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Old SKF bearing catalogues, some more than 100 years old.

I believe that you know what 5S is, the workplace organisation method often seen as the gospel of best practice. Certainly, in a manufacturing plant, the method has been proven to increase efficiency and effectiveness. But some managers decided that 5S should also be applied in design departments, application engineering departments, etc. Listen to them, and you would reach the conclusion that all books, documents and drawings that had not been used in the last 5 years belong in the bin. Some went along with that way of thinking, others created an urgent secret rescue operation, while some convinced their managers that this wasn't a good idea.

- How many sources of today's engineering rules of thumb have disappeared? Where does that 70% of catalogue reference speed, taken as the limit for normal clearance class in that particular application, come from? But twenty years ago, it wasn't called reference speed, but speed rating, wasn't it? It isn't the same.
- How many root cause failure analyses or even operating/installation/repair manuals have disappeared? The machine now has, after six years of good operation, repeat failures with the same symptoms. Where is the 7-year-old RCFA document? Is there an error in the torque tightening value in the mounting procedure? Where is the source, the original document?
- Etc.

Some try, after applying 5S, to recreate the company's technical knowledge by establishing knowledge centres tasked with saving the company's knowledge. Too late, the damage is done. And most often, in such cases, the company's knowledge that remains is transformed into 0s and 1s, and cannot be read without an electronic device with internet access. Internal information can be spread out over a wide range of places, while slow connections and bugs will make you dream of a physical library full of real paper archives.

I am a lucky engineer. I have a physical library full of old technical documents, some more than 100 years old. Unfortunately, not all are in French, and many are in a barbarian language such as Swedish. It's just sad that some documents were printed on paper that aged too quickly.

Just think twice before throwing away old technical documentation, even after scanning it. And why not still print the newly created technical documents?

Regards
Philippe Gachet
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Twisted bearing inner ring after mounting on a tapered shaft

When driving a bearing along its tapered seat to obtain the requested tight fit, the inner ring can be twisted, resulting in axial vibration in operation, due to axial roll/cylinder displacement, in and out of the machine. It can also lead to a deviation of the tight fit, whatever the mounting method (feeler gauge, SKF Drive-up method or SKF SensorMount).

What do I mean by twisted? A picture says a thousand words. **Fig 1** gives an idea of the ring deformation. In this picture, the upper part of the bearing is closer to the journal shoulder (distance B) than the bottom part (distance C). The reason for this is that, during the drive up, there was less drive up resistance between the bearing's inner ring and the journal on the upper part than on the bottom part.

Large bearings, with thin inner rings, can be more easily twisted than ones with thick inner rings. For example, a spherical roller bearing of the 238, 239 or 230 series mounted on a suction roll (**fig 2**) is more sensitive than one of the 241 or 232 series mounted on a solid press roll (**fig 3**), to this issue.

Some OEMs recommend that the distance between an inner ring face and a reference plane in several positions should not have a deviation exceeding 0,05 mm. On **fig 1**, this would mean that C-B must not exceed 0,05 mm.

To avoid the ring being mounted twisted, it is recommended to check sliding surfaces for damages. Sliding surfaces can be:

- bearing inner ring against journal
- bearing inner ring against sleeve (adapter or withdrawal)
- sleeve against journal.

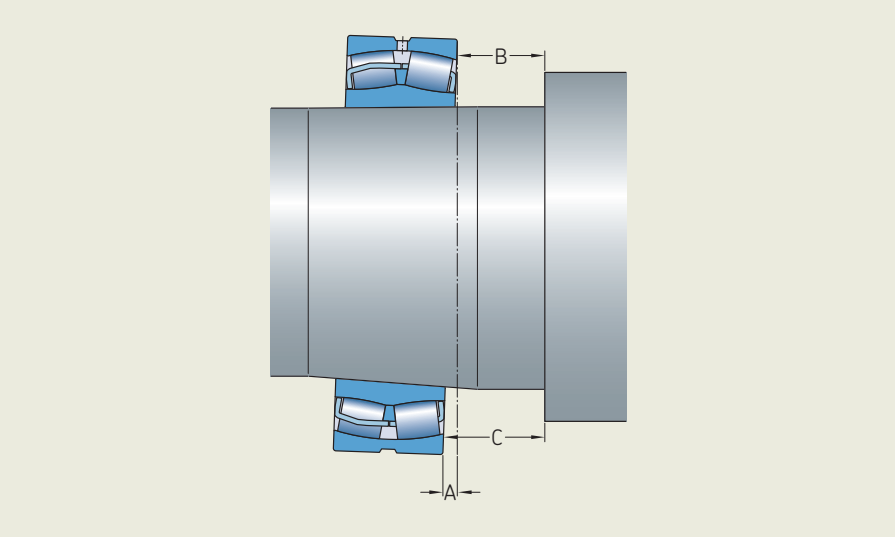

Fig 1: twisted ring

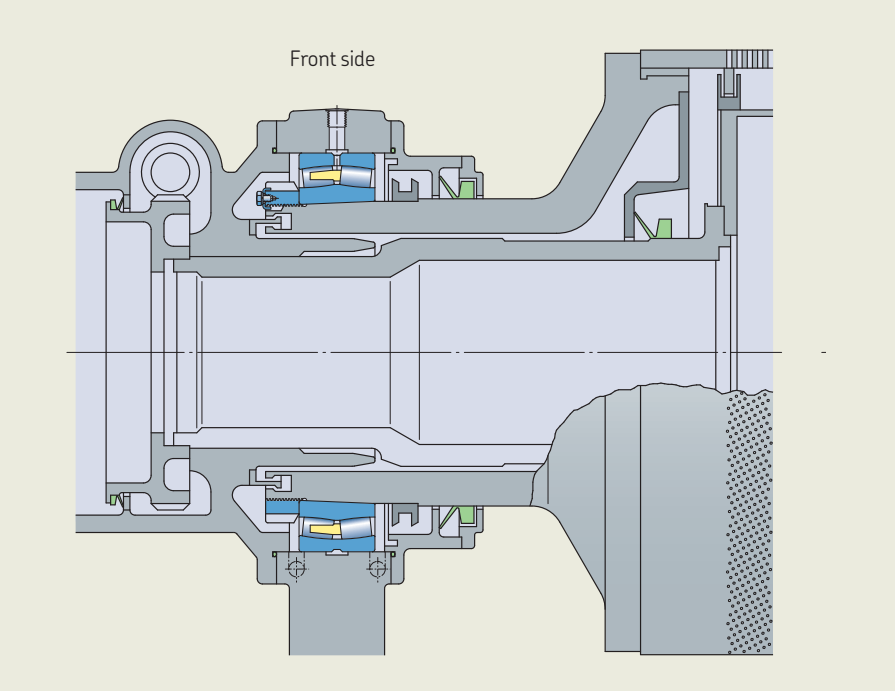

Fig 2: Spherical roller bearing, 239 series, mounted on a suction roll

As written in *Pulp & Paper Practices Issue 17*: Used bearing seats can suffer from fretting corrosion, micro smearing marks and other damage. In such cases, first remove all superficial corrosion and lubricant residues with a scrub pad and White Spirit (mineral spirit), or other greasy solvent, and then remove protuberances with a honing stone.

Large protuberances can be partially removed using a steel file and great care, but finishing should be done with a honing stone. Move your finger over the damaged area to see if more material needs to be removed. You should also check for micro cracks and use the dye penetrant inspection method if in doubt. Very small dents relative to bearing size are not a concern if there are no protuberances.

Always slightly oil all sliding surfaces with oil having a viscosity close or equal to 300 mm/s^2 at mounting temperature (be careful about mounting during a short planned stop when shaft could still be hot: cf. *Pulp & Paper Practices issues 11* and *17*, the oil will lose viscosity quickly). I considered injecting oil on the sliding surfaces as an option, except in some specific cases. After a meeting last year between application engineers, experts in bearing in pulp & paper applications, a meeting at which we discussed the issue of the twisted inner rings and the consequences, I would now recommend oil injection in the contact sliding surfaces for all large and heavy bearings, especially thin section ones.

Of course, the oil injection must not be used during the first part of the SKF Drive up Method, only during the second part, after having reached the pressure for the starting position (*Pulp & Paper Practices issue 17*).

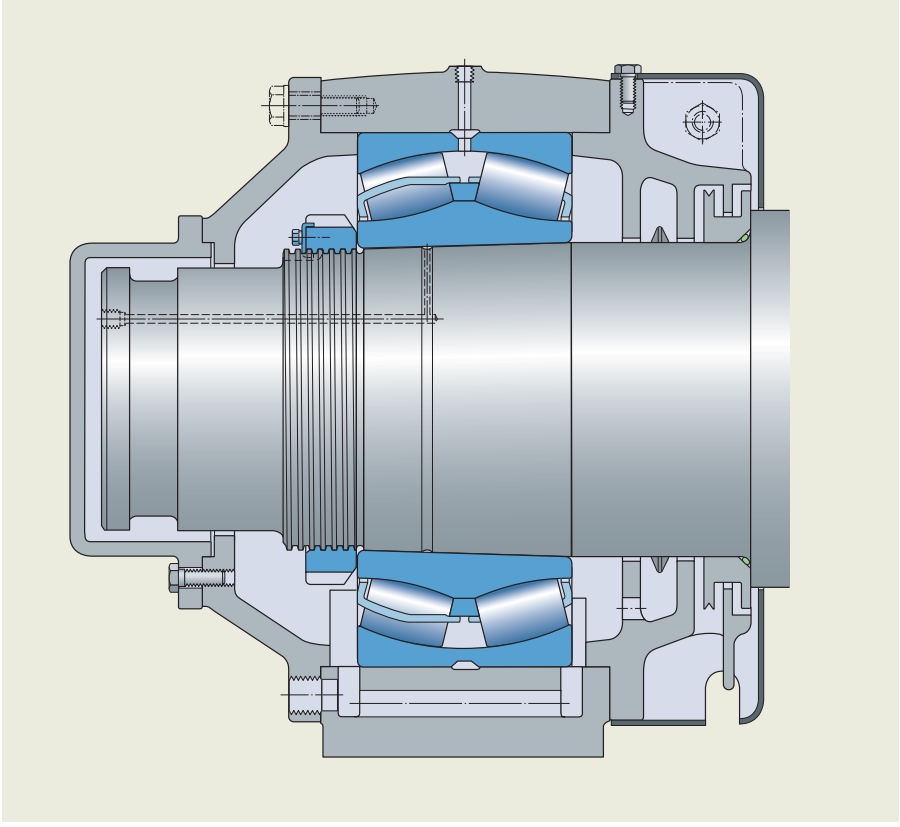

Fig 3: Spherical roller bearing, 232 series, mounted on a solid press roll.

Bearing inner ring heat treatment for drying cylinders and Yankees

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As a reminder, the current SKF recommendations are:

1 If the journals are insulated, bearings with case-hardened inner rings are not needed and standard SKF spherical roller bearings and CARB can be used.
2 If the journals are not insulated, standard SKF spherical roller bearings and CARB can be used if steam temperatures are below 170 °C (*338 °F*). Otherwise, bearings with case-hardened inner rings should be fitted.

SKF bearings with case hardened inner rings have the HA3 suffix. 23152 CCK/HA3C4W33 is one example.

The SKF bainite used for standard spherical roller bearings, CARB and spherical thrust roller bearings is not a basic bainite heat treatment. From basic bainite, SKF changed in 1999 to another bainite, having a steel structure with smaller grains, called X-Bite. And in 2011, another special bainite heat treatment was launched, giving a steel with even smaller grains, referred to externally as upgraded steel. The changes give greater hardness and toughness. Please refer to *Pulp & Paper Practices issue 4* for more information. In fact, the "upgraded steel" name covers more than just the latest special bainitic heat treatment, and bearings manufactured with upgraded steel are marked WR. As we differentiate a spherical roller bearing or CARB made with older bainitic heat treatment with the new one by using the WR marking, I will continue this article by using WR instead of "special bainitic heat treatment used in our standard bearing".

I still receive questions about the bearing inner ring heat treatment for drying cylinders and Yankees.

Here are some of the most frequently asked questions with my answers:

A A customer has insulated journals and requests case hardened inner ring bearings, while you recommend standard SKF bearings (with WR). Can we supply case hardened inner ring bearings?

Of course!

I have an example. For a new tissue machine in Thailand, where the mill belonged to a US-based group, the OEM proposed a standard SKF bearing for the Yankee. The end customer refused and requested a case hardened inner ring. The machine was then supplied with SKF HA3 bearings.

B Why don't you recommend HA3 for all drying cylinders and Yankees, as it is the best technical solution?

It is not always the best technical solution. HA3 has advantages, but also some drawbacks.

It has been seen as the best technical solution in the past, since it was compared to martensitic, and basic bainite.

There was a focus on the crack resistance issue due to high hoop stress in the inner ring, as the uninsulated journal was much hotter and expended radially. And there was no noticeable difference between bainite and case hardened rings in terms of abrasive wear, fatigue life, etc...

But, today, you cannot compare HA3 with a basic bainitic heat treatment anymore.

Inadequate lubrication (too thin oil film and oil ageing due to high temperature) is one of the main issues for drying cylinder and Yankee bearings. WR gives, on average, higher hardness, about 1 HRC, on the raceway surface than the HA3, so WR is less sensitive to abrasive wear due to a too thin oil film.

So, unless there is a spall or a large subsurface fatigue crack that weakens the bearing inner ring, WR wins over the HA3.

SKF recommends the HA3 only when there is a risk of very high hoop stress, and increased risk of ring fracture.

Several decades of field experience show that the SKF standard is sufficient except in cases of high steam temperature without journal insulation. For example, there is, in France, a Beloit machine from 1991, with insulated journal, which has had 26 drying cylinder bearings replaced over 20 years, none with fractured inner rings. These bearings had SKF's older bainitic heat treatment, not the WR, so they had less toughness and were more prone to cracking, but still didn't crack.

And finally, I prefer to recommend standard solutions for cost and availability reasons.

C Some competitors only recommend case hardened inner rings and claim that through hardened inner ring bearings shouldn't be mounted.

These competitors have martensitic heat treatment as standard, not a high performance bainitic treatment like SKF. Martensitic isn't adequate for the application (again, cf. *Pulp & Paper Practices issue 7*), so they have to offer and promote special bearings.

D Shouldn't case hardened inner ring (HA3) be used also when the journal is insulated, just in case there is insulation leakage?

When the insulation leaks, the journal temperature increases and so does the bearing. It can be considered, even if it isn't true, that it is like having no insulation.

Some would recommend case hardened, just in case.

Some would use the SKF recommendations for journal without insulation.

Some would point out that decades of field experience show that it is not absolutely necessary to use case hardened inner rings.

Anyway, in the end, it comes down to the individual choice of the mill.

E Through hardened rings crack, case hardened don't, right?

It is not black and white.

I've seen case hardened inner rings fracture, but none were SKF. I heard one case involving an SKF bearing (HA3), but we are not 100% sure that it was really an SKF HA3 since standard and HA3 were mounted on the machine at the same time, and SKF did not receive the damaged bearing.

There is through hardened and there is through hardened. WR and martensitic have very different crack resistance performances.

If, in the past, you had the choice between standard bearings with martensitic heat treatment and case hardened inner rings, you would find cracked inner rings on drying cylinders if you mounted standard bearings. You would then only accept case hardened inner ring bearings for your drying cylinders. This is often the case if you are located in the USA for example.

But if you have been mounting standard SKF, which have bainitic heat treatment, your field experience wouldn't make you as categorical. In 2008, I held a presentation for mill maintenance managers from different mills in Europe. The mills were from the same paper group, a US-based one. Senior engineers from the US head office were also attending the meeting and told the audience that case hardened inner ring bearings should be mounted on the drying cylinders. One of the mill maintenance managers answered that they have been mounting SKF standard bearings since the machine was new (middle of the 70s) and didn't see why he should change to more expensive bearings.

F The case hardened inner ring bearings have longer service life on drying cylinders, don't they?

The case hardened inner ring, HA3, does not have better corrosion resistance and has less inadequate lubrication resistance than WR. They have even less abrasive wear resistance compared to the SKF WR. They are more prone to surface damage in the drying cylinder and Yankee environment. But once the damage is done and large enough, they have better crack resistance. In my humble opinion, based on my experience:

If you have good condition monitoring and you dismount bearings before damage gets too serious, and can avoid heavy contamination of the lubrication system with hard particles from the failing bearing, you could see that, on average, in a large bearing population, WR has longer service life.

On the other hand, if you run to failure, and accept heavy contamination of the lubrication system and possible damage to other bearings, the conclusions can be different. As the HA3 is more crack resistant and thus can, on average, run for a long time with heavy spall without ring fracture, you might assess that HA3 is superior.

G The bearing size that I want doesn't have case hardened inner ring in the SKF brand, can I order one?

The vast majority of the bearing sizes for drying cylinders and Yankees have been manufactured in the HA3 variant. These sizes can still be supplied in the HA3 variant.

SKF will decline the order if the bearing has never been manufactured in the HA3 variant, unless the order is for a sufficiently high volume due to the fact that:

- when mounting SKF bearings, the main OEMs mount standard ones, with the exception of when an alternative is requested by end customers,
- the main OEMs use insulated journal, so there is less and less need for case hardened inner ring bearings,

The above is today's statement. Tomorrow is another day.

Conclusion:

The discussion between the pro standard and the pro HA3 for drying cylinders and Yankees is a never ending story. I'm not fully on one side or another.

For me, the choice of WR or HA3 depends on the machine generation, level of condition monitoring, maintenance strategy, etc. It is quite strange to see that the SKF recommendation tallies well with my thinking. For a paper machine with insulated journal and maintenance best practices, SKF standard (WR) is sufficient and field experience shows this. For an older paper machine without insulated journal, operating above design speed with very hot steam (leading to poor lubrication), without good condition monitoring level/experience, there is a risk of a lot of bearing damage, when detected late. High steam temperature and thus a large temperature difference between journal and inner ring at start up from cold machine. The recommendation is HA3.

Bearing housing rebuild or replacement projects on paper machines

SKF receives many requests for new housings for existing paper machines, mainly for the drying cylinders and Yankees, less often for fabric rolls. Requests for bearings housings for press or suction are rare.

Reasons for such requests include:

1 damaged housing
2 upgrade project such as change from spherical roller bearing to CARB, change from grease or oil bath to circulating oil, or oil flow increase.
3 etc.

Housing replacement

Although some rolls such as fabric rolls sometimes use standard housings (like SKF SNL, **fig 4**), the same as those used on fans, conveyors, etc., most bearing housings on paper machines are case-specific, designed for the application (**fig 5** and **6**).

Replacing standard housing is straightforward. Replacing special housing could be as straightforward as standard, or not. The reasons could be:

1 The housing is not SKF and no detailed design drawings exist.
2 The housing is an very old SKF housing, but detailed design drawings are no longer available
3 The housing is an old SKF housing, all drawings are still available but the casting pattern is missing.
4 Cost of new special housing for the machine in question is directly linked to number of housings produced in a batch.
5 Etc.

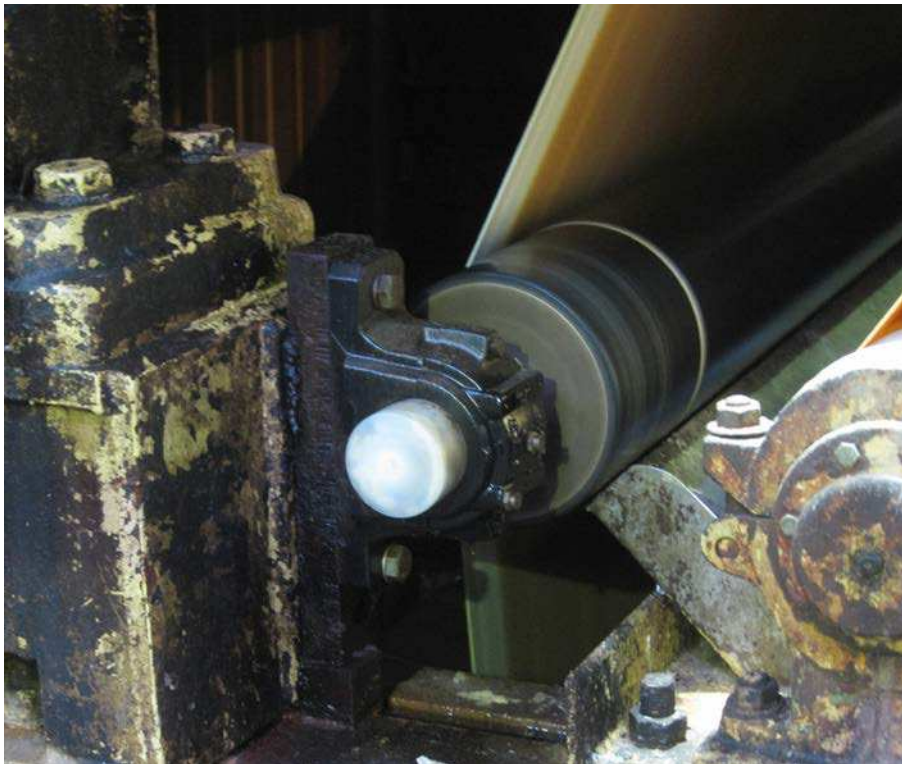

Fig 4: SKF SNL housing used as fabric roll bearing housing.

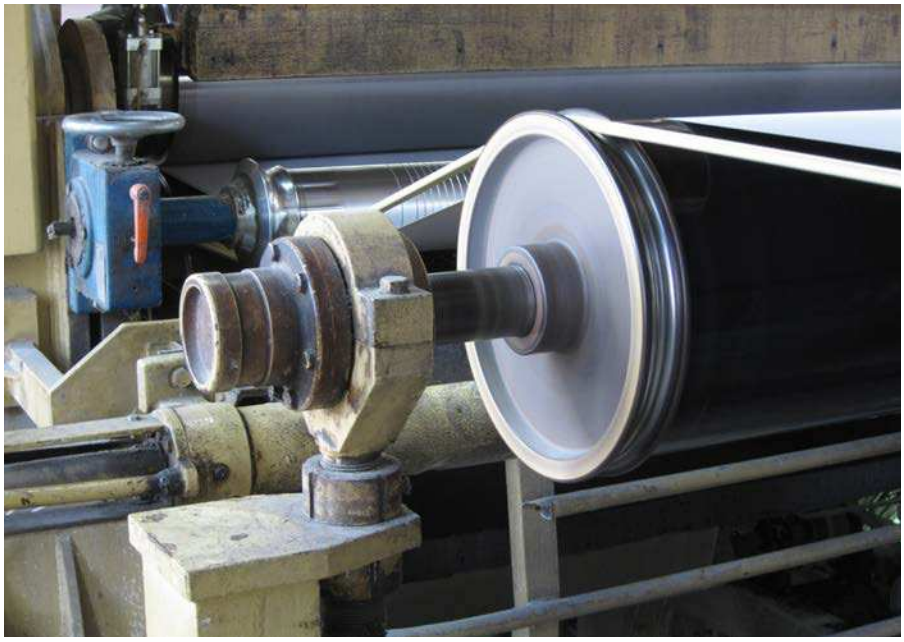

Fig 5: special paper guide roll bearing housing, OEM design

In all my housing replacement or upgrade projects, customers never wanted to modify journal geometry or roll position in the machine. Lifting a drying cylinder by just 5 mm could be very costly as, on the drive side, it would mean modifying the gear casing. Also, machine stop is costly, even if it is planned. So it is preferred to replace bearings and housings during a stop planned for another purpose and which is as short as possible. Any machine modifications that would increase the duration of the stop has to be avoided.

To check if an existing SKF housing could fit, or if we can modify one to fit, or if there is a need to design a new one, certain technical informations is needed as a minimum. The ideal information to have would be:

- design drawing of the existing housing
- design drawing of the journal
- bearing assembly drawing, i.e. drawing of bearing with journal and housing.

Unfortunately, most of the time, design drawings are not available. The mill could measure a spare housing or/and journal, if they have these. If measurement is not possible for the housing, it is possible to move forward in the project with at least the following information:

- dimensions of the journal/shaft. These can be quickly measured during a bearing replacement if no spare or drawings are available
- axis height: distance between housing seat on the frame to the journal/shaft axis
- several pictures of the housing and its surroundings

For example, this is the case of an upgrade to spherical roller bearing to CARB for drying cylinders on an old Beloit paper machine from the 60s. The customer provided a detailed design drawing (**fig 7**) of shaft and axis height.

Luckily, the axis height was high enough that the housing body of a standard housing for drying cylinders could be used. Covers were custom made to fit the existing journal. The result is shown in **fig 8**.

Fig 6: old (48 years old) special SKF 441784, rocker housing supporting drying cylinder bearing. SKF still has the design drawings, but no longer has the casting pattern.

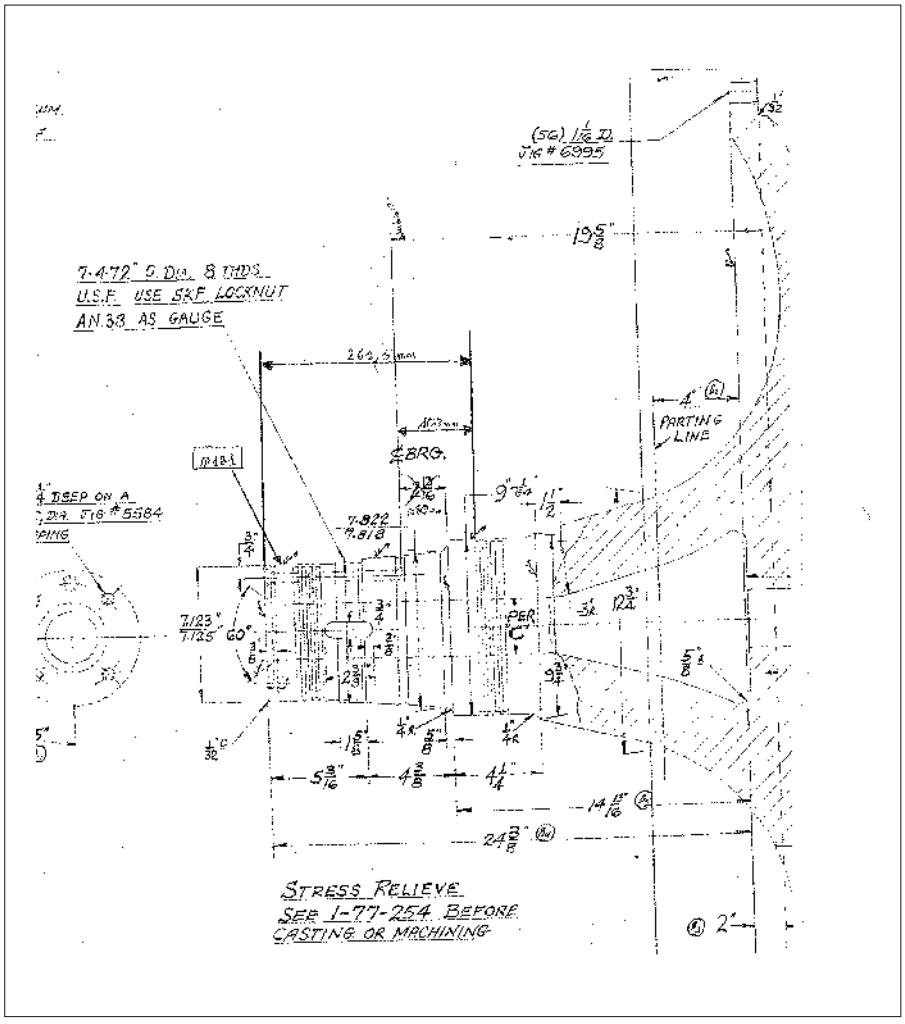

Fig 7: detailed drawing of journal, old drying cylinder on Beloit paper machine

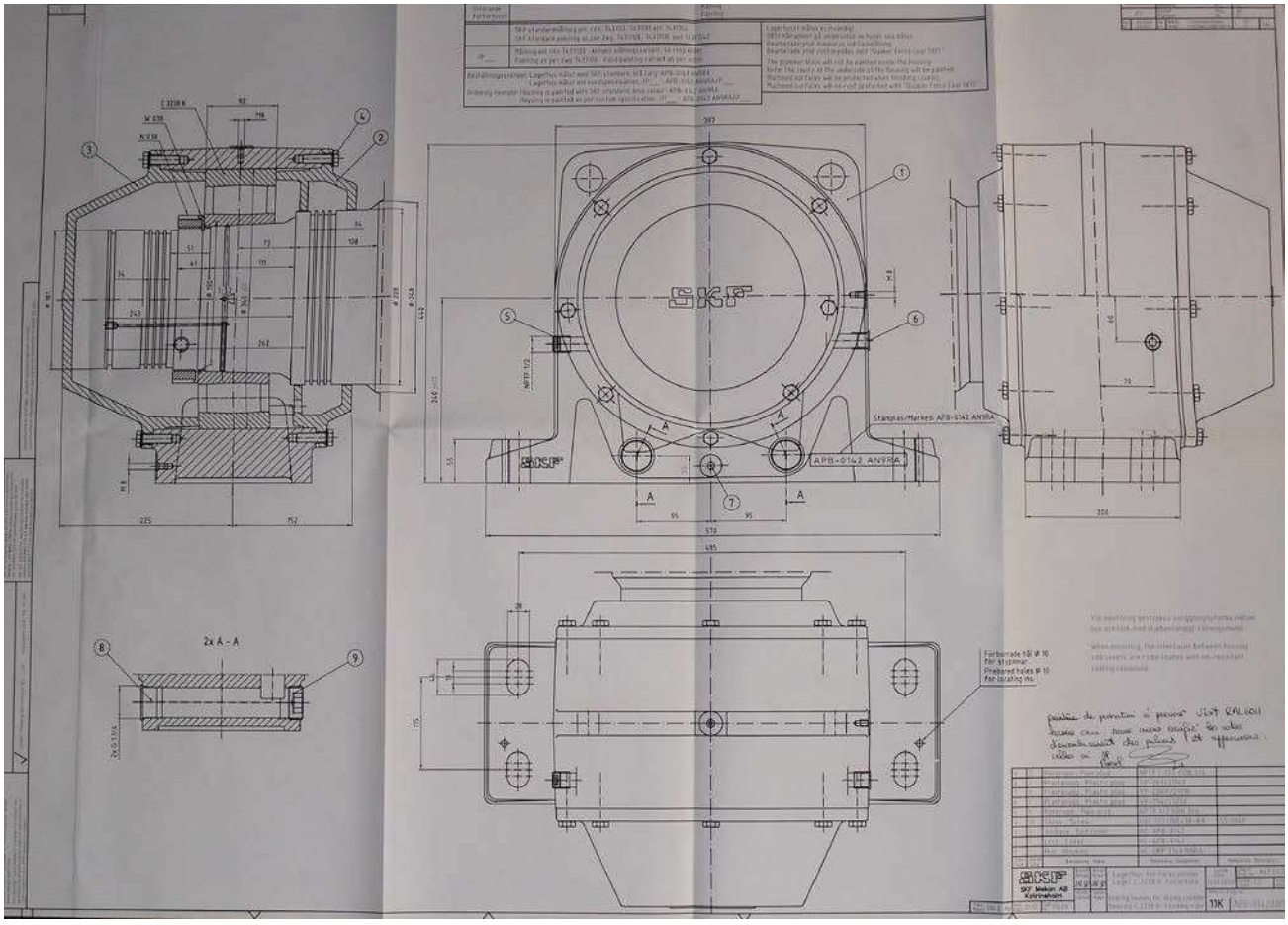

Fig 8: SKF standard housing body with custom made covers to fit existing journal.

After discussions with the mill, which checks that the housing fits, and requested slight modifications (colour of the paint in this case), the customer approved and signed off on the drawing. An initial order of 20 housing and CARB bearings was placed, followed the year after by an order for the remaining number of housings and bearings needed.

Two important things to note:
The mill did not pay for the drawing as they ordered the housing. They would have paid if there was no order for new housing after.

Housings are not manufactured if no clear approval is received from the customer for the housing drawing.

In the case of fabric roll or drying cylinders, where there are many similar housings on the paper machine, the issue is that paper mills rarely upgrade all cylinders/rolls during one planned stop. The upgrade must fit in with normal planned maintenance and not interfere with planned production, so a limited number of cylinders/rolls can be upgraded. In general, for example, a customer would upgrade 4 to 15 drying cylinders (corresponding to a section of cylinders driven at the same speed) per year, meaning that the complete upgrade could be spread over several years. The quantity of housings per order can be low compared to the total needed.

For the machine **fig.9**, the opportunity is 41 similar housings, but the first order could be for only 12 housings. Housing design work and pattern cost is spread over the number of housings ordered. So from the beginning of the project, the mill must give the number of housings per order, not the total same housings on the machine. In some cases, due to low quantities, it could be less expensive to manufacture “Meccano” welded housing instead of cast housings.

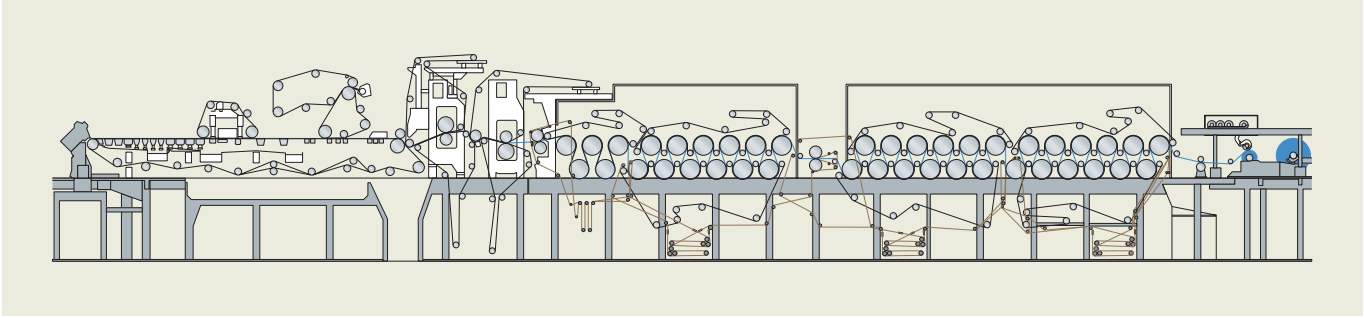

Fig.9: paper machine with 41 drying cylinders

Housing repair/rebuild

I do not remember a case in which I was involved in housing repair, but I was involved in several rocker housing rebuilds in which a spherical roller bearing was replaced by a CARB.

For rocker housing rebuilds (**fig. 10** and **11**), the existing housing design also needs to be known, since rockers are replaced by fixed feet bolted to the housing body, and the oil inlet and circulating oil path in the housing could perhaps need to be modified if the spherical roller bearing is lubricated through holes in the outer ring.

A rebuild project is very similar to a replacement project, except that the housing will be dismounted, sent to SKF, rebuilt and sent back to the mill to be mounted. The housings are dismounted from the machine for several days, or even weeks.

The best method is to send the spare housings to the SKF workshop. The rebuilt spare housings can replace housings that, in turn, will be sent to the SKF workshop and so on.

In the case that there are no spare housings, or not enough, the best option is to mount a few new housings with CARB, and send the dismounted housings to be rebuilt.

Fig 10: old SKF rocker housing

Fig 11: housing of fig 10 rebuild for CARB bearing

Conclusions

Replacing or upgrading housings that are not standard can be straightforward or not. My general rule is to be pessimistic... So any surprises after that are pleasant, rather than unpleasant.

If it is not an SKF housing that needs to be upgraded or replaced, please send the minimum required information to start discussions. Quite often, detailed design drawings of shaft/journal and axis height, with assembly drawing with some dimensions (not necessarily detailed) can be sufficient.

Remember that SKF might not have the drawings of very old housings. The famous 5S isn't always used in a correct way.

Keep in mind also that the important thing is not the total housings to be supplied over several years, but the number of housings in the first manufactured batch.

Finally, I would like to add a warning for those who don't change damaged housings because they feel that some simple small fretting corrosion or smearing marks are not so important. Bearings that need to have their outer ring displaced free in the housing to compensate axial thermal expansion can be axially overloaded. With new bearings and housings, there is a coefficient of friction of adhesion somewhere between 0,10 and 0,25. Due to normal operating conditions, some fretting corrosion will always occur and the values will increase to 0,30 to 0,50. Bearing seats will experience a lot of fretting corrosion, the values will be well above 0,50, even if there is some lubricant left.

Not so important? Let's consider a spherical roller bearing, quite popular in drying cylinders: 23152. Radial load on it could be F_r = 150 kN.

With two of these bearings mounted to support the cylinder, the front side one moves in its housing to compensate the thermal elongation of the cylinder. So there will be an existing axial load of Fa due to the friction between the outer ring and housing bore (for more information refer to *Pulp & Paper Practices issue 6*, **page 6**.)

If you take the Bearing Catalogue you will see that for such a bearing, the equivalent dynamic load P is equal to:

$F_a/F_r < 0,31$ then $P = F_r + 2,2\ F_a$

$F_a/F_r > 0,31$ then $P = 0,67\ F_r + 3,3\ F_a$

OEM could take 0,15 as the coefficient of friction for dimensioning. Load will then be:
$(150 \times 0,15)/150 = 0,15 < 0,31$ so
$P = 150 + 2,2\ (150 \times 0,15) = 199,5$ kN

After some operating time, the coefficient of friction has increased, to let's say 0,5. Now P becomes:

$P = (0,67 \times 150) + 3,3\ (150 \times 0,50) = 348$ kN

P has increased by a factor of 1,74, but because of the basic rating life equation, calculated life was reduced by a factor of 0,16! Instead of 200 000 hours calculated when choosing the bearing size, the new calculation due to increased friction is 31 300 hours. Why put a new spherical roller bearing in a damaged housing?

Hopefully, on the front side, you can install a C 23152, CARB bearing, and there will be no more axial load due to thermal expansion.

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