



Philippe Gachet using a wire tool to check the condition of the raceway on a felt roll bearing.

Back in time

You might wonder why SKF decided to publish this newsletter. Well, it's a long story that started, back in 1994, when the SKF Ball Bearing Journal was retired and replaced by Evolution magazine. The Ball Bearing Journal, which was published from 1926 to 1994, was very much a technical publication. Evolution, in contrast, has a different and more general focus,

I was working as an application engineer for SKF France at the time. A number of maintenance people from paper mills and design engineers from companies manufacturing process machinery contacted me to say they still needed a technical publication like the Ball Bearing Journal. As a result, the French language SKF Info Papeterie was born. It was a simple, black and white, photocopied document with technical content for engineers and practical recommendations for service people. Most of the articles were based on the questions that I was asked and the practices that I sometimes saw when visiting mills.

SKF Info Papeterie stopped, after 20 issues, when I took up a new position in SKF's global pulp and paper segment team. Last year, we decided to revive it. However, as I'm working in a global role, it had to become global too and it ended up being renamed SKF Pulp & Paper Practices.

For this edition of SKF Pulp & Paper Practices, I have decided to write about internal clearance in spherical roller bearings before moving on to cover modern mounting methods in the third issue. The reason for this is that many people are surprised to learn that

clearance reduction is not to obtain the correct clearance, but it is to get the correct tight fit of the inner ring. So the question: "But, what about the bearing clearance?" comes up quite often.

Regarding clearance reduction, the feeler gauge method was covered in this last issue, but it will have to be updated soon. Our recommended values for the reduction of internal clearance will change and the minimum permissible values will disappear by the end of this year. This will have no influence on modern mounting methods for bearings with tapered bores, like the SKF Drive-up Method and SensorMount, which will be explained in the next issue.

Now, I'll leave you to read the second issue of SKF Pulp & Paper Practices. Feedback about the first one was very positive which is highly motivating for us. Please feel free to contact us if you have questions or feedback.

*Regards,
Philippe Gachet*



Rolling bearings in paper machines

The 4th edition of this handbook for the paper machine designers and operators is available now. The publication number is 10580 EN and it is available for download from skf.com.

C4 instead of C3

Sometimes, specific bearing variants are not available and yet the same type with a different radial clearance class is. Can that be used instead? For example, can you mount a 22316 EK/C3 on your felt rolls instead of a 22316 EK? This type of question comes up quite often. So, let's have a look at the different clearance classes, how they are selected and what can happen if you change the clearance class for an application.

In this article we will focus on spherical roller bearings. Much of what is written here is also relevant to other types of bearings e.g. cylindrical roller or deep groove ball bearings. However, it is not relevant to all bearing types and bearing arrangements. For CARB toroidal roller bearing, the basis is the same as with spherical roller bearings but, additionally, radial clearance will change according to the axial offset and/or the misalignment of the inner ring relative to the outer ring.

Before answering some frequently asked questions, let's look at the basics: what radial clearance class is; what influence does it have on bearing life; running accuracy and how clearance class is chosen.

Basics

Radial clearance class

The exact radial clearance of a bearing is the possible radial displacement of the inner ring relative to the outer ring. This radial clearance depends on the diameters of the raceways, the roller diameters and, for the spherical roller bearing, the position of the raceways on the inner ring (→ fig. 1).

For practical reasons, bearings are not supplied with an exact radial clearance. Rather, they come with a clearance which fits into a range specified in ISO 5753:1991.

Radial clearance class is indicated by a suffix on the bearing designation. These suffixes, from the smallest to the largest, are: C1, C2, CN, C3, C4 and C5. CN is considered to be the standard clearance class and is not included in the bearing designation.

Example with a 22320 EK:

	the radial clearance is
22320 EK/C1	0,035 to 0,055 mm
22320 EK/C2	0,055 to 0,080 mm
22320 EK	0,080 to 0,110 mm (suffix CN is omitted)
22320 EK/C3	0,110 to 0,140 mm
22320 EK/C4	0,140 to 0,180 mm
22320 EK/C5	0,180 to 0,230 mm

In addition, letters can be added to the clearance class for reduced or displaced tolerances.

C3L	means the lower half of C3
C3H	means the upper half of C3
C3P	means the upper half of C3 with the lower half of C4
C3M	means the upper half of C3L with the lower half of C3H

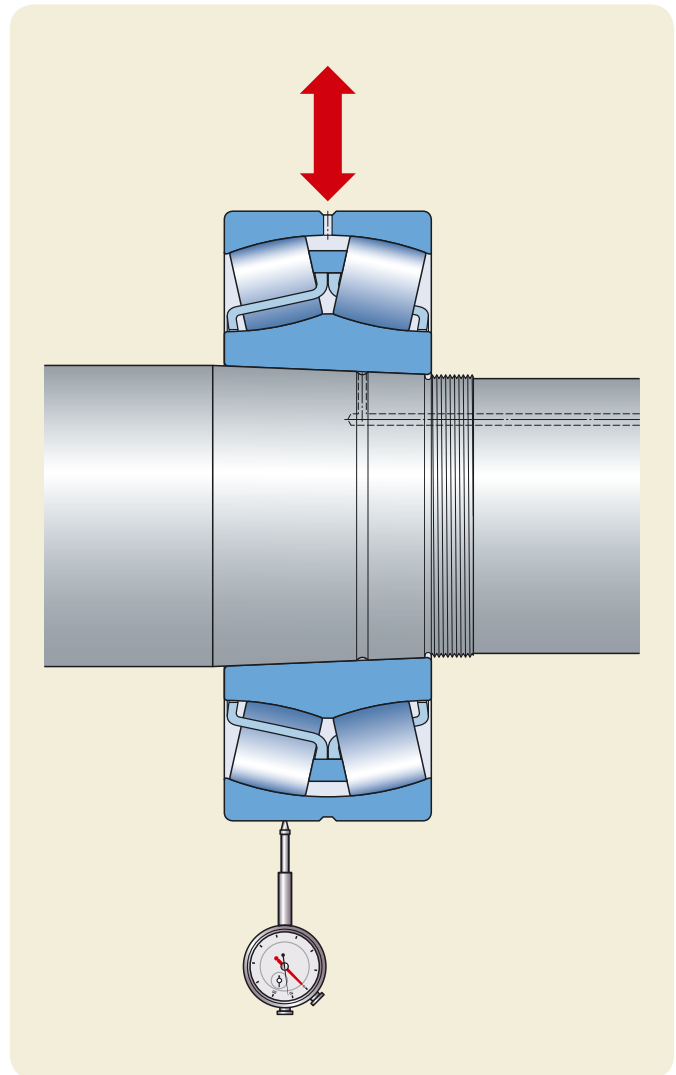


Fig. 1.

In some cases, the clearance class is part of another suffix. For spherical roller bearing mounted on paper machines, the most common are C083 and C084. C08 denotes bearings with improved running accuracy. So, C083 indicates a bearing with improved running accuracy and C3 clearance class.

The radial clearance class should be chosen based on the application i.e. the operating conditions (speed, load, lubrication, heat transfer), any clearance reduction due to interference fits and take in consideration the start-up conditions.

The effect of radial clearance on bearing life

Fig. 2 shows that the bearing with the larger clearance has less rollers supporting the load. Consequently, the load per roller and the contact pressure on the most loaded roller is also much larger. In such a situation, the fatigue life will be lower than for the other bearing.

When calculating the nominal bearing life with the ISO method, clearance in the bearing is supposed to be equal to zero (no clearance, no preload), which corresponds to 50% of the rollers loaded.

If the bearing has no clearance and a small preload, the overall load on the bearing will be larger, but that on the most loaded roller will be lower since load is better distributed over all the rollers. This

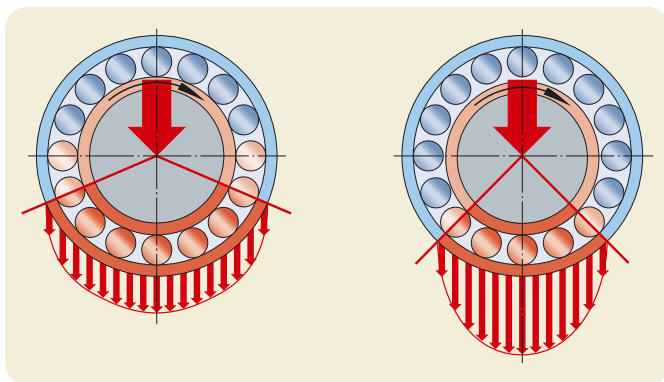


Fig. 2.

means that the fatigue life of the bearing increases. However, if preload becomes too heavy, fatigue life rapidly decreases (see the red curve in **fig. 3**)

In reality, this isn't as simple because the housing isn't totally rigid. A housing is flexible and, as the outer ring of the bearing tends to take to shape of its seat in the housing, the load distribution can be quite different ($\rightarrow$ **fig. 4**).

The fatigue life curve (in red on **fig. 3**) will then change, but there will always be a rapid fall if there is too much preload and a fatigue life decrease when clearance becomes too large.

Clearance and preload also have an influence on friction and, therefore, the heat generated by the bearing. To make it simple, the smaller the clearance, the higher the friction. Friction also increases rapidly with preload.

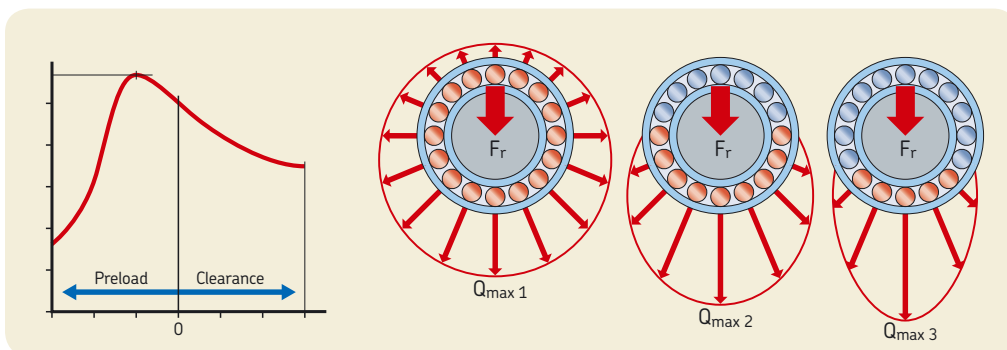


Fig. 3.

The influence of radial clearance on running accuracy

Figure 5 shows a bearing with too much clearance but perfectly round rings and rollers.

If the load is always in the same direction, the relative position of the inner ring compared to the outer ring will remain the same. However, if the load moves to the 3 o'clock position (indicated by the red arrow with the dotted outline), the centre of the inner ring will move upwards to the right. In case of varying load direction, the smaller the clearance in operation, the better the running accuracy.

For some applications needing very high running accuracy, such as printing presses, a spherical roller bearing with higher running accuracy can be mounted with preload (negative clearance). Depending on the

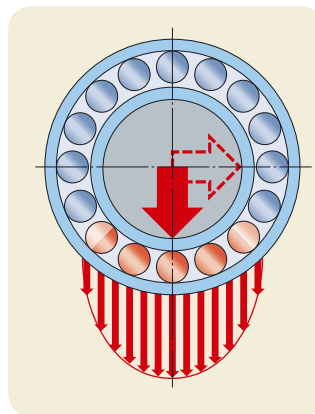


Fig. 5.

mounting method and the operating conditions, these spherical roller bearings can run with a slight preload without risk of going into a too high preload zone.

In some pulp mills, and even in some paper mills, you can find screw presses where the axial load is taken by a spherical roller thrust bearing and the radial load by a radial spherical roller bearing mounted as shown in **fig 6, page 4**.

The thrust bearing is mounted, radially free, in the housing so that it doesn't take any radial load. When the raw material is pressed, a rotating radial load is created and its magnitude can be bigger than the radial load due to the weight of the screw. The spherical roller bearing then is subject to a rotating load on its outer ring. The inner ring, and thus the shaft, will have some radial displacement depending on the internal clearance and whether the bearing is mounted with a loose fit in the housing. It will depend also

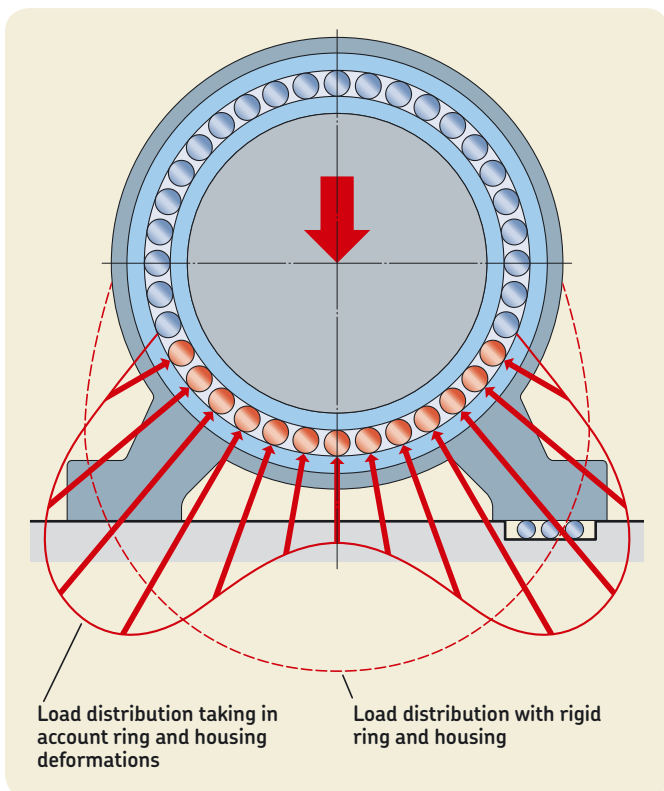


Fig. 4.

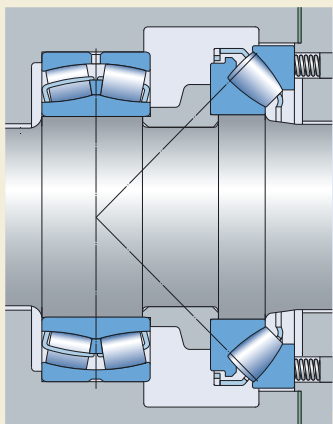


Fig. 6.

on the clearance between the outer ring and the housing. This will make the inner ring (shaft washer) of the thrust bearing experience radial displacement and, in consequence, the outer ring (housing washer) as well (→ fig. 7).

This results in the outer ring (housing washer) of the thrust bearing being forced to perform a scuffing movement against its seat surface to an extent which corresponds to the internal radial clearance and the magnitude of the loose fit of the radial bearing. In many cases this leads to premature failures.

Runout of the raceways (running accuracy) also has an influence. For information, the SKF standard spherical roller bearings and CARB toroidal roller bearings up to 300 mm bore diameter have a P5 running accuracy. This is four times better than the normal ISO standard.

Please remember that the overall running accuracy of a roll press, for example, also depends on other factors such as the bearing seat forms, roll forms, coaxiality between bearing seat and roll part, position of the inner ring high eccentricity point relative to the bearing seat high eccentricity point etc.

What clearance class to choose?

A tight fit of the bearing on and/or in its seat depends on load intensity and direction. Tight fits reduce radial clearance.

In general, though it's not always the case, the bearing inner ring runs hotter than the outer ring. The higher the speed and the higher the load, the larger the temperature difference between outer and inner rings. Furthermore, the higher the operating temperature, the more the roller diameter expands. This decreases the radial clearance in the bearing.

Start-up must be taken into account since during start-up the inner ring temperature increases more quickly than the outer ring. During start-up, the clearance decreases and after a while increases. That said, it stays smaller than is the case when the machine is cold. This phenomenon is accentuated when the shaft or journal is heated e.g. drying cylinders, heated calenders, Yankees. **Diagram 1** shows the temperature difference between the inner ring and the outer ring during start-up.

As an example, if there was no start-up and the bearings were always running in steady state conditions, C4 clearance class would not be a good option for drying cylinder bearings. C3 clearance class

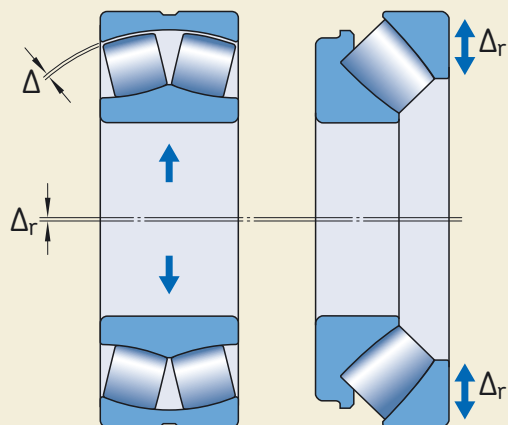


Fig. 7.

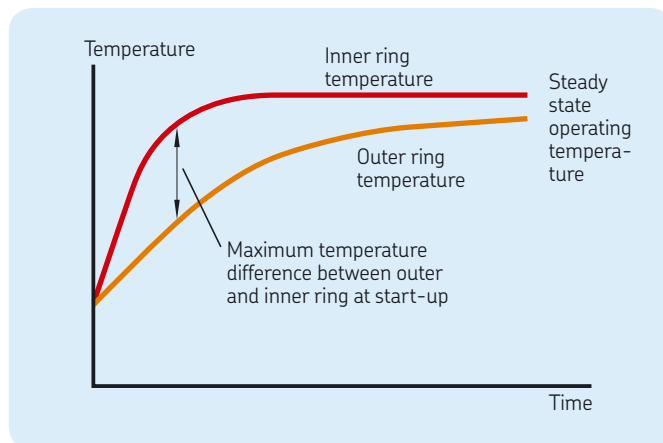
would be preferable due to superior load distribution. To prove it, you just need to look at the load zone of a bearing mounted on a drying cylinder. On average, it's a 90–120° angle. This indicates that the bearing is running with too much clearance at a steady state operating temperature. However, if a C3 clearance class bearing was used, there is the risk of excessive preload because the inner and outer ring temperature difference would have completely removed any clearance during start-up.

Dimensional stability is another important issue when temperatures are high. Structural changes in bearing steel occur and dimensions alter. Unstabilized martensitically heat treated rings experience the biggest changes. They expand initially and then contract.

Diagram 2 shows the diameter variation at 200 °C for martensitic steel that has been stabilized for 120 °C and for a bainitic steel that is stabilized for 200 °C. Remember that all SKF spherical roller bearings and CARB toroidal roller bearings are stabilized for 200 °C.

Bearing mounting procedures and the machine environment must also be taken into account. If the bearing will be mounted with a low accuracy mounting method such as feeler gauges; if the bearing is likely to be over-greased or if the ambient temperature varies a lot, then it will be difficult to hold a precise operating clearance. Even if a bearing clearance class is chosen that gives, in theory, an optimum operating clearance, there is a risk that it will be pre-loaded during operation in reality. For this reason, most radial clearance

Diagram 1.



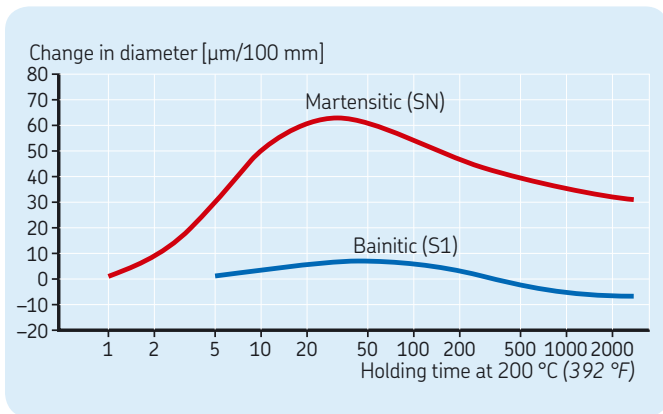


Diagram 2.

classes are selected and most bearings are mounted so that they will run with clearance even if this isn't optimal from a fatigue life point of view.

By the way

- Never blow cool air on a housing if the bearing is overheating. It can increase the temperature difference between the outer and inner rings and create catastrophic pre-load
- Be careful if you increase oil flow or relubricate when a bearing is overheating. It could be overheating due to an excess of lubricant

Choosing the correct clearance class may seem complicated if it is not specified by the machine supplier. In some cases, it can be complicated since speed, load, type of lubrication, external cooling, shaft material and geometry, housing material and geometry, the fits, heat transfer and even the color of the housing can influence the temperature differences between inner and outer ring. But, for general use which represents more than 90% of the applications, the SKF General Catalogue gives the information. It isn't straightforward and the solution might come after several iterations:

- 1 Choose bearing type and size based on the loads
- 2 Choose the correct fits based on the loads. The SKF General Catalogue indicates if a greater clearance class is needed or not. More precise information will be given in future article about how to choose fits
- 3 Calculate the new reference speed based on the load and the lubrication. We will also be more precise about this issue in a future article about speed limits.

Let's look at a quick example

Quick means a quick way to determine a clearance class that allows the bearing to operate without too much clearance and without a dangerous preload. It will not always give the optimum clearance class. It needs a bit of experience, but it works.

A felt roll spherical roller bearing, 22222 EK, rotates at 200 r/min and is quite heavily loaded due to a new felt tension as a result of a machine speed increase. The load equivalent dynamic load, P , calculated with the radial and axial load (estimation based on the friction between outer ring and housing in the non-located position. N.B. this doesn't exist if CARB toroidal roller bearings are used in the

non-located position) is near 96 kN. The bearing is grease lubricated with grease having 220 mm²/s at 40 °C base oil viscosity.

The dynamic basic load rating of the bearing, C , is equal to 560 kN.

The static basic load rating of the bearing, C_0 , is equal to 640 kN.

First let's see what the SKF General Catalogue indicates concerning the fit on the shaft.

Even if the bearing has a taper bore (suffix K), it is good to have a look at the indications for cylindrical bore bearings (→ table 1, page 6).

$P/C = 96/560 = 0,17$ so the bearing is very heavily loaded.

The bearing bore is equal to 110 mm. The table says that the recommended fit is p6 and that a radial clearance greater than normal is recommended. By deduction, it can be said that the bearing with taper bore should be driven up it's seat in the upper half of the drive up range and thus take a C3 clearance class.

Now, let's look at the reference speed. The reference speed, which is 3 000 r/min for the SKF 22222 EK, represents the speed, under specific operating conditions, at which there is equilibrium between the heat that is generated by the bearing and the heat that is dissipated. If the bearing operates in different conditions than those used for calculating the reference speed a new speed, called permissible speed, has to be calculated. Bearings can run above permissible speed under certain conditions and one of the conditions is to take a greater clearance class. All this is given for a bearing running at 70 °C.

The corrective factor depends on load and viscosity. For grease lubrication :

$$n_{perm} = n_r f_p (f_{vactual} / f_{visOVG150})$$

To determine if a greater clearance class is needed for the SKF 22222 EK, the **diagram 3, page 7**, is needed.

$$\begin{aligned} d_m &= \text{bearing means diameter} = 0,5 (d+D) \text{ [mm]} \\ d &= \text{bore diameter [mm]} \\ D &= \text{outside diameter [mm]} \end{aligned}$$

For bearing 22222: $d_m = 0,5 (110+200) = 155 \text{ mm}$.

From diagram,
with $d_m = 155 \text{ mm}$ and $P/C_0 = 0,15$,
 $f_p = 0,53$ and with $P/C_0 = 0,15$ and ISO VG 220,
 $f_{vactual} = 0,83$; with $P/C_0 = 0,15$ and ISOVG150, $f_{visOVG150} = 0,87$. $\Rightarrow$
 $n_{perm} = 3\,000 \times 0,53 \times 0,83/0,87 = 1\,520 \text{ r/min}$

As the rotating speed of the bearing is 200 r/min and is below 1 520 r/min, there is no need to select a greater clearance class than the one selected after looking at the fit.

The 22222 EK/C3 is chosen.

If you don't feel comfortable, call SKF. SKF application engineers have much more precise tools as their disposal for selecting adequate clearance class.

Radial bearings with cylindrical bore

Conditions	Examples	Shaft diameter, mm				Tolerance class
		Ball bearings ¹⁾	Cylindrical roller bearings	Tapered roller bearings	CARB and spherical roller bearings	
Rotating inner ring load or direction of load indeterminate						
Light and variable loads (P ≤ 0,05 C)	Conveyors, lightly loaded gearbox bearings	≤ 17	–	–	–	js5 (h5) ²⁾
		(17) to 100	≤ 25	≤ 25	–	j6 (j5) ²⁾
		(100) to 140	(25) to 60	(25) to 60	–	k6
		–	(60) to 140	(60) to 140	–	m6
Normal to heavy loads (P > 0,05 C)	Bearing applications generally, electric motors, turbines, pumps, gearing, woodworking machines, wind mills	≤ 10	–	–	–	js5
		(10) to 17	–	–	–	j5 (js5) ²⁾
		(17) to 100	–	–	< 25	k5 ³⁾
		–	≤ 30	≤ 40	–	k6
		(100) to 140	(30) to 50	–	25 to 40	m5
		(140) to 200	–	(40) to 65	–	m6
		–	(50) to 65	–	(40) to 60	n5 ⁴⁾
		(200) to 500	(65) to 100	(65) to 200	(60) to 100	n6 ⁴⁾
		–	(100) to 280	(200) to 360	(100) to 200	p6 ⁵⁾
		> 500	–	–	–	p7 ⁴⁾
Heavy to very heavy loads and shock loads with difficult working conditions (P > 0,1 C)	Axleboxes for heavy railway vehicles, traction motors, rolling mills	–	(280) to 500	(360) to 500	(200) to 500	r6 ⁴⁾
		–	> 500	> 500	> 500	r7 ⁴⁾
		–	(50) to 65	–	(50) to 70	n5 ⁴⁾
		–	(65) to 85	(50) to 110	–	n6 ⁴⁾
		–	(85) to 140	(110) to 200	(70) to 140	p6 ⁶⁾
		–	(140) to 300	(200) to 500	(140) to 280	r6 ⁷⁾
High demands on running accuracy with light loads (P ≤ 0,05 C)	Machine tools	–	(300) to 500	–	(280) to 400	s6 _{min} ± IT6/26) ⁸⁾
		–	> 500	> 500	> 400	s7 _{min} ± IT7/26) ⁸⁾
		8 to 240	–	–	–	js4
		–	25 to 40	25 to 40	–	js4 (j5) ⁹⁾
		–	(40) to 140	(40) to 140	–	k4 (k5) ⁹⁾
Stationary inner ring load	Easy axial displacement of inner ring on shaft desirable	–	(140) to 200	(140) to 200	–	m5
		–	(200) to 500	(200) to 500	–	n5
		–	–	–	–	–
		–	–	–	–	–
Easy axial displacement of inner ring on shaft unnecessary	Tension pulleys, rope sheaves	–	–	–	–	–
		–	–	–	–	–
Axial loads only						
	Bearing applications of all kinds	≤ 250	–	≤ 250	≤ 250	j6
		> 250	–	> 250	> 250	js6

¹⁾ For normally to heavily loaded ball bearings ($P > 0,05\text{ C}$), radial clearance greater than Normal is often needed when the shaft tolerances in the table above are used. Sometimes the working conditions require tighter fits to prevent ball bearing inner rings from turning (creeping) on the shaft. If proper clearance, mostly larger than Normal clearance is selected, the tolerances below can then be used

- k4 for shaft diameters 10 to 17 mm
- k5 for shaft diameters (17) to 25 mm
- m5 for shaft diameters (25) to 140 mm
- n6 for shaft diameters (140) to 300 mm
- p6 for shaft diameters (300) to 500 mm

For additional information please contact the SKF application engineering service

²⁾ The tolerance in brackets applies to stainless steel bearings

³⁾ For stainless steel bearings within the diameter range 17 to 30 mm, tolerance j5 applies

⁴⁾ Bearings with radial internal clearance greater than Normal may be necessary

⁵⁾ Bearings with radial internal clearance greater than Normal are recommended for $d \leq 150\text{ mm}$. For $d > 150\text{ mm}$ bearings with radial internal clearance greater than Normal may be necessary

⁶⁾ Bearings with radial internal clearance greater than Normal are recommended

⁷⁾ Bearings with radial internal clearance greater than Normal may be necessary. For cylindrical roller bearings radial internal clearance greater than Normal is recommended

⁸⁾ For tolerance values please consult the SKF Interactive Engineering Catalogue online at www.skf.com or the SKF application engineering service

⁹⁾ The tolerance in brackets apply to tapered roller bearings. For lightly loaded tapered roller bearings adjusted via the inner ring,

js5 or js6 should be used

¹⁰⁾ Tolerance f6 can be selected for large bearings to provide easy displacement

Table 1. Fits for solid steel shafts.

Table from SKF General Catalogue 6000/1.

Most frequent questions:

Can I take a bearing with a larger clearance class?

In general applications such as fans and in most papermaking applications, it is possible to take a bearing with a greater clearance class, without any significant influence on bearing service life or the operating conditions of the machine. It is anyway better to have a machine running with a bearing that doesn't have the right clearance class than having a machine at standstill.

Be careful to use the normally recommended clearance class at the next bearing change. Many mechanics choose a replacement bearing based on the designation of the dismantled bearing. If they have twice used a bearing with a greater clearance, the machine can run with a C4 bearing rather than the CN bearing it is supposed to have.

With a CARB toroidal roller bearing, a simple method, if it is possible on the machine, is to create a determined axial offset of the rings to reduce the internal clearance.

Can I take a bearing with a smaller clearance class?

No, it isn't recommended, without technical study, to replace a bearing with another with a smaller clearance class due to the risk of excessive preload during operation.

One solution is to increase the clearance of the available bearing by reducing the raceway(s) diameter of the inner ring. Depending on where and how it is done, the bearing performance (friction, running accuracy, fatigue life) can be decreased and be far from original SKF design parameters.

Is the running accuracy of a C3 bearing better than the one of a C4 bearing?

Running accuracy doesn't depend on the clearance class.

SKF standards 22320 E, 22320 E/C3 and 22320 E/C4 have all a P5 running accuracy (four times better than ISO normal running accuracy class). But, as indicated on **page 3**, the residual operating clearance can have an influence on the overall running accuracy.

It is also important to understand that a C4 bearing can operate with less residual operating internal clearance than a C3 bearing. It depends on the operating conditions and the way the bearing was mounted.

A bearing with a radial clearance near the maximum value of the C3 class, mounted with a very light fit can have a radial clearance, after mounting, with a bigger residual clearance than a C4 bearing, which clearance is close to the minimum value of the C4 class mounted with a very tight fit.

- 22320 EK/C3: the radial clearance is between 0,110 and 0,140 mm
- 22320 EK/C4: the radial clearance is between 0,140 and 0,180 mm

Let's take a 22320 EK/C3 having 0,135 mm radial clearance and a 22320 EK/C4 having 0,145 mm radial clearance. The recommended clearance reduction is between 0,045 and 0,060 mm.

- If the 22320 EK/C3 has a 0,045 mm clearance reduction the residual clearance after mounting is equal to 0,090 mm.
- If the 22320 EK/C4 has a 0,060 mm clearance reduction the residual clearance after mounting is equal to 0,085 mm.

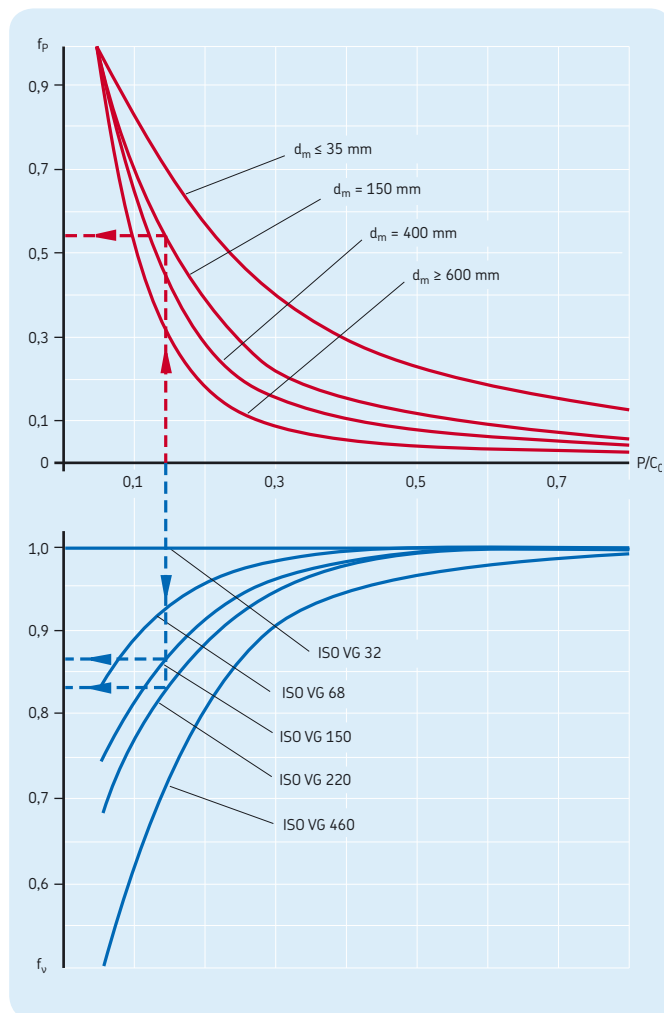


Diagram 3. Adjustment factors f_p and f_v for radial roller bearings.

Of course this doesn't happen very often and, statistically, C3 bearings have less residual clearance after mounting than C4 bearings. The demonstration was just to show that it wasn't true 100% of the time.

The bearing list in the storehouse shows that I need 22320 EK and 22320 EK/C3. Can I just store the C3 variant?

The answer is why not? In some cases, especially for low to medium loaded bearings, the increase of clearance from CN to C3 has only a small effect on service life and running accuracy or is within acceptable limits. The decision has to be taken case by case. There is no general rule.

Does lubrication influence the choice of the clearance class?

The answer is yes since depending on lubricant (grease or oil, viscosity), and quantity of lubricant, the bearing temperature will be different and the temperature difference between the inner ring and the outer ring will be different.

So, changing from oil bath to grease lubrication due to unwanted oil leaks can be risky. The SKF General Catalogue gives enough information for most of the cases.

My machine vibrates too much, should I take a bearing with less clearance?

The clearance is rarely the cause of the vibrations. Mounting a bearing with a smaller clearance doesn't take away the cause. The cause of the vibrations should be investigated. Then, when the cause is well understood, corrective actions can be taken.

In addition, mounting a bearing with a smaller clearance can be risky and create premature failure due to excessive preload.

Conclusion

I hope that this article gives a better view of what clearance class is and its influence on operating conditions. Choosing the adequate clearance class for a bearing isn't always straightforward since it depends on several parameters like shaft and housing fits, speed and lubrication. In a future article we will look at these things in more depth. In the meantime, in all cases, SKF can support you.

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The case of the split inner race

In a mill in New England during the early eighties, the printing & writing paper machine had just "crashed". When the Engineering & Maintenance manager, Sam, arrived on the scene it had become obvious that at least one backside dryer bearing had failed and several drive gears had sheared teeth. The situation was, in a word, messy.

The immediate problem was to get the machine back in operation as soon as possible, so a plan was developed to begin round-the-clock repairs until the job was completed. Some forty-two hours later the machine started up and ran successfully. That was only part of the story, now came the problem solving session.

The "Upteam", a group of individuals assigned the task of solving problems that had occurred but should not reoccur within their respective operating areas, began their preliminary evaluation of the events surrounding the incident. The "Upteam" is a rudimentary, multi-faceted area operating team with one objective, eliminate re-occurring lost time incidents.

Generally the team "leader" is the Operating Manager (Ted, in this case) for the department. If not, the team leader must have that level of authority and decision-making. The team "facilitator" is the Maintenance or Reliability Engineer for the particular operating area. Generally a Maintenance Planner (Hank) and the area Maintenance Foreman (Bob) are also members.

Engineering effort is represented by the Area Engineer (Terry). Other departments, such as Purchasing and Personnel are asked to attend as required, for example if a supplier or training issue is involved. In this particular meeting, Sam was also in attendance.

The Maintenance Engineer (Jim) had gathered as much factual data as was available and proceeded to pass that information out to the other team leaders. This information is displayed in a simple tabulation. The basic questions asked are What, When, Where, Why, Who and How. The essential question though, after a cause is determined, is "What can be done to prevent this from reoccurring?"

It was determined that the failure of #10 backside dryer bearing had occurred just a few minutes after the machine had started up following a planned maintenance and machine clothing shutdown. The dryer bearing had failed completely. Pieces, becoming debris in the drive gear train, caused teeth on these gears to fail.

The dryer bearing had been lubricated, as evidenced by the oil still flowing. The rollers and outer ring were so destroyed that any attempt to use them for evaluation was fruitless, however the inner race was still attached to the dryer journal, after the failure.

The inner race showed evidence of overheating, and, more importantly, had a crack across the race. This was the key clue to the failure mode experienced.

Jim contacted the bearing manufacturer and after discussions with one of their applications engineers learned that this crack was strong evidence of thermal fatigue leading to failure.

Jim reasoned, with help from the bearing manufacturer's engineer, that the bearing had experienced severe overheating just prior to failure. One piece of data was the record of bearing "noise" (vibration) taken just prior to the shutdown. This was standard operating procedure for each machine scheduled shutdown. That particular bearing and the gear train near it were not suspected of any problems based upon the "good" readings taken at the time.

This was the data presented at the "Upteam" meeting. The discussion that followed was guided by Ted.

"Where would the overheating have come from?" Ted asked, addressing no one, and everyone, in particular.

"Well," volunteered Bob, "if there wasn't any oil in the bearing the metal surfaces rubbing together will generate plenty of heat, in a hurry."

"Was there oil to the bearing?" Ted asked.

"Yes" Bob replied, "in fact, we could still get oil flow to the bearing after the failure."

"Is oil supply a problem then?" asked an irritated Ted.

"Could be, sometimes," Bob answered.

"How do we make sure the oil supply is working?" Ted asked, directing his stare at Bob.

"First, the oiler for the machine", Bob replied.

"Was he looking after the oil system?"

"Always does, and was this time, as far as I know."

"What can be done to be absolutely sure that the oil supply is flowing, to all the bearings." Ted asked.

"I guess some type of flow indication or alarms, or something, although I don't think that is the problem." Bob responded.

Sam jumped in to the discussion, "Don't get sensitive, this is not a witch hunt or even a finger pointing session. We are here to find the cause, a solution, and prevent this from happening again. We are not going to waste our time by pointing fingers, making accusations or covering ourselves. Clear?"

"Yes." Bob responded, Others nodded their heads too.

"Okay, so if we could alarm the loss of oil flow we could have indication of that particular cause and eliminate failure, right?" After general agreement by nodding of heads, Ted continued, "Jim, make a note of that to assign follow up, I want Terry to follow this through and see what is available for alarming."

He was looking at Jim who was responsible for recording and follow-up with others from the group who would be assigned tasks.

"What is the normal start-up procedure for this machine?" he asked the attending Machine Foreman.

"Well, we start rotating the dryers as soon as we get the all clear from our crews and the maintenance crews. Usually that means as soon as all the locks are taken off the turbine".

"Then what?" continued Ted.

"We open the steam valves to the dryer steam supply to get the dryers warmed up." answered the machine Foreman.

"I think that's part of the problem," chimed in Bob.

"Why is that?" Ted asked.

"Well, the oil is not really warmed up before the steam is put on the dryers. It might only be 80 or 90 °F [26–32 °C] and it's thick, like molasses until its warmed up to operating temperature. That's the biggest part of the oilers job during start-up, going around adjusting flows until the oil and the piping is heated up and the oil flow settles down. In fact it is a real pain for the oilers."

"What else?" queried Ted.

"When the steam is put into the dryers, it's hot, and the steam is piped right through the bore of the backside journal," answered Bob, "All that heat, all at once, without cooling has got to cause some type of problem."

What temperature is the steam at this point?" Ted asked darting his eyes around the table.

Terry said, "I guess it could be 300 °F [149 °C], and it's probably superheated because we don't cool until after we get enough condensate back from the dryers to operate the coolers."

"You mean to tell me that we heat the metal up to some 300 °F and then subject it to cold oil of 80 to 90 °F during start-up?"

"Not every time," suggested Terry, "only after long shutdowns like this one, where the oil supply is shut off and the steel has cooled down to room temperature, or so. Normally, depending upon what work we are doing on the machine, we leave the oil system running and the metal doesn't cool down as fast."

"What about the oil temperature?"

"Well, the heater for the oil is steam coils and when the turbine is down so is the steam supply for the heater. We have had to make some changes in the heating system because it takes a lot of maintenance." Bob responded.

"So, let me get this straight, first we don't heat the oil when the machine is down when the oil needs heating. Then we turn on superheated steam to the dryers before the oil can be used for cooling and, of course, lubrication. Then the oiler has to scurry around trying to maintain some type of oil flow, without flooding the bearing housings, while the machine is warming up. Then, finally, after a couple of hours, the oil is heated to operating temperature? And we begin to cool the steam after we get enough condensate back from the dryers? Is that about right?" asked Ted, disbelief written all over his face to a general nodding of heads.

"Okay, so what do we do about this comedy of errors?" he asks.

"We could put insulating sleeves on all the backside journals to reduce the heat." Terry suggests.

"How much and how long will that take?"

"A lot of money and a lot of time. Each dryer would have to be refitted, I guess that would be out of the question."

"Next suggestion?"

"We could put in electric heaters in the oil system reservoir to maintain operating temperature even when we're down."

"How much and how long will that take?"

"Shouldn't cost too much, a few thousand dollars, don't know about installation time, would have to drain the tank. I'll look into that." ventured Terry.

"Good, make a note Jim, and I want a follow-up by the end of the month." stated Ted. "What else?"

"You know," Sam started, "at one other place I worked we had warm up loops on the oil circulating system to allow the oil to circulate in the headers prior to startup. It helped the oil flow during the startup, it kept a lot of the piping warmed up so there wasn't so much scurrying around by the oilers during start-up. Maybe we could look at doing something like that on this machine? It only takes a small change in the piping, connections and valves between the pressure header and the drain line."

"Are you volunteering?" asked the Uptime leader.

"Sure, I'll ask a few questions and put together an estimate for the next meeting." Sam responded.

"Good, any other suggestions?"

"This superheated steam problem should be easy to solve," suggested Terry, "we could either save enough condensate for startup instead of dumping it or we could bring some demineralized water over from the steam plant for cooling. It's not that far away, I'll look into it."

"Great, now we're clicking."

"I guess we could take a look at our startup procedure," said the Machine Foreman, "we could check with the oiler to see if he's ready before we just crank up the steam. I'll make those changes in our procedure."

"Anything else?" asked the Uptime leader. No response.

"Then let's plan to meet again on Wednesday, the 23rd, at 13:00 hours, right here. Okay? Be ready to give your report on your part of the solution."

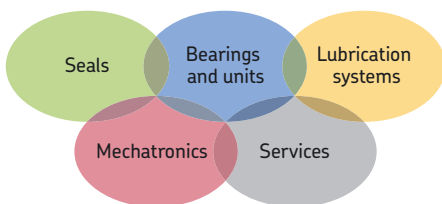


This problem-solving process may not seem like such a big deal, but it was to this mill. They now had a system for dealing with downtime and production losses that involved more than one point of view, and more than one person thinking about a particular problem. A simple process that develops a plan and follows up on each element of that plan. What more could a Mill Manager expect?

Solutions take time, but the important aspect of this procedure is follow up. The Maintenance Engineer is the facilitator, the scheduler, the person responsible for making sure that ideas and tasks are followed. Of course he has support from the Team Leader and the team members.

The key is successful elimination of a recurring problem. One problem eliminated is reward for continuing the process another time.

John Yolton is approaching his 46th year in the industry. A many-journeyed, seasoned veteran of pulp and paper manufacturing, Yolton currently assists global paper industry clients with asset reliability improvement strategies. He can be contacted at john.yolton@skf.com.



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