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# Wear investigation of finish rolled powder metal gears

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*Abstract*— **When manufacturing powder metal (PM) gears lead crowning is not achievable in the compaction process. This has to be accomplished by either shaving, grinding or honing. Each of these processes have their merit and draw back. When employing rolling using a roll burnishing machine lead crowning can be accomplished but due to errors in profile a hard finishing operation such as grinding is used by the industry [1]. In this paper a helical PM gear that has sufficient tolerance class after rolling has been tested in a test rig for durability and the wear has been studied.**

**Keywords** – Powder metal gears, densification, wear

## I. Introduction

Powder metal gears for automotive transmissions are becoming a reality and GKN is the first company to deliver PM gears for car transmissions [2]. However these gears are surface rolled and likely to be hard finished . Adding both processes will take away some cost advantage. It would be preferable to have only hard-finishing or surface rolling. So far the rolling technology can not meet the tolerances obtained by hard-finishing and hard-finishing can not give the high dens layer on the gear teeth that boosts mechanical properties to solid gear steel levels. Rolling can still deliver tolerances compared to shaved gears but with a surface that is smoother and more comparable to superfinishing technology than traditional gear grinding or honing. In a joint development effort a finish-rolled gear replaced the original 6:th driven gear in 6 speed manual transmission, see figure 1. The whole transmission was put in a test rig and the gears were tested for durability and vibration. The findings will be presented in this paper.

## II. Testing

The test sequence used was an OEM test cycle for a European premium car and equivalent to 300 000km service life of the drivetrain. For the 6:th gear the cycle was set as follows: 230Nm input torque, which is maximum engine torque, for 21.6 Million cycles at 3000 rpm. This corresponds to a contact pressure of 1285MPa and root bending stress of 677MPa.



Fig.1. Upper: 2 views of 6:th output gear- Lower: Gearbox before case is bolted together. 6:th output gear is clearly seen, see arrow.

The gears were measured before and after running on a Wenzel GearTec gear inspector for comparison. The output from the gear inspector was filtered both mechanically and in the software but it still gives an understanding of the amount of wear that has taken place throughout the testing, see figure 2 and 3.

## III. Results

Wear results were recorded by measurement of profile and eyeball inspection.

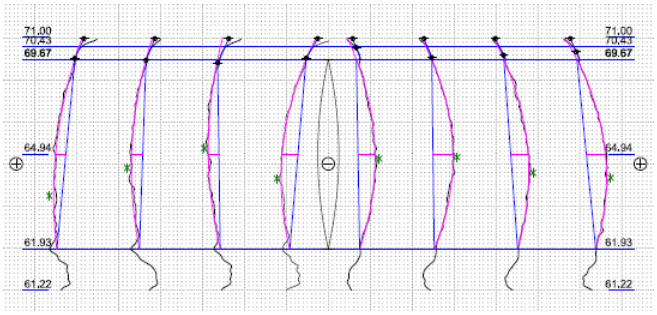



Fig.2. Left and right flank of 4 gear teeth on tested gear **before** testing

Figure 2 demonstrates that a high degree of accuracy is obtainable with the finish rolling process. There is good convex curvature on top of the involute with tip relief visible on the driven flank. Very little to no waviness. What can not be seen on these measurements is the mirror like surface finish, but that is depicted in figure 4.

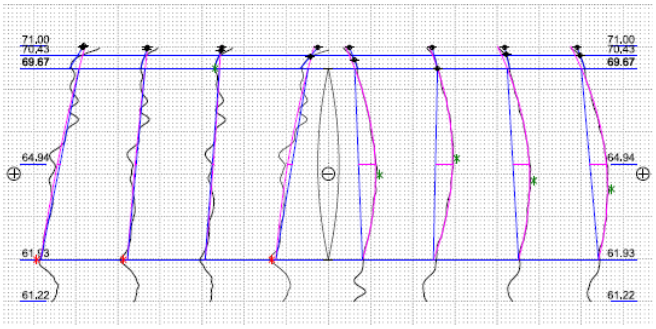
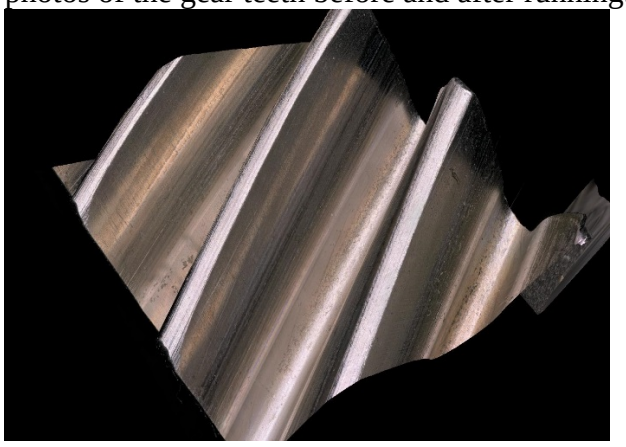



Fig.3. Gear flanks after testing, left flank is the driven flank and the right flank is the coast flank that have not seen any contact.

Figure 3 shows some wear off approximately 5-8 microns and the convex crowning of the involute is worn off, so now the tooth shape is closer to the perfect involute. Some waviness can be seen and around the pitch point there is a hump in the involute curve indicating the no sliding zone or rolling point. This is in line with what can be found in literature [3],[4],[5],[6]. Figure 4 are photos of the gear teeth before and after running.



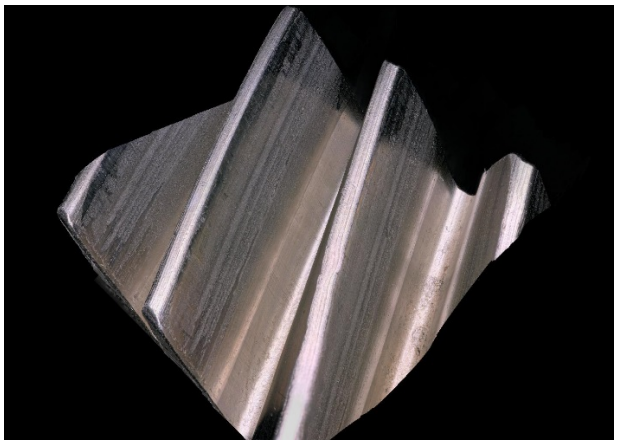


Fig4. Left column non worn gear, right column worn gear after completed durability cycle.

In figure 4 the left column photo reveals some wear marks with the pitch line and some gray areas that are micro pitted. Since this is end of life of this gear and equivalent to 300 000Km driving there seems to be more life left in the tooth, no macro pits and no noticeable NVH increase occurred during testing which is a very good result. Vibration was also tested for this gear and was found to be considerable lower than for the reference gear which was the OEM ground steel gears. See figure 5.

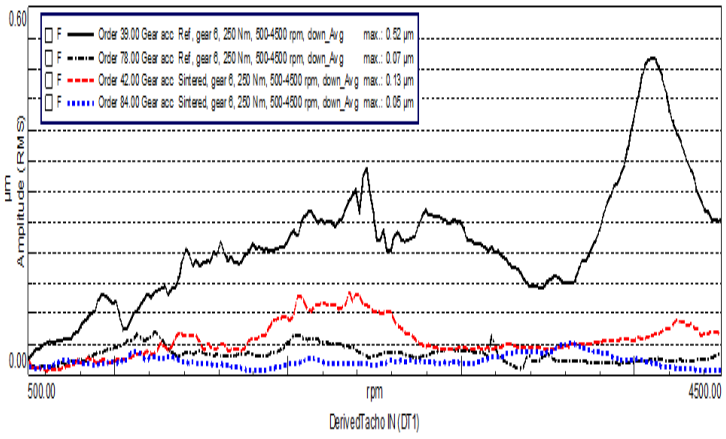



Fig.5. Acceleration amplitude from pick-up on gearbox housing. Black lines are reference steel, red and blue lines are PM gears.

Figure 5 shows a very significant difference between PM and the reference steel gears to the advantage of PM. The test was done at several different torques and speeds with the same advantage for PM in all the tests.

## IV. SUMMARY

The 6:th output gear has been finish rolled and hardened with no further machining on the teeth and bench tested in a 6 speed manual

transmission. The gear showed, after full durability cycle, some mild wear of around 5-8 microns but no significant failures such as pitting or tooth root breakage was observed. The gear mated with another hard finished gear pair in PM and displayed a significant reduction in vibration levels for all torques and speeds.

## V. CONCLUSION

In this paper a finish rolled gear in a commercial automotive 6 speed manual transmission has been tested in test rigs for durability, wear and vibrations. The results were very promising and shows that finish rolling to a high degree of accuracy is possible with results that meet and exceed OEM standards for durability, vibration and wear.

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