Memorandum

U.S. Department
of Transportation

**National Highway
Traffic Safety
Administration**

Subject: Forwarding documents to public file
Related to BMW Motorcycle Final Drive Petition

Date: August 30, 2012

From: *Bob Young*

To: Public file, DP12-001

Please file the attached material, related to media coverage concerning the referenced DP subject matter, for public access.

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[redacted]LLetter,9-06

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Member Letters

More on final drives

On April 3, 2006, about 50 miles from Deals Gap, where we were to meet two other couples for a few day of touring the area, I started to experience rear tire instability on my 2000 K1200LT (43,000 miles). Thinking I had picked up a nail and lost air pressure, I immediately pulled over to check it out. The entire rear wheel and tire was coated with oil.

After delivering the bike (by truck) to the BMW dealer in Knoxville, and $1431 later, I retrieved the bike with a new final drive installed. Of course, our touring vacation was ruined.

Coincidentally, upon returning home, I found the April issue of BMW *ON* in my mailbox, with the Final Drive Failures article. Now I receive Anton Largiader's article (Final Drives, July *OTL*) in which he unequivocally concludes, "There is a problem …," that the problem is in the preload on the main bearing at time of assembly by BMW, and that "the new 17-ball SKF bearing is … not a cure for improper assembly."

Even though the final drive failure rate exceeds 4%, BMW has their collective heads in the sand, or elsewhere, and refuses to acknowledge responsibility for these potentially catastrophic failures. They do extend something called goodwill coverage when other failures occur after expiration of warranty, but refuse to do so on final drive failures (for fear of implicitly acknowledging liability in future lawsuits?).

If these failures were occurring on automobiles, there would have been an immediate recall. Safety recalls trump warranty limitations. I have reported my failure to NHTSA and to www.bmwlt.com, which is compiling a database. I intend to further pursue this matter further. What is *OTL* doing about this dangerous major product defect issue?

[redacted]

[redacted]

The preload is a significant assembly-related variable affecting crown bearing life, so I believe that it's not a good idea to repair a final drive without reshimming it. However, I didn't say that preload is the problem on all of these drives. I don't have any way to know that without disassembling drives that have not failed and then tracking them in the field. I tried to show that with the increased weight and power of the newer bikes, the crown bearing leads a harder life even when the preload is correct, and this design probably reached the end of its usefulness.

As to what *OTL* is doing about it, we're trying to do some education with articles like the one mentioned. Hot topics like this one tend to spawn a lot of misinformation and by showing a few basic principles of operation we can help some riders form their own opinions about what's important and what's not.

Iron butts and soft heads?

[*Overheard in cyberspace*] Did you read in the latest *OTL* about Higdon riding around the DC beltway 62 times (1000 miles) in 24 hrs?

When I was 19 and just bought the Honda 750, I was on a trip to the South and I rode around the beltway 3 times in a row. After the first lap I started noticing things I had seen before and realized that I was going around again. Then I missed my exit and went around a third time to take the exit.

Those guys are nuts!

[redacted]

For the record, they rode 62 times not around the beltway (which is 64 miles around and would take only about 16 laps for 1000 miles) but rather on a roughly 16-mile loop that did not stray beyond the District's 10-mile square area. The beltway just barely touches an edge of the DC border at the Wilson bridge. None of this, however, changes the veracity of Mr. [redacted] final conclusion. –Ed.

The cover photo wa taken by [redacted] of West Chester PA, on his way to Boise.

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[redacted]Article,7-08

Final Drives

by [redacted]

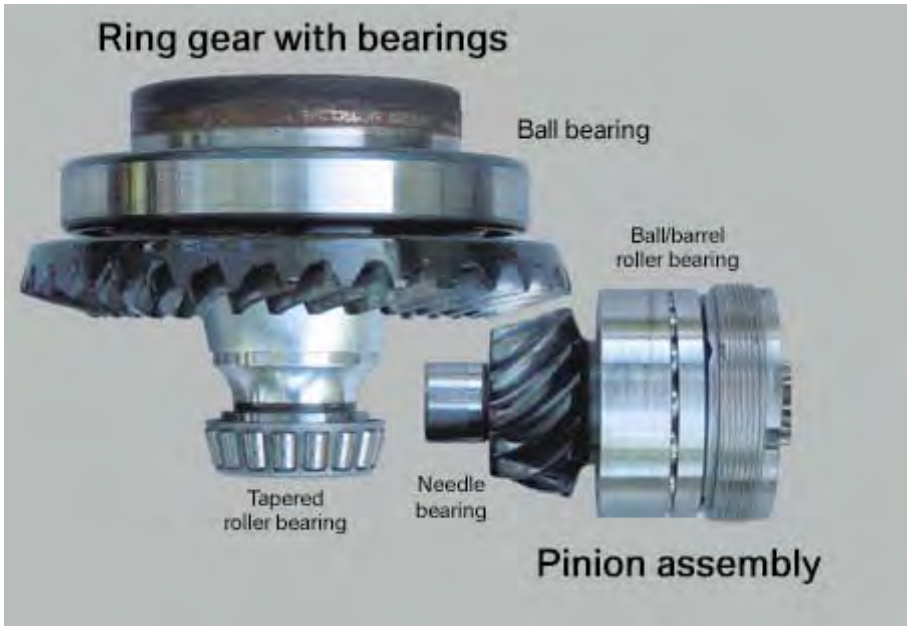
The intent of this article is to augment the information that has been written recently regarding the design (and failures) of the final drive gearboxes used on K and R models from the 1980s through the last R1150 models.

There are basically two moving parts within a final drive. The pinion gear is driven by the driveshaft and usually has ten to twelve teeth. The ring gear (sometimes called the crown gear) is driven by the pinion gear and has about thirty teeth. Each is machined as a shaft which is supported by a bearing on each side of the gear.

When the R80G/S was launched, it brought with it a new final drive design which immediately became as significant a recognition feature as the opposed cylinders had been. The single-sided swingarm, where the wheel bolts on as it does in a car, was here.

Prior to this, the wheel had ridden on an axle which was supported at each end. The power was delivered by a hollow spline which fit around the axle and was supported by its own bearings within the final drive. With the new Monolever design, the drive spline was gone and the wheel fastened directly to the ring gear of the final drive. The axle was eliminated, or more precisely, the ring gear now served as the axle. This meant that the bearings supporting that gear now needed to be strong enough to support the weight of the bike. The Paralever bikes, which started in 1987 and continued through the R1150GS Adventure, used the exact same design.

Bearing layout



Here's how the bearings are arranged in these final drives:

The pinion shaft is held by needle bearings on the inner end and a heavy roller/ball combination bearing on the outside. Because the teeth are helically cut, there is some axial* load on the pinion shaft as it tries to screw itself in or out, but most of the load is sideways: it pushes up and down on the ring gear and tries to push itself away from it due to the angled gear teeth. Since needle bearings cannot resist any axial load, the large bearing is the only thing keeping the pinion from sliding back and forth.

The ring gear is supported by a tapered roller bearing on the inside and a heavy ball bearing on the outside. The main loads are borne by the ball bearing, and the tapered bearing holds the end of the shaft in alignment.

In order to properly maintain the gear mesh, it's vital that the ring gear stay at a controlled distance from the pinion, so it is slightly compressed between these two bearings when the drive is assembled.

There is a problem, though. As it is compressed between the housing and the housing cover during assembly, the ball bearing is axially loaded. Ball bearings generally do not withstand axial loads very well, and most failed bearings show signs of excessive axial loading. Some of this is inherent in the fact that the ring gear is compressed, or preloaded, on assembly, some of it is due to the axial forces from the pinion shaft, and some is from the reaction at the tapered bearing when load is placed on the wheel. Why do we hear more about failures now, if the same design has been used for more than two decades? Let's take a closer look at the forces on the bearings as bikes get heavier and tires get wider.

Bearing forces

The arrows marked "Wheel force" are from the static load of the bike. There is an upward force from the ground acting through the wheel, several inches away from the final drive. This is countered by a force acting downward on the large bearing (think of this as the weight of the bike) and another force at the tapered bearing, countering the twisting effect which results from the contact patch not being directly under the big bearing. As tires get wider, the contact patch gets farther away and this last arrow gets larger. As it gets larger, the axial component of the force on the tapered bearing grows also, which results in a corresponding axial load on the ball bearing. For a 400-pound load on the wheel of an R1100RT, the horizontal component is about 175 pounds.

The arrows marked "Preload" are the compressive forces resultant from the specified assembly stress. These are constant, and I estimate them at several hundred pounds.

The "Pinion force" arrows represent the force of the pinion gear pushing on the ring gear to make it turn. This is angled due to the shape of the gear teeth, and therefore exerts an axial force on the ring gear which is resisted by the big bearing. When coasting, this force is nearly nothing, but under full acceleration it can be well over 1000 pounds.

This can be seen by looking at the three loads on the far left of the diagram. Each of them tries to push the ring gear to the right, which beans the ball bearing has to push back.

So the big bearing has to resist three different lateral loads for which it isn't so well suited. Are we doomed to suffer bearing failures because the design places axial loads on a ball bearing? No. This is a lifetime (200k mile or more) bearing in most bikes. When it isn't, something is wrong, and the main variable in the system is the amount of preload on that bearing. The preload is set by shims which fit between the cover and the bearing, and BMW specifies that there should be 0.05~0.10mm of interference when assembling the final drive. If there is too much, you will place excessive side loads on that bearing. What happens to this interference when the unit is assembled? It causes a minute amount of 'stretch' of the housing and cover, which is in turn relieved by expansion as the final drive heats up in use.

Many articles have been written about replacing the bearing, but most of

them suggest replacing the shims exactly as found. I don't understand this at all; here is an assembly which has failed and we're going to replace the damaged component and pretend it never happened? It didn't go bad by itself. The new 17-ball bearing is undoubtedly better, but it's not a cure for improper assembly. Any time a final drive is rebuilt, it should be thoroughly checked out.

After the Tacoma Narrows Bridge collapsed, local engineers proposed strengthening and reusing the same design. Theodore von Karman, whose work in aerodynamics showed the design's flaws, responded "... and it will fall in the same place."

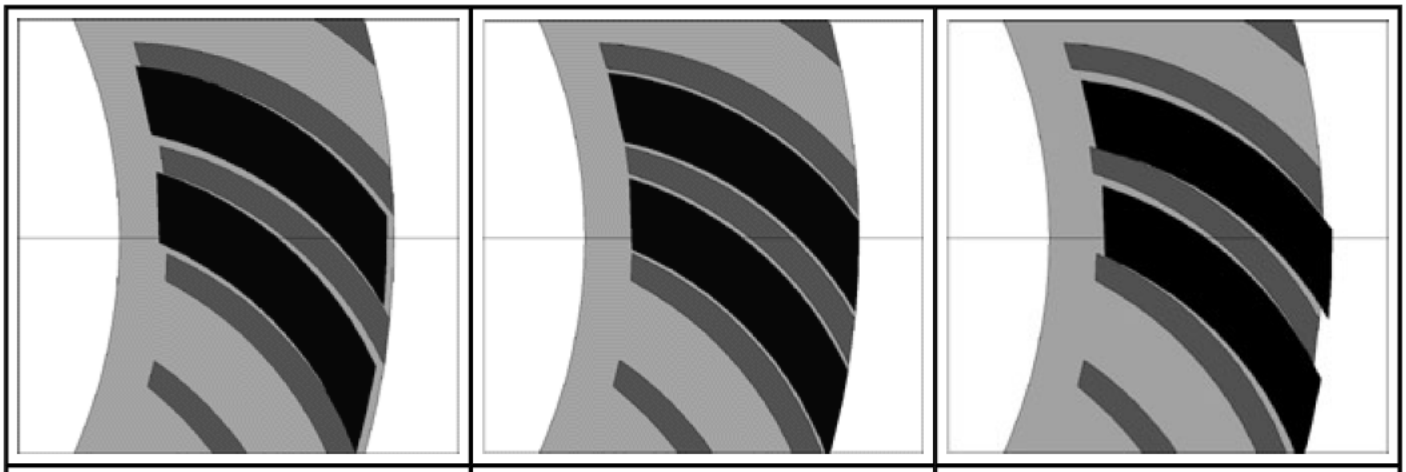
Shimming

What does the all-important shimming do? On the standard Monolever and Paralever drives, there are three areas that need to be shimmed to provide the correct fit between parts.

1. Pinion

The teeth on the ring and pinion gears are cut in what is known as a Klingelnberg profile. These are essentially bevel* gears with a helical cut, but the helix has a pronounced curve. If you fit the two parts together, you can see that as you slide the pinion towards the center of the ring gear it will rock counterclockwise, and as you try to slide it away it will rock clockwise.

In the diagrams below, the light colored teeth are the ring gear and the dark teeth are the pinion. Notice that if the pinion is not centered, the teeth make contact at the upper left and lower right (too far in) or the upper right and lower left (too far out). In the middle diagram, there is even loading across the tooth face.



Too far in - pressure is on the ends of the teeth	Centered - pressure will be even across the tooth face. The gap represents the backlash.	Too far away - pressure on the ends of the teeth

There is only one distance (from the center of the ring gear) where the pinion is aligned properly, and the pinion shim holds the pinion in that one position. Positioning the pinion too close or too far from the ring gear will place all of the load on the edges of the teeth.

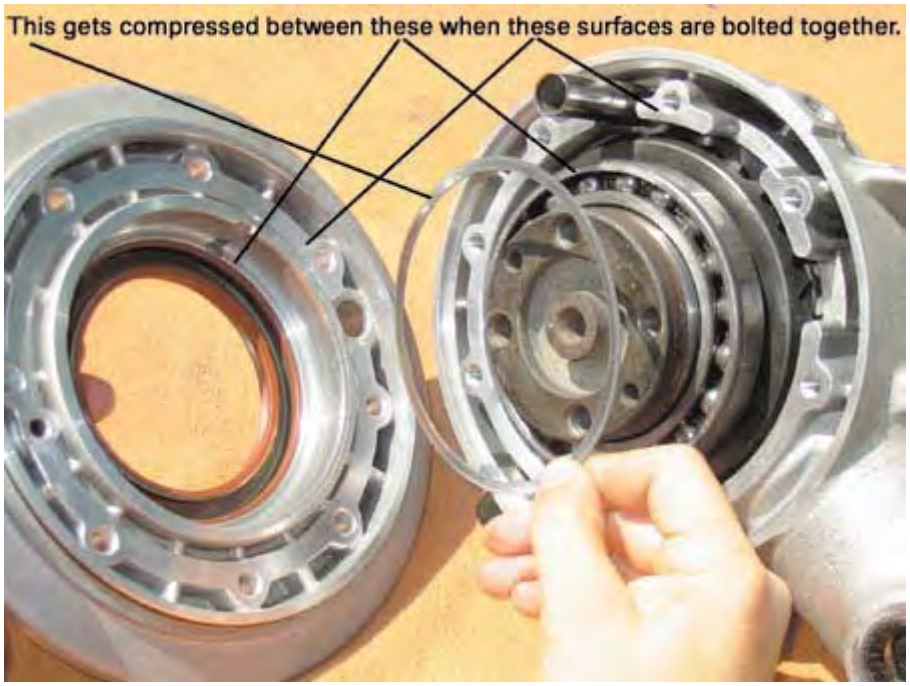
2. Backlash

With the pinion meshing properly, there should be a small amount of free play between the two gears.

This is measured by immobilizing the pinion, rotating the ring gear and measuring the amount of movement. A shim under the tapered bearing controls the depth to which the ring gear seats in the housing. The closer it gets to the pinion, the less free play there will be. The specified free play at the gear teeth is about a tenth of a millimeter. If there's too much or too little distance between the gears, the teeth will wear.

3. Cover

Once the ring gear has been positioned in the housing properly relative to the pinion, the cover is installed so that it provides a certain amount of preload, or clamping force, to hold the ring gear in place.



This is done with shims between the cover and the ring gear bearing. The flat areas on the cover and housing with eight holes are the mating surfaces. The distance that the bearing protrudes above this surface in the housing is compared to the depth of the bearing recess below the corresponding surface in the cover. Shims are selected to make the bearing taller (or make the cover shallower, take your pick) so there is a slight amount of interfecrence as the two are bolted together.

Evo Paralever

With the R1200GS, BMW introduced a new design for the final drive. The EVO Paralever is recognizable by the large hole through the middle. Where have we seen this before? Yes, the twin-shock Airhead final drives had a hole in the middle, where the rear axle went. With the single-sided swingarm there is no longer a separate axle, of course, but design similarities between the Twin-shock final drive and the EVO Paralever go farther.

On the EVO, the small end once again has a needle bearing, so the ring gear bearing cannot be preloaded. Axial position of the ring gear is now controlled entirely by the ball bearing at the wheel, and the needle bearing does not (and cannot) contribute any axial load due as a result of the weight of the bike. Those axial loads on the main ball bearing, therefore, are eliminated. Furthermore, there are only two clearances to shim: the pinion and the backlash.

That ball bearing is held in the cover, and the backlash is controlled by positioning the cover with shims. Without preload on the ring gear, the inherent play in the bearings can be felt as a tiny bit of looseness in the wheel. This is normal; BMW specifies that up to 1mm of play can be measured at the rim before a final drive is considered defective.

The twin-shock Airheads also had a needle bearing on the small end of the ring gear, but axial position was controlled by a thrust bearing shim, much like the Airhead crankshaft is. Counting the pinion and cover bearing shims, these drives still had three adjustments to make upon assembly.

** The term "Bevel" means that the axes of the two gears intersect. A worm gear would be a different type where the pinion axis is tangential to the ring gear, and a hypoid gear is anywhere in between the two. Bevel gears (like BMW final drives) and spur gears (engine, transmission) have only rolling contact between the gear teeth. Hypoid and worm gears have sliding contact.*

**Note: "Axial load" refers to loading which results from a force applied along the central axis of the gear. For example, the sideways loading on a car tire as you go around a corner. Forces which act perpendicular to the axis, or towards the centerline of the gear, are referred to as radial forces.*

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MCN,Nov'08Lttrs

Why didn't you include the V-Strom 1000 in your adventure touring test? I think it would have beat the Buell in probably every category and come in first or second in some of them. I have never driven the V-Strom 1000, but if it is at all like the 650, it would have probably scored well in ergos, engine, transmission, handling and especially in value. It would have been a great way to introduce people to the V-Strom as it is so affordable and does so much.

[redacted]

[redacted] *you're probably right about the V-Strom 1000, but we wanted to test new and improved adventure-tourers this time.*

BMW Final Drive Failures

Thank you for the informative article "Tarnished Roundel" (September). But the roundel is tarnished more than the article suggests. Clutch and transmission spline failures have become an ever more reported problem on R1150 motorcycles. Like final drive failures, this is a major driveline failure, frequently leaving riders stranded. But unlike final drive failures, spline failures tend to occur after the warranty expires and are typically much more expensive to repair. BMW has been silent on these failures. Although many have been reported to NHTSA, it hasn't commented, presumably because there have been no injuries. BMW MOA hasn't pressed BMW for spline failure data or repair assistance because they profess to be strictly a social organization and not an advocate for their members. Thus, many of us have been left stranded and holding the bag for a very costly repair.

Reliability is why many riders pay extra to own BMW motorcycles. I will probably continue to ride and buy BMWs mainly because I like how they ride, their comfortable ergonomics, and I enjoy a kinship with other BMW riders. However, I will probably only buy BMW motorcycles with a belt or chain drive until BMW polishes their roundel by either showing final drive and spline failures are really not excessive or significantly extending the warranty on their drivelines.

[redacted]

Ogden, UT

I have a 2000 BMW K1200LT. The final drive failed in September 2008 with just over 21,000 miles. Some of the cost was warrantied, but the dealer told me that it came out of his pocket. He gave me the impression that BMW did not assist with this. Their service order notes said: "Disassembled rear drive unit, found crown wheel bearing had failed and scored the housing. Replaced rear drive unit. Half the cost of the parts provided under the BMW Goodwill Program." When the dealer saw it, he said there was no "BMW Goodwill Program" and that they were covering the cost.

[redacted]

I own an '04 BMW R1100S with 12,000 miles on which I just had the transmission seals replaced. I had noticed oil seeping at the motor/transmission joint. It seems oil was leaking into the clutch. The tech told me the clutch would have started to slip in about 500 more miles.

I used to feel pretty good about the fact I'd been able to acquire a reliable, well-made Beemer. Now I'm not so sure. I look forward to any comments or action BMW may take regarding this matter.

[redacted]

I'd like to respond to your original story on BMW final drive failures, and Mike Miller's response in the October issue.

First, thanks for running the story. It is clear you did your homework, and that you accurately portrayed a serious issue. As an owner of a 2003 K1200LT, I am grateful for the attention. It is a weak spot in an otherwise excellent motorcycle, and it has ruined the touring vacations of many of my friends and colleagues. Even the most dedicated among us is sorely disappointed in the lack of support from BMW.

Second, I'd like to lay to rest Mike Miller's contention that final drives fail because they are not properly serviced. BMW riders are among the most diligent when it comes to service and maintenance. The vast majority of rear drive failures have occurred on bikes that were religiously maintained, many with oil changes occurring at double the recommended frequency. We know this because we keep a detailed log of failures, including maintenance histories.

I love my bike. I don't think any other touring rig out there combines handling and comfort like it. But this is my first BMW, and it will also be my last. Partly because of this engineering flaw, but mostly because of BMW's response to its loyal customers.

[redacted]

Newark, CA

Thank you for this excellent write up. It is good to have our frustrations validated by experts. Have you had any discussions on transmission input shaft spline failures?

I ride a '99 R1100SA and several in my community have had these splines strip off of the shaft. I disassembled my engine pre-emptively at 28,000 miles and found the splines to be worn halfway through. The wear appeared to be metal on metal fretting. There was not a trace of lubrication on the splines. The spline area was very rusty as well.

[redacted]

Jefferson, NJ

Tom, this is what I know (which isn't much): 1. BMW does not have a service schedule for lubricating clutch splines. It used to be 15,000 miles on some Airheads and 40,000 on some K-models, but there's nothing on the new generation bikes.

2. BMW boxers with six-speed transmissions (like the R1100S) appear to be the most susceptible to this problem—which can be catastrophic—failing without any advance notice. It doesn't appear as though you had an issue with the performance/shifting on your R1100SA, even though the splines were dry. According to [redacted] *—who really is a better source of information about this matter as I simply don't have the technical expertise—that's not necessarily a problem.*

[redacted]

Helmets

I would like to address this question to [redacted] When I took a riding class, they let me use both a full-face helmet and a three-quarter helmet. It was a lot easier to hear using the three-quarter helmet. Is there any way around not being able to hear when you're using the full helmet?

[redacted]

[redacted] *the most important purpose of a helmet is to pad the brain against injury should the head strike something hard. The greater the coverage around the skull, the more coverage by the EPS (styrofoam) liner. Hearing may be easier on a training range at slow speeds, but hearing is secondary to impact protection when riding in traffic.*

If you're interested in "crash padding" your brain, you should know that the two areas most likely to sustain impact are the left and right jaw areas. That's why so many of us wear "full coverage" helmets that provide face and jaw protection. I prefer a flip-front (modular) helmet that opens when needed, but I only use a flip front that has metal locking latches.

Hearing is another important consideration. At highway speeds, wind buffeting around your head creates a loud but low-

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MCN,September'08