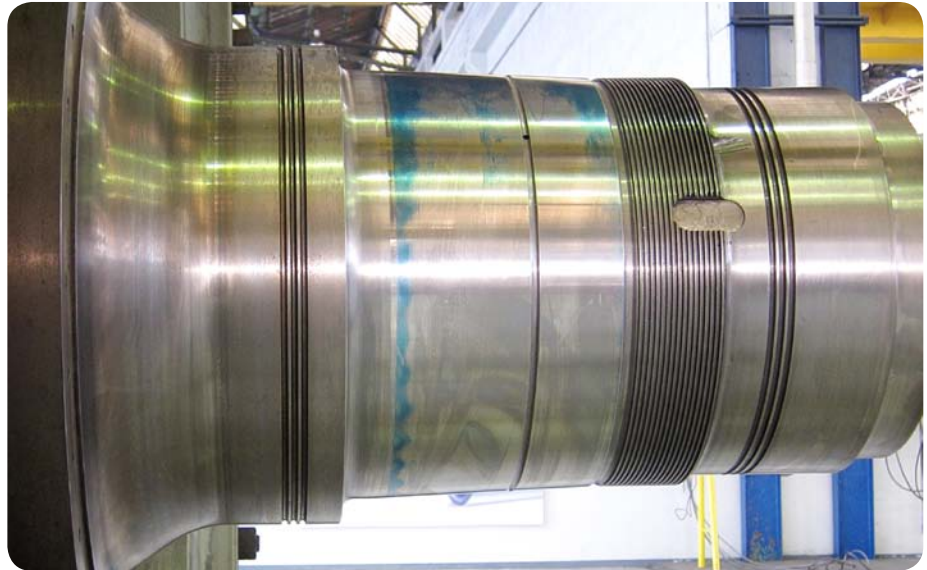




We don't talk about microns in a mill workshop



Faulty Prussian blue test due to too low axial force on the bearing

As a teenager, I used such cheap measuring tools that I was never really sure whether the crankshaft bearing seats on my motorbikes were within tolerances or not. I remember using Prussian blue to check the flatness of cylinder heads and engine blocks and thinking that industry must be another world. A world with access to high precision measuring tools in which measurement uncertainty would be very small compared to manufacturing tolerances. One in which I would never use Prussian blue again except, perhaps, for gears.

The reality, I learnt, was quite different. I've seen chisels rather than impact spanners used to tighten lock nuts, hot oil and even flame used instead of induction heaters, twisted feeler gauges used instead of hydraulic nuts and dial gauges to mount tapered bore bearings and so on. I found that using inadequate tools has a cost in terms of reduced bearing lives, damaged bearing seats, increased maintenance man hours, lost production etc. It continues to surprise me that many companies simply accept these costs.

Maintenance teams, of course, do not always have access to all the measuring tools they need. Even if they do, they're not always calibrated properly. The situation is such that I've stopped counting the number of times that I've had to check a bearing seat diameter with a micrometer without a calibration standard nearby. Even if

the right tools are available and they're properly calibrated, it's not unusual for measurements to be skipped due to pressure to get machines up and running as quickly as possible.

To further complicate things, we also need to consider the individual. Two mechanics will often find different clearance values when measuring spherical roller bearings with feeler gauges, for example. While we're used to talking about microns in the bearing world, you don't often hear them mentioned in workshops. Instead, decisions are often based on feeling. The feeling of a new mechanic tends to be based on that of the experienced mechanic that trained them. But how do you calibrate the feeling of the experienced mechanic?

So, imagine the uncertainty when measuring a distance over a taper gauge to check the bearing seat for a press roll bearing. You don't have a taper gauge? Do you have Prussian blue instead?

Regards,
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Checking tapered journal geometry

Most questions about the condition of tapered bearing seats relate to surface issues like dents, fretting corrosion, corrosion, wear due to the bearing rotating on its seat and smearing marks. The issue of geometrical form is often forgotten as many suppose that this doesn't change. In fact, surface damage can modify seat geometry (→ figure 1) and journals can be out of tolerance when new.

I have seen a number of bearing failures due to out of tolerance tapered seats changing the load distribution and the fit. As such, I recommend that seats – new or old – are checked before mounting bearings. An exception can be considered when a journal has been in operation and doesn't show uneven contact marks and the dis-mounted bearing does not have strange contact marks or load distribution.

While there are several ways to check a tapered seat, I will not examine modern methods such as laser measurements or computer aided metrology in this issue of *SKF Pulp & Paper Practices*. Instead, I will focus on Prussian blue and other good, old, reliable methods using tools that don't run out of battery power and which still work even when submerged in oil.

Before going into detail about these old reliable methods, here are my recommendations for pre-check preparations:

- 1 Remove any fine rust particles and oxidised oil or grease with a heavy duty scrub sponge. Petroleum-based solvents such as white spirit can help with this.
- 2 Remove any bumps – smearing marks, raised metal at dent edges etc. – with a flat file. No bumps should be felt when you pass your hand over the journal surface, but small dents are acceptable.
- 3 Clean the journal surface with a petroleum-based solvent such as white spirit and a clean rag.

1. The Prussian blue method

Prussian blue, as you know, is a dark blue pigment which can be mixed with oil to check the contact between two metal surfaces. The resulting mixture is known as engineer's blue or machinist's blue.

The way the Prussian blue method is supposed to work is that a gauge ring, with checked and calibrated bore geometry, has its bore blued – i.e. a thin layer of Prussian blue is applied to the entire bore surface – and then the gauge ring is placed on the tapered journal and firmly pushed axially. Some engineers would say that the ring is slammed against the journal to ensure intimate contact. When the gauge ring is removed, the parts of the journal where there was good contact with the ring will be blue.



Fig. 1 *Fretting corrosion and smearing on a press roll journal, but why is it only on the left hand side?*

As a simple rule:

- For new journals, a minimum of 90% of the contact surface should be blue.
- For old journals, a minimum of 80% of the contact surface should be blue.

In practice, gauge rings are often not available for all journal dimensions, especially large ones. In such cases, an option is to use a new bearing that will subsequently be mounted. A significant advantage of doing this is that the contact between the two elements that will be in contact during operation is checked.

A drawback is that a new bearing, which needs to be unpacked, is required. That said, unpacking should not be an issue if journal checking is done just before mounting the bearing. Another drawback is that if the contact is below the previously mentioned 80% or 90% target, it can be difficult to tell whether the journal or the bearing are out of tolerances or whether both are within tolerances, but the geometrical forms are not close enough for Prussian blue transfer.

It's worth noting that bearing bores are manufactured with larger tolerances than calibrated rings gauges and large bearings deform under their own weight. Also that the maximum bearing bore taper angle is larger than that of the journal and the minimum taper angle on the journal is smaller than that of the bearing. Consequently, it's not unusual for a new bearing and journal to achieve less than 80% contact, with little or no circumferential contact in the upper part of the taper, even if both are within tolerances.

Deviations other than taper deviations revealed using Prussian blue are most likely to be the result of one of the components being



Fig. 2 Checking the contact between bearing and journal with Prussian blue. Note that the hammer is for gently knocking the inner ring to ensure intimate contact.



Fig. 3 The inner ring of a drying cylinder bearing with no load zone between the red lines.

out of tolerances. The question is which one. To get a clue simply mark the position of the inner ring relative to the journal, dismount the bearing, clean the journal, put a new coat of Prussian blue in the bearing bore and rotate the bearing so that the inner ring doesn't seat in the same position. If the contact pattern is the same on the journal, it's a journal issue. If the contact is still in the same position in the bearing bore, it's a bearing issue.

Let's look at the example from the cover of *SKF Pulp & Paper Practices 11*. It showed my colleague checking the tapered seat of a drying cylinder with the inner ring of a dismantled bearing (→ **figure 2**). The load zone on the inner ring raceway wasn't normal as there was no load zone on part of it. This is unusual for a ring that rotates relative to the load direction (→ **figure 3**).

We found that part of the journal was not in contact with the inner ring and that the width of this closely matched the surface distress on the bearing's raceway.

So, was it a journal or an inner ring bore issue? After rotating the bearing inner ring relative to the journal and repeating the Prussian blue process, the pattern on the journal was the same. This suggests a journal form issue in this particular case (→ **figure 4**).

With heavy bearings supported by a strap from a crane, it is difficult to move the bearing coaxially to the journal and slam it. In such cases, it is usually impossible to achieve intimate contact. This is because a bearing displaced from its equilibrium position under a crane will move upwards following a curve that is a chord of a circle. This is also a problem when mounting heavy bearings on cylindrical seats as the bearing has to be pushed quickly into its final position before it cools down and creates a tight fit. To make things easier, a spring can be mounted between the strap and crane hook (→ **figure 5**).

Fig. 4 The absence of Prussian blue indicates no contact between the ring and the journal.



Fig. 5 Using a spring to make mounting heavy bearings easier.

The photograph shown in figure 5 was taken during a Prussian blue check (→ figure 6). Strange patterns were apparent on the dismantled bearing's bore and the journal (→ figure 7). The ring was slammed against its seat, but it was not driven up as this would have distorted the result. In this case, oil had to be injected between the journal and the inner ring in order to dismount the latter. The problem turned out to be with the journal, but the lesson is not to slam the bearing against the journal too violently.

Another method for use with heavy bearings that deform under their own weight is to place the bearing on the journal and to screw a mechanical nut against it. The nut is then tightened with an impact spanner and a hammer until the sound of hammer hitting the spanner becomes more metallic. To be frank, this is only something that I'd suggest for people with significant experience of this method.

Overall, the Prussian blue method has a number of shortcomings:

- It gives an idea of the contacts between two surfaces, but it can be misleading.
- It indicates whether there is contact or not, but it doesn't measure deviations.
- The amount of transfer depends on the thickness of the Prussian blue layer.
- Within manufacturing tolerance bearings and journals can achieve less than 80% contact.
- For heavy bearings that deform under their own weight, achieving correct positioning of the bearing on the journal isn't easy. If the bearing is pushed too gently, there won't be enough contact for the test. If too much force is used, there will be too much contact.

However, the Prussian blue method should not be dismissed out of hand as other methods will not check all the surfaces between a bearing and a journal. Measuring the diameter and circularity of a shaft is often done with just three measurements at 120 degree angles from each other. In the case of the journal shown in figure 6 and depending on the axial positioning of the measurements, the circularity could have been either inside or outside tolerances. Only the Prussian blue method could have been used to highlight the areas that were possibly out of tolerances.

Fig. 6 An inner ring ready to be slammed against a Prussian blue coated tapered seat.

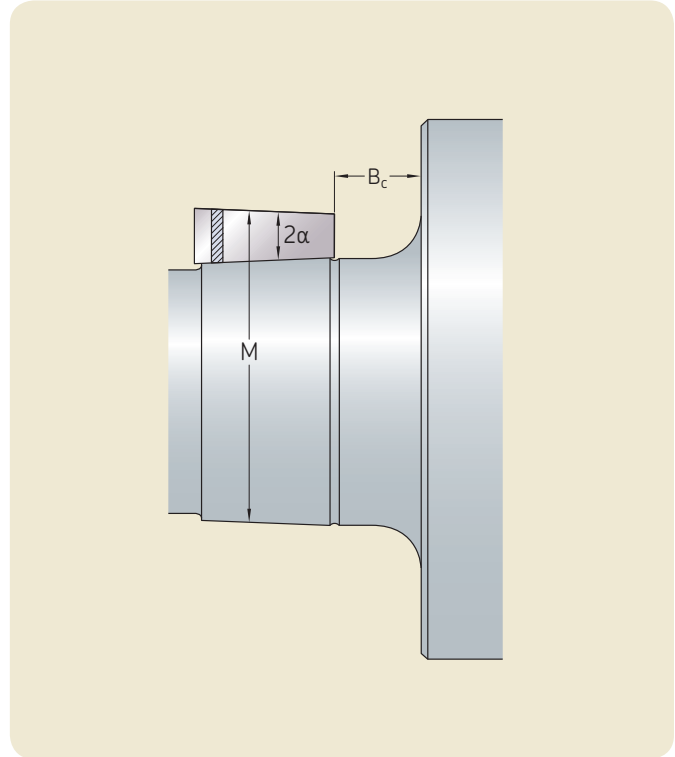


Fig. 8 Gauge method theory

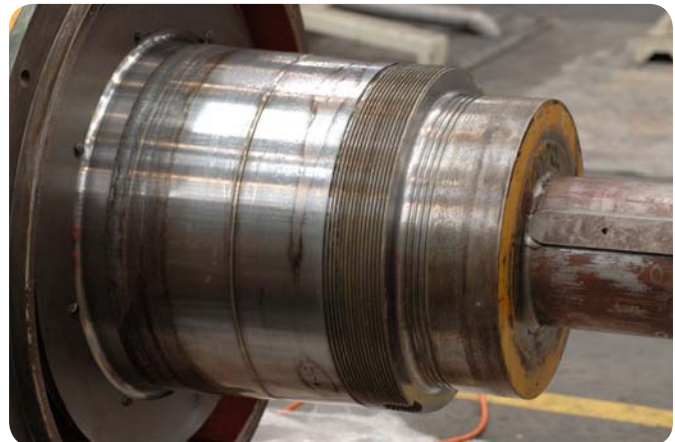
2. Gauge methods

Gauge method theory is quite simple. Figure 8 shows it well, albeit in an exaggerated way.

A straightedge with the same angle as the journal (2α) is placed on the journal. The top edge of the straightedge is parallel to the diametrically opposite side of the journal. The dimension M is the same along the length of the straightedge and the journal. This is still true whatever the angular position of the straightedge around the journal. If dimension M varies, either the angle of the journal taper isn't equal to 2α and/or the journal profile isn't straight.

SKF has two gauge methods – a US one and a European one.

Fig. 7 Strange contact pattern on a journal.



2.1 The USA taper gauge

The USA taper gauge uses a straightedge called a sine bar which is held in place so that its face is flush with the narrower end of the shaft taper (→ **figure 9**).

Before the sine bar is put in position, a straightedge coated with Prussian blue is moved backwards and forwards along the entire length of the tapered seating (→ **figure 10**). If blue covers 90% of the seating length for new journals or 80% for old journals, the straightness deviation can be considered acceptable. If not, it doesn't definitely mean that the straightness is out of tolerance, it indicates that a more objective method should be used.

A more objective method is to place a straightedge on two gauge blocks (→ **figure 11**). The gap between the straightedge and the tapered journal can be measured by passing a feeler gauge along the gap. If a suitable block gauge thickness is chosen, precision can be kept to 0.005 mm +/- the precision class of the tools (e.g. the straightedge) used. Keep in mind, however, that permissible deviations are small (IT5/2 for a 600 mm diameter shaft is only 0.015 mm) and that it isn't that easy to align and secure a straightedge in an exact axial plane.

A quicker alternative is to place a straightedge on a journal and place a lamp behind it. Very experienced fitters are often able to judge by eye whether the deviation in straightness is acceptable for the application or not. Even though I do not have their experience, I sometimes use this method. When I do, I base my resulting decisions on the application and whether the smallest feeler gauges will pass under the straightedge. A 0.03 mm feeler gauge should never pass, but a 0.02 mm can pass if the bearing bore is above 800 mm. However, as the 0.02 mm feeler gauge has poor rigidity, it's best to place it on the journal and then put the straightedge on top before gently pulling it.

Once the straightness is checked, the taper deviation can be measured. This is done by taking measurements at each end of the sine bar with a micrometer. In the SKF literature about the so-called sine bar method, H_1 and H_2 are referred to (→ **figure 12**). If the shaft taper angle matches the sine bar angle then $H_1 = H_2$.

For each bearing size above a certain bore diameter SKF gives a sine bar designation, a nominal value and tolerance for H_1 and a tolerance for H_2 . H_2 is the measured value for H_1 not the nominal value.

Using the example of a 230/750 CAK/C083W33 spherical roller bearing, H_1 would be 31.3519" (-0.0045; +0.0) with the SKF B-8491-4 sine bar. If the measured value of H_1 is 31.3500" then the narrow end diameter of the tapered seat is within tolerance. The seat taper angle would be in tolerance if the measured value of H_2 equals 31.3500" (-0.0010; +0.0020) i.e. between 31.3490" and 31.3520".

If H_2 is bigger than H_1 , then the actual taper angle is greater than nominal i.e. the taper is more open. If it's smaller, then it's less than nominal i.e. the taper is more closed.

The whole procedure – straightness and taper angle deviation measurements – needs to be repeated at least twice more around the journal every 120 degrees.

Fig. 9 The SKF USA taper gauge.

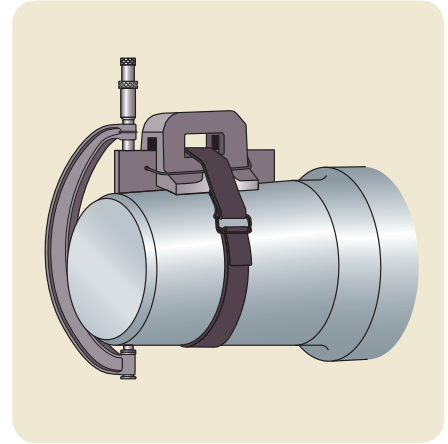


Fig. 10 Using a Prussian blue coated straightedge to check straightness.

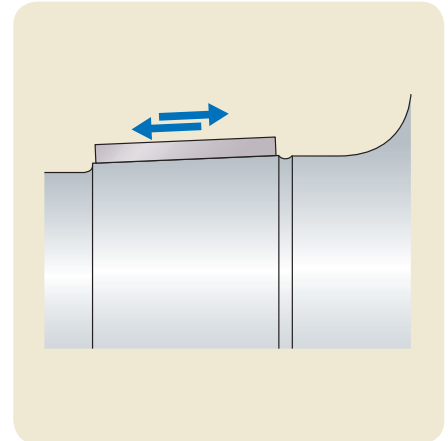


Fig. 11 A straightedge placed on gauge blocks for more objective straightness measurement with feeler gauges.

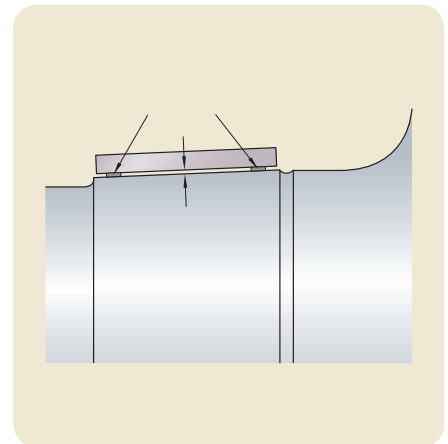
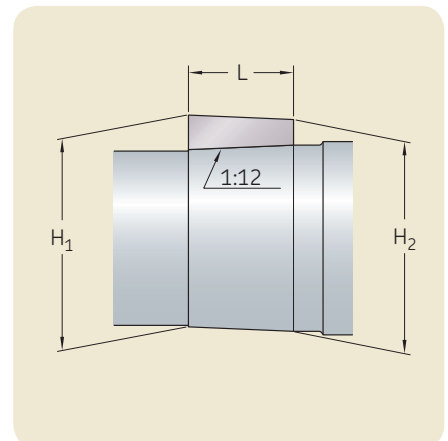


Fig. 12 When the shaft taper angle matches the sine bar angle, $H_1 = H_2$.



A 241/900 spherical roller bearing weighing 3,500 kg had to be mounted against a spacer ring due to very heavy loads and vibration. The customer's normal procedure was to:

- 1 Mount the bearing using feeler gauges to measure clearance reduction.
- 2 Measure the distance from the bearing side face to the journal shoulder.
- 3 Dismount the bearing and machine a suitable spacer ring.
- 4 Mount the spacer ring and then the bearing against the ring.

With such an approach there is a large risk of error when mounting the bearing with the feeler gauge method as it is not easy to bring the 24 kg rollers into their equilibrium position. Furthermore, mounting such a heavy bearing twice wastes a lot of man hours.

I proposed that the customer measure the tapered bearing seat just after manufacturing with the SKF 9205 taper gauge and send me the measured values. With this information, I was able to tell them the spacer ring width for each journal they made. They could machine spacer rings to the required width and mount the bearings against them when they were delivered. They agreed and we have never had to dismount a bearing due to an incorrect spacer ring width since. I think that this is a good result given that we are talking about 35 new machines over the past 20 years plus all the replacement bearings that have been driven up against the same ring spacers.

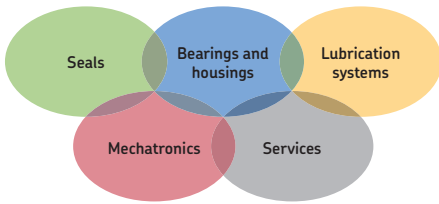
I'll finish here, but I will write more about the SKF 9205 taper gauge in the next issue of *SKF Pulp & Paper Practices*. In it, I will cover selecting the right size taper gauge, how to calculate M and ring spacer widths as well as some thoughts about tolerances and measuring uncertainty.

In closing, please remember two things:

- 1 If Prussian blue doesn't result in 80% or 90% coverage, it doesn't mean that the bearing, its seat or both are out of tolerances; it just means that more advanced verification measurements need to be taken.
- 2 When using a micrometer, don't forget to make sure it's calibrated both before and after taking measurements.

Regards,
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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.

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