FEATURE

Meet Norm Parker—Bearings Blogger

In case you missed them, following are three recent blog postings by our popular *PTE* bearings blogger—Norm Parker. We also felt that, should you not be a blog follower, this would be a good way to introduce you to Norm's bearings wisdom. Parker is currently the global senior specialist/roller bearings at Fiat Chrysler Automobiles (FCA). With his bachelor and master degrees in mechanical engineering from Oakland University (Rochester, Michigan), Parker has developed a keen interest in the academic, commercial and engineering aspects of the bearing industry. Prior to joining FCA, he rose through the ranks of traditional bearing companies and served as bearing technical specialist for the driveline division at General Motors. He is a regular contributor to *Power Transmission Engineering* Magazine, appearing often in the publication's popular Ask the Expert feature, as well as authoring a number of bearings-oriented feature articles.

Demystifying Bearing Fit Practices

Posted January 16, 2017…

I had a couple of recent conversations with different people regarding ball bearing fit practices. We have covered this before, but these issues reminded me that the topics of fit and clearance are always fair game. If you enjoy ambiguity and uncertainty, there are few better places to start than fitting a small ball bearing with tight clearance. Just to keep things simple, I'll use Koyo's (JTEKT) main Ball & Roller Bearings catalog for the technical information. All full-size bearing catalogs will have the same information.

The place to start when determining fit is with clearance. When dealing with ball bearings, the term "clearance" always means radial internal clearance, whereas when we preload tapered bearings, we are usually talking about axial preload/endplay (Fig. 1). For your reference, axial clearance is around 10× the distance of radial clearance.

Let's just walk through a quick example with my favorite bearing, i.e.—6205. When ordering these you must know what clearance you are ordering; this will usually be indicated somewhere in the title. Even though there is a "normal" clearance designated with CN, C3 is by far the most common clearance.

Ok great—you now have a C3 6205; what does that mean? Fortunately, ISO ball bearings are very standardized, so you can find clearance tables similar to what you'll find in Table 1 just about anywhere online or in any catalog; and it will be the same for any brand. Since a 6205 has a 25 mm bore (multiply the last digit by 5), under the C3 column you see that we have a clearance range of 13–28 microns (μm). This is basically how much room we have to work with. Unlike tapers, we do not want to preload a ball bearing. There are a few situations with lightly loaded bearings where you can add a light axial preload via spring or similar method; but we will never try to radially preload a ball bearing.

For most normal ball bearing applications you will want an interference fit on one ring and leave the other ring loose

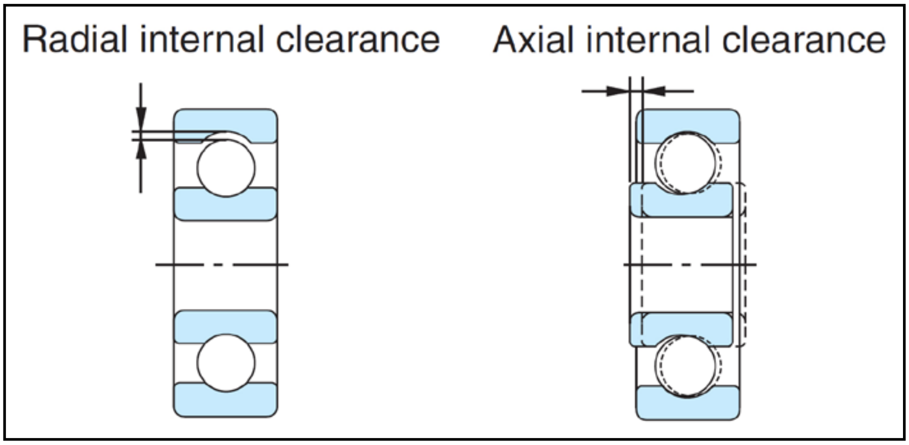

Figure 1 Distinguishing bearing radial internal clearance from preload tapered bearings (axial preload/endplay).

or leave the other ring as a loose fit (aka clearance fit). There are three reasons for this: 1) there is not enough internal clearance in the bearing to press both rings; 2) one slip ring prevents over-constraining the bearing system; and 3) without special tooling, you will need to press one of the rings through the bearing, which is a *huge mistake* (e.g., pressing the bearing into the housing with the shaft). You will damage the bearing by doing this. If you need

Table 1 Radial internal clearance of deep-groove ball bearings (cylindrical bores)

Nominal bore diameter d, mm		Clearance (in µm)									
		C2		CN		C3		C4		C5	
over	up to	min.	max.	min.	max.	min.	max.	min.	max.	min.	max.
2.5	6	0	7	2	13	8	23	*14*	29	*20*	37
6	10	0	7	2	13	8	23	14	29	20	37
10	18	0	9	3	18	11	25	18	33	25	45
18	24	0	10	5	20	13	28	20	36	28	48
24	30	1	11	5	20	13	28	23	41	30	53
30	40	1	11	6	20	15	33	28	46	40	64

Table 2 Recommended shaft fits for radial bearings (classes 0, 6x and 6)

Conditions [1)]		Ball bearing		Cylindrical roller bearing Tapered roller bearing		Spherical roller bearing		Class of shaft tolerance range	Remarks	Applications (for reference)
		Shaft diameter (mm)								
		over	up to	over	up to	over	up to			
Cylindrical bore bearing (classes 0, 6×, 6)										
Rotating inner ring load or indeterminate direction load	Light load or fluctuating load $\left(\frac{P_r}{C_r} \leq 0.06\right)$	–	18	–	–	–	–	h5	For applications requiring high accuracy, js 5, k 5 and m 5 should be used in place of js 6, k 6 and m6.	Electric applicances, machine rools, pumps, blowers, carriers, etc.
		18	100	–	40	–	–	js6		
		100	200	40	140			k6		
		–	–	140	200	–	–	m6		
	Normal load $\left(0.06 < \frac{P_r}{C_r} \leq 0.10\right)$	–	18	–	–	–	–	js5	For single-row tapered roller bearings and angular contact ball bearings k 5 and m 5 may be replaced by k 6 and m 6, because internal clearance reduction due to fit need not be considered.	Electric motors, turbines, internal combustion engines, wood-working machines, etc.
		18	100	–	40	–	40	k5		
		100	140	40	100	40	65	m5		
		140	200	100	140	65	100	m6		
		200	280	140	200	100	140	n6		
		–	–	200	400	140	280	p6		
		–	–	–	–	280	500	r6		
	Heavy load or impact load $\left(\frac{P_r}{C_r} > 0.10\right)$	–	–	50	140	50	100	n6	Bearings with larger internal clearance than standard are required.	Railway rolling stock axle journals, traction motors
		–	–	140	200	100	140	p6		
		–	–	200	–	140	200	r6		

Table 3 Nominal shaft diameter (mm)

Nominal shaft dia. (mm)												
over	up to	k 5	k 6	k 7	m 5	m 6	m 7	n 5	n 6	p 6	r 6	r 7
3	6	+6	+9	+13	+9	+12	+16	+13	+16	+20	+23	+27
		+1	+1	+1	+4	+4	+4	+8	+8	+12	+15	+15
6	10	+7	+10	+16	+12	+15	+21	+16	+19	+24	+28	+34
		+1	+1	+1	+6	+6	+6	+10	+10	+15	+19	+19
10	18	+9	+12	+19	+15	+18	+25	+20	+23	+29	+34	+41
		+1	+1	+1	+7	+7	+7	+12	+12	+18	+23	+23
18	30	+11	+15	+23	+17	+21	+29	+24	+28	+35	+41	+49
		+2	+2	+2	+8	+8	+8	+15	+15	+22	+28	+28

to constrain the loose ring, you need a mechanical retainer — such as a snap ring.

When possible, the rotating ring should have the interference fit. The only reason for this is that the turning ring is most likely to try to walk around the shaft due to inertial effects. Some light walking or creeping is harmless as long as you aren't moving material or creating heat. For our 6205 example, let's say we are pressing onto a rotating shaft, which carries a stationary load.

Table 2 gives us a recommendation, but we still have more work to do. If we are working with a normal load (6–12 percent of the dynamic load rating), a k5 shaft fit is recommended. Usually hidden somewhere in the appendices there will be standard shaft and housing fit tables. As shown in Table 3, our 25 mm shaft diameter has a k5 fit of +2/+11 µm. These dimensions are applied to the diameter class of the bearing (not the average diameter). For instance, a 6205 has an inner ring diameter tolerance of -10 µm, leaving the true average around 24.995 mm, rather than 25.0. Fit tolerances are applied to 25.0 mm. For our 6205 the recommended shaft is 25 +2/+11. Sometimes unilateral tolerances can make for easy proofing (rather than 25.002/25.011); your choice.

You may quickly realize that you have been handed a 9-micrometer tolerance to work with. This is tighter than the bearing tolerance that you are buying and, for most places, unrealistic. A k7 or k8 is the more likely reality for most places. You can see that all of the fits in the k series have a minimum press of 2 µm. I will often use 5 µm as a minimum threshold for a "press fit," but I'm not going to argue about 3 µm. Where the hand-wringing starts is when we look at the stack-up for these fits. Again recalling that our inner ring has a –10 µm tolerance, a k5 leaves with a fit range up to 21-µm interference. All things considered, the residual clearance ranges from 11 µm interference to 26 µm clearance.

But what about the clearance?

Ok, there *is* a slight caveat; you can have a *little* radial preload before you fall off the edge. The reason I recommend not trying to design this in is, as you can see, trying to avoid any chance of preload would leave you with a very loose shaft on the other end; that will create problems for you. As we are threading this needle, the small amount of potential preload at the limits can be tolerated (more so than an excessively loose shaft).

Now let's see how this looks with a more realistic range. For me, I would target about +5/+30 for this application. That puts our effective clearance at 16 µm interference to 24 µm clearance. If you are looking for a rule of thumb for how far you can play this game, I like to have my clearance range about 2x the interference range. Statistically, this will rarely get you into the fringes of your clearance window. My +5/+30 would be a few microns on the tight side, but with a bearing that has a healthy life margin, there is nothing to worry about. If I were pushing the life limits of the bearing, I might back down to +2/+27. Many bearing suppliers will agree with this approach; some get nervous when relying on statistics. This is just the reality of bearing fits.

The housing fits are quite a bit easier. Start with a line to line fit and let your tolerance decide the upper end. So for my 6205 with a 52 mm outer diameter I am going to set my lower housing diameter at 52 and the upper end is going to be whatever I can hold. Easy-breezy.

Follow these simple rules and your fits will be perfect:

Know your bearing clearance, dimensions and tolerances up front.

Press fit one ring (preferably the turning ring) and slip fit the other. Follow the tables for guides, but also double-check your stacks to make sure you aren't running more than ~ 30% into potential preload.

Start line to line on the housing. Too loose of a housing can create alignment and/or noise problems. Sometimes too close of a housing fit can be difficult to install. Adding a little oil to the outer ring is common practice. Leave opening up the diameter as a last resort.

PRELOAD!

Posted December 8, 2016…

There is never a shortage of challenging and interesting bearing topics to discuss. Let's begin with everyone's favorite topic — *PRELOAD*!

I eventually will turn this into a full article, but I wanted to throw this out to see if anyone has had any experience with modeling differential housing preload in a somewhat flexible housing. I am working on trying to develop a true analytical model opposed to the usual method of start with some and then add more as needed.

In this application, we physically stretch the housing, insert the shims and bearings and then release the housing in hopes that we hit the correct preload — preferably the first time. The preload is verified by measuring the torque required to turn the differential with the preloaded bearings. This result is compared to a known bearing torque vs. preload relationship. In theory, our shim selection would give us the correct amount of housing stretch to achieve our desired preload. Often is the case, we find the analytical model and reality do not match and adjustments need to be made on the shop floor. What makes this problem trickier than it appears at first glance is the bearing compression vs. the housing stretch relationship and that the housing does not stretch uniformly. Keeping in mind that this entire process will take place within 0.2 mm, a few microns of lost deflection results in missing the preload window.

As we dive into this problem, we will need to have accurate housing and bearing stiffness measurements — preferably analytical and physical. Usually, the shim and differential contribute negligible amounts of deflection but is good practice to include them in the initial model.

The model shown in Figure 2 is where we begin. Some interesting conversations came up as we discussed where and how the differential is fixtured. We will get into all of this and more in a full article.

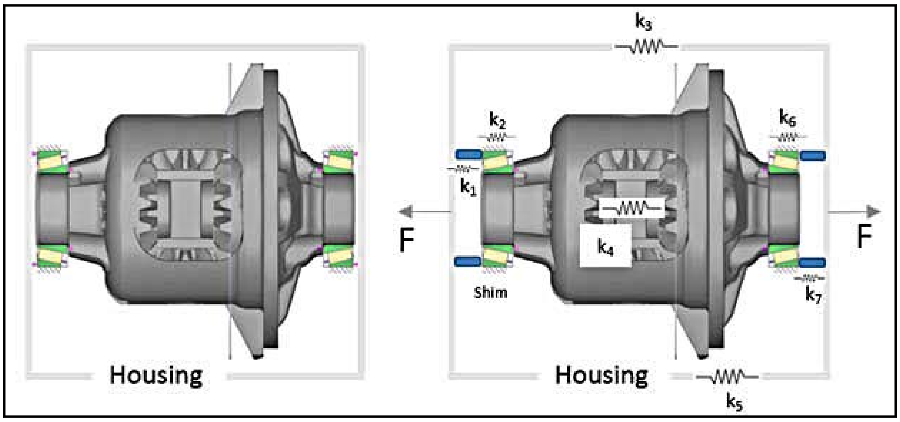

Figure 2 Where and how differential is fixtured.

Avoiding Bearings Made in "Wherever"

Posted February 21, 2017…

You can always tell when times are good in the automotive market due to the flurry of acquisitions, mergers and divestitures. As we are coming off a record 2016 in vehicle sales, many companies are flush with cash burning a hole in their billion-dollar pockets. There isn't enough front-page space for the number of companies reporting record profits for 2016. Others, however, realize that if they didn't see black in 2015–16, the writing is on the wall and it is likely time to start looking for a willing buyer ready to spend some new money on a discounted, struggling company.

As they say around here, "If you can't beat 'em, buy 'em."

In Detroit we saw some huge, industry-changing acquisitions, with AAM buying Metaldyne; Dana buying part of USM; and FCA looking for a buyer while GM is in THE process of dumping Opel. Many companies are doubling down on domestic manufacturing; meanwhile, Chinese companies continue to aggressively invest in U.S. markets.

All of this churn in the marketplace can make it tricky to differentiate the real competition from dotted line allies. As we deal with the Big 6 global bearing companies — Timken, SKF, NTN, NSK, JTEKT, Schaeffler — and an ever-increasing powerhouse — Nachi, along with the emerging Chinese behemoths ZWZ, LYC, HRB, TMB, Wanxiang, C&U and CW — you may be frequently left with the question of who exactly is doing what. Out of the thousands and thousands of bearing companies, (someone told me there were around 9,000 bearing companies in Ningbo China alone) only a small fraction is actually *producing* bearings. Indeed, the companies mentioned above produce well over 90% of the world's bearings. Of course, many, many smaller bearing companies do produce their own products. In global terms however, those numbers make up a very small part of the market. Supporting this ~ $70 billion roller bearing marketplace are what I would call assemblers, partial manufacturers, resellers, rebranders and distributors.

Now, more than ever before, it is common for bearing companies to purchase components that are in the least bit unfavorable to the bottom line. In this incredibly competitive marketplace the public companies need to show profitability to keep the stock price stable. This often means that if they are faced with the option of producing a custom ring at a single digit or flat rate of return, they are likely to shop out the business to another manufacturer. These deals are usually kept very close to the vest for obvious reasons, a major one being that if you spent tens of millions of dollars in marketing to tell people that your product is the best, people expect it to be your product.

The point I am making is the need to hold your suppliers accountable. Often a large supplier will not tell you whom they are buying your components from, but you absolutely have the right to know where your parts are being manufactured. If you are paying top dollar for what you believe to be top quality steel from a top quality producer, you don't need to be shy about asking questions. If you can't get a plant tour of where your bearings are being manufactured, there is a good chance it is because they are buying it somewhere else. If they are buying cheaper offshore rings — and then finishing them in a high-priced manufacturing country so that they can stamp them with Made in "Wherever" — you have some work to do, my friend. **PTE**

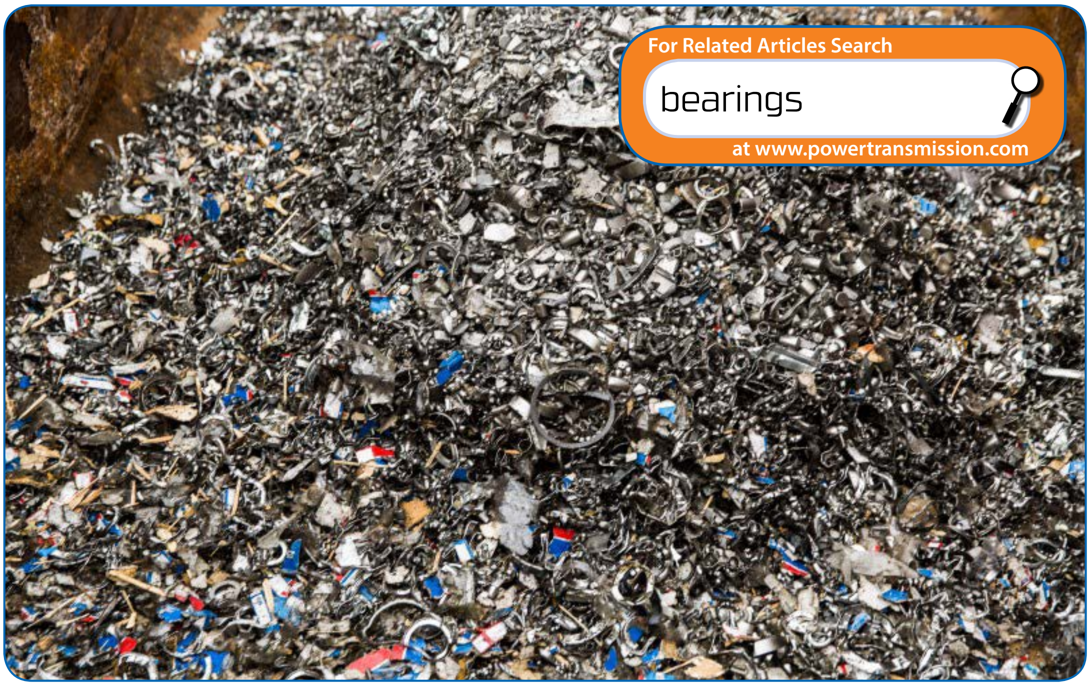

Photo courtesy of SKF

Norm Parker is currently the global senior specialist - roller bearings at Fiat Chrysler Automobiles (FCA). With his bachelor and master degrees in mechanical engineering from Oakland University (Rochester, Michigan), Parker has developed a keen interest in the academic, commercial and engineering aspects of the bearing industry. Prior to joining FCA, he rose through the ranks of traditional bearing companies and served as bearing technical specialist for the driveline division at General Motors. He is a regular contributor to *Power Transmission Engineering Magazine,* appearing often in the publication's popular Ask the Expert feature, as well as authoring a number of bearings-oriented feature articles and *The Bearing Blog*.