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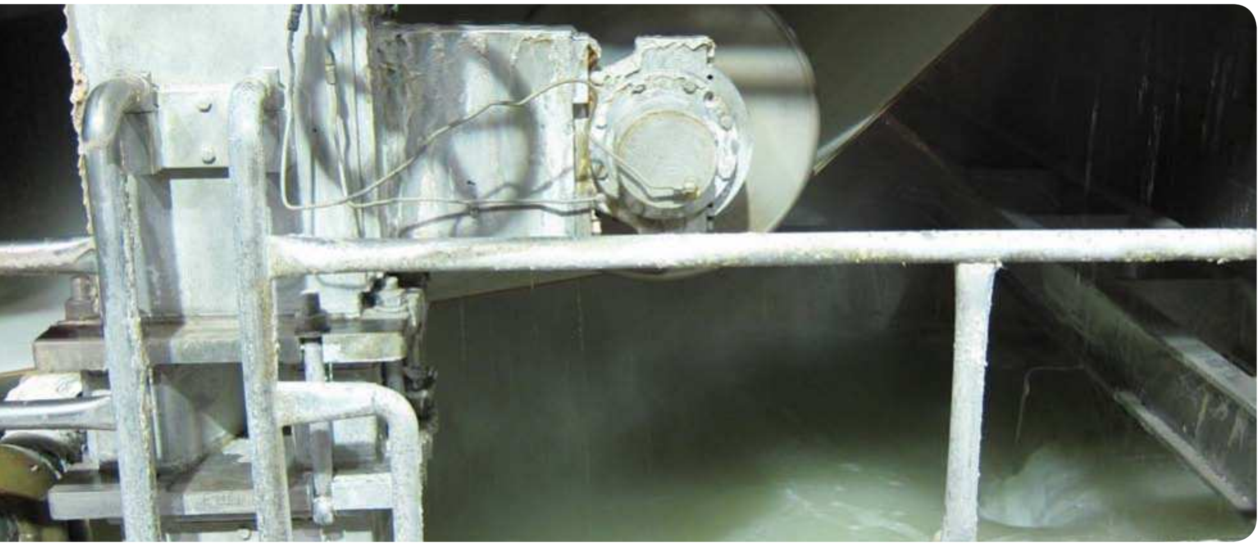
SKF Pulp & Paper Practices



Contamination, corrosion and inadequate lubrication

"In my business development role for SKF self-aligning bearings I work with lots of customers from many different industries all over the world. The industries they are involved in are different and their processes, equipment and applications vary, but a common theme in my conversations with them is their need to increase output and efficiency. I believe that self-aligning bearing systems can often make a significant contribution to this."

The handling and initial mounting of bearings can have a significant influence on how they perform in service in all industries. This is also true for those bearings that suffer from contamination either prior to mounting or in service. While my customers in the mining and steel industries would be amused to hear a paper mill described as a harsh environment, the fact of the matter is that a large percentage of bearings that fail prematurely in the paper industry do so due to liquid contamination.

This issue of SKF Pulp & Paper Practices looks at the things that can be done about contamination in the pulp and paper industry. There are a number of options of course, but sealed self-aligning bearings can often be a good choice when liquid contamination is an issue. Such bearings are manufactured in the same production process as their open counterparts with additional steps to the fill them with appropriate grease and to insert the seals. As they are "factory sealed", contamination prior to or during mounting is extremely unlikely. In service they offer additional security against liquid contamination and resulting problems with corrosion or inadequate lubrication.

Kindest regards,

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Sealed Spherical Roller Bearings

This issue of SKF Pulp & Paper Practices is about why I recommend mounting sealed spherical roller bearings when it's appropriate and possible to do so. Essentially, it's about protecting bearings from contamination. Of course, there are a large number of possible sealing solutions, but to cover them all would take a book. So, think of this as just a first taste.

Before I go any further, I should say that the SKF range of sealed spherical roller bearings is growing every year. Large size bearings, such as the 231 series up to 400 mm (15.748 in) bore – which can be found in some twin press rolls, screw presses and press rolls – are now available. As such, it's time to remind everyone that sealed bearings can be a good way to increase service life.

Main bearing failure causes

While inadequate lubrication is the main cause of reduced bearing life generally, this isn't the case in paper machine applications. For all applications in all industries, it is estimated that 90% of bearings outlive the machines that they are installed on, 9.5% are replaced during planned maintenance and that 0.5% fail. Of the failed bearings, 36% fail due to inadequate lubrication and 14% due to liquid or solid contamination. The situation for bearings in paper machine applications is quite different. Very few bearings outlive the paper machine they are installed on with 40–50% failing due to liquid contamination. Corrosion marks can often be seen on these. Even if they cannot, the problem is inadequate lubrication due to too high water content in the lubricant.

The difference between inadequate lubrication and liquid contamination is not always clear. For instance, there can be enough water in the lubricant to disrupt the oil film between the bearing surfaces without creating corrosion marks (see **figure 1**).

The corrosion protection properties of lubricants have improved over the years and most damaged bearings sent to SKF for analysis come without a lubricant sample. As such, it is often only possible to diagnose inadequate lubrication from the damage that can be seen. Consequently, my opinion is that failures due to liquid contamination are underestimated especially in the paper industry.

After liquid contamination, sold particle contamination is thought to be the most common cause of bearing failures in the paper industry. That said, this conclusion is open to discussion. Let me explain using an example to show why.

A number of damaged bearings were either sent to SKF or examined during visits to the mill in question. Most of these had failed resulting in unplanned stops. A number were costly large size bearings. As they had been mounted on the paper machine, the pulp press and pulp washers, most of the failure causes were liquid contamination and/or inadequate lubrication. We signed a maintenance contract with the mill and one of the key performance indicators (KPIs) was to reduce bearing consumption.

To reach the KPI, I proposed examining all replaced bearings with the mill's maintenance staff. As there were so many bearings to inspect, we decided to do quick inspections on most and detailed Root Cause Failure Analysis (RCFA) reports on a few. We agreed that the mill would store, in good conditions, all replaced bearings together with details of the bearing, the application and the reason for replacement.

Before the contract was signed, most of the bearings that I examined would have simply been replaced and scrapped without any damage analysis. Very quickly it was established that most bearings had raceway damage due to solid contamination. Further investigation showed that a large proportion had been contaminated with solid particles either during mounting or when they were lubricated. Some had been contaminated when in store (see **figure 5**).

Fig. 1 Surface distress and spalling can be seen on the outer ring raceway of this wet section press roll bearing. The cause is inadequate lubrication. The remaining grease on the cage looks like it has been contaminated with water which leads to the conclusion that inadequate lubrication is the consequence of liquid contamination. If no grease was present, it is likely that the failure analysis would have incorrectly been simply inadequate lubrication.

We took several steps in an attempt to improve the situation:

1 A wooden workbench on which pumps, gearboxes and other equipment were assembled was topped with stainless steel to make it easier to clean (see **figure 2**).
2 The workshop doors were modified to prevent drafts blowing dust around.
3 Dirty and inadequate lubricating tools were replaced (see **figures 3** and **4**).
4 The maintenance team was given special training on workshop cleanliness.

Fig. 2 Wooden workbenches are difficult to clean properly.

Bearing consumption fell as a result of these actions, but there were still some bearings replaced due to solid or liquid contamination during operation. This was due to lack of sealing efficiency.

So, what more can we do to reduce bearing damage due to contamination? There are a number of options, each with pros and cons, in my experience.

Storage conditions

The fourth edition of SKF Pulp & Paper Practices included some information on this. Namely, that the storage area must be clean, dry and free from drafts. I should also add that bearings should be stored flat and in a vibration-free environment.

But what does dry mean? It means that the recommended relative humidity should be kept below 60% with a peak of 65% accepted. This guideline is based on knowing that unprotected bearing steel will start to corrode at a relative humidity of 50%, that corrosion accelerates when relative humidity increases and that it will happen quickly when above 75%.

Temperature fluctuation is also important. When moving packed bearings between different locations, the temperature is likely to vary. The air confined in the bearing packaging differs from that outside in that its water content changes much more slowly, while external temperature changes have immediate effect. If the temperature of the package drops the relative humidity inside will increase. For example, if a packed bearing has been stored for a long time at 30 °C *(86 °F)* and 50% relative humidity and it is transferred to a place where the temperature is only 20 °C *(68 °F)*, the relative humidity will reach 100% and water can condense inside the packaging. Conversely, if a packed bearing is moved from a cool to warm environment, condensation on the relatively cool steel surface may occur. This is why SKF has a conservative recommendation i.e. a maximum storage room temperature fluctuation of 3 °C *(5,4 °F)* per 48 hours.

Fig. 3 and 4 A cut down plastic bottle used to transfer grease from its original drum to a bucket that is used to lubricate open bearings.

Fig. 5 Bearing stored without protection from dust.

Following these recommendations on temperature fluctuation and relative humidity will help to avoid corrosion marks.

Avoiding solid contamination is simple in theory. Just don't open the bearing packaging until it's time to mount the bearing! I say simple in theory because, in reality, paper mill staff will often open the packaging to check the bearing is the same as the one that needs replacing or to check that the designation indicated on the box is correct. In practice, many bearings are opened and then put back in storage for use later on. Bearings in good condition that are dismounted and put back in the store are another issue. They need to be cleaned and protected against corrosion and solid contamination. I will write more about this in a future issue of SKF Pulp & Paper Practices.

What can be said with certainty is that bearings with integrated seals protect themselves against dust. As far as their internal surfaces are concerned, at least.

Mounting conditions

Can I write anything more than bearings should me mounted in a clean environment that is as free as possible of drafts? Yes, but real life shows that you sometimes just have to do your best to avoid the bearings being contaminated in environments and time frames that you would not have picked given the choice. People do not always help as they have little idea that a 0.1 mm *(0.004 in)* brass particle can reduce the life of a 500 kg *(1 100 lb)* bearing by a factor of 10.

Sometimes mounting bearings in less than ideal conditions is bad for the morale of the engineer who has calculated the bearing rating life accounting for the contamination factor. That said, you don't need to be in a sandstorm to be in a harsh environment for bearings. You could be mounting a bearing in the wet section while someone is working above you or changing a bearing on the floor of a dirty workshop when the doors are open to catch the breeze.

The worst case I ever had to face was in my mining days mounting a bearing on a vibrating screen in a quarry. Two men from the quarry were holding a plastic sheet trying to protect the bearing and me. I remember wishing at the time that the bearing had integrated seals.

During operation

Bearings in operation must be protected against contamination that could bypass the housing seal assembly. This contamination can be either:

1 Solid and liquid such as fibre in the pulping process (see **figure 6**)
2 Liquid like process water in the forming section (see **figure 7**)
3 Solid only

The first step is to keep the contamination out of the housing. I'm not going to write about all the different seal arrangements that SKF can offer, but will just cover some considerations based on my personal experience.

Seal assemblies need to be efficient and reliable. This all depends on the possible contamination and the life required from the sealing arrangement. By life, I mean how long it keeps contamination from reaching the bearing. A small amount of contamination can pass the seal and still be considered acceptable if the bearing service life is not dramatically reduced. For example, some process water can enter a suction roll bearing housing if it is then quickly removed by the lubricating oil and efficient water separators. Similarly, if fresh grease inserted during lubrication purges old and contaminated grease from the bearing and seal.

Fig. 6 Fibre leaking out of the gland seal on a pulp washer. Note the additional protection in front of the housing to protect the housing seal.

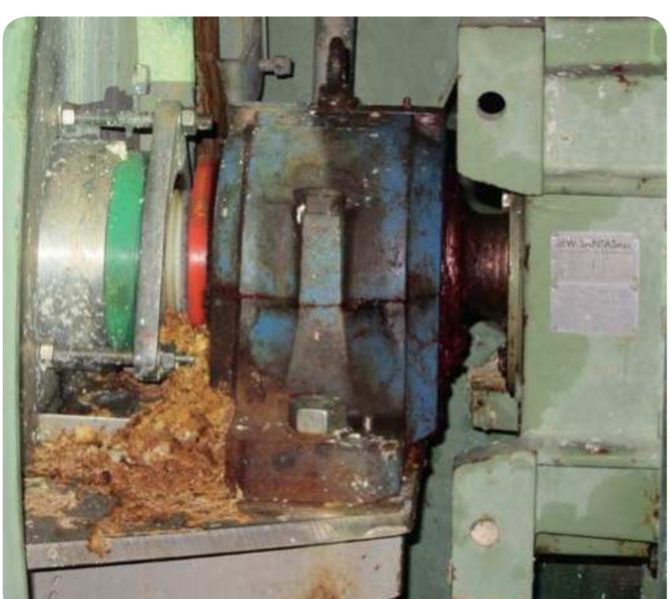

Fig. 7 The high humidity environment of a wire stretch roll in a paper machine forming section. Grease in the labyrinth seal stops process water entering the bearing housing.

Each seal design has advantages and disadvantages. It isn't easy to have high performance seals without creating friction and/or a complicated sealing arrangement. Factors like friction and cost tend to limit seal efficiency. However, I have some of my own rules based on my experience:

1 Try to avoid friction seals whenever possible. Note that I use V-Rings as deflectors or as a kind of one direction valves (see **figure 8**).
2 It is better to add several small barriers for cascading protection rather than a single high performance barrier (see **figure 9**). The idea behind this point is that a barrier can always fail, especially if there is friction and thus wear.
3 Lubricant, such as grease, can be considered as a barrier.
4 Remember that rotary shaft lip seals need to have their lip lubricated and that they have a pumping effect.
5 Excess grease in a bearing must always be able to escape to avoid overheating. There are exceptions for very slow rotating bearings.
6 Sealing arrangements should use standard seals, simple do it yourself components such as covers or rotating discs or quickly made machined seals like those available from SKF Economos (see **figure 10**).
7 With rotary shaft lip seals, the lip seat must be easy to repair (e.g. with a thin wear sleeve such as SKF SPEEDI-SLEEVE) or easily changeable. If the lip seat is a wear sleeve, it has to have a sufficiently tight fit that it doesn't rotate with the lip and to prevent liquid passing under the wear sleeve's bore. An "O-Ring" or seal paste can prevent liquid from passing underneath the wear sleeve. Lip friction on the wear sleeve can increase the temperature of the sleeve and make it expand radially.

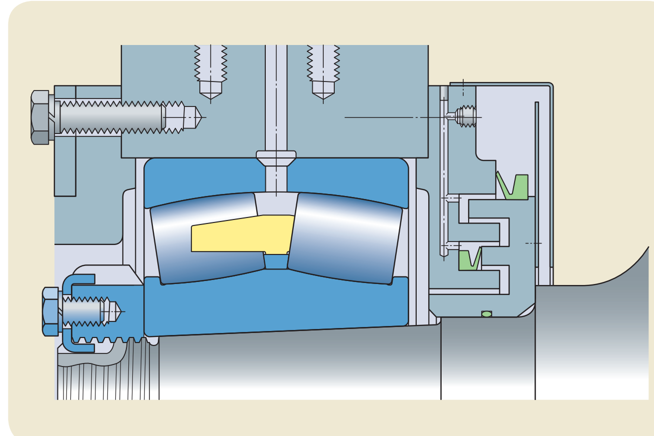

Fig. 8 The addition of a cover, a rotating disc and an additional V-Ring on a suction roll.

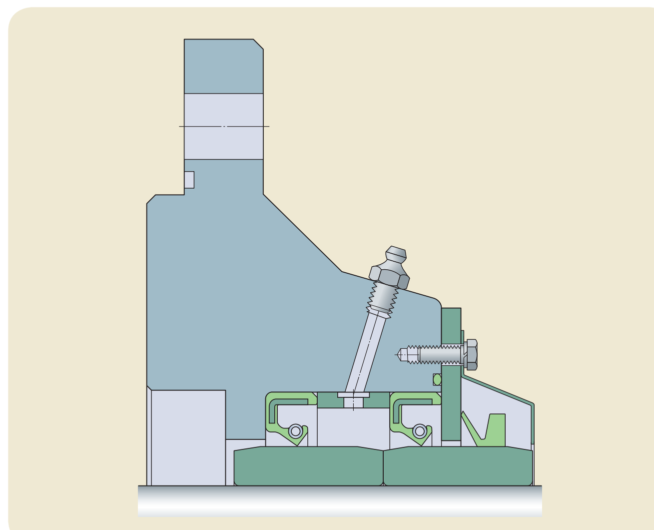

Fig. 9 Example of a seal arrangement for a harsh environment.

Fig. 10 SKF SEAL JET is able to machine polymeric seals to tailor made shapes and dimensions to fit a customer's application. It is often used as an alternative in cases where adding a standard seal to increase sealing efficiency requires costly modifications.

So, when it is possible to avoid friction seals, do so. **Figure 11** shows an example with four barriers: a cover to protect the labyrinth seal, a rotating labyrinth seal that acts like a disc deflecting liquid contamination, a grease-filled labyrinth seal and the grease between the bearing and the labyrinth seal.

If this isn't good enough, it might be possible to add V-Rings. **Figure 8** shows an old suction roll whose original seal arrangement was just a labyrinth seal filled with grease. After a few bearing failures due to liquid contamination, the following modifications were made:

1. The addition of a cover made by the paper mill and a disc made of stainless steel sheet.
2. The addition of V-Rings that allowed excess grease in the bearing to escape, but which prevented the contamination and/or the contaminated grease in the labyrinth from entering the bearing housing.

Note that there is an O-Ring between the shaft and rotating labyrinth since water can pass between these two due to form errors.

In some cases there is a need for friction seals. In pulp press applications, for example. My favorite seal arrangement for harsh environments looks like the one in **figure 9**. Two rotary shaft lip seals are placed in tandem, lips facing outwards, to let excess grease escape. As the grease escapes it lubricates the seal lip and forces away contamination. New grease in introduced between the two rotary shaft lip seals.

Such arrangements are often used for low speed applications. With these, the bearings don't necessarily have to be lubricated as often as the seals. This can help reduce grease consumption. It also allows different greases to be used for the bearings and seal arrangements. For example, high viscosity grease with solid additives such as SKF LGEV 2 could be used for the bearings while SKF LGHB 2, which has good mechanical stability when mixed with water and very good anti-corrosion properties, can be used for the seal arrangement.

In this arrangement, the V-Ring and cover act as deflectors to minimise contamination reaching the right hand rotary shaft lip seal which could increase lip wear. It is a good example of the barrier cascade principle. The cover protects the V-ring, which protects the right hand rotary shaft lip seals, which protects the grease, which protects the left hand rotary shaft lip seal. The wear sleeves are mounted with a slight tight fit and seal paste.

But what happens if contamination passes through the housing seal assembly anyway?

Well, if it is an open bearing, you will have to rely on the lubricant surrounding the bearing to keep the contamination away from it. Circulating oil with good filters and liquid separators is one solution, but you can do more than just rely on the lubricant.

In cases of solid contamination, SKF can offer a bearing completely filled with a polymer matrix saturated with oil called SKF Solid Oil (see **figure 12**). As all the free space in the bearing is filled with the polymer, solid contamination cannot enter. Because the polymer completely fills the free space in the bearing, speed is limited and start up friction is higher than with grease or oil. For E type spherical roller bearings the ndm limit is 42500 and for CC type spherical roller bearings it is 85000.

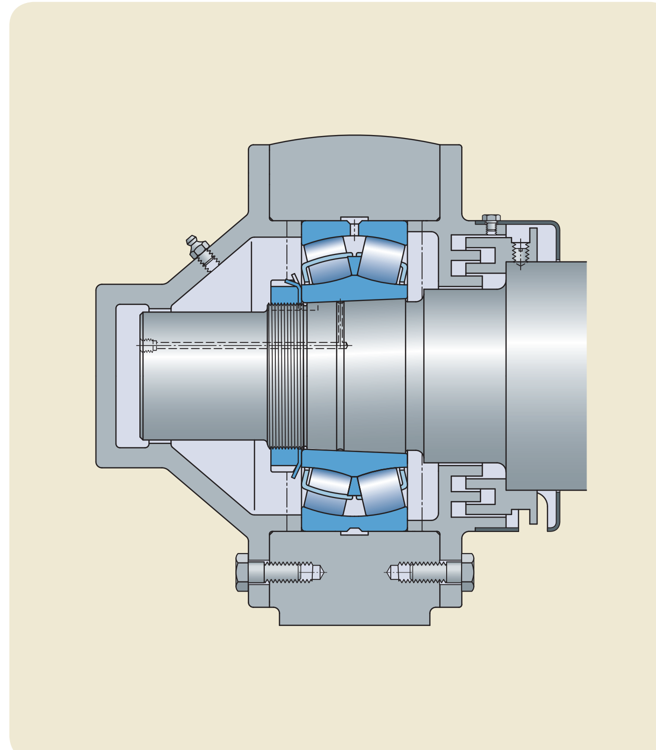

Fig. 11 Wire roll bearing housing without friction seal.

Fig. 12 SKF Solid Oil bearing.

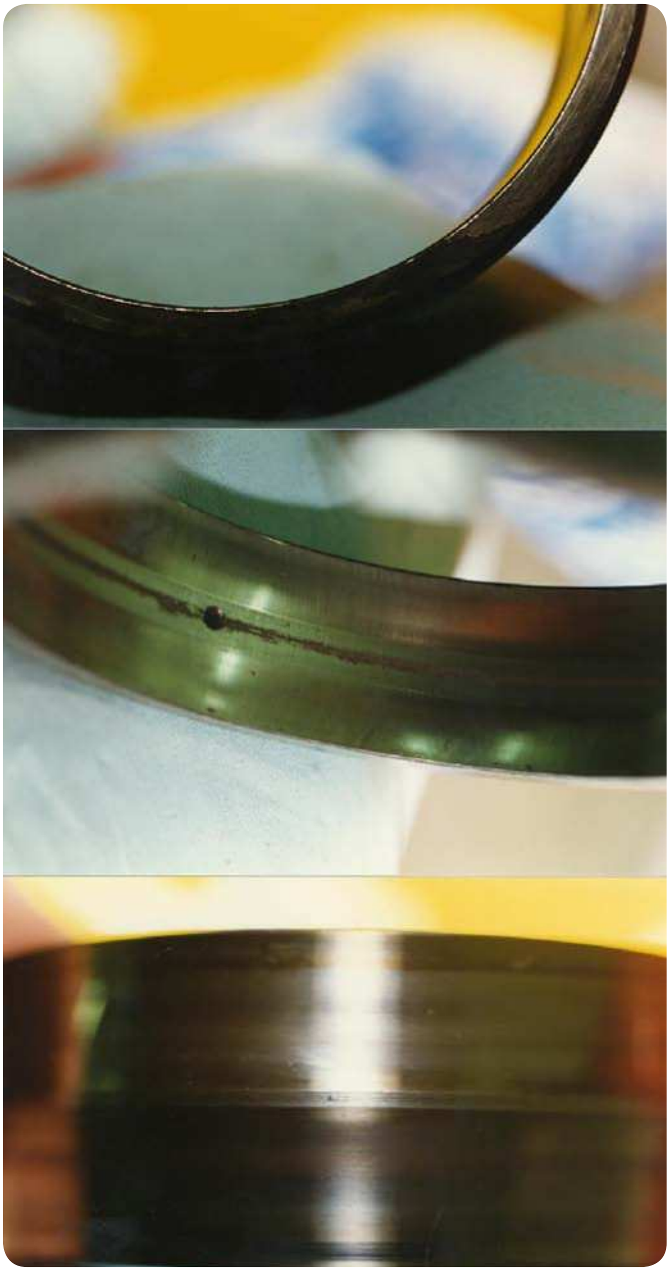

Fig. 13 Solid Oil bearing after 8 months in operation on a felt roll with water in the housing. The water level in the housing can be seen from the corrosion on the outer ring side face in the upper photograph.

Fig. 14 SKF HNCR spherical roller bearing for the wet section of a paper machine. Photograph taken for SKF Pulp & Paper Practices before being packed and sent to the customer earlier this year.

Note that ndm = speed x mean bearing diameter (see **issue 7** of SKF Pulp & Paper Practices). The temperature is also limited to 85 °C *(185 °F)* in continuous operating conditions. Therefore, the Solid Oil solution is perfect in slow rotating dusty applications such as material handling or in the converting plant.

Even though it isn't recommended for humid environments, we have tried Solid Oil bearings in felt roll applications. Three spherical roller bearings were mounted on a felt roll in France in December 1992. The customer understood that there was no need to fill the housing with grease. Maybe I wasn't precise enough on the fact that grease in the housing would protect the bearing against water ingress and possible corrosion of the outer surfaces of the rings and the housing bore. The bearings were dismounted in August 1993 after they had run in a process water bath. You can see the water level based on the corrosion on the outer ring side face in **figure 13**. It was a success, but I promote Solid Oil with caution after a customer complained that the roll wouldn't rotate at start up and that the felt was sliding on the roll. The felt wrap angle over the roller was too low leading to low contact load between felt and roll. Felt rolls can be put in several positions so there is a risk that a felt roll equipped with Solid Oil is put in a position where the contact load between felt and roll is too low. I recommend that Solid Oil spherical roller bearings should have a minimum load equal to 0.02 Co (Co = basic static load rating).

In addition to the friction and the temperature and speed restrictions, Solid Oil has another disadvantage. It cannot be relubricated. It is a bearing lubricated for life and it isn't a standard bearing. So, are there other options? Yes, there are.

With liquid contamination that causes corrosion, one idea is to mount a stainless steel bearing. SKF has a range of nine spherical roller bearings covering the most popular felt and wire roll bearing sizes. These bearings are not made from regular 440C stainless steel, but rather from a highly corrosion-resistant, due to nitrogen addition, and clean stainless steel. The stainless steel is called HNCR, which is indicated in the bearing designation, and the bearing is produced by MRC which is part of the SKF Group (see **figure 14**).

It was decided to create a range of bearings for felt and wire rolls after a success in a paper mill in the USA. The previous bearings had an average service life of 36 months due to process water ingress in the bearing. They were replaced by HNCR spherical roller bearings and the external seal design was slightly modified. These HNCR bearings now achieve a seven year service life.

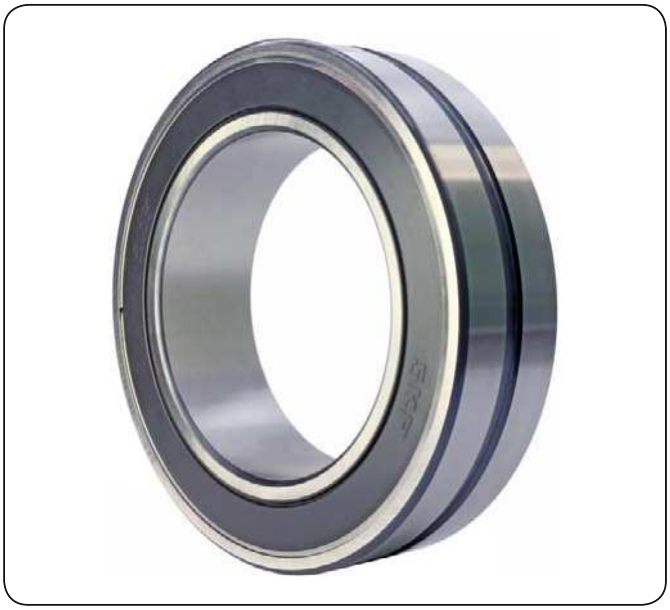

Fig. 15 SKF sealed spherical roller bearing.

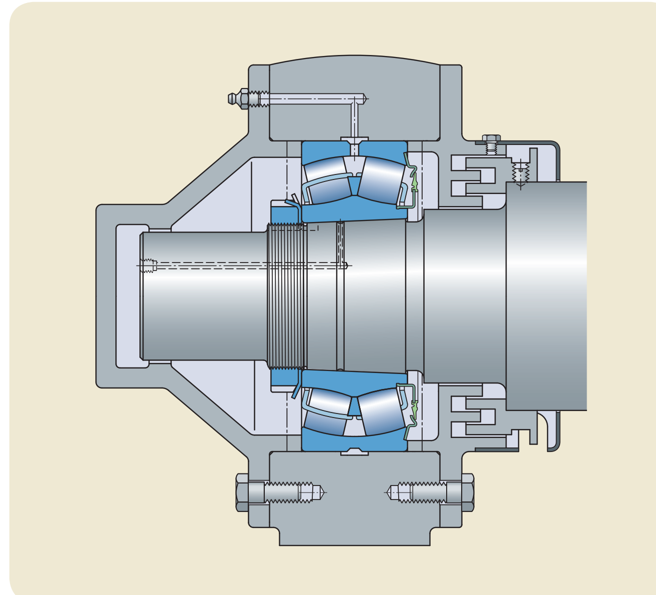

Fig. 16 Celia type sealed spherical roller bearing on a felt roll. In this particular case, there is a single seal. The bearing seal is designed to allow excess grease to be purged. Purged grease pushes out grease and contamination in the labyrinth seals and acts as a barrier to further contamination. Even if contamination enters the bearing housing, it will have difficulties to enter the bearing.

As standstill corrosion - which happens when a paper machine is stopped for maintenance - is one of the primary causes of bearing failure, these HNCR bearings can be seen as a good solution. That said, we must keep in mind that if liquid contamination enters the bearing, there is a risk of inadequate lubrication and low service life. This bearing is also less sensitive when its packaging is subjected to condensation. Unfortunately, the cost and small range limit the general use of these high quality stainless steel bearings in paper mills.

Another alternative, which I believe to be the best, is to use sealed bearings (see **figure 15**). Everybody knows about the sealed deep groove ball bearings, but most are not aware that SKF has the largest range of sealed spherical roller bearings with bearing bores from 25 *(0.984 in)* up to 400 mm *(15,748 in)*. Like the Solid Oil bearing, the sealed spherical roller bearing is protected against contamination during storage, when left unpacked and during mounting. However, it is a standard bearing that can run faster with less friction and it can be relubricated. Technical information about theses bearings can be found in the SKF General Catalogue or on the SKF homepage (www.skf.com).

The fact that it isn't possible to measure the internal radial clearance with a feeler gauge for mounting purposes shouldn't be a concern. SKF generally recommends the SKF Drive-up Method (see SKF Pulp & Paper Practices **issue 3**) which is far superior to the feeler gauge method.

The first time I saw a sealed spherical roller bearing, it was an SKF one, code name Celia. It was when I started to work for SKF some 23 years ago. That sealed spherical roller bearing had ISO dimensions and as there was little space for the seal since it could, in some cases, touch the cage or the rollers, the seal needed to be protruding. Bearings could be delivered with a seal on each side or just one seal on one side. One of the first applications for it was for felt rolls (see **figure 16**).

Paper industry customers were satisfied since these sealed spherical roller bearings had a longer service life. Unfortunately, the main customers for such bearings were steel mills and they complained about the protruding seals as they could be damaged during handling. The second generation of SKF sealed spherical roller bearings didn't have protruding seals. Some bearings, mainly the CC type, could integrate the seals without increasing the width of the bearings. These are mainly medium and large size bearings that can be found in many applications and which are dimensionally interchangeable with open bearings. They can be found in standard housings in the wood yard, on pulp presses, in some paper machine applications (e.g. suction roll internal bearings – see **figures 17** and **18**), on winders and in the converting plant.

The smaller bearings with increased load carrying capacity (SKF E type) don't have much space for the seals and must have wider rings. This means that it a customer replaces an open bearing with one, some modifications might be required. For example, **figure 19** shows a larger sealed bearing mounted in place of the bearings shown in **figures 11** and **16**. In this case, housing covers and the shaft had to be modified.

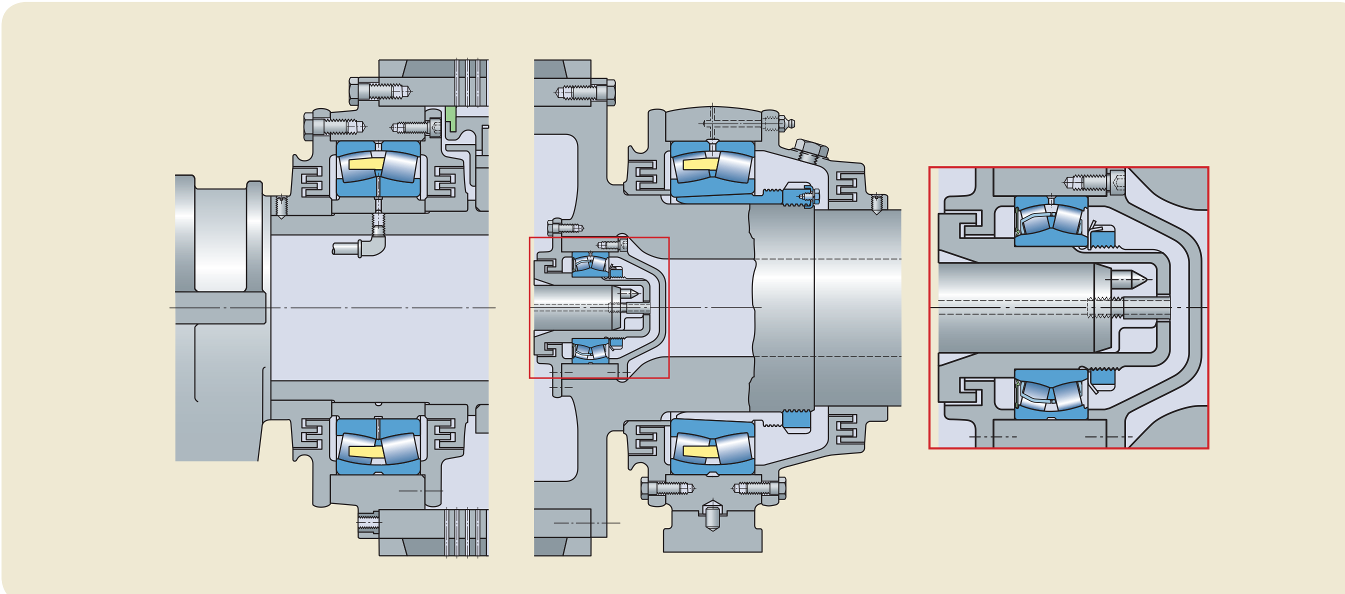

Fig. 17 Suction roll internal spherical roller bearing with a seal on one side (the other having been removed during mounting). Grease is able to travel through the bearing.

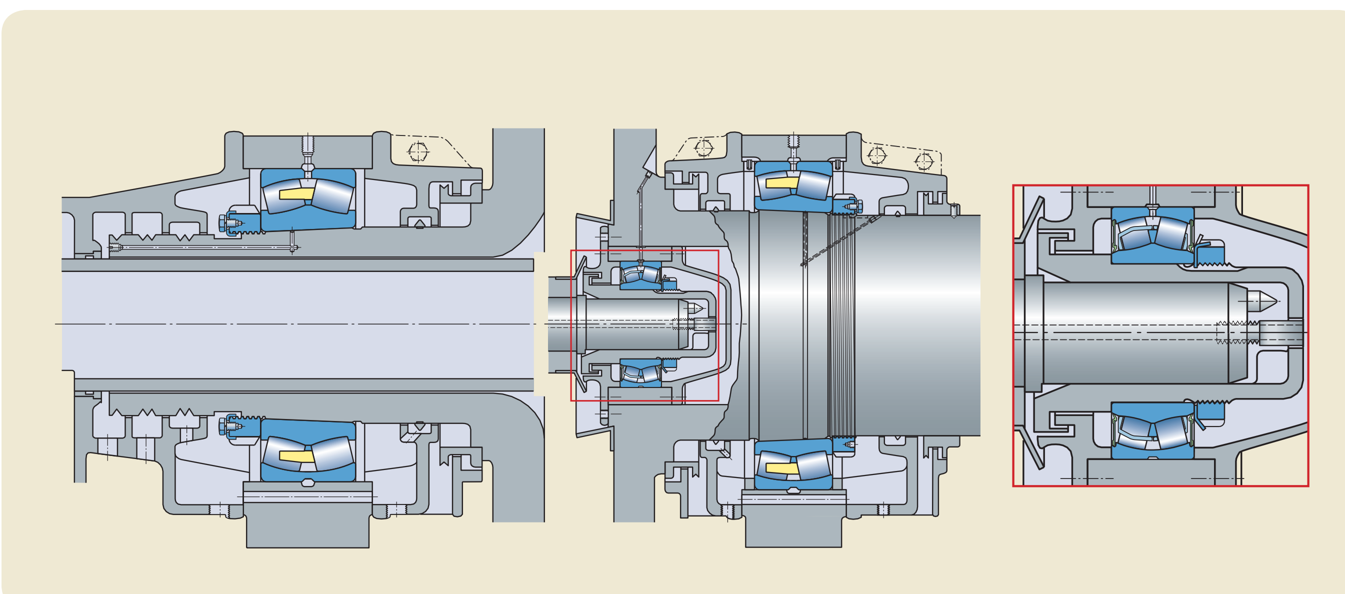

Fig. 18 Suction roll internal spherical roller bearing with a seal on each side. This bearing is lubricated via the lubricating holes and groove on its outer ring

In most applications, the seals of the sealed spherical roller bearings are used to offer a last barrier against contamination. The SKF literature often talks about the "Three Barrier Concept". The first barrier is the housing seal arrangement. The second barrier is the grease between the bearing and the housing seal arrangement, and the last barrier is the integrated bearing seals. This, of course, follows my rule number two about adding small barriers with cascading protection.

Like sealed deep groove ball bearings mounted in automotive gearboxes, sealed spherical roller bearings can be mounted in industrial gearboxes lubricated by oil. Gearboxes can have heavy solid contamination in the oil. The integrated seals will eventually let some oil pass, but the solid contamination is kept out of the bearing.

In closing, I hope that I have given you some ideas on how to reduce your bearing consumption due to contamination and that the sealed spherical roller bearing, which is a widely available standard product, can be an economical way to increase your bearing service life. Unfortunately, SKF Pulp & Paper Practice has a limited number of pages so I cannot go into as much depth as I would have liked to. So, for more technical information on seals, Solid Oil and sealed spherical roller bearings see the SKF General Catalogue or the SKF Industrial shaft seal Catalogue. For more information on the HNCR bearings, please contact SKF and ask for the M890-600 publication called "Corrosion resistant spherical roller bearings".

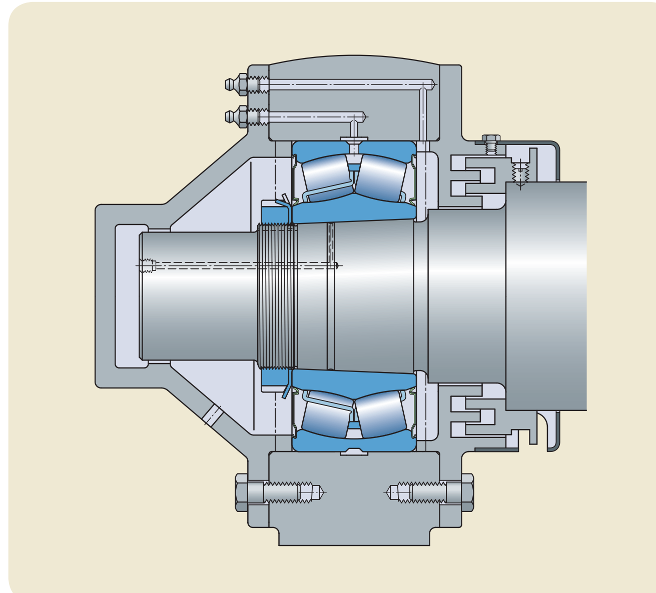

***Fig. 19** Sealed spherical roller bearing in a felt roll application. It is wider than a standard ISO bearing. The seals on both sides are retained to avoid contamination during mounting. Excess grease in the bearing can be purged from either side. In such applications, short relubrication intervals are used to push contamination out of the housing rather than to relubricate the bearing. With such an arrangement, it is possible to pick the most suitable grease for the bearing and a different grease to act as a barrier to process water. Note the addition of an O-Ring under the rotating part of the labyrinth.*

Regards,
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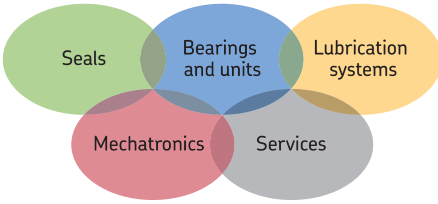

The Power of Knowledge Engineering

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

SKF Global Pulp & Paper Segment

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