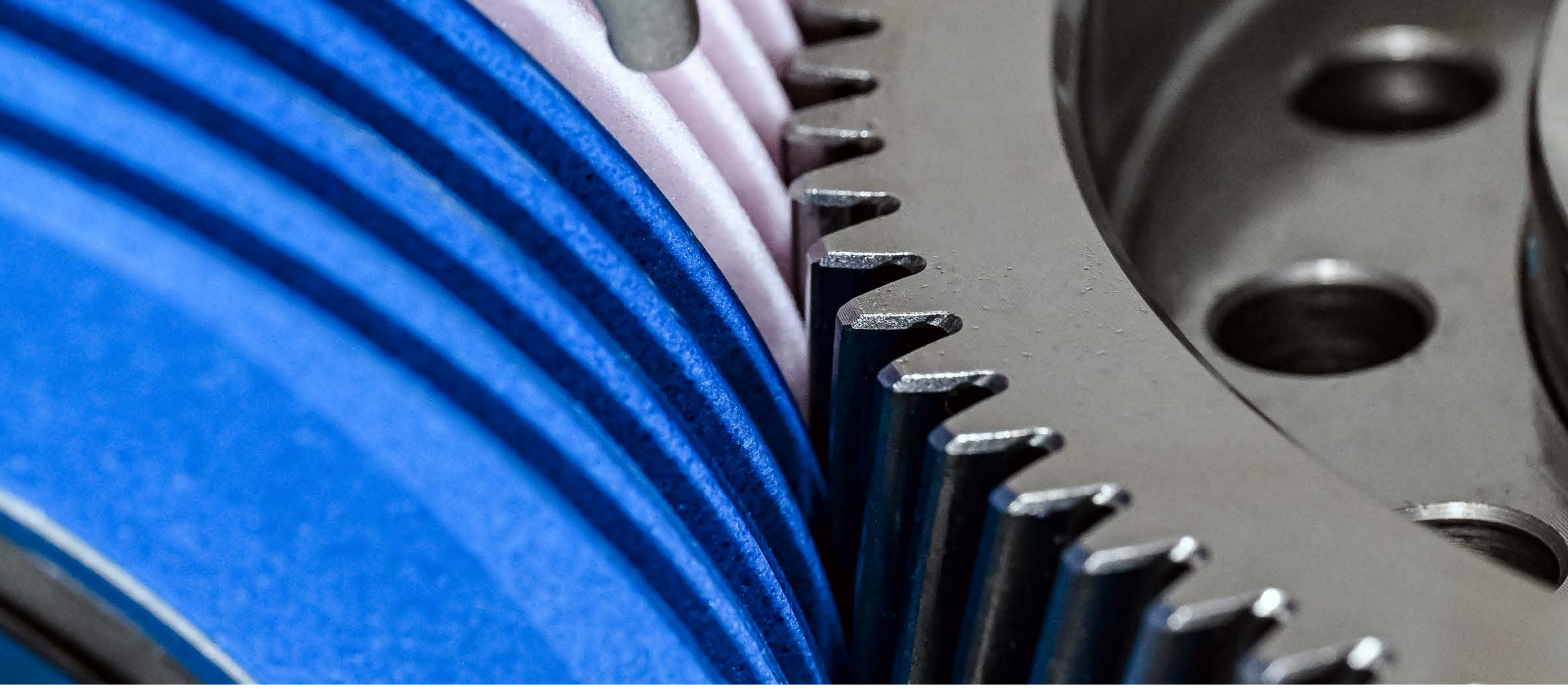

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Polish Grinding of Gears

Walter Graf, Reishauer AG

This article introduces the process of polish grinding of gears. Improved surface quality increases the overall efficiency of gearboxes, resulting in reduced torque loss, higher power density, and noise-optimized gears (lower NVH); all these factors are highly relevant, especially for electric drives.

The Process

The basic technology for polishing grinding is continuous generating grinding. Based on a dressable grinding worm, this method has proven itself in flexibility and high productivity. The kinematics of this process can be understood as a worm drive, see Figure 1, with additional abrasive machining movements consisting of an infeed X, vertical feed Z, and lateral shift movement Y. Polishing grinding is performed as a final machining sequence, with the workpiece remaining clamped on the same workpiece carrier during both grinding and polish grinding.

Polishing grinding is performed as a final machining sequence immediately after conventional generating grinding, which consists of a rough and finish grinding pass. For this purpose, the grinding worm is divided into two zones, the grinding and polishing zone, as shown in Figure 2.

This final sequence is a polish grinding pass using the elastic, resin-bonded section of the grinding worm. There are some fundamental differences between grinding and polishing grinding. Simply put, grinding uses larger grain sizes and more rigid bond structures. For grinding, grain size 80 is used, with an average grain diameter of 185 µm. For polish grinding, a grain size 800 is used, with an average grain diameter of 7 µm.

Grinding aims to achieve perfect geometry, a «good» surface quality, gear flanks free of waviness, and high material removal rates. As a subsequent step to grinding, polish grinding should not alter the geometry created by grinding. However, it increases the load-bearing capacity of the tooth flanks. Moreover, for technical purposes, polish grinding should only remove the peaks of surface roughness and leave the roughness of the surface valleys intact so that an oil film can adhere to the polished surface. The increase in the load-bearing portion of the gear tooth flanks allows gear designers to boost the power density of the gearboxes.

After both roughing and finishing grinding passes, the grinding worm shifts via a jump from the vitrified bonded zone to the polishing zone for the final machining pass, as shown in Figure 3.

Using a combined grinding and polishing wheel offers a significant advantage over alternative methods, such as vibratory finishing, which requires a prior grinding process and, thus, two different machine tools and more complex material handling. Continuous generating grinding requires only one machine tool. It grinds and polishes the component in one clamping, making it economically viable for mass production. In the combined process, polish grinding perfectly follows the gear profile and flank line›s precision-ground micro and macro geometries.

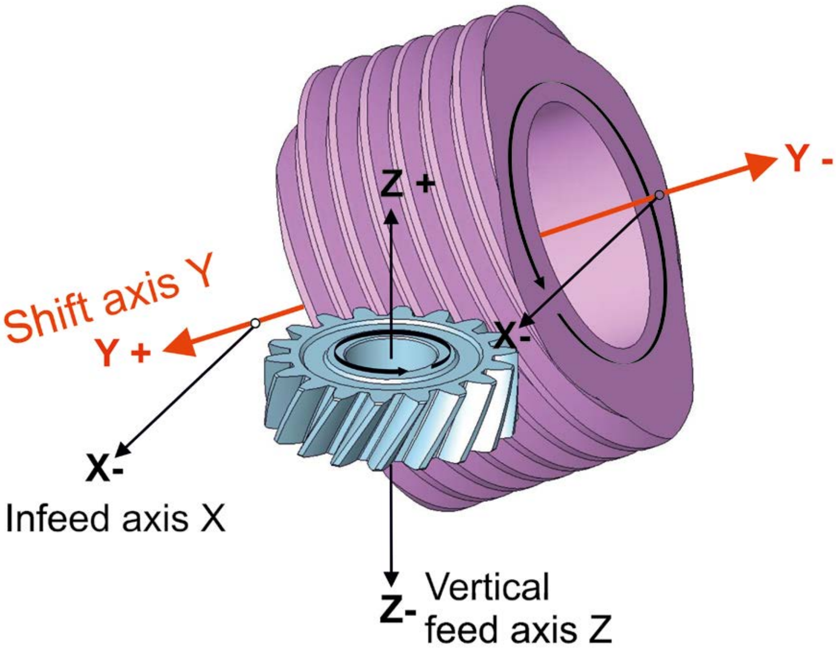

Figure 1 – Principle of continuous generating grinding

Scientific Basis

A research project by NASA's research center confirmed as early as 2002 that superfinish-ground (polished) gears have a fourfold lifespan compared to conventionally ground gears [1]. In this case, the polishing finish was achieved by immersing the gear parts in an abrasive medium and subjecting them to vibratory finishing.

Surface Characterization

The surface parameter Ra for characterizing surface quality is insufficient to describe surface quality in terms of load-bearing capacity and functionality. As M. Stewart writes in an SME paper from 1990:

«Tribology studies have shown that the ideal sliding surface is smooth with relatively deep valleys to hold and distribute the lubricant. However, quantifying and specifying these surfaces has always been a problem. Since its introduction, the bearing area curve – the Abbott curve – has been recognized as the only effective method for characterizing these surfaces but is rarely used in specifications.» [2].

Figure 2 – Two-zone grinding worm

The Abbott curve, Figure 4, is a much better indicator for predicting the load-bearing wear behavior of gear flanks than the roughness value R_a. The arithmetic mean deviation R_a does not differentiate between peaks and valleys and therefore has a relatively weak informational character [3]. Furthermore, it should be highlighted here that there are no common standards for polishing grinding, and users have different ideas concerning the polishing characteristics they aim for. Thus, an identical R_a value can describe a surface with high peaks and shallow valleys or a surface with low peaks and deep valleys. For this reason, users today prefer the R_{vk} value, which describes the reduced groove depth. This parameter is used to characterize valleys that retain lubricant. During the polishing process, the R_{pk} value (the peaks) is altered more than the R_{vk} value (the valleys). The goal of polish grinding should be to reduce the R_{pk} and leave the R_{vk} as much as possible intact, with the further goal that the R_{pk} value remains identical on both flanks.

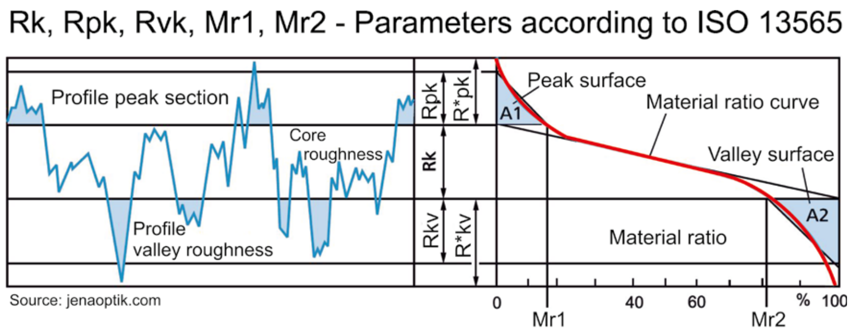

Figure 4 – Abbott material ratio curve (Source Jena Optik)

Economic Considerations and Conclusion

The direct integration of polishing grinding as a subsequent step in the conventional generating grinding process results in minimal investment costs if customers already have Reishauer generating grinding machines. Moreover, the diamond dressing tools remain the same as with conventional methods. Polishing grinding also requires only minimal additional operator training. Although the cycle time increases slightly due to the additional polishing stroke, this is offset by the gain in product quality.

Additional costs arise from purchasing special grinding wheels with two different areas for grinding and polishing. The higher process costs compared to conventional gear grinding are more than offset by the benefits of reduced torque loss, higher load-bearing capacity of polished ground gears, and higher power density in the gearboxes.

References

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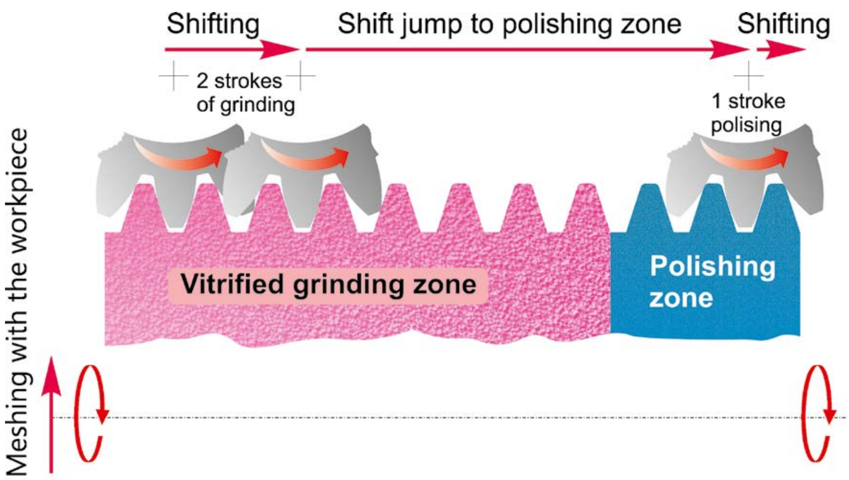

Figure 3 – Principle of continuous generating polishing grinding