SKF Pulp & Paper Practices
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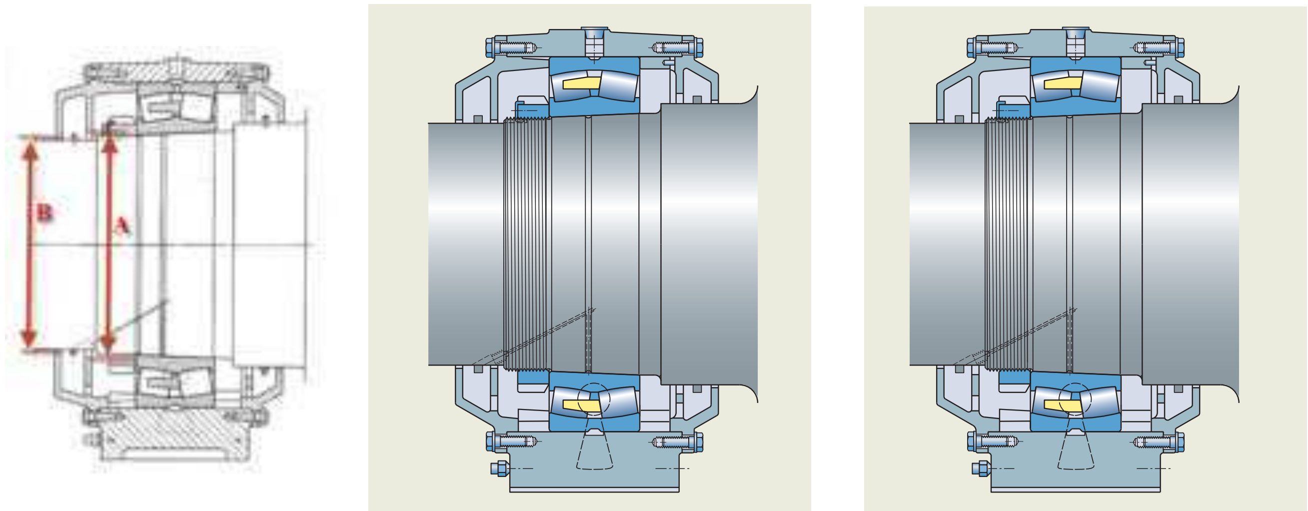

Figure 1: from left to right: in handbook dated 1991, in handbook dated 2002, and in handbook dated 2016.

Letter from the editor

Reading every issue of a magazine, I noticed that some topics would crop up in articles and again after a certain length of time. I felt like I'd spent my money for nothing. I could understand, since they were often hot topics or frequently asked questions, and of course, new readers didn't have the old issues. I didn't see why it was necessary to write about the same subjects in Pulp & Paper Practices until one of my colleagues, Matt, who was supporting me a lot with Pulp & Paper Practices, explained that it was necessary to spread more information about drying cylinder bearing heat treatment. Once it was published, I met customers who had read it but were not aware of the first article on the same topic. I also got feedback from colleagues that a second article, written in a different way and with more information, helped a lot with understanding the pros and cons. That was an important lesson for me.

In the past, when I spotted an error in a book or document, I would lose all faith in the expertise of the writer. These days, after overreacting, I would start to ask myself whether it was just a typo or an error in the source. The difference between then and now is that now I write a lot. Creating and updating handbooks, and being the main contributor and owner of Pulp & Paper Practices and its local ancestor, SKF Info Papeterie, made me humble and more tolerant. Editing is difficult. Not only because your brain sees what it wants and because you focus on some things and not on others, but also because time is short, you don't always do a thorough check of an older document you're using as source or are updating. **Figure 1** above shows a good example of this. In the 1991 handbook, the front housing cover can be mounted with the oil flinger in place. Diameter A is bigger than diameter B, and A is bigger than the outer diameter of the oil flinger. All drawings for the 2002 handbook were redone to be consistent with the new SKF rules for external documentation. An error was introduced by the graphic designer and wasn't spotted during the edit. I updated the handbook in 2011 and 2016, and just kept the same drawing as in the previous edition (2002). As there is nothing about oil flingers in the text, I didn't really give oil flingers and covers any thought and relied on an "official SKF drawing" from my predecessors. On the back cover, there is actually a radial split one.

When a colleague told me that he couldn't work out how to install covers using the drawings in the 2016 handbook and wanted more information, I then spotted the error and felt very alone.

Pulp & Paper Practices is reviewed by at least two other engineers before being sent to the communications department for editing, layout and the creation of drawings and diagrams from my drafts. After this, there are several rounds of proofreading. Despite all this, there is still potential for good old Murphy's law to be at play. No matter how much effort you put in to removing all errors, there will always be something that pops up after you've published.

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Checking bearing clearance and bearing condition with feeler gauges

Checking the bearing clearance

As I do several times a year, last week I received a request for technical support with regards to a quality concern for a thin-section spherical roller bearing. The bearing clearance should be C3, but it is measured as C4 with a feeler gauge. The question is always:

- Is there another bearing available?
- If there is no other bearing with the specified clearance available, can I install the C4 instead of the C3?

This is such a frequent case that I started Pulp & Paper Practices with an article about clearance measurement with feeler gauges (*Pulp & Paper Practices, issue 1, January 2011*) and with an article about installing a bearing with a higher clearance class (*Pulp & Paper Practices, issue 2, June 2011*).

The application is a suction roll, as shown in **Figure 2**.

The bearing is a 239/500 CAK/C083W33, C083 meaning C08 (better run-out tolerance) and C3. The customer measured the clearance and got 0.700 mm, whereas for a C3 the clearance should be between 0.490 and 0.630 mm. Knowing the application, that bearing could be installed, even if it is out of its clearance class by 0.070 mm. But knowing the bearing and by experience, my first question is: is that bearing out of its clearance class or not? It can happen, but this isn't normally the case.

What rings alarm bells in my head is that the 239/500 CAK/C083W33 is in the thin-section bearing series: 238, 239,248 and 249 series (**Figure 3**). These deform quite easily under their own weight. More interestingly, it has been shown that for a bearing of that size, it is possible to force a feeler gauge that is approximately 0.1 mm too thick between the roller and the outer ring. Do thicker series deform too? They certainly do – even a 223 series does – but they deform much less.

The customer was asked to measure the clearance again following rule 7, which you can find in the first issue of Pulp & Paper Practices.

Rule 7: Clearance = (a+b+c)/2

He got a clearance close to the maximum value of the C3 clearance class, but still within it. The bearing was then installed without further deliberation and without causing any problems during operation.

Let's come back to rule 7 (*page 5 of Pulp & Paper Practices, issue 1*) and expand on it.

Because the rings deform elliptically under their own weight and the weight of some of the rollers, the clearance measured in one single position will not give the true radial clearance. The clearance measured at the 12 o'clock position in a bearing standing upright on the shop floor is smaller than the clearance measured at the 6 o'clock position in the same bearing hanging from a strap or loosely fitted on a shaft. The thinner section the bearing has and the bigger the bearing is, the larger the deflection and the variation between the actual clearance and the one measured with feeler gauges.

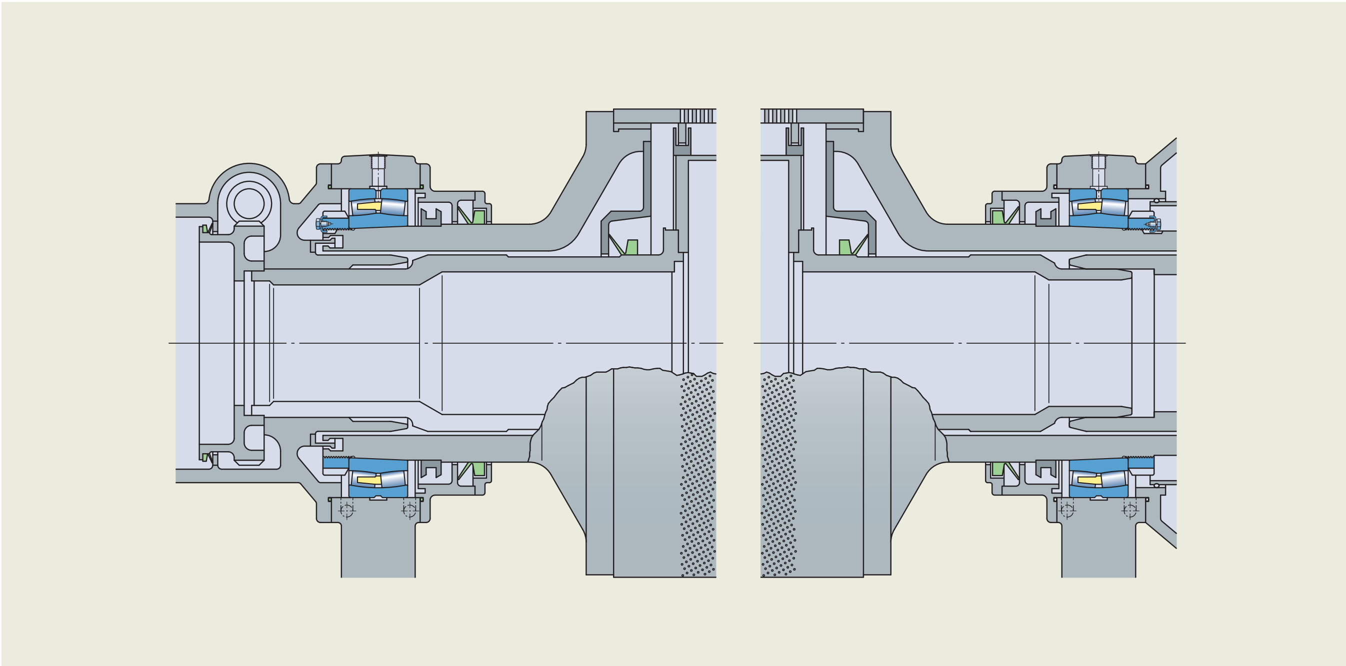

Figure 2: Suction roll with thin-section spherical roller bearings.

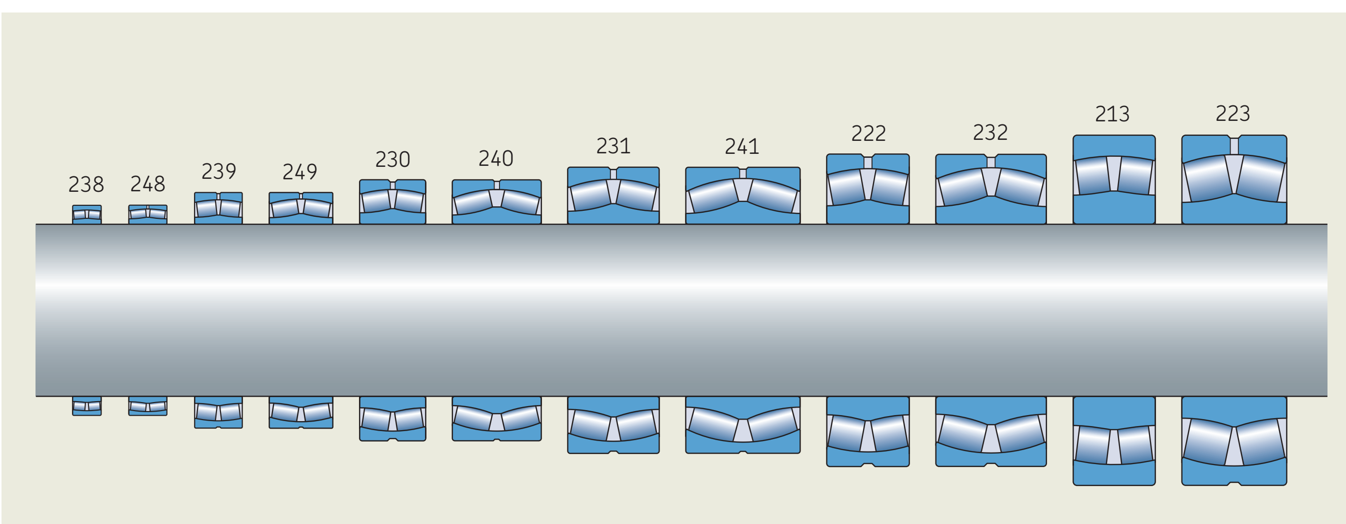

Figure 3: Different sections of spherical roller bearing series have the same bore diameter.

Now take **Figure 4**.

To find the true clearance, first rotate the bearing by hand so that the rollers are in their equilibrium position.

If the outer ring is not perfectly aligned (co-axial) with the inner ring, this isn't an issue for spherical roller bearings. The outer ring raceway is a sphere. This isn't the case for the CARB.

Then check the bearing at 12 o'clock (**c**) for a bearing standing on the floor or at 6 o'clock for a bearing hanging on a shaft. Then measure the clearance at position 3 o'clock (**b**) and 9 o'clock (**a**) at the same time.

It is very important to measure the clearance at the 3 o'clock and 9 o'clock positions at the same time. The reason is that inserting a feeler gauge at 9 o'clock can decrease the existing clearance at 3 o'clock. The best practice is to leave a feeler gauge in position at 3 o'clock after trying to find the clearance at that position, and then measure the clearance at 9 o'clock with another feeler gauge set. Because you could inadvertently deform the rings with the feeler gauges, you might decrease the clearance at 12 (or 6) o'clock. So, in that last position, the feeler gauge must be left in place. As shown in **Figure 5**, you need several sets of feeler gauges.

The best estimation of the true clearance can be found by (a+b+c)/2.

If the rings were perfectly round, then a=b=c/2. This is why the formula is (a+b+c)/2 and not (a+b+c)/3.

However, the spherical roller bearing has two rows of rollers.

If there is any radial clearance in the bearing, then there will be some axial clearance in it too. This means that the inner ring may displace axially relative to the outer ring (**Figure 6**), and one row may have less radial clearance than the other. It might not even have any clearance at all.

Some people use one long feeler gauge across both rows, over two rollers. A large radial clearance difference between the two rows can be clearly found by simply trying to insert the feeler gauge, but not when there is only a small difference in clearance. Furthermore, the two rollers may not be in the same position. For example, one could be at 12 o'clock and the other at two minutes past 12.

I prefer to avoid taking clearance measurements with one feeler gauge across both rows, although sometimes the second row cannot be reached once the bearing is installed.

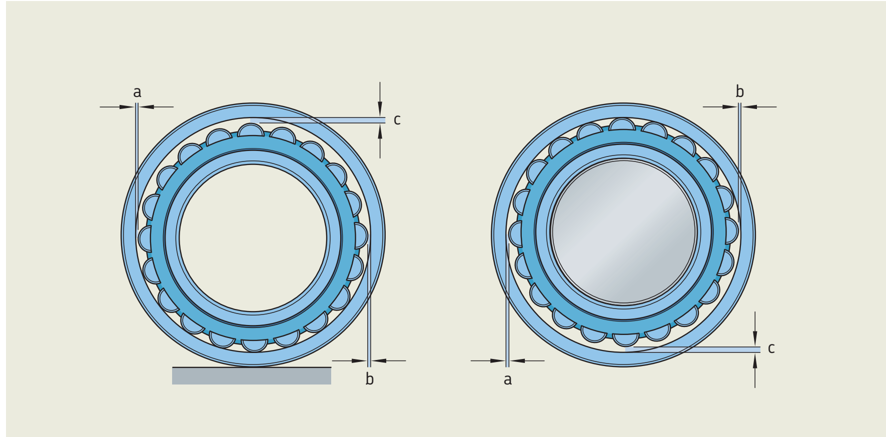

Figure 4: Bearing on shop floor or table (left) and bearing on the shaft (right).

Figure 5: To find the true internal radial clearance, you need more than one set of feeler gauges.

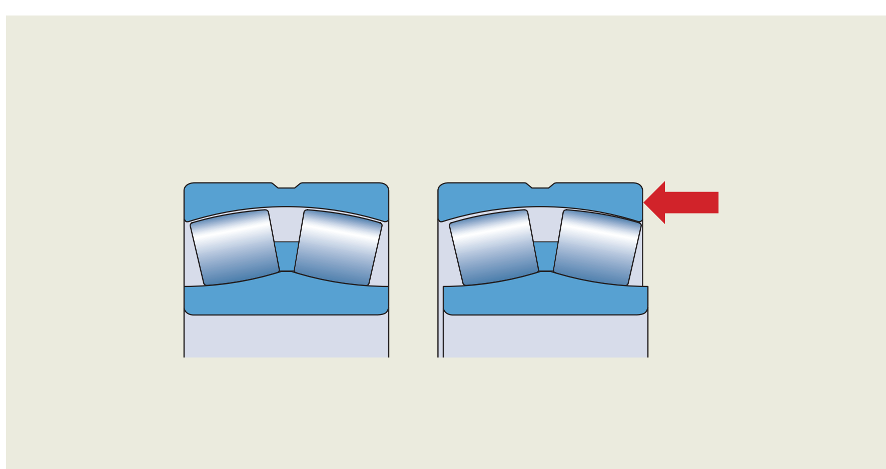

Figure 6: Axially displaced rings affect the radial clearance of each row differently

Important reminder: There is no need to know the true clearance of the bearing when driving the bearing up along its tapered seat. You only need to have a bearing whose elements (rings and rollers) don't move relative to each other, and you always make the same measuring error. If you want a 0.100 mm reduction in clearance, and you initially get a measurement of 0.200 mm or 0.250 mm between the roller and raceway at 6 o'clock with the bearing sitting on the taper, you don't need to worry. If you measure 0.200 mm, then you will want to get a final clearance of 0.100 mm to get to correct tight fit. If you measure 0.250 mm, you will want to get a final clearance of 0.150 mm to get the correct interference fit.

Therefore, there is no point in measuring the clearance on both rows during installation. You only need to check that there is enough clearance on both rows before starting the drive-up to avoid one row having zero or negative clearance (pre-load) during drive-up.

I understand that the customer wants peace of mind before installing the bearing. They want to make sure the bearing they're installing has the right clearance. My experience, however, is that most customers measure the bearing before drive-up to get a value for clearance reduction calculations. If the measured value is outside the minimum or maximum indicated in the bearing catalogue for the bearing size and clearance class, they call the supplier to make a quality claim.

Measuring the clearance to obtain the true clearance, and measuring the clearance for the clearance reduction to obtain the correct interference fit, are two different things.

If you want to find the true clearance or just check that a thin-section bearing is indeed in the clearance class as indicated in its designation, you need several sets of feeler gauges (up to six in some tricky cases). Also, check it straight after unpacking the bearing, not once it's been installed and there is no way of easily accessing the two rows.

If the intention is to reduce the clearance, then you only need one set of feeler gauges.

Therefore, when trying to find the true clearance, you will do it just after unpacking the bearing, you'll always be able access both rows and won't need long feeler gauges to measure between both rollers and the raceway at the same time. When making a clearance reduction, however, you may might to have a set of long feeler gauges to reach the row you cannot access, but only to make sure there is enough clearance.

Learning to use feeler gauges

I first started using feeler gauges for checking and adjusting valve clearances on engines. An old mechanic living near my parents' house taught me how to measure with a feeler gauge. Position the feeler gauge between the valve stem and rocker and then pull gently. The feeler gauge should come out, although with a certain amount of resistance, similarly to if you were dragging it through grease. At home I tried to replicate this feeling by dipping a feeler gauge in multipurpose NLGI 2 grease.

When the workshop manual indicated a valve clearance of 0.20 mm, I would waste time trying to get the exact 0.20 mm clearance with a 0.20 mm thick feeler gauge and the same feeling as pulling a feeler gauge out of grease.

It was at my engineering school ESTACA, which specialises in aeronautical and automotive engineering, that I started to take a different view on how to use feeler gauges. First of all, my friends and I didn't experience the same feeling as I did, and so they didn't adjust the valve clearance in the same way. One would get 0.19 mm, another 0.20 mm. Despite this, we couldn't see much difference in engine performance on an old Renault 4 engine on the test rig. We ended up using the pass/not pass method, instead of an optimised feeling that was different for all of us. If the manual indicated 0.20 mm, then the 0.18 mm thick feeler gauge should pass very easily, whereas two feeler gauges, one 0.10 mm and 0.12 mm placed side by side (0.10 + 0.12 = 0.22), should not pass.

Another thing I learned at engineering school was metrology. The accuracy of the measuring tool, the accuracy of the measuring method and the effect of the environment, mainly the temperature, left me dubious. We would do design calculations on the micron level. But manufacturing precision couldn't reach the micron level, and in the repair shop, things were even worse. Depending on the application, the question at the design stage is what the acceptable maximum tolerance is, taking into account reliability, manufacturing costs and the repair environment (accuracy of tools, mechanic skill level, workshop conditions).

For a drying cylinder bearing, C4 clearance, insulated journal, an error of 30 microns has very little or no impact on the bearing's service life or on paper production. On a small machine tool spindle, an error of 30 microns in the bearing axial preload (negative clearance) can have a huge impact on the bearing's service life and machining or grinding quality.

Over my SKF years, I've met plenty of people trying to find the exact true clearance on spherical roller bearings using a feeler gauge who started worrying if they got a measurement of 0.01 mm outside the clearance class range on a very large bearing. I have also seen engineers and/or mechanics not get the same clearance on the same bearing, and who then disagree about whether the bearing can be installed or not.

Let's take a step back.

1. As I mentioned earlier on, it is not necessary to know the true radial clearance when making clearance reductions to get the correct interference fit between the inner ring and the shaft. The clearance reduction isn't to adjust the final clearance, but rather the interference fit. You just need to make the same measuring error.
2. Bearings aren't supplied with a precise radial clearance, but rather a clearance class. If you want to check the bearing before installing it, there is no need to find the true radial clearance. Simply check whether the clearance is within the clearance class range using the pass/no pass method, or for thin-section bearings, try to find the true clearance to see how far you are outside the clearance class limits.
3. Due to the subjectivity of feeler gauge readings, bearing ring deformation, the fact that rollers are often not in their equilibrium position and the relative positions of the inner and outer rings, the measurement error can be quite big. I do not have an example, but on a very large spherical roller bearing 241/900 of three and a half tonnes, I have seen 0.200 mm differences between two measurements on the same bearing. Therefore, worrying about measurements of 0.010 mm outside the clearance class is pointless except for small bearings.
4. Most of the bearings on a paper machine can run with a higher internal radial clearance than the "initially" specified one. However, the doing the opposite is risky and can lead to premature failure. In other words, if the application requires a C3, installing a C4 isn't risky, but using a CN (normal clearance) is risky. Using a higher clearance can reduce bearing fatigue slightly on very heavily loaded bearings, however most bearings in paper machines do not fail due to fatigue.

So, my view is this

I don't worry about the true radial internal clearance of a spherical roller bearing or a CARB before installing it. Just for peace of mind in some cases, I check that the clearance is within the clearance class limits.

I check the clearance with the pass/no pass method, except for thin-section bearings. Let's take an example:

The bearing is a press roll bearing of 241/500 size, taper bore, C3 clearance class. For this bearing size, the internal clearance range is 0.490 mm to 0.630 mm straight out of the box before being installed. I know that my feelings when using the feeler gauge could give me an uncertainty of ±0.010 mm at this bearing size. I take two feeler gauges, one 0.300 mm and one 0.200 m, both less rigid than the 0.500 mm thick gauge, so I can more easily follow the gap profile between the roller and raceway. If both the feeler gauges pass, then I consider it to be above the minimum clearance. If they do notpass, I then try rotating the bearing and

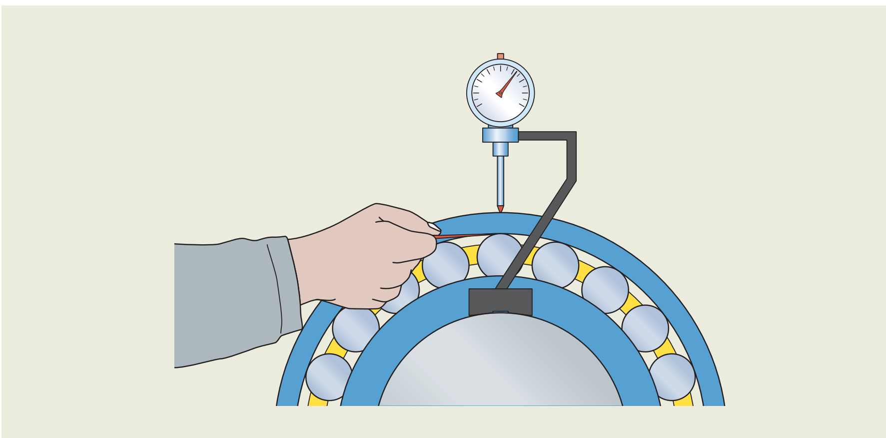

Figure 7

trying again. If the feeler gauges still don't fit, I'd rather not install the bearing.

If I'm confident about the minimum clearance, I will then use several feeler gauges: 0.300 mm, 0.200 mm and 0.150 mm. Some people wish to avoid using feeler gauges thicker than 0.250 mm, while others avoid ones thicker than 0.300 mm. Together, these make 0.650 mm, which is greater than 0.630 mm. I won't accept a clearance below 0.490 mm, so I need at least 0.500 mm for my measurement, but I will accept it being slightly above 0.630 mm. The three feeler gauges, 0.300 mm, 0.200 mm and 0.150 mm, should not pass. If they pass, I try measuring the radial clearance to decide whether or not to install the bearing. My decision depends on the load on the bearing and how far outside the clearance class it is.

If it is a thin-section bearing, the pass/no pass method is less effective. It will take more time, since there should be measurements from three positions. Therefore, in this case it is necessary to try and find the true clearance to see whether you are near the clearance class limit. Again though, trying to get closer to the true clearance is only necessary if you are close to the lower limit of the clearance class.

Over the past 20 years, I must admit that I only measured the true clearance class with a feeler gauge upon customer request or if there was customer quality complaint.

For driving the bearing up along its tapered seat, I rarely use the feeler gauge method, instead I use and recommend the SKF Drive-Up Method.

Thus learning how to find the true internal radial clearance is sometimes necessary. Here are some ways you can practise.

One way of learning to recognise the right feeling is to practise using a bearing that easily deforms, such as a thin-section large size spherical roller bearing, a 238 or 239 series. These are often found on modern suction rolls or some deflection compensated rolls. A dial gauge is positioned as shown in **Figure 7**. The correct feeler thickness is the thickest that doesn't cause any movement on the dial gauge.

Then there is the need to learn how to put the rollers into their equilibrium position. For that, I recommend medium-size bearings, one spherical roller bearing, and one CARB. The best way would be to disassemble the bearings to measure the inner ring and outer ring raceway diameters, and roller diameters, so the true internal radial clearance is known. Then for practice, measure the clearance of the bearing using a feeler gauge and practise until you can easily find the true clearance.

For CARB bearings, I recommend reading *Pulp & Paper Practices, issue 11, pages 4–6.*

Radial clearance given on installation reports

When radial clearance, in before mounting conditions, is indicated on an mounting report without any other information, this doesn't mean very much to me.

How was the measurement done?

Was it an estimation of the true clearance, or was just a value used for the clearance reduction? Sometimes, it isn't clear.

For many, it is the true radial clearance and a clear fact when doing RCFA. Not for me.

This information is only valuable with more information, such as how it was measured.

When there is a radial clearance value after mounting, some use this as a reference for tracking the condition of the bearing over the years. This is bad practice.

The residual clearance after drive up is normally the clearance when the bearing is unladen. With the weight of the roll or the cylinder, the bearing deforms and the measured radial clearance increases. Even with the same load on the bearing, relative axial displacement between the inner ring and outer rings may have occurred due to thermal expansion or simply an axial load. Remember **Figure 6**. You need to measure both roller rows every time to make sure you can compare measured values over time.

Over many years, there will be many different technician taking measurements. This means different feelings, and different results.

If there is indeed an increase in radial clearance, then the wear is already quite significant (heavy spall or strong abrasive wear). Minor wear, such as dents due to contaminants, surface distress due to inadequate lubrication or small spall, is insignificant in comparison to the contact surface between the roller and the raceway. The radial clearance will not increase. The damage in **Figure 8** cannot be seen by a clearance increase.

Minor damages can be felt with a bent wire with a sharp point (**Figure 9**), just as you would do with your fingernail. You will be able feel very minor damage. If you do not have good vibration analysis tools, find a wire, bend it and grind it to a sharp point, and stop relying solely on clearance measurements for tracking the condition of bearings.

Figure 8: Surface distress and small spalls.

Figure 9: Bent wire with sharp point for feeling surface damages on a bearing.

Conclusions about radial clearance measurements

Most people measuring the internal radial clearance of spherical roller bearings and CARBs do not measure the true clearance. I hope that with this issue of Pulp & Paper Practices, which is a reminder of topics from the very first issue in 2011, this time with a bit more information, you will be able to get a better idea of the true clearance if you do want to know what it is.

In general, knowing the true clearance isn't needed.

And to finish, monitoring the condition of bearings by only measuring the clearance over the years is not good practice. The best practice is vibration analysis, even at low speed.

"Rolling bearings in paper machines" handbook: Corrections

The "Rolling bearings in paper machines" handbook, fifth edition, published in 2016 (**Figure 10**) requires some corrections.

SKF Sensor mount

The SKF Sensor Mount system for easy and fast spherical roller bearing and CARB mounting, explained on pages 9:14 to 9:17, has been discontinued. In my humble opinion, this is because the wire had to be cut, so the Sensor Mount could only be used once. A new wire and sensor could be installed if the bearing was sent to the SKF remanufacturing centre. Knowing that suction rolls and press rolls are often removed for maintenance and the bearings removed, checked and rein-stalled again if they are in good condition, the single-use Sensor Mount system wasn't convenient. Customers also occasionally asked why they should use the SKF Sensor Mount if the SKF Drive-up Method gives good results. I can only agree, as it is a very reliable and practical method.

Cover and oil flinger

As I discussed in my edito in this issue of Pulp & Paper Practice, a drawing shows a cover that cannot be installed. Please refer to **Figure 1** on the front cover of this issue. Diameter A is the same as diameter B in the handbooks since 2002. Diameter A should be bigger.

This concerns **Figure 4.21** in the handbook.

The back cover is a radially split cover. So diameter A being equal to B is fine.

Figure 10: "Rolling bearings in paper machine", fifth edition, 2016.

Return oil hole missing on cover

Figure 11 shows a split cover without a hole to allow oil centrifugated by the oil flinger to re-enter the housing. This would lead to oil leakage. **Figure 12** shows the correct drawing. This concerns figure 1.16 page 1:15.

Wire roll, felt roll

On page 1:1, the caption for **Figure 1.1** states that item 11 is a guide roll (wire roll). This is of course not a wire roll, as this is in the dryer section. Replace the wire roll with a felt roll or fabric roll. In the next edition, for the dryer section, "felt roll" will be replaced with "fabric roll".

Units on page 4:13

On page 4:13, q is in kN/mm and L is in mm.

Technically this isn't an error, but elsewhere in the handbook, q is in kN/m and L is in m. It's better to be consistent.

Oil level difference

Another error was made when the drawings were redone to follow new rules. The oil level difference in **Figure 1.19**, page 1:19 (shown here as **Figure 13**) is not correct, the correct figure is shown in **Figure 14**. The lowest level is at the lowest part of the return pipe.

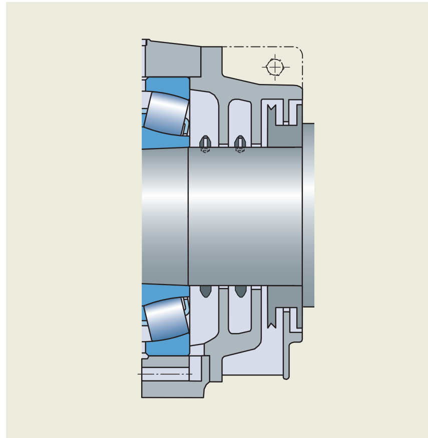

Figure 11: Incorrect

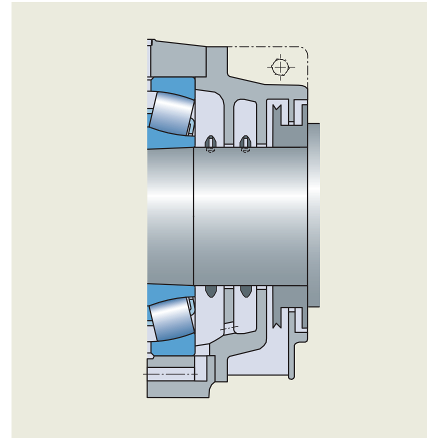

Figure 12: Correct

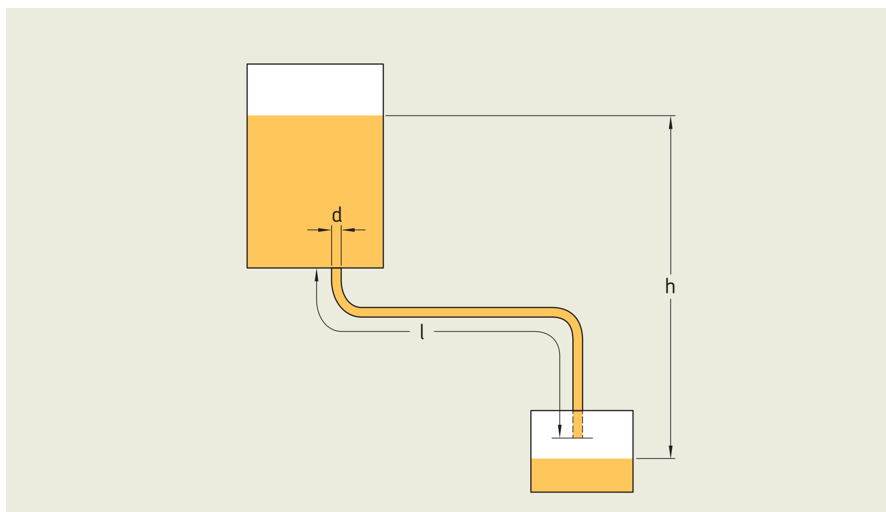

Figure 13: incorrect

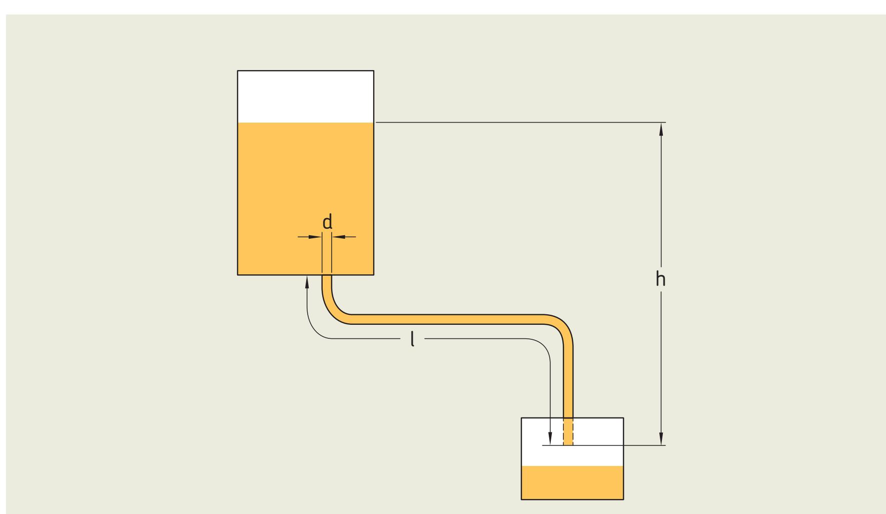

Figure 14: correct

Clearance class for felt and wire rolls

Since 2002, the third, fourth and fifth editions of the handbook have indicated that the clearance class is usually CN (Normal clearance class) for wire rolls in the forming section and C3 for felt rolls in the press section. What they do not say is that CN is recommended for wire roll bearings and C3 for felt roll bearings. You can find CN or C3 in both sections, it will depend on speed, load and temperature. To avoid misinterpretation, this text will be changed in the next edition.

Conclusion

Errare humanum est, perseverare diabolicum[1)].

We are committed to continuous improvement.

1) To err is human, but to persist in error is diabolical.

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