Ball Bearing Inner Ring Fits and Creep (Part 2)

Norm Parker, Technical Fellow, Stellantis

Welcome back to Part 2 of our inner ring and creep discussion. We left off with our creep calculation resulting in a 10.5 µm minimum inner ring fit to avoid creep. For the sake of making clean dimensions, let's call it 10 µm on the lower end and the upper end is simply whatever your manufacturer can hold. For the 6205, something around 20–25 µm tolerance range would be expected. Often this can be accomplished with hard turning alone. Surface finish is not *too critical* here. Most bearing manufacturers will recommend a 0.8 Ra for *small* bearings and 1.6 Ra for large bearings, without clearly defining what a *large* bearing is. The main consideration for surface roughness is that if the surface is too rough, the peaks of the material will plow off during the bearing press resulting in less of a press fit than intended.

Figure 1—Differential hub cracking on high load test due to wear of material from insufficient press fit.

j5	j6	j7	k5	k6	k7	m5	m6	n6	p6	r6	r7	Diameter Classification (mm) over	incl.
+ 3 − 2	+ 6 − 2	+ 8 − 4	+ 6 + 1	+ 9 + 1	+ 13 + 1	+ 9 + 4	+ 12 + 4	+ 16 + 8	+ 20 + 12	+ 23 + 15	+ 27 + 15	3	6
+ 4 − 2	+ 7 − 2	+ 10 − 5	+ 7 + 1	+ 10 + 1	+ 16 + 1	+ 12 + 6	+ 15 + 6	+ 19 + 10	+ 24 + 15	+ 28 + 19	+ 34 + 19	6	10
+ 5 − 3	+ 8 − 3	+ 12 − 6	+ 9 + 1	+ 12 + 1	+ 19 + 1	+ 15 + 7	+ 18 + 7	+ 23 + 12	+ 29 + 18	+ 34 + 23	+ 41 + 23	10	18
+ 5 − 4	+ 9 − 4	+ 13 − 8	+ 11 + 2	+ 15 + 2	+ 23 + 2	+ 17 + 8	+ 21 + 8	+ 28 + 15	+ 35 + 22	+ 41 + 28	+ 49 + 28	18	30

Figure 2—NSK Rolling Bearings E1102k c.19.

Now we consider our shaft tolerance range of 10–20 µm. If we review the standard shaft fit chart in Figure 2, we see that this custom range falls between m6 and n6.

If we review our standard fit table in Figure 3, you will notice on the load condition column that a Heavy Load is defined as > 13 percent of the dynamic load rating Cr. We have designed our creep loads for 50 percent of Cr, so falling near the n6 range makes perfect sense. Applying these fits is very easy. The 6205 inner ring bearing tolerance is 25 0/-0.010 mm. Bearings are usually written in negative unilateral tolerances like this. The *nominal* diameter (what we call it by), 25 mm is the largest diameter. We size our shaft by taking the bearing nominal bearing diameter and applying the fit tolerances. Our shaft diameter is simply 25.01–25.03 mm.

Now let's see how we use this value for our internal clearance. For this example, we will look a solid and hollow shaft. Most of the large bearing manufacturers have a fit tool on their website. I like Koyo's, it is easy to use and customize, they include both 3 sigma and min-max methods.

Editor's Note: *For the Koyo Bearings/JTEKT Corporation example in Figure 4 the name 'Koyo' is immediately associated with the word 'bearing.' This is the website for JTEKT's Koyo bearing brand. Here, you will find product information and case studies relating to bearings and oil seals. You can also download technical calculation tools, CAD drawings and various catalogs to help you with the bearing selection process.*

The 3-sigma method can be useful if you have confidence that your parts will follow a normal distribution. If you expect to see parts at the limits, you may prefer the min-max method which uses the true limits of the parts.

Load Conditions		Examples	Shaft Diameter (mm) Ball Brgs	Shaft Diameter (mm) Cylindrical Roller Brgs, Tapered Roller Brgs	Shaft Diameter (mm) Spherical Roller Brgs	Tolerance of Shaft	Remarks
Radial Bearings with Cylindrical Bores							
Rotating Outer Ring Load	Easy axial displacement of inner ring on shaft desirable.	Wheels on Stationary Axles	All Shaft Diameters			g6	Use g5 and h5 where accuracy is required. In case of large bearings, f6 can be used to allow easy axial movement.
	Easy axial displacement of inner ring on shaft unnecessary	Tension Pulleys Rope Sheaves				h6	
Rotating Inner Ring Load or Direction of Load Indeterminate	Light Loads or Variable Loads ($<0.06C_{\mathrm{r}}$([1]))	Electrical Home Appliances Pumps, Blowers, Transport Vehicles, Precision Machinery, Machine Tools	<18	—	—	js5	
			18 to 100	<40	—	js6(j6)	
			100 to 200	40 to 140	—	k6	
			—	140 to 200	—	m6	
	Normal Loads (0.06 to $0.13C_{\mathrm{r}}$([1]))	General Bearing Applications, Medium and Large Motors([3]), Turbines, Pumps, Engine Main Bearings, Gears, Woodworking Machines	<18	—	—	js5 or js6 (j5 or j6)	k6 and m6 can be used for single-row tapered roller bearings and single-row angular contact ball bearings instead of k5 and m5.
			18 to 100	<40	<40	k5 or k6	
			100 to 140	40 to 100	40 to 65	m5 or m6	
			140 to 200	100 to 140	65 to 100	m6	
			200 to 280	140 to 200	100 to 140	n6	
			—	200 to 400	140 to 280	p6	
			—	—	280 to 500	r6	
			—	—	over 500	r7	
	Heavy Loads or Shock Loads ($>0.13C_{\mathrm{r}}$([1]))	Railway Axleboxes, Industrial Vehicles, Traction Motors, Construction Equipment, Crushers	—	50 to 140	50 to 100	n6	More than CN bearing internal clearance is necessary.
			—	140 to 200	100 to 140	p6	
			—	over 200	140 to 200	r6	
			—	—	200 to 500	r7	

Figure 3—NSK Rolling Bearings E1102k Fit Table A85.

Operating conditions

Initial internal clearance ⓘ [C3]

min 0.013 mm ~ max 0.028 mm

Tolerance class ⓘ [0‹‰]

Outer ring tolerance class

min -0.013 mm ~ max 0 mm

Inner ring tolerance class

min -0.01 mm ~ max 0 mm

Shaft tolerance range class ⓘ [n6]

min 0.015 mm ~ max 0.028 mm

Housing tolerance range class ⓘ [H7]

min 0 mm ~ max 0.03 mm

Figure 4—koyo.jtekt.co.jp/en/calculation/operating_clearance/?pno=6205

You can usually rely on bearings falling within the center 50 percent of the tolerance range. If we say that we want to the 3-sigma method to stay above zero, our solid shaft falls a little off by 2.7 µm. This is an easy enough fix by dropping the shaft diameter by ~ 3 µm, but recall, that number was set for a reason, creep. This is the game we have to play. Revisit your creep calculations and see what that does for your operating load. Perhaps it only affects a very small portion of your cycle, or it may cut into a high load test that you need to avoid creep on. Effective clearance includes temperature conditions which we aren't worrying about right this minute.

3σ method | Max-Min method

Residual clearance	-0.0027mm ~ 0.0153mm
Effective clearance	-0.0027mm ~ 0.0153mm

Figure 5—Internal Clearance Results for solid shaft.

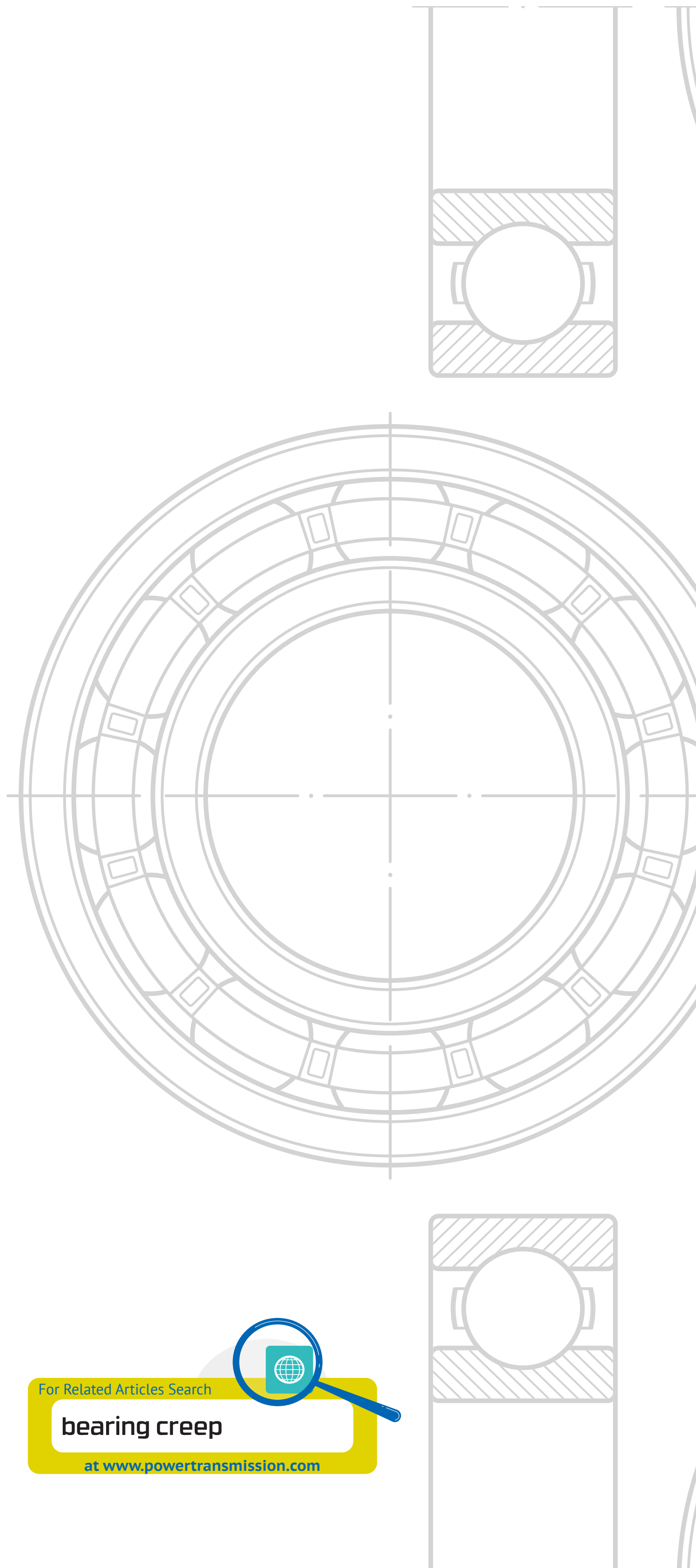
Now I take this exact same calculation and add a 15 mm through hole to the shaft (5 mm wall thickness if you prefer) and look how dramatically the clearance changes. I get almost 7 µm of internal clearance back due to the shaft compliance. Recall in the previous article, I mentioned that I often assume a 1 class higher fit for hollow shafts—this is the reason.

3σ method | Max-Min method

Residual clearance	0.0004mm ~ 0.0175mm
Effective clearance	0.0005mm ~ 0.0175mm

Figure 6—Internal Clearance Results for hollow shaft.

Ok, I'm going to leave you with that to stew on for this article. I have a blast with shaft and housing fits; I find this an enjoyable part of the job. It is often challenging, there is often not a perfect answer. You will find yourself with simultaneous problems of not hitting your creep numbers and having high hoop stress and pushing your clearance to the limits. I hope I can talk you into enjoying this process rather than losing sleep over it. Think of this like being a meteorologist and learn to confidently say that we have a 50 percent chance of rain. Until next time, enjoy!



Norm Parker is currently Technical Fellow at Stellantis. He has contributed articles for *PTE* since 2014.