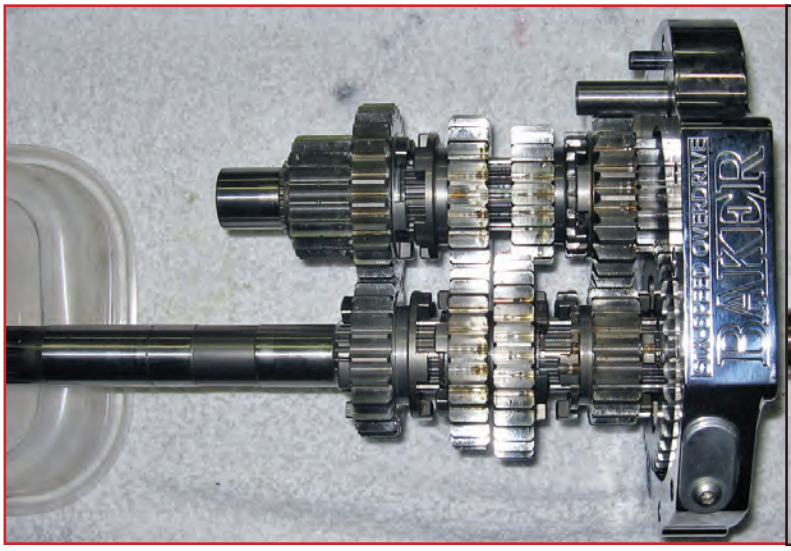
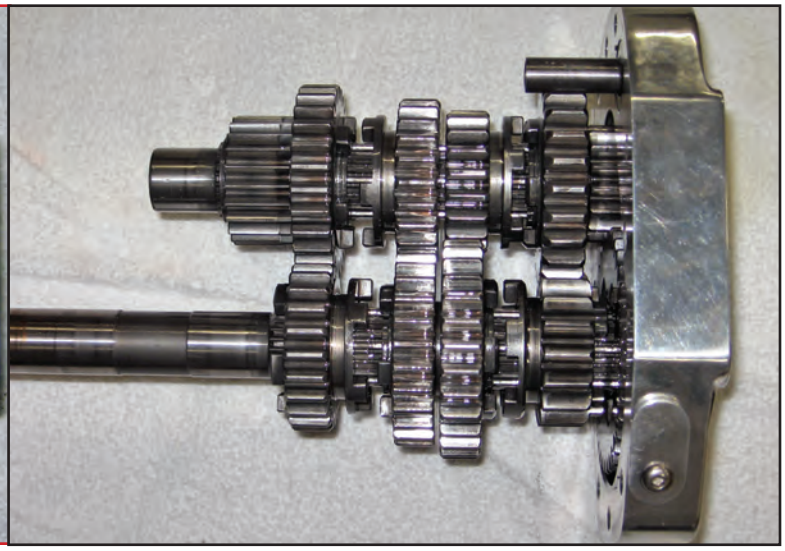
ROADMAX™ 6 SPEED VS. BAKER™ 6 SPEED





By Pete Benschoter

It all started back in August as Hammer and Englishman paid me a visit in Toledo to talk about doing a story comparing a used Roadmax 6-speed to a used Baker 6 speed. Having been a gear design engineer for the better part of 30 years, this was not a new task for me, but after drinking a few of their beers I was lubricated enough to agree to the task sans compensation. I will get my time back in parts from them when I need them. I still have some buddies in the gear industry that could help out with some of the gear tooth profile analyzing as well as material evaluation work. Since they are doing this under the header of 'Government Work' let's just say that they work for reputable companies, with up to date certified machines and test equipment.

AGMA and gear attributes

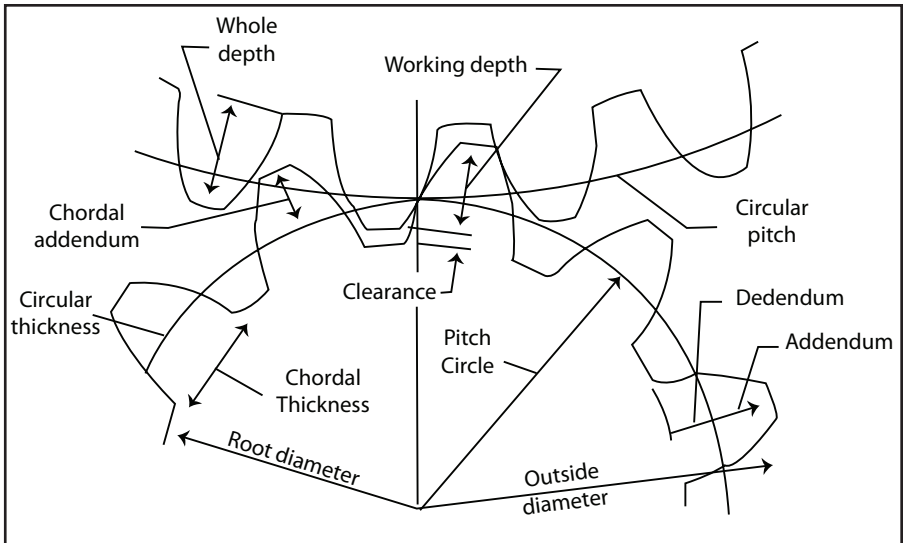
For this comparison, I measured Lead, Tooth Profile and Runout on an M&M™ Analytical Gear Inspection machine. The M&M gear checker to a gear engineer is like a set of micrometers to a machinist. Comparing these 3 attributes will help us the most in being able to compare overall design and manufacturing quality.

AGMA (American Gear Manufacturers Association) is the standard to which most American based gear makers base their gear classifications. As noted in Figure 2, there are many different measurable points concerning a gear tooth's profile and the resultant amount that it interacts with its gear pair. When measured, they are then entered in a lengthy formula to calculate a single AGMA Tooth Profile value that ranges from 1 to 15. With 1 being a gear tooth manufactured with 100 year old gear making machines, and 15 being a master gear, made with state-of-the-art CNC machines that lesser gears can be measured from.

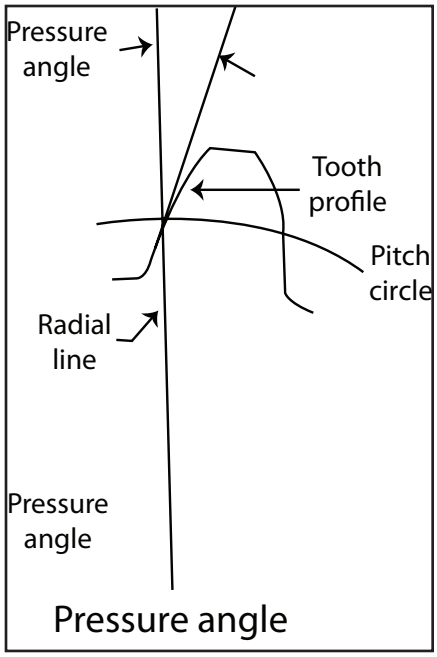
In addition to checking the AGMA attributes, I also checked the heat treat, gear pair backlash, and examined the dog teeth.

Lead

Lead is a measure of the straightness of a tooth when compared to the centerline of the shaft that it rides on. The ability to control the lead is a great factor in determining the life of the gearset, as you can help to control the loading points across the face of the gear tooth. Whether that is center, left bias, right bias, etc. The measurable lead is almost solely a result of manufacturing precision. In this test for instance we found the certain Roadmax gears had both positive and negative lead values on the same gear. The teeth were pitching back and forth basically in relation to the shaft centerline, when they were supposed to be straight. Being that both of these gearsets are used in relatively low hp applications of less than 125 or so horsepower at the gearbox, I assumed



Spur Gear Terms



the intended tooth profile to be straight across the contact face. (Some high horsepower applications utilize crowned teeth to compensate for deflection enabling flat tooth contact under full load, rather than edge only loading when the middle of the tooth deflects.)

Profile

The tooth profile controls the manner that the gears relate together. The radius of the tooth profile at the pitch diameter transitions directly to the involute dimension of the flank fillet. The flank fillet flows right into the root circle at the point of tip contact through the meshing of the gear pairs, etc. On a basic level you want the gears to roll as smoothly off of each other with big smooth round mushy looking teeth for noise suppression, while you also want the gear tooth to be as square to their mates as possible for maximum strength under full power transfer. It is a fine line balancing act that through the management of the tooth profile variables yields the final contact ratio value with out sacrificing torque carrying capacity. Design of the tooth profile is the hardest thing to get right, the most important factor in determining the noise of gear under load, and quite often the first thing to get screwed up due to lack luster manufacturing.

The manner is which the tooth profile is formed does make a noticeable difference in gear noise at speed. Whether that is through hobbing and shaving (Roadmax) or hobbing and diamond ground (Baker). The smoother and higher quality micro the tooth surface finish, the quieter it will be throughout its usable life. The use of grinding vs. shaving also helps to hold a tighter as designed profile and that was the case in this side by side study.

Runout

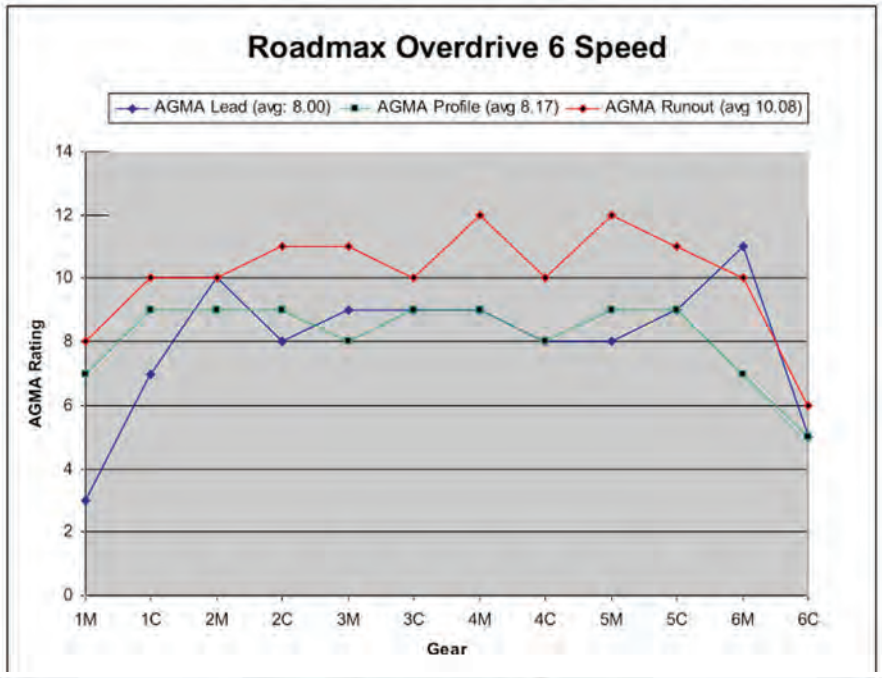
Next we measured the runout as it relates to the Pitch Circle which controls the interaction of the tooth profiles as the gears spin. You would like to shoot for a runout of .003" as the worst case scenario. Basically the worse the Runout, the more that you are spinning two eggs against each other, rather than 2 round discs.

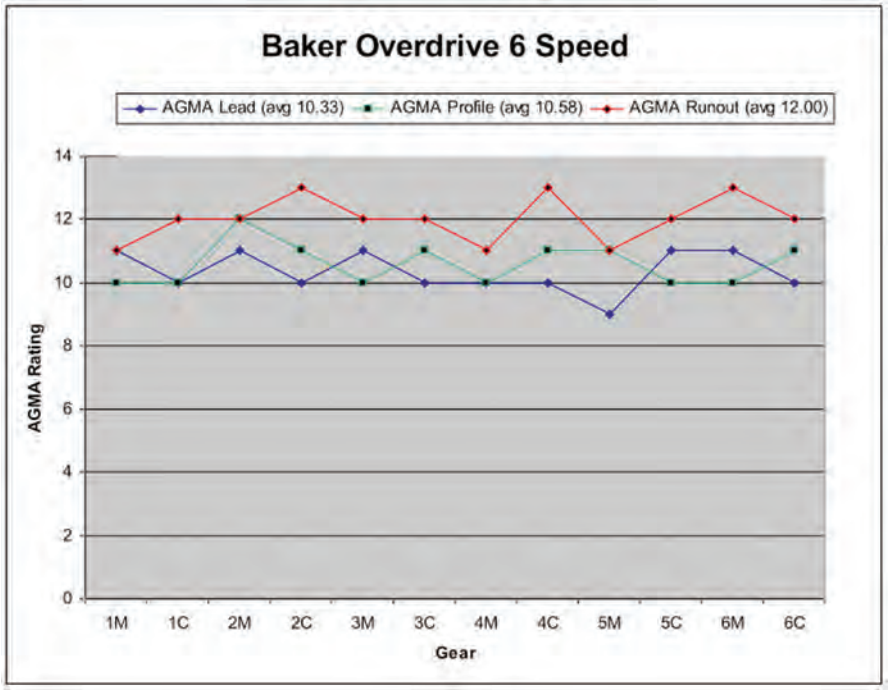
AGMA results

The graphs in Figure 3 summarize the results obtained with the M&M gear checker with a rating of 1 being terrible and 15 being a perfect score. Notice the average values across the top of each graph. The difference in ratings of roughly 2 points for each attribute is huge in the gear world.

Spline runout

In measuring the shafts I found negligible differences in the ground





bearing journals, but incurred greatly different results for spline runout. The Roadmax unit had a total indicated spline runout of .0039" vs. the .0014" for the Baker. The Countershaft was basically the same story, Roadmax .0022" and the Baker came in at .0010". Once again, control of the manufacturing process was the difference.

Heat treating and material

The costs involved to do a full alloy composition test were way beyond the budget I was given for this project (3 measly beers). Had we done this, we would have been given a report that would have told down to .01% volume the elements found within the given sample of alloy. We instead went about checking for case hardness, case hardness usable depth, and core hardness to tell us the general grade of the base steel used. Solid core hardness numbers are usually a sign of good quality steels. We found the gears and shafts of the Roadmax had Rockwell Hardness C readings of 58-62 at the surface, with an effective case depth of .025-.029". The lower than expected number was the core hardness readings of 27-29. I would like to see that number in the 32-36 range as commonly found with a gear grade 8620 alloy. Although we do not know the exact alloy composition, it is a safe bet to say that the Roadmax was made of a low grade lesser quality alloy based on the core hardness numbers.

The Baker tests came out more as I suspected they would for gear grade steel. Surface hardness of 60-62 Rockwell C with an effective case depth of .030-.034". While the core hardness numbers were in the 34-36 HRC range.

So the case hardness and the core hardness can be likened to an ice cream cone dipped in that chocolate shell stuff; hard shell on the outside with a softer core. The Roadmax gears appear to be soft serve ice cream dipped in chocolate and the Baker gears are double dipped in chocolate with rocky road ice cream underneath.

Gear pair backlash results

Along with the 85 other things that an engineer has to worry about in the design of a transmission, no matter what industry or use it will have, is gear pair backlash. The gear pair backlash is a number though that could be attributed to many minute tolerances adding up to a big number. For these Softail transmissions, the dimensions held for the center distance between the shafts in both the cast case and billet trap doors can make a gear pair with perfect tooth profiles have gear backlash values that are out of spec. In order to measure the gear backlash, I used my Bridgeport to cut a hole in the sides of both cases to be able to get a dial indicator on each gear pair. To the best of my ability I positioned the dial indicator perpendicular to the


Roadmax 4th Gear on mainshaft


Baker 4th Gear on mainshaft

tooth face. While holding one gear still, I rocked the countershaft gear back and forth to measure total backlash. Knowing that tolerance stack up in the wrong direction could cause gear pair binding, I would shoot for .002" as the very minimum backlash dimension in this application.

After finding the AGMA Profiles of the Roadmax to be a lot 'looser' than that of the Baker, I would expect the backlash on the Roadmax to be a larger number, and they were. For the 6 Roadmax gear pairs, I found a range of .0042"-.0071" with a median value of .0056". The Baker on the other hand had a data range of .0026"-.0043", with a median value of .0035". This .0021" difference in the median values may not sound like much, but in the world of gear geometry, it's a mile.

A loose backlash number is a sneaky way to compensate for loose tooth profiles, runout and lead by adding a fudge factor to the system. A loose backlash will add to the slapping noise that you hear when you rip the throttle off of coasting down the road, as well as contributing to premature failure and unintended wear patterns. Tighter backlash will aid in reducing noise, but must be accompanied by better gear tooth profiles as well as tighter machining tolerances on the case, door and door locating dowels.

Dog teeth as it relates to shifting

The dog teeth play a role in shift quality, and the ability to stay in gear under load. Both units had 4° dogs with the same dog tooth heights. The 4° angle on the side of the dog tooth is what holds you in gear when you are going down the road. The shift drum and fork move the adjacent gear over to engage the chosen gear, but the dog teeth angle holds it in gear. Back-cutting of the dog teeth is shown in figure 4. The Baker gears have a more generous back cut on the faces of the dog teeth, which yields better shift quality.

Overall results

The table below spells out the cold hard facts:

Attribute	Roadmax	BAKER
Lead (AGMA rating)	8.00	10.33
Profile (AGMA rating)	8.17	10.58
Runout (AGMA rating)	10.08	12.00
Shaft spline runout (mainshaft, in)	.0039	.0014
Shaft spline runout (countershaft, in)	.0022	.0010
Heat treat (case harness, HRC)	58-62	60-62
Heat treat (case depth, HRC)	.025-.029	.030-.034
Heat treat (core hardness, HRC)	.027-.029	.034-.036
Backlash (in)	.0056	.0035
Dog teeth	4° w/ mild back cut	4° w/ generous back cut

Conclusion

The Roadmax scored less than the Baker in every measured attribute. From this, it is easy to conclude that the Roadmax will be a noisier transmission and would be susceptible to durability problems related to overall strength and long term service life. Worth noting here is the AGMA attributes on the Roadmax 6th gear pair which were borderline commercial, the table above just shows the averages. Those values were significantly less than the average which is not good considering a lot of time is usually spent in 6th gear going down the highway.

From an engineer's point of view, the cold hard facts above tell the whole story, you get what you pay for. The guys at Baker have paid a great amount of attention to the details. I had always heard that the Roadmax was a Korean made knock off of the Baker, and after getting down to the nitty gritty and seeing how truly similar they are in layout, I would say that is true. However, the Roadmax guys in Korea did not do a very good job of copying the design or duplicating the manufacturing quality.

Next issue I will investigate the cases, bearing doors and shift systems.