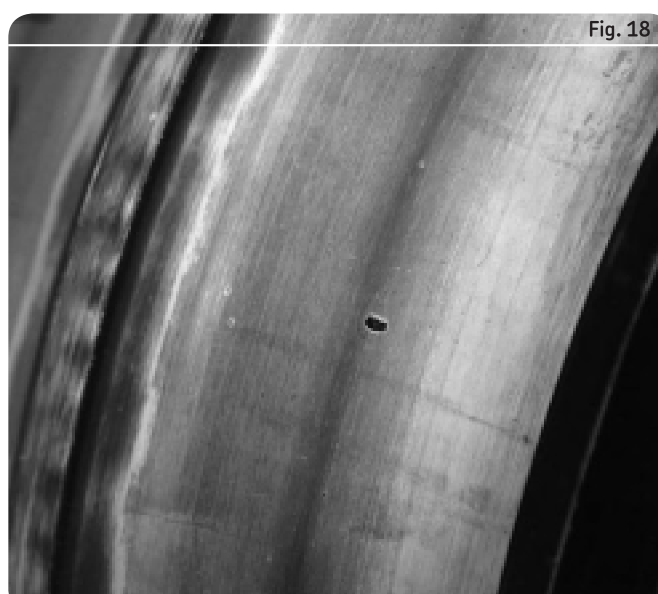
Spalling caused by fatigue

Fig. 17



Spalling caused by normal fatigue

Fig. 18



Premature failure due to indentations

If the lubricant contains hard contaminant particles larger than the oil film thickness, or the bearings are handled in an improper way during mounting or dismounting, there is a risk of heavy indentation to the surfaces in the rolling contact. Raised material, due to plastic deformation by heavy indentations, causes fatigue. The reason is the load concentration on the raised rim around the indentation.

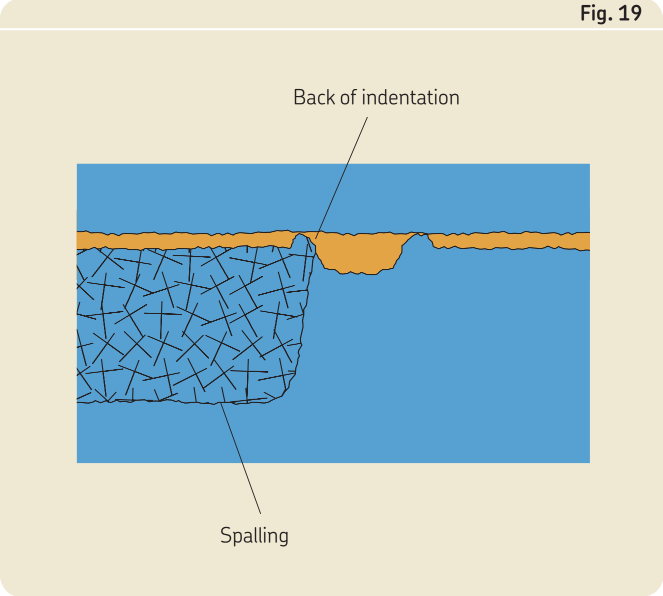
When the fatigue reaches a certain level, it leads to premature spalling starting at the far end of the indentation (→ **figs. 19** and **20**). The spalling starts as a crack beneath the surface and occurs sooner than normal subsurface spalling. This is why it is called premature. Subsurface spalls and also spalls starting at an indentation, are normally at least one millimetre in size.

The SKF Life Method makes it possible to calculate the life reduction caused by indentations. The most important operating data required for the calculation are the bearing type and size, the rotational speed, bearing load, oil viscosity at operating temperature and the size, hardness and concentration of the contamination particles.

Lubricant cleanliness, and careful handling during mounting are of course important factors in the prevention of heavy indentations. In some papermills, around half of the paper machine failures are caused by improper mounting, due to lack of knowledge and improper mounting tools.

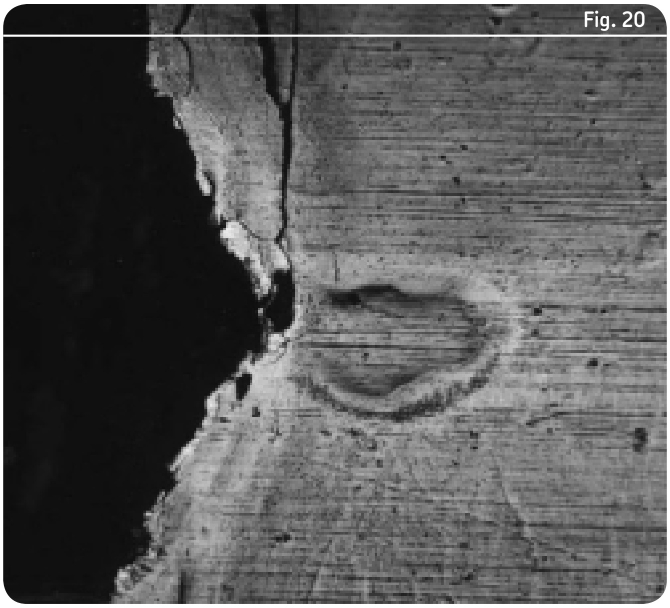
Spalling caused by indentation

Fig. 19



Spalling caused by indentation

Fig. 20



Premature failure due to abrasive wear

Abrasive wear is a relatively mild form of wear and does not cause any major problems until the internal geometry of the bearing changes too much. Abrasive wear occurs between two mating surfaces sliding in relation to each other. The sliding motion causes abrasive wear of the surfaces in much the same way as when a surface is sandpapered.

Sliding would not be expected to occur in rolling bearings, but in actual fact, there is always some sliding in the rolling contact. In most cases, this sliding is very small and therefore it is also called a micro slip.

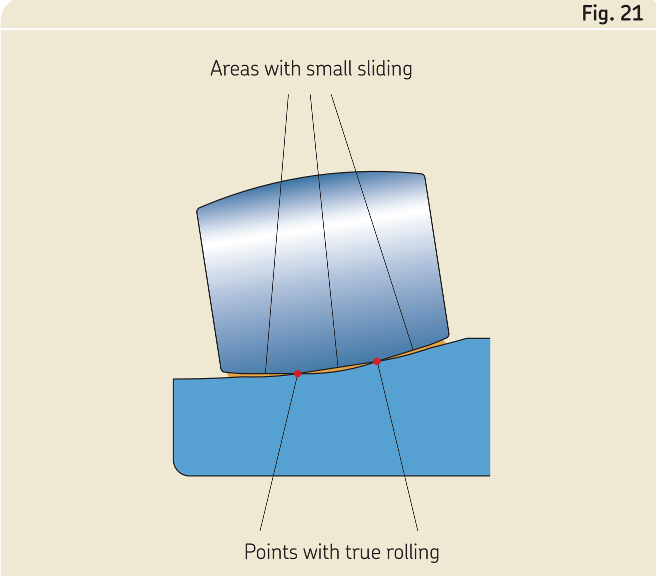
Fig. 21 shows how micro slip occurs in spherical roller bearings, which are the most common type of bearings in paper machines. The roller surface speed will be highest at the middle of the roller where the diameter is greatest. The diameter at the ends of the roller is smaller which means a lower surface speed. This difference in surface speeds will lead to the micro slip in the rolling contact. While in rolling contact, the distance slipped is short and long scratches will not be produced by contaminants, although small particles will abrasively wear the raceway surfaces.

Fig. 22 shows a bearing where abrasive wear has led to fatigue spalling. Two ridges remain where true rolling has taken place. Where micro slip has occurred, there has been abrasive wear. When loading is concentrated at these ridges, they become overloaded and fatigued, i.e. premature spalling occurs. The oil is almost certain to be equally contaminated in these true rolling zones, but there is negligible abrasive wear. The two bands where true rolling has occurred are clearly visible in the photo showing a Yankee cylinder bearing (→ **fig. 22**). Note that the bearing in the photo is of an old design.

The best ways to avoid abrasive wear in paper machine bearings are to increase the oil film thickness, to improve the cleanliness of the oil, and use an oil with good AW properties.

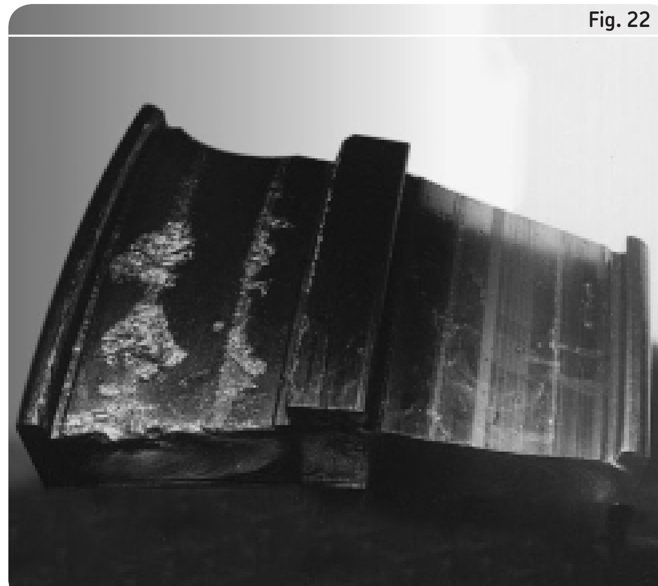
Small sliding in spherical roller bearings

Fig. 21



Overload and spalling caused by wear

Fig. 22



 4th Edition SKF

Polishing wear

The raceway surfaces of new roller bearings are shiny but not highly reflective. Therefore, mirror-like surfaces in a roller bearing mean that something, sometimes referred to as polishing, has happened during operation.

The most usual explanation for mirror-like raceway surfaces in a rolling bearing is that the bearing has been poorly lubricated, which normally means a thin oil film. A thin oil film allows metal-to-metal contact that leads to wear and plastic deformation of asperities (→ **fig. 23**).

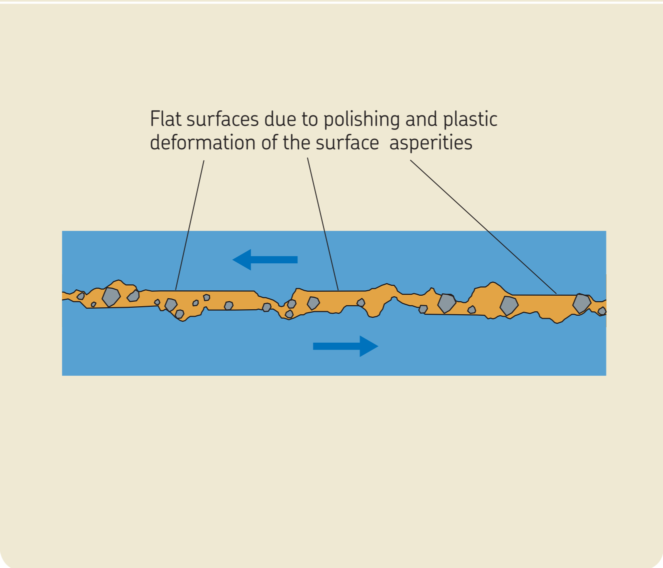
Mirror-like surfaces are an advantage as long as wear and plastic deformation of the surface asperities are mild, i.e. the "treatment" of the surface is confined to the asperities only.

Sometimes mirror-like surfaces are combined with heavy wear (→ **fig. 24**). The question is how the surfaces can wear down by up to one millimetre and still be mirror-like? The explanation is that the surfaces have not been able to build up an oil film, despite the surface roughness improvement produced by the first polishing action. Viscosity of the oil is too low and there are a lot of very small abrasive contaminant particles in the oil. The bearing has been subjected to continuous polishing wear.

These microparticles are always present in a lubricant, but not every bearing with a thin oil film becomes polished. Why is this? It is presumed that there are additional factors influencing the start of the polishing wear process, e.g. a certain combination of low speed, heavy load and thin oil film. The best way to avoid this kind of abrasive polishing wear is to increase the oil film thickness and use oils with good EP or AW properties.

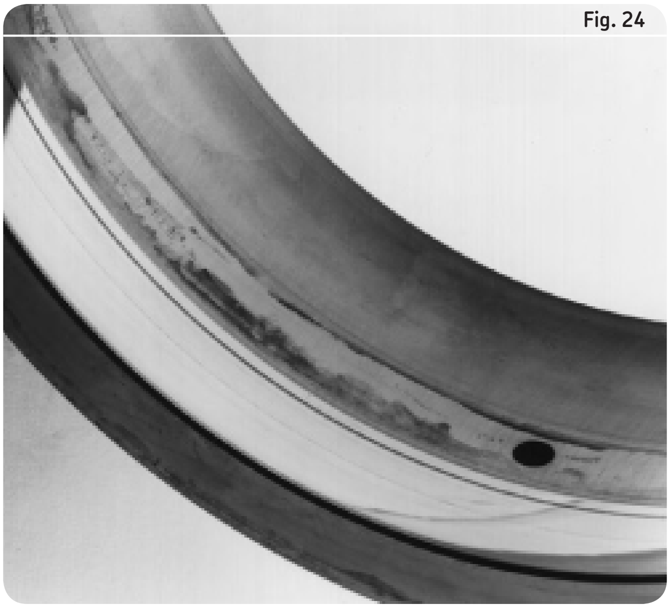
Polishing wear causes mirror-like surfaces

Fig. 23



Polishing wear: *Mirror-like surface combined with heavy wear*

Fig. 24



Surface distress

There is a risk of surface distress in all bearings with a thin oil film. That risk is increased if there is sliding in the rolling contact. As stated earlier, rolling bearings show some sliding (also called micro slip) in the rolling contacts. Surface distress falls into two categories – general and local.

General surface distress is the consequence of asperities coming in direct contact under mixed or boundary lubrication conditions (→ **fig 25 a**). When the loading and the frictional forces rise to a given magnitude, small cracks form in the surface and these cracks can in turn develop into microspalls (→ **figs. 25 b** and **25 c**). Generally, these microspalls are not visible to the naked eye, because they are only a few microns in size. The surface just looks dull and grey, but under a microscope a number of cracks and spalls can be detected.

Microspalls can also be caused by the EP additives being too aggressive, especially at elevated temperatures.

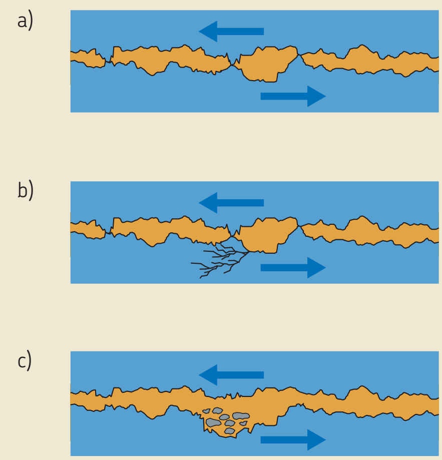
Figs. 26 and **27** show surface distress in an advanced stage, i.e. how microspalls have developed to medium size spalls of 10 to 100 µm in size. Note that the debris from microspalls can also increase the abrasive wear.

The best way to avoid general surface distress is to increase the oil film thickness and use oils with good EP or AW properties.

The second category of surface distress is called local surface distress.

Raised rims, as around heavy indentations, are even more likely to cause surface distress because the lubricating oil film can easily be broken at these local defects.

Fig. 25

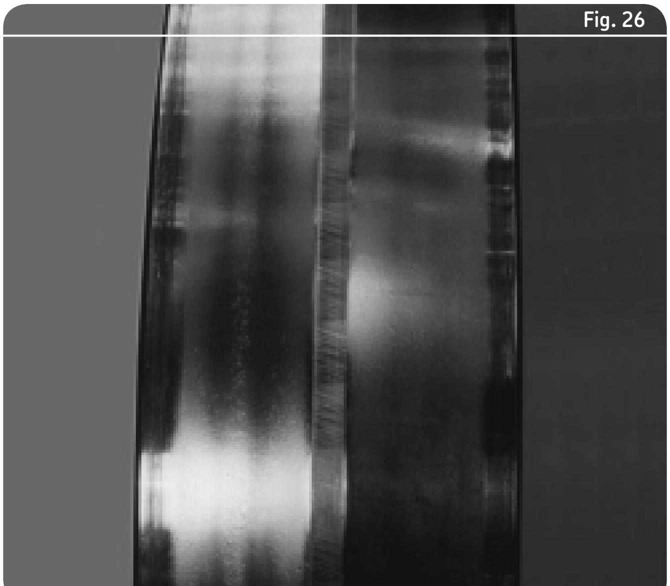


Surface distress: *Microspalling caused by metal-to-metal contact*

The risk of local surface distress and the load concentration on the raised rims are the reasons why bearings with heavy indentations should be replaced as part of the preventive maintenance programme.

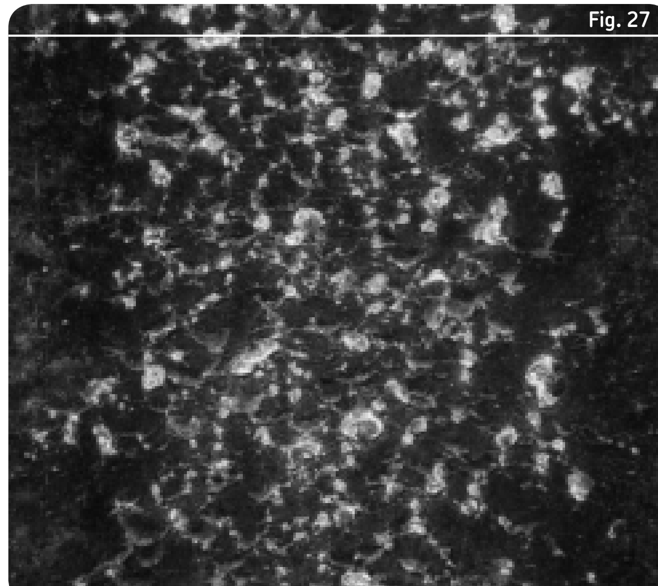
Dull surface due to microspalling

Fig. 26



Microspalls in high magnification

Fig. 27



Smearing

Smearing, just like most other lubrication-related damage, occurs between two mating surfaces sliding in relation to each other. The difference is that smearing is a severe type of wear that occurs at rolling contacts when the oil film is broken due to high sliding speed and/or heavy loads.

Therefore, smearing is not common in the rolling contact under normal operating conditions. The sliding speed must be much higher than in the slip mentioned on earlier pages.

One critical position is, for example, where the rollers are accelerated as they enter the loaded zone in bearings operating at high speeds. Another example of critical positions is the surfaces for cage centring.

In the old-fashioned spherical roller bearing design with a central integral flange on the inner ring (→ **fig. 28**), there is a great risk of smearing between the roller end and the flange. SKF does not manufacture such bearings today.

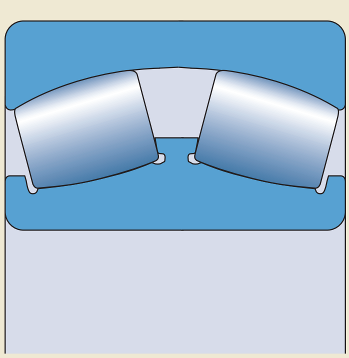
Note that the two retaining flanges, that SKF also has on CA bearings, (→ **fig. 4**, *chapter 1*, *General requirements and recommendations*, **page 6**) are never in contact with the roller ends and therefore never cause smearing.

The heat generation in sliding contacts mentioned earlier, may be so great as to cause the oil film to collapse. The two surfaces melt together at the points of metal-to-metal contact (→ **fig. 29**). This welding process causes material to be transferred from one surface to the other, which leads to higher friction as well. This phenomenon is also called galling, scuffing or adhesive wear.

Smearing is the most dangerous type of surface damage as the surfaces affected normally become progressively rougher. As the rough surfaces lead to decreased oil film with a lot of metal-to-metal contact, the bearing is in a vicious circle. In heavily loaded bearings, smearing may lead to serious damage like blocked rollers due to a broken cage.

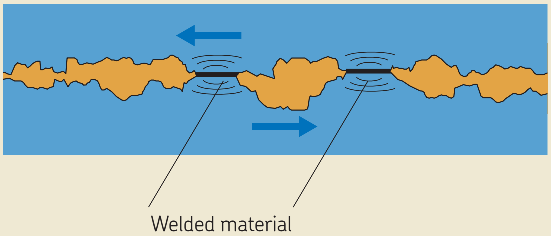
Old design, still used by some manufacturers

Fig. 28



Heavy sliding causes smearing

Fig. 29



In lightly loaded bearings, which are common in paper machines, smearing normally leads to premature spalling, (→ **figs 30** and **31**).

The best ways to avoid smearing in normally loaded bearings like those in press rolls are to increase the oil film thickness, to use lubricants with efficient EP additives and to reduce the water content in the lubricant.

In bearings with radial loads below those recommend in the *SKF General Catalogue*, SKF recommends the use of NoWear bearings with coated rollers (L5DA). With such bearings, the standard lubricant used for the other rolls in the calender can be used.

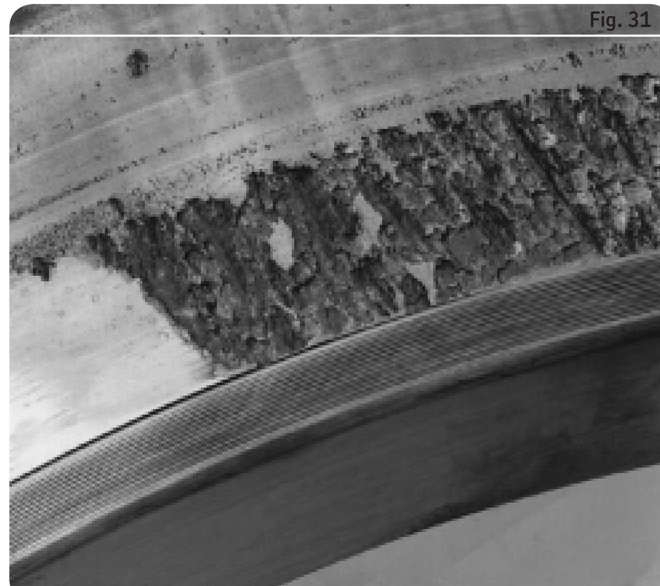
There are also some polyglycol oils on the market that can prevent smearing. However, consideration needs to be given to cost and environmental issues when using such oils.

Some polyglycols have a tendency to dissolve water, which in turn will decrease the lubricant viscosity and increase the risk of corrosion and hydrogen embrittlement.

Figs 30 and 31: Smearing normally leads to premature spalling

Fig. 30

Fig. 31



Corrosion

Corrosion is perhaps the most common reason for short service lives in paper machine bearings. Bearing applications in paper machines are exposed to the ingress of water, especially in the forming and press section of the machine. Water, either from the papermaking process itself or from hosing down when the machine is cleaned, is very dangerous. The risk of corrosion is highest in non-rotating bearings, e.g. in the roll store. If a non-rotating bearing has free water in the lubricant, this water will accumulate at the bottom of the bearing. Concentration of the water will be highest at a certain distance from the rolling contact (→ **fig. 32**). The reason is that the free water in the oil, being heavier, will sink until it comes to a suitable gap between the roller and the raceway.

The bearings in the dryer section are subjected to another type of corrosion. High temperatures and aggressive chemicals may cause a type of corrosion referred to as etching. For example, some EP additives have proved to be aggressive at high temperatures.

Deep-seated rust usually leads to premature, extended spalling as the material is subjected to structural change and the area of the load carrying surface is reduced to such an extent that overloading occurs.

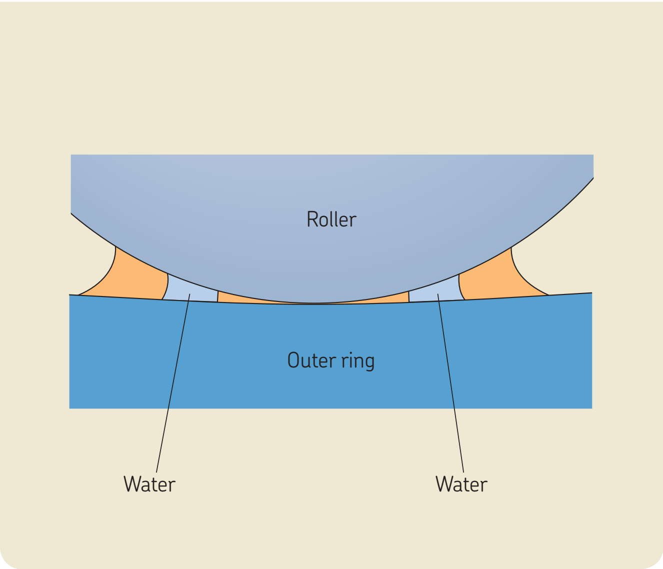
Fig. 33 shows a bearing which has developed deep-seated rust under static conditions. The best way to avoid corrosion is to keep the lubricant free from water and to use a lubricant with good rust inhibitor additives.

Cracks

Normally some kind of initial damage is needed to cause ring cracking. Examples of initial damage are surface distress, indentation, smearing, corrosion, handling marks and mounting damage. The best way to avoid ring cracking is to use special through hardened bainite such as SKF X-Bite or case hardened rings. Therefore, SKF recommends SKF X-Bite or case hardened inner rings (HA3 or ECB) for drying and Yankee cylinder bearings.

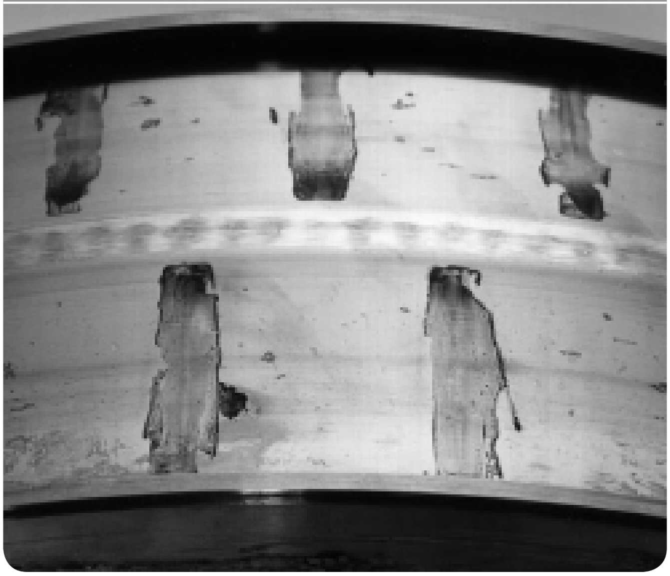
Water concentration in a stationary bearing

Fig. 32



Deep-seated rust under static conditions

Fig. 33



How to avoid surface damage

As mentioned, bearings in paper machines are subjected to different types of surface damage, mainly caused by insufficient lubrication. As such damage is often a combination of two or more failure modes, it is difficult to propose a single action which can prevent the damage. The best lubrication conditions, which result in the smallest risk of surface damage, are obtained when all the guidelines in this handbook have been followed. However, **table 3** can give some guidance on suitable actions when different types of surface damage have occurred.

In extreme cases, like smearing because of zero load in calenders, NoWear bearings can be a problem solver. Please contact SKF for further details.

There are other special guidelines for the avoidance of damage to bearing contact surfaces. For example, in order to avoid premature spalling, it is also necessary to ensure that hard particles and water are removed from the lubricant. Further information can be found in *Chapter 7*, *Lubrication*, *Cleanliness control*, (→ **pages 17–23**).

Sometimes one or two parameters are more important than the others. Viscosity ratio κ is one example of such an important parameter. Therefore, SKF has some special guidelines for oil lubricated paper machine applications with respect to these parameters.

Changes in running conditions, especially temperature, result in oil viscosity variations. So even if κ = 1 is considered adequate lubrication, it is preferable to choose a lubricant to reach a κ value between 2 and 4.

Sometimes it is not possible to reach the recommended κ value. In such cases, SKF recommends checking the minimum acceptable κ value, called κ_{min}. The κ_{min} is based on field experience and is restricted to paper machines only.

$$\kappa_{min} = n\,d_m/80\,000$$

where

κ_{min} = minimum value for κ
n = rotational speed, r/min
d_m = bearing mean diameter, mm

Recommended actions to avoid surface damage

Table 3

Recommended actions	Type of damage Abrasive wear	Polishing wear	Surface distress	Smearing (welding at normal load)	Smearing (welding at light load)	Corrosion etching	Inner ring cracking
Increase the oil film thickness (κ-value)	X	X	X	X			
Improve AW additives	X	X	X				
Improve EP additives		X	X	X			
Decrease activity of EP additives (sulphur/phosphorous type at elevated temperatures)			X			X	
Improve water extraction			X			X	
Improve particle removal	X		X				
Improve rust inhibitor additives						X	
NoWear	X		X	X	X		
SKF X-Bite or case hardened inner ring (HA3 or ECB)							X

Restriction

If calculated κ_{min} is below 0,25, κ_{min}=0,25 should be chosen.

The equation for the κ_{min} value is based on the risk of surface distress and smearing which, in turn, are dependant on the bearing size, load and speed.

The κ_{min} value cannot always be reached in drying cylinders without journal insulation or with very high steam temperatures. Dryer bearings in such machines are therefore subjected to a higher risk of surface distress. High filtration rates and lubricant cleanliness are highly important in such cases.

When optimal lubrication is required, each application has to be calculated separately by SKF.