Grinding Alternatives

A series of Fine-ground and Polish-ground gears are currently being tested by various gear manufacturing companies and transmission developers around the world.

By Walter Graf
As the original inventor of continuous generating gear grinding technology, Reishauer has been a leader in hard finishing of gears for decades, with a particular focus in the automotive industry in the past few years.

Among the best-known company's developments, are: continuous-shift generating grinding, high-performance generating grinding, low-noise shifting and twist-control grinding. The newly developed Fine and Polish grinding technology extends the range of process options.

Reducing energy consumption and automotive CO2 emissions require further engine developments, but more importantly, today these reductions demand substantial increases in transmission power density. This requires greater gear tooth load-carrying capacity and reduced transmission power loss. Improvements to both material properties in the surface zone of gear teeth and complex modifications of the gear flank geometry help to optimize tooth meshing under load. In addition, numerous research projects have shown that reducing gear flank surface roughness increases the load-carrying capacity and reduces transmission power loss. The effects of improved surface roughness which result in the proof of strength required by DIN 3990 that act on the specific factors have been investigated in a series of FVA projects at the FZG Gear Research Centre at the Technical University of Munich. The experimental investigation verified that reducing the surface roughness of the gear flanks from a conventional $Ra \approx 0.4 \text{mm}$ to $Ra \leq 0.1 \text{mm}$ produced an increased load-carrying capacity of approximately 14%. This improvement was seen as the direct result of a substantially reduced amount of micro-pitting. As with the majority of previous scientific tests, the experiments were carried out with gears that had been machined using vibratory super finishing.

**Improved Surface Quality**

As a consequence of these promising results, automotive transmission manufacturers have begun looking for a more suitable method other than vibratory finishing to reduce surface roughness on ground gear flanks. Continuous generating gear grinding is widely seen as the most productive hard finishing machining method for the manufacture of automotive transmission gears. For this reason, automotive transmission manufacturers are now focused on a suitable extension to this process so that surface quality targets can be met based on this alternative machining technology. Reishauer's proven Low Noise shifting technology produces specifically modified ground surface structures which reduce overall noise emissions caused by gear meshing. Furthermore, now the company's Fine-grinding and Polish-grinding method results in considerable improvements to the load-carrying capacity and working efficiency of gear teeth. These improvements are due to the superior surface quality achieved with the modified continuous generating gear grinding process. Reishauer's Fine-grinding and Polish-grinding were specifically developed to create a surface finish level comparable to that of vibratory finishing to reduce the initial surface roughness of gear teeth machined using the continuous generating gear grinding process. Contrary to vibration finishing, the flank design and surface zone characteristics of the active tooth flanks are not adversely affected by this new method.

**The Process**

Without interrupting the overall machining process, Reishauer's Fine-grinding and or Polish-grinding are performed as a final machining pass immediately after conventional grinding. This final pass could consist of Fine-grinding with a vitrified bonded grinding wheel set or, alternatively, after conventional finishing, of a Polish-grinding pass with a vitrified or resin bonded grinding wheel set. During Fine-grinding and Polish-grinding, the roughness peaks are removed. This reduces the roughness profile height and, therefore, increases the contact area of the gear flanks. In comparison to the quality achieved with the previous finishing method, the geometric accuracy of the gear flanks in the active range is also improved. During the Polish-grinding machining step, an additional machining pass is usually sufficient to achieve the required surface finish. To apply this new process, the customer will require a special Reishauer grinding worm set which consists of a conventional ceramic grinding worm combined with a fine grit vitrified bonded grinding worm, or combined with resin bonded Polish-grinding worm. This innovative grinding worm set is manufactured in-house by Reishauer's tooling division. Depending on the chosen grinding wheel specifications and the corresponding machining technology, the process delivers surface qualities with mean roughness values of $Ra \approx 0.211 \mu\text{m}$ in the case of Fine-grinding, and $Ra < 0.1 \mu\text{m}$ in the case of polish-grinding. Regarding the grinding kinematics, Reishauer's Fine-grinding and Polish-grinding differs greatly from the various vibration finishing methods used in previous scientific studies and R&D projects. For this reason, Reishauer commissioned an independent assess-

(Left) Grinding wheel set developed for Reishauer Fine-grinding and Polish-grinding.
ment by the FZG institute at the Technical University of Munich to investigate the effects of various finishing options during continuous generating gear grinding on the efficacy of gear teeth in transmissions. The tests were carried out and evaluated based on the test method defined by the FZG in the FVA-Drive Technology Research Association research project FVA 345 Efficiency Test. This assessment confirmed an approximate 15% reduction in total power losses for the Polish-ground samples, and therefore, considerably reduced friction values for operation under load compared with a conventionally ground reference sample. This result was further confirmed on a test bench running at a lower lubricating oil steady state temperature.

CONVINCING RESULTS

A series of Fine-ground and Polish-ground gears are currently being tested by various gear manufacturing companies and transmission developers around the world. As well as testing load carrying capacity and effectiveness, these tests investigate the influence of fine-ground gears on changes to flank clearance in...

Figure 1: Gear ground by conventional gear grinding (left) compared with a Polish-ground gear (right).
precision transmissions on the overall service life of coated gear flanks, and on noise generation in transmissions. The initial test bench results also confirmed the positive results shown in the initial research project regarding increased load-carrying capacity. In addition to this, tests are planned to investigate potential additional power loss reduction by using lower viscosity grades of transmission lubricating oils. The direct integration of Fine-grinding and Polish-grinding as a subsequent step in the conventional continuous generating grinding process translates into comparatively low additional investment costs. For this reason, these methods are an interesting alternative to the vibratory process in the finishing of gears with improved surface quality.

Figure 2: After the conventional roughing and finishing pass of generating gear grinding, the Polishing pass reduces the peaks of the roughness profile without changing the flank design.

### ABOUT THE AUTHOR

Walter Graf completed his tool making apprenticeship in 1974. He worked for 10 years in tool and mold making workshops. Following this, he continued his studies in Australia and the UK and was awarded a Bachelor of Science Degree (Honors). Some 21 years ago, he began as a product manager for superabrasives at Winterthur Schleiftechnik AG, Switzerland. Three years later he became their sales manager and prior to the purchase of Winterthur by 3M in 2011, he held the position of chief marketing officer for the entire Winterthur Group.

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