Tales from the Bearings Blog

The following short articles first appeared on *www.powertransmission.com*. They are part of the ongoing series of hints, technical tidbits and inside knowledge presented by our resident blogger, Norm Parker. If you like what you see here and are interested in learning more, visit *www.powertransmission.com/blog*.

Why Are Cast Iron Housings More Problematic When Fitting Tapered Bearing Cups into Bearing Caps of Salisbury-Style Axles?

I was recently approached for the 9,000th time (at least) about fitting tapered bearing cups into bearing caps.

Bearing caps can be a fairly generic term, so let me clarify that I am specifically talking about bearing caps in a Salisbury-style axle — which are the majority style of light-duty truck axles used today.

Generally speaking, you don't want an interference fit on these bearing caps because they will distort when you tighten them down.

If only it were that easy!

For as long as bearing caps have been around, keeping them round has been the issue. Typically, the caps will be mated to carrier and machined as one assembled pieces. The prevailing theory was that if the cap bolts were tightened down enough so that the cap wouldn't move during machining, the cap should be able to be removed and reassembled with the same tolerances it was machined to — right? Wrong.

It has been found that after the cap/carrier interface is machined, the measurements may be perfect — until you loosen the bolts for the first time. The cap will often contract and give you an out-of-round cap. There are a couple of theories; I'm of the opinion that the machining operation imparts some compressive stress into the machined surface of the cap which aids in the contraction when the cap is removed.

How much does the cap contract?

It can be substantial. Substantial enough to fail a bearing at the split line location. Figure 1 is a cap that was machined to perfection prior to removing the bolts and, upon removal, measured 120 µm out-of-round at the split line location — far beyond acceptable

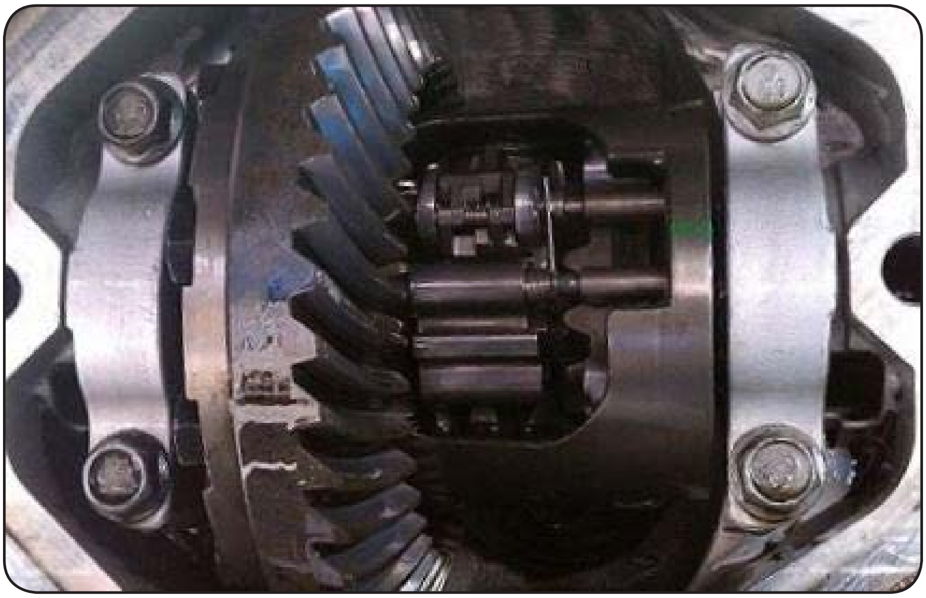

Figure 1 Rear-view Salisbury-style axle.

Figure 2 Bearing cap after machining and removal.

Figure 3 Bearing cup spalling at the cap interface.

tolerances. To make matters worse, the out-of-round is very localized—creating almost an edge at the split line. In testing, this cap wound up failing a bearing cup as the first failure in the axle, taking about one-half of the life out of the axle.

For reasons I don't yet completely understand, this problem seems to be more prevalent in cast iron housings. Aluminum housings don't seem to exhibit this problem nearly as often as iron housings. It could be because the AL doesn't get as hot during machining, but that is speculation on my part.

We'll really get into this deeper in a full article, but for now, keep your cap fits light. I like to start off somewhere around a line-to-line fit. There are occasions, if you are having really bad contraction with heavy loads, when you may have to back off farther than that.

Bolted or Welded Ring Gears? Which and Why?

There is often a lively debate early in a program when we are discussing the pros and cons of laser welded ring gears vs. bolted ring gears. Just about every company that makes gears has both styles to some extent.

There is no right answer for every application. Mass savings with welding often dominates the conversation, but let's take a high level look at some of the other pros and cons to consider if you find yourself if this conversation.

There are clearly more check boxes in favor of the bolted assembly. However, if someone if offering up 1kg or more in mass savings for a welded assembly, depending on the vehicle, welding very well may be a worthwhile venture. Looking at the comparison, it becomes obvious why companies typically employ both methods. For high performance, lightweight vehicles, laser welding becomes very attractive. For larger, heavy duty type applications where mass does not have as high of a premium, bolting wins the contest. The upside to welding is that after you make the investment, you will always have both technologies available to suit any application that comes your way.

	Welded	Bolted	Things to Consider
Mass	✓		This is often the driving force behind the welded ring gear
Serviceability		✓	A common complaint among the welded ring gear is that the entire differential must be replaced if anything needs replaced
Customizing		✓	There are many enthusiasts who will immediately replace a ring gear set with a high performance gear. Again with the welded, the entire differential must be replaced.
Strength		✓	Usually the brute strength winner will be the bolted assembly, though both will be designed to meet the intended usage of the vehicle.
Development		✓	Welding takes considerable development in weld placement, interface design, distortion, material types, etc. Bolted joints tend to be much more straightforward.
Production Equipment		✓	Welding equipment will run at least 2x the cost of a bolting station.
Production Cost		✓	Between electrical cost, welding material and maintenance, production is generally more expensive with welding.
Scrap Rate		✓	This is also driven by need to replace the differential and ring gear if anything happens to either one.
Complexity	✓		Welding is the winner in complexity just due to having 10-15 fewer parts (bolts) in the assembly.
Reliability	✓	✓	We'll call this one a tie since both will be designed to meet the reliability requirements of the vehicle.

Bearing Cup Fits in Aluminum Housings

The interference fit that cups should have in an aluminum housing is a subject that comes across my desk in regular intervals. Of course, there are numerous reasons why you would need certain fits in different areas. If there is a bearing cap involved, you may have a light or loose fit. If you need something that is going to be serviced at intervals, you are likely going to want a fit as light as possible. In gear housings, the highest priority is often the stiffness of the system, which drives a cup fit that you never want to lose contact because the cups will start to float in the bore, creating misalignment in the shaft. In a perfect world we could run a CAE stress analysis to determine how the cup interferes with the housing and then run a thermal study to make sure we hold our position at peak temperature.

But as a great person once said, "Ain't nobody got time for that."

The bore expansion can be simplified to a simple diametrical expansion. It's not 100% perfect—but its close enough for our purposes. A perfect calculation would use the linear expansion around the circumference, but when you use the same simplification for both cup and cone, the end result is nearly identical as the more elaborate approach. Using this simplified equation, a 100 mm bore at 120°C will expand by 85 µm from room temperature, 25°C. If you were trying to maintain fit up to a 120°C, that is going to be

$$\Delta D_T=(\alpha_1\cdot\Delta T_1-\alpha_2\cdot\Delta T_2)D \text{ (mm)} \quad \cdots\cdots\cdots\cdots \quad (1)$$

where ΔD_T: Change of clearance or interference at fitting surface due to temperature rise

α_1: Coefficient of linear expansion of housing ($1/°C$)

ΔT_1: Housing temperature rise near fitting surface ($°C$)

α_2: Coefficient of linear expansion of bearing outer ring

Bearing steel .... $\alpha_2=12.5\times10^{-6}$ ($1/°C$)

ΔT_2: Outer ring temperature rise near fitting surface ($°C$)

D: Bearing outside diameter (mm)

Figure 1 Linear Thermal Expansion. NSK Ltd, Cat. No. E728g 2009; p 67.

Editor's Note:

"Bearing Cup Fits in Aluminum Housings" was Part 1 of a three-part series on the issues of dealing with aluminum housings. It was originally posted on February 13. Visit *www.powertransmission.com* to see:

- Part 2, "Cup Distortion After Installation" (Feb. 20).

- Part 3, "Preload Change Due to Bearing Span Change with Temperature" (March 4).

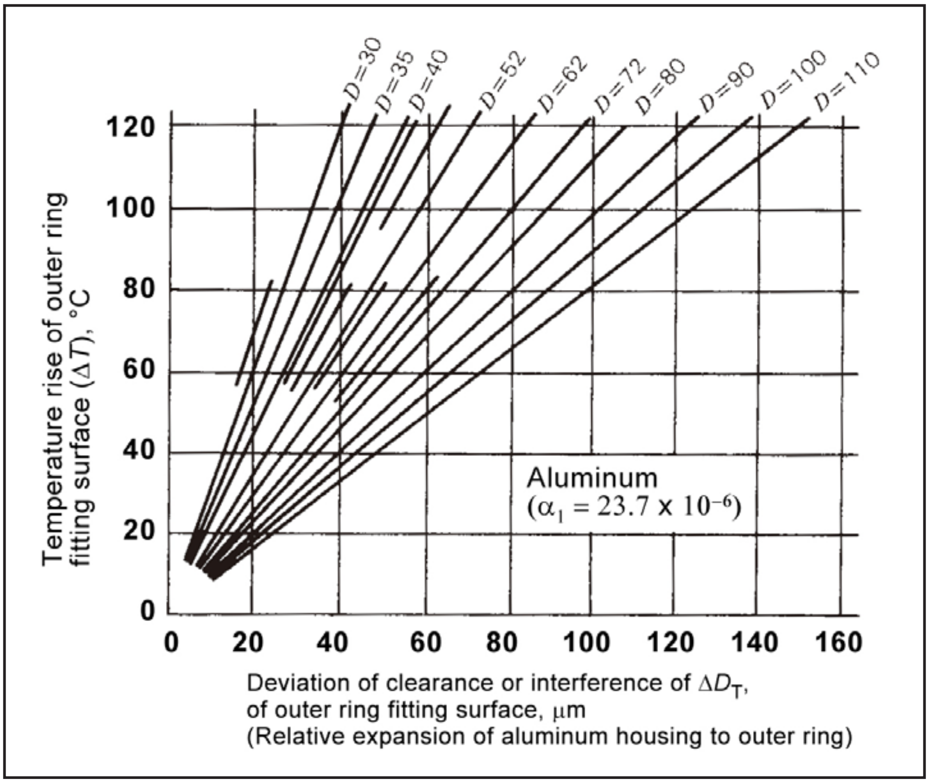

Figure 2 Chart of the Equation Above. NSK Ltd, Cat. No. E728g 2009; p 69.

your target interference fit. Depending on where your tolerances are, that might be your maximum or minimum target, with your bearing + housing tolerance defining the other end.

In my February post, I discussed how to use hoop stress calculations to determine how much the cup will grow and shrink with moving temperatures. Don't make the rookie mistake of using the 85 µm as your potential cup expansion; your cup will only expand as far as you compressed it. In a 25 mm wall housing, most of the interference is going to expand the housing wall, with the cup only compressing by as little as one-fifth of the overall interference.

Norm Parker is the bearing technical specialist for the driveline division at General Motors LLC. Located onsite at the Milford (MI) Proving Grounds, he is regularly tasked with testing theoretical models in the real world, in real time. 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 GM, he rose through the ranks of traditional bearing companies; by so doing he acquired invaluable experience in working with some of the largest customers — with the toughest applications and demands — on the planet. Parker plans to continue expanding his expertise and providing substantial personal contributions to bearing technology through metallurgy, design and processing.

Visit *www.powertransmission.com/blog* to read more of Norm's posts and stay up-to-date on the latest in rolling bearing advice and technical tips.