SKF Global Pulp & Paper Segment | Volume 3 | No. 11 | May 2014

SKF Pulp & Paper Practices

SKF technician checking bearing seat geometry with an inner ring and Prussian blue

The power of knowledge and getting your hands dirty

It's not that easy to create an issue of SKF Pulp & Paper Practices because our readers range from maintenance workers in mills to engineers and designers at equipment manufacturers. This makes it a challenge to write content which appeals to everyone. While a piece about how to measure clearance with a feeler gauge is likely to be interesting for fitters mounting bearings, it's going to be less relevant for design engineers concerned with selecting and calculating the correct interference fit for bearings.

One reader recently told me that the first few issues of *SKF Pulp & Paper Practices* were very interesting, but he stopped reading them after that because he felt the trend was towards more information for those working with bearings on their computer screens and less tips for those with them in their hands. With this in mind, I decided that issue 11 would be written primarily for those with their hands in the grease.

Engineers and designers will hopefully find this issue useful too. After all, how can you design a bearing assembly without an understanding of the reality of mounting and the time pressure on maintenance workers during a machine stop? In my time, I've seen many arrangements where changing the bearing was both time-consuming and costly. While some of them were probably the result of trying to reduce cost, others were almost certainly because bearing replacement had not been properly taken into account.

Just as understanding mill realities helps engineers and designers, knowing the basics of what happens to bearings during operation is useful for maintenance workers. Such knowledge can help avoid many common causes of bearing failures such as overfilling with grease, excessive clearance reduction and so on. To reassure any nervous readers, I'm talking about a basic understanding rather than knowing all the formulas and running the calculations.

The marriage of practical experience and theoretical knowledge is very powerful. The gentleman in the photograph above, Belaid Ait Hamouda, and I mounted many bearings together. I think we made a good team and we certainly learnt a lot from each other. Unfortunately, some still believe that you just need to know how to use a spanner or tighten a screw. These people badly underestimate the value of well-trained, knowledgeable and experienced mechanics.

Regards,
Philippe Gachet
Senior technical consultant
Philippe.gachet@skf.com

Just some tips

This issue of SKF Pulp & Paper Practices will focus on sharing knowledge about:

1 Mounting tapered bore bearings on hot journals
2 Checking internal radial clearance on CARB toroidal bearings
3 Increasing drive-up to compensate for wear and/or increased clearance
4 How to check whether a nut it tightened to the correct torque. You'd be surprised at how many mechanics and engineers get this wrong!

Fig. 1 SKF TIH L induction heater for bearings up to 800 mm bore diameter and 1 200 kg weight e.g. many Yankee cylinder bearings.

1. Mounting tapered bore bearings on hot journals

There is not always enough time during unplanned stops or short planned stops to mount bearings using methods that would be preferred if there was less pressure to do things fast. In such cases, there can be issues related to giving journals and replacement bearings sufficient time to reach ambient temperature.

Driving up a cold bearing on the taper seat of a hot shaft and adjusting the interference fit while the bearing inner ring and shaft are at different temperatures will result in less of a tight fit than if they were at the same temperature. This can lead to fretting corrosion in the contact surface between the inner ring bore and the taper seat. In some cases, the inner ring will rotate on the shaft creating wear, smearing marks and fractures.

One solution is to place the bearing on its seat and to let the inner ring heat up to the shaft temperature. There should be no need to use a thermometer if the shaft temperature is below 55 °C as you can get an approximate, yet adequate, idea of the temperature difference by feel. However, when the clock is ticking, production colleagues are not going to be happy to see maintenance staff taking a coffee break while the inner ring slowly reaches the shaft temperature.

When time is of the essence, the fastest and most accurate solution is to heat the bearing up to the shaft temperature with an induction heater (→ **figure 1**). Such heaters are easy to use.

Simply:

1 Place a suitable induction heater close to the machine while the housing is opened or dismounted to allow access to the bearing that needs to be replaced.
2 Put the new bearing on the induction heater.
3 Dismount the bearing being replaced and measure the shaft temperature of the bearing seat with a thermometer.
4 Heat the new bearing up to the measured shaft temperature and then place it on the shaft without delay.
5 Drive-up the new bearing to obtain the desired fit.

N.B. A suitable induction heater is one that is an adequate size for the bearing and which has an automatic demagnetization feature. The latter is important to prevent ferrous debris from contaminating the new bearing.

Unfortunately, not all paper mills have induction heaters. I still visit some where they heat bearings in an oil bath like in the old days. I would never recommend this as there are many drawbacks. For a start, it's too slow and imprecise. Furthermore, there are health and safety concerns. There's also a risk of contaminating new bearings with old, dirty oil.

People without access to induction heaters often ask me how to adjust drive-up. With the temperatures of the bearing inner ring and the bearing seat you can calculate the increased tight fit needed to compensate for the difference. Consider a bearing inner ring of bore diameter 400 mm at 20 °C and a shaft at 60 °C i.e. a temperature difference of 40 °C. The coefficient of thermal expansion is 1,05 mm per metre per 100 °C for cast iron and 1,2 mm per metre per 100 °C for steel. While the bearing inner ring is made from steel, the cylinder or roll journal could be either steel or cast iron. To make it simple – and because the inner ring will start to heat up as soon as it's in contact with the hot seat – let's use 1 mm per meter per 100 °C. In this case, there's a need to the drive the bearing up further so that it seats on a larger diameter giving a tight fit that will decrease when the inner ring and the journal reach the same temperature. The question is how much further?

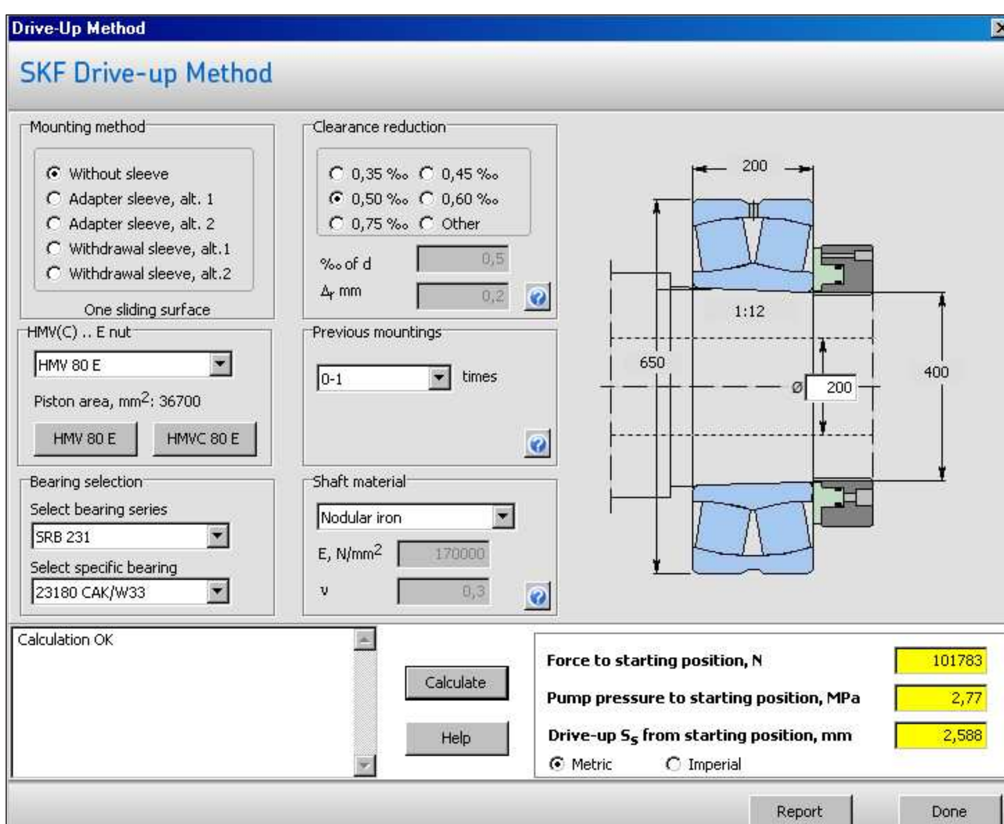
With a coefficient of thermal expansion taken as 1 mm per meter per 100 °C, a temperature difference of 40 °C and a diameter of 0,4 metres, we have 0,16 mm in excess of the diameter. If the bearing is a K bore variant – that is one with a 1:12 tapered bore – the additional axial increase should be 0,16 × 12 = 1,92 mm. For K30 variants with 1:30 tapered bores, the additional axial increase should be 0,16 × 30 = 4,8 mm. These seem large compared to normal recommended values, don't they?

A 23180 CAK/C4W33 mounted on a Yankee cylinder with a 200 mm journal bore has an axial drive-up using the SKF Drive-up Method of 2,6 mm (→ **figure 2** and *SKF Pulp & Paper Practices issue three*). Using the calculation method in the previous paragraph would call for around an additional 2 mm of axial drive-up. This should raise the question of the whether the bearing can withstand this without cracking the inner ring. The answer is yes in this particular case.

As soon as a bearing is in contact with a hot seat the temperature difference between the two reduces quickly before gradually slowing down as temperatures equalise. It is possible to measure journal and inner temperatures during mounting and adjust the axial drive-up. Could I recommend an easy rule of thumb such as driving up half the calculated value? I did it once to save time, but I really don't recommend it.

For those using feeler gauges who want to know how much more clearance reduction is needed to compensate for the temperature difference between a bearing and its seat, I advise using the SKF Drive-up software and selecting "Other" in the clearance reduction section. The clearance reduction value Δ_r should be changed until the drive-up value S_s equals the normal drive-up value plus the additional drive-up due to the temperature difference between the bearing and its seat. For those who think that this is too complicated and/or imprecise, I can only recommend buying SKF induction heaters and adjusting the bearing fit on its seat as you do when the machine is cold and the bearings and shaft seats are at the same temperature.

Fig. 2 Screenshot of SKF Drive-up software calculation for a 23180 CCK/C4W33 mounted on a tapered journal (like on most modern Yankee cylinders).



2. Checking internal radial clearance on CARB toroidal bearings

I showed in issue one of *SKF Pulp & Paper Practices* that checking the radial clearance of a spherical roller bearing isn't easy. I also mentioned that it is more difficult for CARB toroidal bearings and stated that "we do not recommend that that the feeler gauge method should be used when mounting a CARB toroidal roller bearing unless the fitter is well trained and very experienced." Let me explain why.

Just like for a spherical roller bearing, the rollers on a CARB toroidal bearing must be in their equilibrium position as if it was in rotation under load. With a spherical roller bearing, one ring must be rotated and to reach the approximate equilibrium position (if the rollers cannot find it themselves) you should simultaneously slightly push two neighbouring rollers, one from each row, against the floating guide ring. In contrast, a CARB toroidal bearing has one row of rollers, no guide ring and moves in various directions to accommodate misalignment and axial displacement. This makes it difficult to find the roller equilibrium position. Once you believe that the rollers and centered and the inner and outer rings are aligned, you check the radial clearance with a feeler gauge. The chances are that you will find, like most people, a much smaller clearance than there actually is.

I have a C 3040 CARB toroidal bearing in my office and like to challenge colleagues and visitors to try and find the actual internal clearance with a feeler gauge. So far, nobody has managed to do so. This is not due, as some believe, to the rings not being precisely enough aligned (since axial displacement of the inner ring relative to the outer ring reduces clearance). The relationship between radial clearance and axial displacement of one ring relative to the other can be seen in **figure 3**.

Note that the curve between zones **I** and **II** in **figure 3** represents the boundary between clearance and no clearance. As you can see, a radial clearance of 0,082 mm without any axial offset between the inner and outer rings allows an axial displacement of one ring relative to the other of 8,20 mm before there is no clearance. If, under the same conditions, radial clearance was 0,328 mm, the permissible axial displacement would be 16,40 mm.

If there is 0,328 mm radial clearance without axial offset and there is 8,20 mm axial displacement of one ring relative to the other, the remaining radial clearance would be 0,328 – 0,082 = 0,246 mm. A small radial clearance can give a large possible axial displacement (→ **figure 4** and **5**). Note that a small axial displacement (±2 mm for C 3040) around the zero axial displacement position gives very, very little clearance reduction. So, if the two rings of the bearing are aligned by eye, it is sufficient.

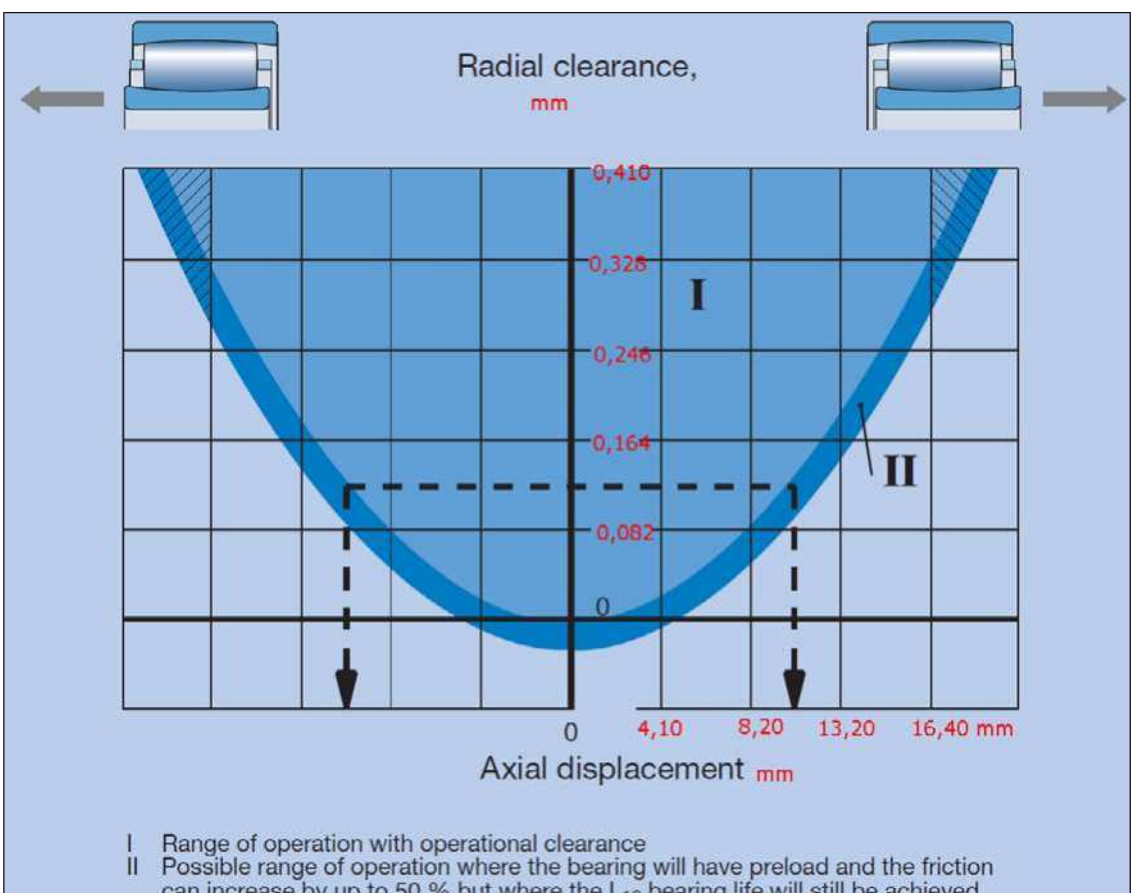


***Fig. 3** Relationship between radial clearance and axial displacement for a C 3040 CARB toroidal bearing.*

The important thing is the axial position of the rollers in the bearing (see **figure 6** which explains this better than words can do).

A small axial displacement of the roller away from its central equilibrium position will change the clearance along the roller profile. If the clearance is measured with a feeler gauge and you try to pass it over the middle of the roller you will find a smaller clearance than there is in reality. To approach the true clearance, you need to move the roller back and forward with your fingers while you try to pass the feeler gauge between roller and ring without forcing it. You will notice that initially it doesn't want to pass and then it will suddenly do so easily. You can then take a thicker feeler gauge and repeat the same process until it passes with slight friction.

The real issue is that most workers do not have enough experience of checking the radial clearance of CARB toroidal bearings with feeler gauges. This can be problematic when mounting small bearings on a taper seat without a hydraulic nut as hitting the lock nut to push the bearing along the seat will make the rolling elements move and it takes more experience to put CARB components back in position than it does for a spherical roller bearing. As a result, many small CARB toroidal bearings are mounted either too tight or too loose. Furthermore, if the clearance after mounting is checked by another worker, my experience is that he will invariably believe that there is a lower clearance than there is in reality.

To be frank, the best way to avoid the issues that I've described is to mount CARB toroidal bearings using the SKF Drive-up Method or, if the bearing is large enough, with SKF SensorMount. If there isn't the space to use a hydraulic nut, as is often the case with some fans, use the nut rotating angle method just like you would for a self-aligning ball bearing.

***Fig. 4** Inner and outer rings aligned, roller in the equilibrium position and limited radial clearance. Note the scale is in cm.*

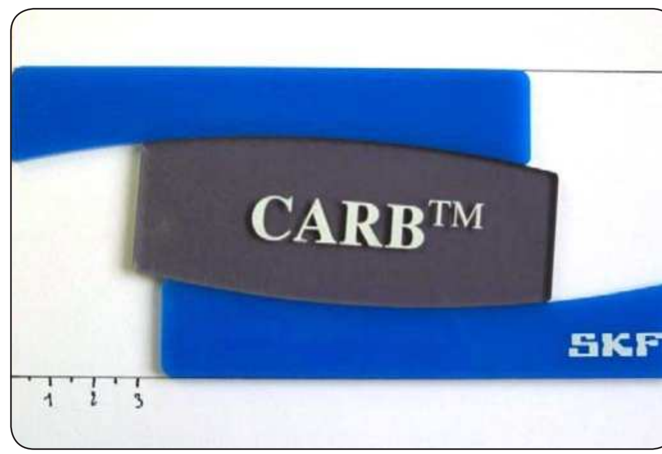


***Fig. 5** With the radial clearance shown in figure 4 the possible axial displacement of one ring relative to the other is important. Note that under certain operating conditions the load distribution along the roller profile allows part of the roller to run outside the raceway as shown.*

***Fig. 6** Axial displacement of the roller leads to uneven clearance over the roller length.*

To reiterate, I do not recommend mounting a CARB toroidal bearing with the feeler gauge method unless you are experienced. You can train yourself by trying to find the real clearance on a medium sized CARB. How? It's quite simple, really. You need a ruler or straight edge and either a vernier caliper or another tool to measure the relative offset between the inner and outer rings (→ **figure 7** and **8**).

Measurements should be taken in at least four positions that are 90° from each other. To minimise inner ring versus outer ring misalignment, check that all roller faces are equidistant from the edge of the outer ring. This is not that easy since the rollers supporting the inner ring do not move at the same time as the others when you pull the inner ring axially. If the bearing gets blocked in one position, don't push the inner ring back. Simply rotate the inner ring (→ **figure 9**)

Once all the measurements have been taken, calculate the average. In the case of my C 3040 CARB toroidal bearing, the average was 13,8 mm. In the *SKF rolling bearings catalogue* (publication number 10 000) there are equations for the relation between the axial displacement and radial clearance when the inner and outer rings are aligned.

$$S_{cle} = \sqrt[2]{\frac{B\,C_{red}}{k_2}}$$

$$C_{red} = \frac{K_2 S^2{}_{cle}}{B}$$

S_{cle} = maximum axial displacement from a centered position, corresponding to a certain radial clearance reduction (mm)
C_{red} = reduction of radial clearance as a result of an axial displacement from de centered position (mm)
B = bearing width in mm
K_2 = operating clearance factor that can be found in the product tables in the catalogue.

For the C 3040 :
B = 82 mm
K_2 = 0,095

So if S_{cle} = 13,8 mm, then:

$$C_{red} = \frac{0{,}0095 \times 13{,}8^2}{82} = 0{,}220 \text{ m}$$

The real bearing radial clearance is then 0,220 mm.

You can now train yourself to measure the bearing clearance with a feeler gauge. Challenge your colleagues to measure the clearance and bet that they will find a value below 0,220 mm. I would expect between 0,140 and 0,190 mm.

***Fig. 7** Using a ruler and a vernier caliper to measure inner ring versus outer ring axial offset I.*

***Fig. 8** Using a ruler and a vernier caliper to measure inner ring versus outer ring axial offset II.*

***Fig. 9** Rotating the inner ring to free up a bearing blocked by too much axial displacement.*

3. Increasing drive-up to compensate for wear and/or increased clearance class

Sometimes, for various reasons, a bearing with a greater than desired clearance class has to be mounted e.g. C4 rather than C3. In such cases, I'm often asked whether it's possible to drive the bearing further up on its taper seat to reduce the radial clearance.

My normal recommendation is not to increase the drive-up. The reason being that it will increase hoop stress in the inner ring and the bearing service life could be reduced since micro cracks caused by fatigue and surface damage will propagate more quickly. In extreme cases, it will increase the risk of ring fracture. That said, remember that:

1 There can be a small increased clearance compared to the original recommended clearance class e.g. 23152 CCK/C3W33 has an unmounted radial clearance between 0,300 and 0,390 mm while a 23152 CCK/C4W33 has an unmounted radial clearance between 0,390 and 0,490 mm. So, if a 23152 CCK/C4W33 has a radial clearance before mounting of 0,410 i.e. just 0,020 mm above C3 clearance class range, only a small increase of drive-up is needed to make it operate like a C3 clearance class bearing. Calculations can be made to estimate the hoop stress increase caused by the radial clearance reduction increase.

2 For a given radial load, the bigger the clearance in the bearing, the higher the load on the most loaded roller and fatigue life is reduced (see issue two of *SKF Pulp & Paper Practices*). There is a balance to be achieved between increased hoop stress, which reduces life when driving up the ring harder, and the reduction of clearance which gives a better load distribution on the bearing rollers and a longer life.

3 Many other manufacturers' spherical roller bearings are made from standard martensitic heat treated steel. In contrast, SKF spherical roller bearings and CARB toroidal bearings are mostly made from bainitic heat treated steel. While martensitic steels have tensile hoop stress near the surface, bainitic steels have compressive hoop stress. Those being case hardened have compressive hoop stress as well. This allows them to withstand higher hoop stress resulting from increased drive-up.

4 Adjusting drive-up with the feeler gauge mounting method isn't very accurate and can lead to quite a wide spread of resulting fit values. There is a risk of too tight fits. This can be avoided by using the SKF Drive-up Method or the even more accurate SKF SensorMount method. More information on both of these can be found in issue three of *SKF Pulp & Paper Practices*.

5 For some applications such as suction press rolls, where bearings are mounted on large hollow journals and the journal bores are close to 80% of their external diameter, high drive-up is needed to prevent fretting and creeping between the bearing and the journal. Normally, the clearance reduction is around 0,065% of the bearing bore diameter (cf. the 0,050% generally recommended for pulp and paper applications). With more accurate mounting methods like the SKF Drive-up Method and SKF SensorMount, we can accept higher drive-up values.

In conclusion, increasing drive-up to reduce radial clearance in a bearing can have a positive effect on its service life. However, the risk is that if the feeler gauge method is used and the points listed above are not considered, service life will most likely suffer and the chances of ring fracture will increase. It is for these reasons that we generally do not advise driving up further than recommended.

4. Checking that bolts are tightened to the correct torque

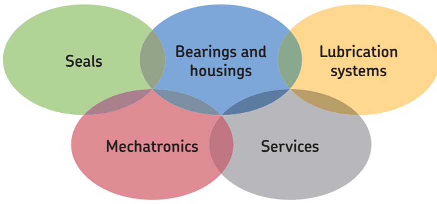
When a nut or bolt is tightened it's not possible to check that it's at the correct torque value without unscrewing it and retightening it to the correct value. A common mistake is to set a torque wrench to the recommended value and check that the nut/bolt does not move when this is reached. The error is believing that is has been tightened to a value equal to or greater than that recommended.

In reality, the nut/bolt can be below the recommended torque value if checked using this method. This is because the coefficient of friction in the threads and at the contact surface between the nut/bolt head and its supporting surface varies depending on whether there is sliding or not. This is exactly the same phenomenon as the stick-slip axial movement of the non-locating spherical roller bearing that displaces under thermal expansion of the cylinder (see page six, issue six of *SKF Pulp & Paper Practices*).

The torque value when tightening is obtained when there is movement so the coefficient of friction when sliding (μ_{sl}) must be taken into account. Once the nut/bolt is tightened and doesn't move a higher torque value than the one set on the wrench is needed to make it turn again. This is because the coefficient of friction when there is adhesion (μ_{ad}) needs to be taken into account and μ_{sl} is smaller than μ_{ad}.

Finally, as a reminder, please remember that the final actual tightening value depends not only on torque wrench accuracy and set value, but also on the surface conditions (roughness, whether there's any damage or not), the type of coating (if there is one) and the lubrication of the thread and the nut/bolt head support surfaces.

Regards,
Philippe Gachet
Senior technical consultant
Philippe.gachet@skf.com



The Power of Knowledge Engineering
Combining products, people, and application-specific knowledge, SKF delivers innovative solutions to equipment manufacturers and production facilities in every major industry worldwide. Having expertise in multiple competence areas supports SKF Life Cycle Management, a proven approach to improving equipment reliability, optimizing operational and energy efficiency and reducing total cost of ownership.

These competence areas include bearings and units, seals, lubrication systems, mechatronics, and a wide range of services, from 3-D computer modelling to cloud-based condition monitoring and asset management services.

SKF's global footprint provides SKF customers with uniform quality standards and worldwide product availability. Our local presence provides direct access to the experience, knowledge and ingenuity of SKF people.

SKF Global Pulp & Paper Segment

Contact/Responsible editor
philippe.gachet@skf.com

PUB 72/S9 11147/10 EN · May 2014