

SKF Pulp & Paper Practices

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You shouldn't neglect your fans

When I was asked to write the introduction for this issue of SKF Pulp & Paper Practices, my first reaction was that it's not easy to get excited about fans, is it? They're used everywhere, they often run without any problems and are relatively easy to monitor and analyse due to their simple configuration and steady speeds. I don't think this is an uncommon reaction and it might explain why many of the problems that we see in some areas can be traced back to neglect. Fans work unseen in the background and all too often, little attention is paid to them until they break. It's not surprising, therefore, that many fans are not classed as critical and are run to failure.

The simple fact is that fans are a vital part of the pulp and papermaking process from the recovery boiler to the kiln and on the paper machine itself. Some fans, like supply and induced draft fans for the boiler, are usually recognised and treated as critical assets. Other important ones, like dryer hood exhaust fans and moisture profiling

fans, are often overlooked. However, these fans have a direct effect on runnability and paper quality through control of temperature, moisture and airflow around the sheet. Part of the problem is that these fans are generally found on the mezzanine level which is hot, dusty and sometimes difficult to access.

We intend to include more services content in future issues of SKF Pulp & Paper Practices as we believe that topics such as condition monitoring and reliability complement the bearing related information that has been the focus of the publication previously. I can say from personal experience that it's a significant advantage to be able to draw on different competencies when working with the pulp and paper industry on bad actors. Having joined SKF with a condition monitoring background, my manager made me learn about bearings. This training increased my understanding and opened many discussions with maintenance departments that probably

wouldn't have happened if I'd only been able to talk about vibration and spectrums. Similarly, mechanical engineers can benefit from knowing the operating history of a bearing gleaned from condition monitoring information. Understanding whether it was subject to excessive loads from imbalance or misalignment, when it started to show signs of distress, whether the damage appeared gradually or suddenly, if there were signs of insufficient lubrication, looseness, improper mounting, increasing temperature and so on are vital to understanding a problem and the best way to resolve it.

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My fan is running hot!

When I was a local application engineer working for SKF in France, I regularly received phone calls from customers who wanted to know why their bearings were running hot and what could be done about it. More often than not, they were talking about their fan bearings.

As bearings can run at higher than expected temperatures for many different reasons, my initial response was: "It depends." This was followed by me asking them lots of questions about the operating conditions and maintenance regime. I'd ask about the bearing and housing designation, how the bearing was mounted, the loads on the bearing, the lubrication method and the lubricant brand and type, the fan type and speed, the air/gas and ambient temperatures, whether the fan was belt or direct driven etc. Usually, the customer did not have the answers to all my questions. Sometimes, during the course of the discussion, a most probable cause could be established, but in most cases, deeper investigations were necessary.

An important part of an investigation is that the bearings are dismantled and inspected before they are too heavily damaged. This is because early damage, providing evidence of the root cause of the problem, is often removed by secondary heavy damage. As such, it is an issue when a fan cannot be stopped. An issue that is often compounded by two common mistakes made with "overheating" bearings:

- 1 The customer adds grease thinking that the overheating is due to lack of lubricant. While this can be true, it can further reduce the bearing life if there's too much grease and no way for the excess to escape. Tip: if the seal arrangement does not allow grease to evacuate, remove the grease nipple. If grease then comes out, there's already too much grease present.
- 2 The customer tries to cool the bearing either by blowing air on the housing or even pouring water on it. While this can stabilize the bearing temperature, it can also increase it by creating higher

preload and reducing the bearing service life even more. The problem is that cooling the bearing outer ring increases the temperature difference between it and the hotter inner ring. This reduces the radial clearance and increases the preload in an uncontrolled way. When bearings are mounted axially free in the housing to allow for thermal elongation of the shaft, cooling can remove the clearance between the housing and the outer ring necessary for displacement and lead to axially overloading. Tip: Reduce bearing temperature by cooling the shaft, not the housing.

Let's move on to the main causes of fan bearing overheating. The list below is based on my experience and is not complete. I haven't included cases where the fan was badly designed, was used outside its design parameters or where there were bearing quality issues as all these things are comparatively rare.

Too much lubricant

Newly greased bearings normally experience a slight temperature increase due to the grease churning effect, but this reduces as the grease is pushed away from the rolling path. This will not happen if the housing becomes full with grease which cannot escape via the seal arrangement or an escape hole or valve. In fact, temperature can even increase if more grease is added by maintenance staff thinking that more lubricant would help to reduce friction.

It is important to check that all bearing housings with grease nipples should have some way of allowing excess grease to escape. If excess grease cannot easily escape through the seal arrangement, the housing should have at least one escape hole. Standard SKF SNL housings can be supplied with one escape hole in the base and will then have the suffix V (see **pages 81, 176 and 215** of the *SKF bearing housings and roller bearing units* catalogue). Customers can, of course, drill the hole themselves if

they want to. In urgent cases without the proper hole dimensions to hand, I just drill a 10 mm hole in the position shown in the photograph on the next page for small SNL housings of series 2, 3, 5 and 6 (see **figure 1**).

Mixed housing caps and bases

This very common mounting error was described in SKF Pulp & Paper Practices issue 16 on page 11. N.B. always check that the markings on the cap and the base match (see *SKF Pulp & Paper Practices issue 16, figure 19*).

Too high load due to the drive

Excessive belt tension creates overload on the drive end bearing. It can also unload the bearing on the non-drive end which can cause problems, especially for roller bearings, as rolling elements slide rather than roll in the loaded zone. For direct drive fans, misalignment between the drive shaft and the fan shaft can either cause overload or insufficient load.

My experience is that customers are more aware of the need for alignment on direct drives as I see more measurement being done than I do for pulley alignment or belt tension. Belt tensioning still seems to be based on workers' experience and gut feelings.

Too high drive-up on the tapered seat

In fans, this point mainly relates to self-aligning ball bearings mounted on adapter sleeves. Such bearings in unmounted condition have a smaller radial internal clearance than roller bearings because they generate less friction (and, thus, lower temperature differences between their inner and outer rings) and they don't need as tight a fit to prevent ring creeping and/or fretting

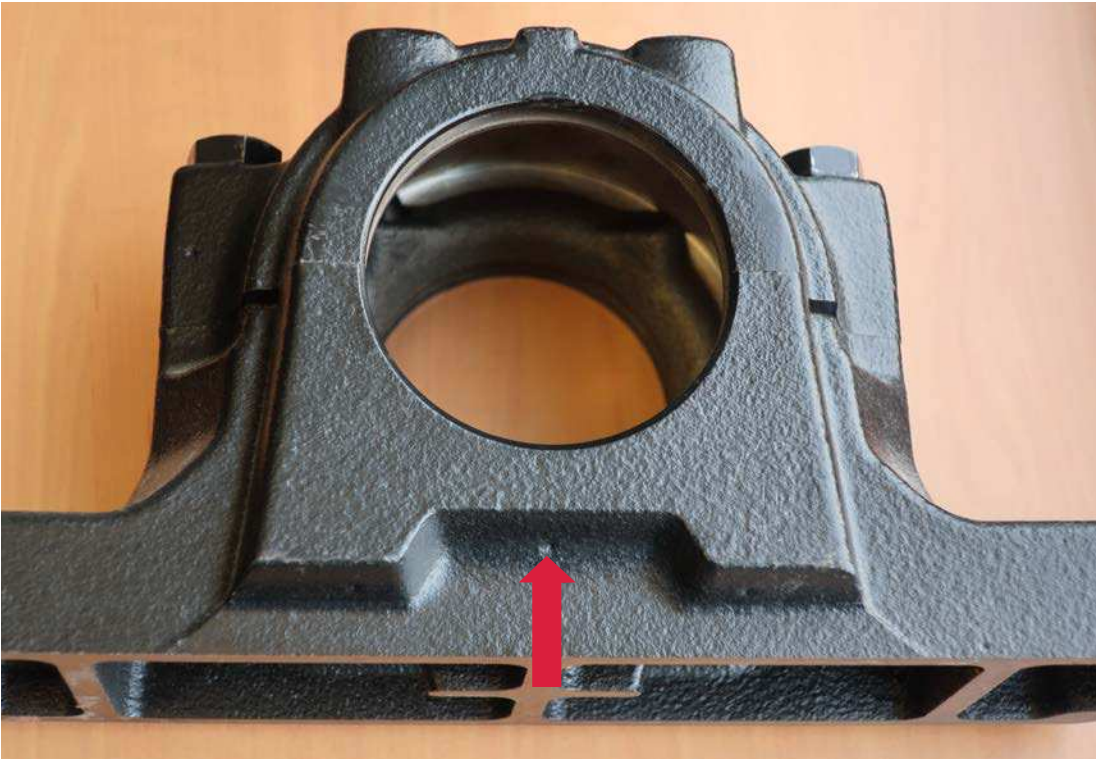


Fig. 1: The red arrow indicates the position of the grease escape hole on this housing. Note that the position can vary depending on the housing design used

corrosion. Also, the feeler gauge method cannot be used and the SKF Drive-up Method is rarely used because the use of a hydraulic nut can be problematical. As such, SKF has noticed that such bearings are often mounted with too tight a fit which means that there is insufficient clearance after mounting. Consequently, the bearings can operate with negative clearance (preload) and overheat.

To avoid potential problems, I recommend mounting C3 clearance class self-aligning ball bearings when replacing normal clearance class ones.

Too low drive-up on the tapered seat

When it comes to fans, this mainly concerns CARB bearings where the drive-up is controlled by measuring radial clearance reduction with feeler gauges and inexperienced workers. The worker believes he has achieved the right clearance reduction, but actually the fit is not tight enough and the inner ring can creep or even rotate on the shaft creating heat due to the friction between them. The best practice would be to use the SKF

Drive-up Method, but fan designs do not always allow the easy use of a hydraulic nut. See the next article in this issue of SKF Pulp & Paper Practices for solutions to this.

Cross-location

Nearly all industrial fans have one bearing that axially locates the shaft and another than compensates for thermal elongation of the shaft. This compensation can be internal to the bearing if the inner and outer rings can axially displace relative to each other as is the case in most cylindrical roller bearings and all CARB bearings. It can also be achieved by outer ring displacement in the housing when self-aligning ball bearings, spherical roller bearings or deep groove ball bearings are used as the non-locating bearing. Cross-location happens when the outer ring cannot displace in the housing. When this occurs, thermal elongation cannot be compensated for, and both the locating and non-locating bearings must withstand the axial load created by it. The result can vary from slight additional axial load on the bearing system to axial overload and temperature increase.

The main causes of cross-location are:

- A** Mixed housing caps and bases as described on the previous page.
- B** Insufficient radial clearance between the housing bore and the bearing outer ring. In operation, especially during start up, the housing is colder than the bearing outer ring. The clearance can disappear and become a tight fit due to the temperature difference. Due to experience, SKF offers a certain loose fit on the SNL plummer block housings to avoid cross-location during normal operating conditions. This means that there is enough clearance for the bearing outer ring to displace. Strangely, some customers check housing quality with Prussian blue on the outer diameter of the bearing. For them, the housing is good quality if the blue is transferred to the entire surface of the housing bore. In reality, it means that there is a high risk of cross-location in operation since there won't be sufficient clearance between the bearing outer ring and the housing bore.
- C** Housing deformation due to poor support. **Figure 2** shows housings on uneven support with the red ovals indicating the

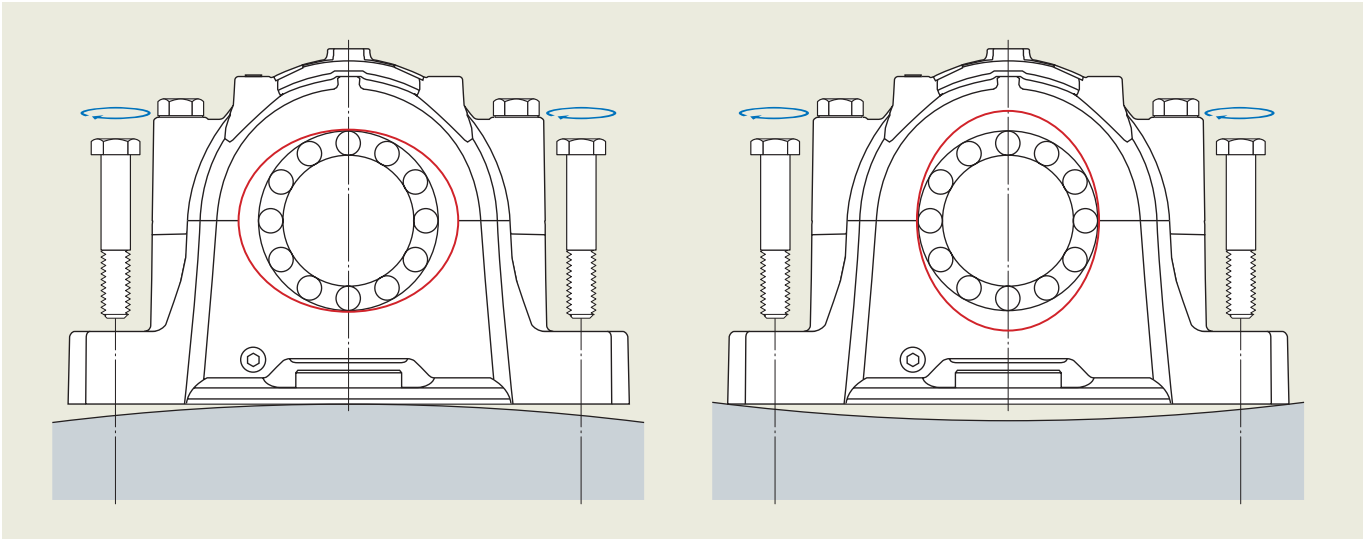


Fig. 2: Housing bores after attachment bolts are tightened

housing bore shape once the attachment bolts are tightened. As you can see, the bearing outer rings are squeezed, become oval and will have difficulty in displacing axially. Note that this can also happen if the housing support is insufficiently rigid and deforms under load. SKF recommends that the flatness of the housing support should be to tolerance grade IT7 in accordance with ISO 1101.

D Fretting corrosion on the bearing seat. When bearings are replaced, the housings are often kept even if there is fretting corrosion on the seat (for more information on fretting corrosion and its causes, see *SKF Pulp & Paper Practices issue 16*). Fretting corrosion increases the friction coefficient between the housing and the bearing outer ring, so high axial loads due to thermal expansion of the shaft are needed to make the bearing displace axially. The heavier the fretting corrosion, the higher the axial load required to force the bearing to move. Once it reaches a certain point, the bearing can become axially overloaded and will overheat.

Note that the use of CARB bearings solves the cross-location issue. Therefore, SKF recommends them when the bearings are mounted in separate housings and the operating conditions allow it.

Inadequate lubricant

I could write several issues of *SKF Pulp & Paper Practices* just about the use of inadequate lubricant, but to keep this short I will only cover the most common error. That is the use of high temperature grease, often NLGI 3, for roller bearings when the bearing operating temperature is not high.

A typical case is the use of a grease, that bleeds enough oil to lubricate roller bearings over 80 °C, for bearings that normally operate between 50 and 60 °C. A while after initial bearing regreasing, once the grease has migrated during the churning phase, oil bleeding from the grease, located on the cage and near the rolling path, will lubricate the contact between the rolling elements and the raceways. If there's not enough oil bleeding, friction increases leading to overheating and perhaps some bearing surface damage. When the bearing temperature increases to above 80 °C, the grease starts bleeding oil, the friction decreases and the temperature falls back to normal. A cycle starts that continues until the bearing overheats for the final time and fails.

As a rule of thumb, only use grease that bleeds at least 3% of its oil over seven days at normal bearing operating temperature. SKF can help you estimate the normal operating temperature based on speeds, loads, fan design and ambient/gas temperatures. While ball bearings are less sensitive than roller bearings, I recommend erring on the

side of caution and using this rule of thumb for them as well.

It isn't always easy to find the base oil bleeding tests for grease. SKF provides this information for SKF greases and has created a traffic light concept to check whether a grease bleeds enough oil. With the traffic light concept, this is shown using the Low Temperature Performance Limit (see diagrams '1' and '2')

Too long grease relubrication intervals

In most cases, the reason for bearing damage due to too long relubrication intervals is because regreasing has been forgotten or skipped due to access difficulties or lack of time.

If a bearing overheats and adding more grease decreases the temperature, it's likely that the relubrication interval is too long or that there is a grease bleeding issue. Either way, the bearing may well have suffered damage due to the lack of a lubricant film and the service life can be shortened even if the bearing temperature goes back to normal after relubrication.

Note that SKF gives the L_{01h} of the grease as the relubrication interval while some other bearing manufacturers give the L_{10h} . L_{01h} is the grease life reached in 99% of cases, based on bearing operating conditions, while the L_{10h} is 90% meaning that 10% of the bearings have failed due to

CARB axial offset

The internal radial clearance in a CARB bearing is at its maximum when the inner and outer rings are aligned without any axial offset. Displacing one ring relative to the other will reduce the internal radial clearance (see *SKF Pulp & Paper Practices issue 11, page 5*). This can be a great advantage to those wanting to precisely adjust the radial clearance and thus the internal load distribution on the rollers for optimum bearing life. Others can simply align the two rings by eye except for very hot gas fans with a large distance between the locating and non-locating bearings.

An issue can be that CARB is unfamiliar to some workers. I experienced two such cases in the 1990s where CARB bearings overheated due to heavy preload during operation. The reason was that the bearings had been mounted without taking care of the axial offset between the rings. The offset was at maximum, so there was little or no radial clearance in the bearings when they were cold. Once in operation, the inner rings were hotter than the outer rings, so the bearings experienced too much preload and overheated. While this was twenty years ago, I still think that many customers aren't very familiar with CARB bearings, so I fear such overheating is still a possibility.

Too low load

Too low loads leading to rolling elements sliding instead of rolling in the load zone don't always lead to overheating. However, if overheating starts due to heavy smearing, damaged cages and so on, failure can quickly follow.

Low load in fans is mainly a concern for roller bearings with inadequate belt tension or direct drives that aren't well aligned. There can, of course, be other reasons like using replacement bearings with higher load capacity in an attempt to increase fan reliability when the recommended minimum load has not been checked. For a good example of this, see *SKF Pulp & Paper Practices issue 20, page 8*.

A common error is replacing a self-aligning ball bearing with a roller bearing without fully considering the ramifications.

Roller bearings need higher minimum loads to function properly and are more sensitive to lubrication. Customers can make this mistake when trying to increase bearing life solely based on calculated rating life or when trying to solve a cross-location issue by replacing a self-aligning ball bearing on the non-locating side with a CARB. You always need to check the recommended minimum load and lubrication considering grease base oil bleeding, relubrication intervals etc.

In conclusion, there are other causes of overheating, but I've covered the main ones above. My intention with this article was not to go deeply in to the explanation of causes and the corrective actions, but to show that an engineer cannot diagnose the reasons for a fan bearing overheating without sufficient information. I hope, however, that it provides you with enough information to help you with your primary investigations into the main root cause of any problems that you experience with your fans.



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Mounting CARB on a fan without a hydraulic nut

On June 25th 1997 I mounted a C 2238 K/ HA3C4 CARB toroidal roller bearing. This would be completely unmemorable if it wasn't for the fact that it was the first CARB mounted on a fan in France and that the customer told me that we wouldn't be able to use the recommended mounting method when we were stood in front of it.

It was a circulating air fan on a Through Air Drying (TAD) machine. A 2700 kW fan, made in 1989 by Buffalo Forge, with two SKF 22238 CCK/C3W33 spherical roller bearings installed. These bearings were mounted on SKF SNW 38 - 6^{15/16} adapter sleeves with lock nuts and locking washers. They were C3 clearance class and lubricated with circulating oil as the air temperature was approximately 150 °C.

For availability reasons, a case hardened inner ring and C4 clearance class CARB was mounted. A through hardened bearing would have been fine and C4 clearance was accepted as, if necessary, it would have been easy to reduce it by axially displacing the inner ring versus the outer ring (see *SKF Pulp & Paper Practices 2* for more information).

The customer had decided himself to mount CARB after reading about it in the French language predecessor of *SKF Pulp & Paper Practices*. He was experiencing high vibration while starting up the fan and was sure that outer ring of the axially-free (non-drive side) spherical roller bearing couldn't move easily in its housing and that mounting CARB would solve the problem. Such hot gas fans experience a similar stick-slip issue during thermal elongation as drying cylinders do (see *SKF Pulp & Paper Practices 6, page 6*).

The customer was right. Once CARB was mounted, high vibration during start-up was just a bad memory. A visual inspection of the spherical roller bearing it replaced showed that while the raceway, rollers, cage and inner ring were in good condition after seven years in operation, the outer diameter of the

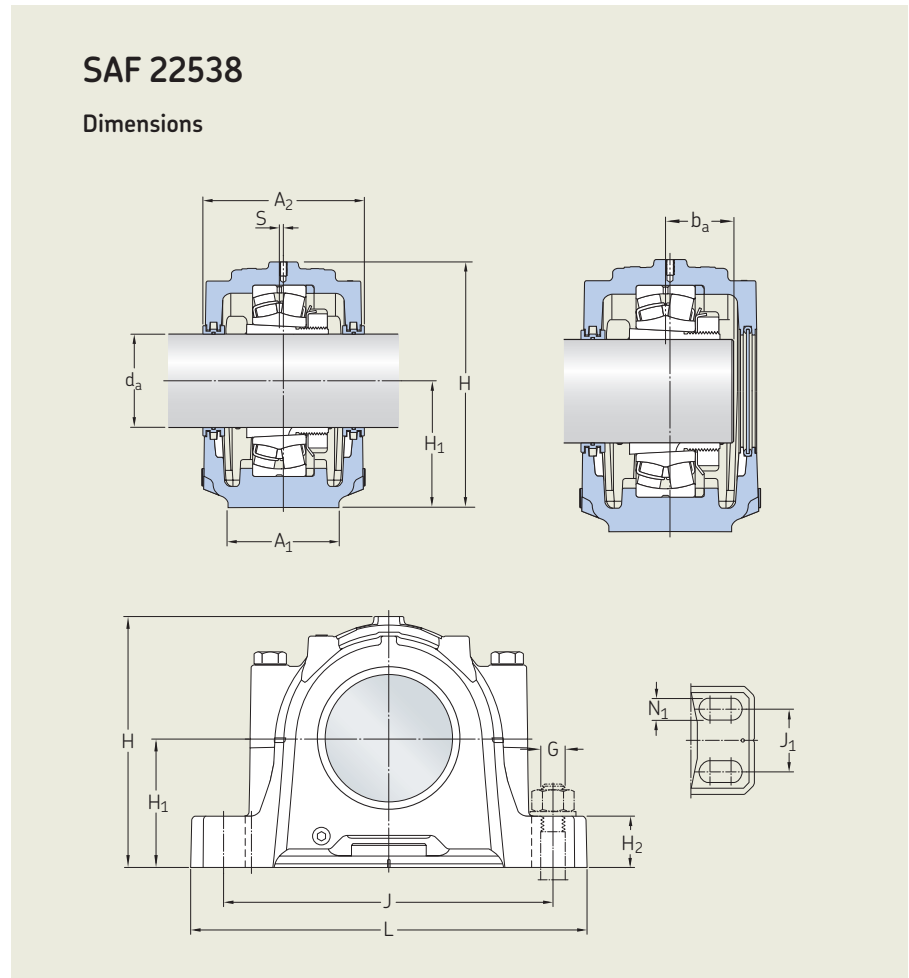


Fig 1: SAF 22538 housing with spherical roller bearing and adapter sleeve



Fig 2: Impact spanner

outer ring and the housing bore had heavy fretting corrosion.

When I was told that I was going to supervise CARB mounting, I'd done SKF Drive-up Method calculations as it's much more accurate than using feeler gauges. I'd envisioned driving up the bearing on its adapter sleeve with a hydraulic nut, but had not taken into account that the housing was a North American SKF SAF 22538 housing used in a fan application (see **figure 1**).

Due to the fan casing, which maintenance staff generally do not want to move due to the increased work hours involved, it is not possible to lift the fan shaft much. Depending on the fan design, it can be as little as a few millimetres to as much as a few centimetres.

With the SKF SAF 22538 housing, the shaft needs to be lifted around 160 mm to be able to remove or place the housing base with the bearing mounted in its operating position on it. Sometimes it's not even possible to replace the lock nut without removing the bearing and housing from the shaft. In this case, the shaft could not be moved more than 4 mm in all radial directions. So, the only way to replace the bearing without touching the fan casing was to:

- 1 Lift the shaft a few millimetres so that the bearing did not touch the housing base.
- 2 Untighten the lock nut and hammer the inner ring to loosen it from the adapter sleeve. In cases of difficulty doing this, heating the bearing with a flame can help, but this can cause damage which is a problem if you want to reuse it.
- 3 Slide the bearing and housing base axially along the shaft to dismount them.
- 4 Remove the preservative from the replacement bearing's inner ring face that will be in contact with the locking washer, but leave it in the bearing bore. This is rarely done, but it reduces the risk of damaging the washer during mounting.
- 5 Place the adapter sleeve in the bore of the replacement bearing.
- 6 Clean the locking washer face that will be in contact with the bearing and the face of the bearing that will be in contact with the washer, but lubricate the nut and threads.
- 7 Mount the locking washer and the nut on the adapter sleeve.
- 8 Place the replacement bearing in the housing base.
- 9 Slide the bearing, adapter sleeve and housing into position along the shaft

taking into consideration the final position of the bearing on the sleeve after drive-up and thermal elongation of the shaft.

- 10 Check that the bearing doesn't touch the housing so that no mounting forces are transmitted to it through the rolling elements and outer ring.
- 11 Drive-up the bearing along the adapter seat to obtain the correct tight fit.

Since it not possible to mount a bearing with a hydraulic nut with the housing base already in position, the SKF Drive-up Method cannot be used. The only way is to turn the lock nut to force the inner ring up its seat on the adapter sleeve. To avoid damaging the lock nut and potentially the locking washer, it's best to use an impact spanner and a hammer to do this (see **figure 2**). In the case in question, a customer owned impact spanner was used.

For decades, maintenance people have used the feeler gauge method to check radial clearance reduction and evaluate the fit of spherical roller bearings. For my opinion on this method, I invite you to read the first issue of SKF Pulp & Paper Practices though regular readers will already know that I

recommend the SKF Drive-up Method and the SensorMount method for very large bearings.

The feeler gauge method is tricky with CARB (see *SKF Pulp & Paper Practices 11*, page 4-6). I wasn't comfortable using it, so I opted to use the axial drive-up method and double check the axial drive-up. I did this in two ways.

Firstly, using the angle of rotation of the nut as there is a direct relationship between this and the nut axial displacement due to the thread design. In my case, the SKF AN 38 locking nut has eight threads per inch. Consequently, each full rotation the nut will push the bearing 3,175 mm. In 1997, the SKF General Catalogue recommended an axial drive-up for a 22238 bearing between 1,40 and 2,00 mm. Today, it would be between 1,30 and 1,60 mm. So, in 1997, I decided to have 1,80 mm as my target. This meant a lock nut rotation of $(1,80/3,175) \times 360 = 204^\circ$. For practical reasons, I decided to accept between 200 and 210°.

Secondly, using the distance of the bearing drive-up along its seat measured with a dial indicator or another suitable tool. In my fan case, I used two reference planes: the bearing inner ring face 'A' and the adapter sleeve end face 'B' (see figure 3). We used Johansson gauges, that when wrung together would give the distance A-B, together with a small straightedge against the sleeve face to help increase the accuracy of the measurement. We then subtracted 1,80 mm from the A-B distance and wrung together Johansson gauges to the new calculated value $((A-B)-1,80)$. We then drove the bearing up its seat until the Johansson gauges placed on bearing face A touched the straightedge against adapter face B. I don't recall why we used this method instead of a dial indicator. Maybe it was the lack of space.

There are some other ways of measuring axial drive-up. For example, the one shown of page 56 of the *SKF bearing maintenance handbook* (see figure 4).

The main issue is to find the starting position when there is enough good contact between the bearing inner ring, the adapter sleeve and the shaft to make the inner ring expand radially due to the beginning of the tight fit.

My preferred method is the 'noise' method. I wrote about this in *SKF Pulp & Paper Practices 3*. To recap, you screw the nut by hand and then use a spanner and a hammer. The sound of the gentle tapping of

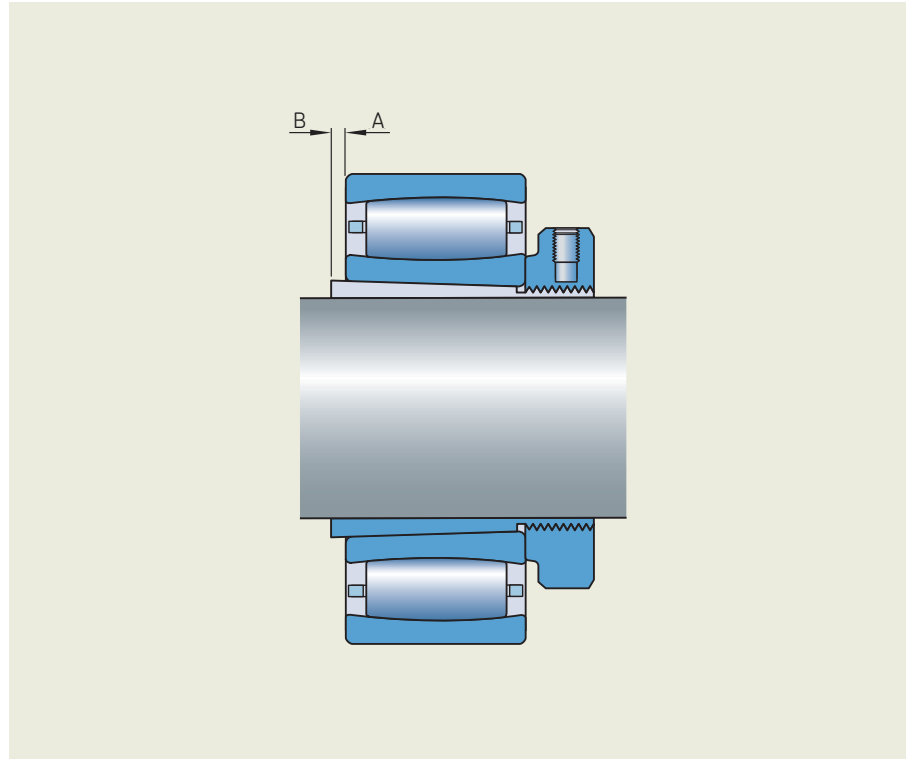


Fig 3: The distance A-B. N.B. The lock nut shown is not the one used in my 1997 fan case

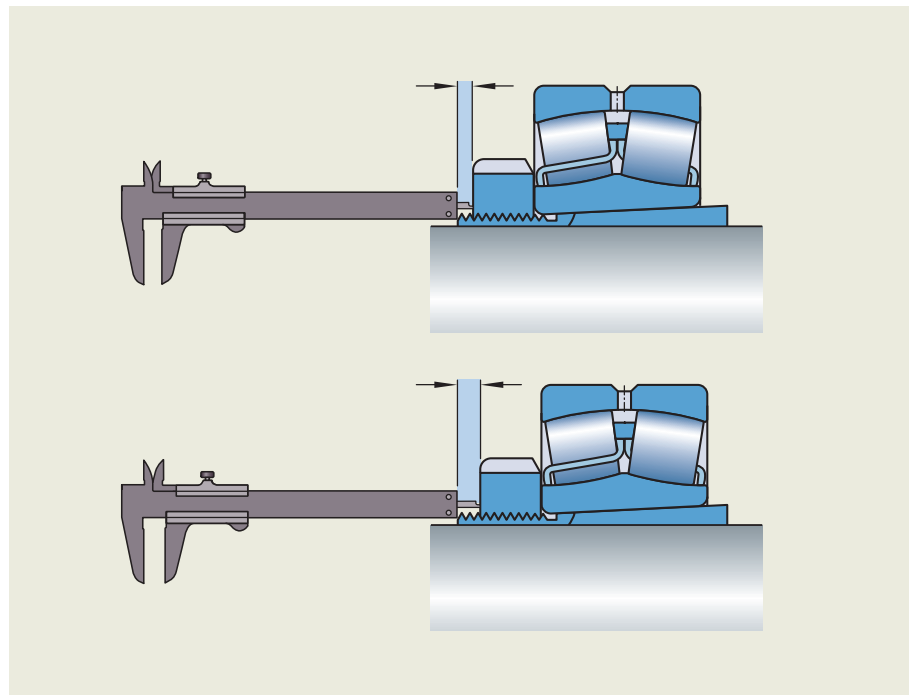


Fig 4: Measuring axial drive-up with a Vernier caliper

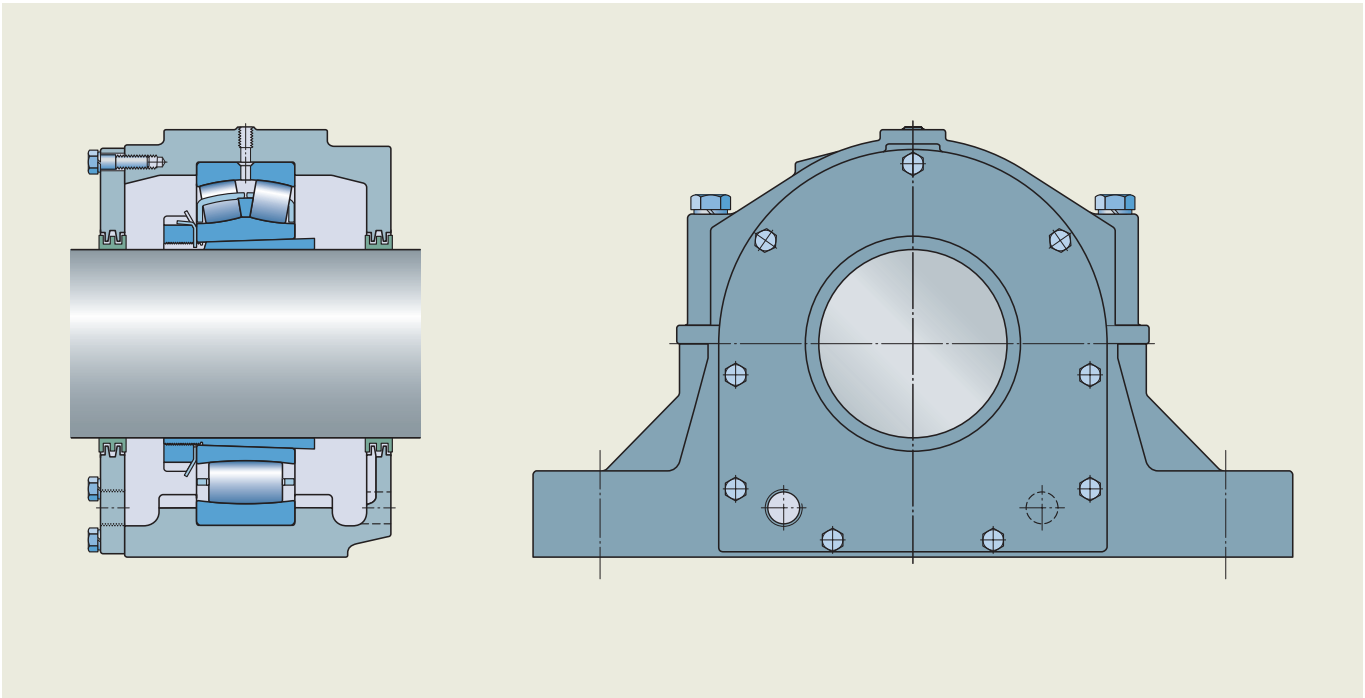


Fig 5: Customised SKF SAF housing for use with a hydraulic nut on the TAD fan at the mill

the hammer on the spanner becomes more metallic when the system - bearing, nut, shaft and sleeve, if there is one - becomes more rigid. That is my starting point. Another method, less accurate in my experience, is when the bearing and sleeve stop rotating when torque is applied to the nut with a spanner. This is why the SKF Drive-up Method is easier and more accurate though you need to be able to use a hydraulic nut and replace it afterwards with a lock nut (for more information, see *SKF Pulp & Paper Practices 3*, pages 5-6).

So, in summary, the C 2238 K/HA3C4 was mounted by finding the starting position using the noise method and the driven up the adapter sleeve about 1,8 mm with a drive-up distance double check. The starting position of the bearing took the 1,8 mm drive-up and the thermal elongation of the shaft on a hot gas fan into account. A simple calculation of shaft elongation only would show just over 6 mm. However, the actual elongation is less since the fan support frame is also in a hot environment. In addition, the customer had previously measured the axial relative displacement between the shaft and the housing on the non-drive end at 2 mm. 2 mm axial

displacement of the inner ring relative to the outer ring for this bearing size, if the two rings have no axial offset, changes the radial clearance very little. So, once the final position was reached, the inner ring had a slight axial offset relative to the outer ring with the inner ring being closer to the fan wheel.

Understanding that it wasn't as easy to mount a CARB bearing with a feeler gauge compared to a spherical roller bearing and convinced about the SKF Drive-up Method, the mill manager asked for a housing that could be used with a hydraulic nut which could replace existing housings without any modifications. A modified SKF SAF 22538 with an end cover added was proposed and accepted (see figure 5).

The locking washer issue

SKF does not recommend mounting a lock washer between the nut and the bearing during drive-up, but it's not possible to remove the lock nut once mounted to place the washer in some applications. The reason for this is that the locking washer has an inner tab that is positioned in the adapter

sleeve slot (see figure 6). The washer doesn't rotate, but the nut rotates against it with high axial force during drive-up and the friction between the two tries to move the washer. This can damage the washer's inner tab and even tear it off. There is a risk that the washer becomes free to rotate thereby losing its locking function.

The old SKF bearing maintenance handbook recommended that when a locking washer must be in position during mounting, the threaded portion and side face of the nut and washer which abut each other be adequately coated with molybdenum disulphide paste or a similar lubricant. The latest version of this handbook contains nothing about this. SKF doesn't recommend mounting a locking washer between the bearing and nut during drive-up, so don't do it and as you don't do it, no warning is needed. Instead, you should use a self-locking nut instead, like the KMK or KMFE, or design the machine such that a locking washer doesn't need to be in position during bearing drive-up.

However, reality is that a locking washer is often in place during bearing drive-up especially in fan applications. So, remember to lubricate the contact surfaces between



Fig 6: Locking washer in position on the adapter sleeve

lock nut and locking washer well to reduce friction and clean dry the contact surfaces between the washer and the bearing to increase friction.

2 CARB solved the vibration issues during start up by eliminating the axial stick-slip motion of the previously installed spherical roller bearing in its housing on the non-driven end of the fan shaft.

Conclusions

1 I highly recommend using the SKF Drive-up Method to mount CARB bearings and spherical roller bearings. If it is not possible, the feeler gauge method is a well-known, though less accurate, method for spherical roller bearings. However, the feeler gauge method is tricky with CARB bearings and I have seen many instances of them working loose because of too short drive-up since the clearance reduction wasn't measured correctly. The old axial drive-up method, even if the starting position is difficult to find, is a more accurate method than the feeler gauge one for the CARB bearing for me.



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