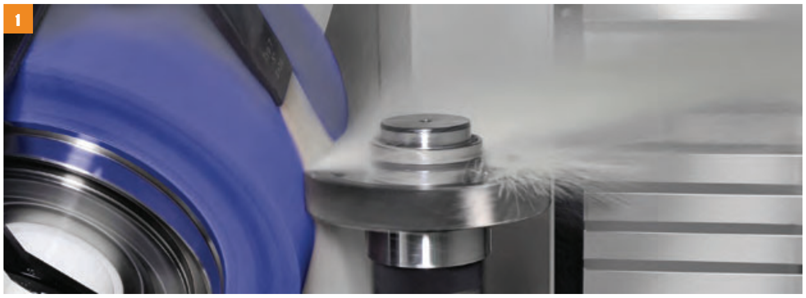
Gear grinding



Process monitoring systems can enable zero-defect gear production through intelligent real-time data processing and proven algorithms

The definition of grinding is 'a machining process with geometrically undefined cutting edges'. This description often leads to the misconception that the grinding process itself is only vaguely definable. However, even a process as complex as continuous generating gear grinding can be defined, made stable and have its limits established by Reishauer's new process monitoring system.

This system makes the gear grinding process transparent and analyzable, as well as making zero-defect production possible through the monitoring of dressing and grinding intensities via intelligent real-time data processing and proven algorithms. The dressing and grinding data of each ground gear is captured and stored in a database and remains 100% traceable, which offers comprehensive data analysis possibilities.

One of the essential characteristics of continuous generating grinding is the high output of parts in short cycle times. For automotive transmissions, grinding cycle times range from eight seconds for small pinions to one minute for ring gears. Hence, not all ground parts can be measured by coordinate measuring machines (CMMs) due to inherently longer measurement times. Consequently, the automotive gear industry relies on sample measurements of around 5% of gears ground.

1. Continuous generating gear grinding process

2. A Reishauer machine with process monitoring

A 100% check and constant monitoring of the grinding process is gaining in importance as sample testing processes carry the risks that faulty gears may end up inside transmissions. The real-time analysis of the grinding intensity signal identifies a faulty workpiece during the grinding process. Moreover, this method translates into a 100% check, meaning any faulty workpieces are automatically removed from the manufacturing process.

Grinding intensity, in the context of the monitoring system, is a force model used to calibrate and standardize the grinding forces. The force model takes into account the continually changing chip forming zone, including the local cutting kinematics, during changes to the grinding wheel diameter, the changing grinding condition due to variations in wheel RPM, and the prevalent lever ratios across the grinding wheel width. This calibration makes it possible to set very narrow limits that result in a high level of error evaluation.

GRINDING INTENSITY

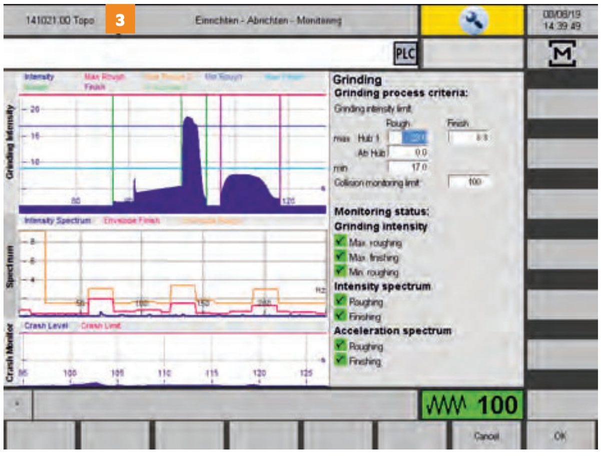
The typical progression of a two-step grinding intensity signal is illustrated in Figure 3, as it appears on the machine tool's CNC monitor. The higher dark blue peak on the left corresponds to the roughing pass, and the lower dark blue area on the right corresponds to the finishing pass. The orange/brown line represents the upper limit of the roughing grinding pass. The light blue line represents the upper limit of the finishing grinding pass. If the limits are exceeded, the workpiece is automatically removed from the production cycle.

The grinding intensity force model shows whether a grinding wheel maintains a consistent cutting performance across its full width and usable diameter. As a rule, grinding wheels are evaluated on a subjective level by the operators as empirical data is unavailable, and as the inhomogeneous hardness variation can only be indirectly assessed via deteriorating gear flank profiles. The Reishauer process monitoring system enables the hardness gradient across the grinding wheel width and the changing diameter to be made visible, measurable and classified.

Figure 4 shows the grinding intensities across the usable wheel width of some 5,300 workpieces, with the upper point cloud representing the roughing strokes, and the lower, denser point cloud representing the finishing strokes. From right to left, the roughing stroke illustrates a diminishing grinding intensity, whereas the finishing strokes show the reverse. The decrease in grinding intensities during the roughing indicates a process-induced wear of the threaded grinding wheel. The wear effect on the threaded wheel led to an unstable process and to rejected workpieces that had to be removed during the process. These workpieces are shown as dark red dots on the lower left side of the point cloud of the roughing stroke.

ROUNDNESS DEVIATIONS

The use of the grinding intensity model also allows an insight into the out-of-roundness levels of clamping fixtures or roundness deviations of pre-machined workpieces. Figure 5 illustrates the roundness indicator of the Reishauer process monitoring system, which, in this case, shows a situation where there is a marked roundness differential between the machine's two identical work spindles, C1 and C2. Both spindles alternately rotate by 180° into the grinding position. For a straightforward interpretation of the dynamic effects of the out-of-roundness of the workpieces on the grinding intensities, the monitoring system uses proven algorithms for the processing of time signals captured by the measuring sensors. The monitoring system's scalar format for the data parameters makes graphical representation easy, even with thousands of measured datapoints. Moreover, the system does not require specific evaluation software and hardware, and can be operated with a simple web application on standard web browsers.



3. Grinding intensity progression graph

4. Hardness variation across the threaded grinding wheel width

5. Out-of-roundness on one clamping fixture

The red dots in Figure 5, representing work spindle C1, show a consistently small out-of-roundness characteristic across 5,300 workpieces. The scattering within the bandwidth of the red dots is typical and acceptable due to variation in the pre-machining quality. However, the blue dots, within the first three-quarters of the bandwidth from left to right, show a much broader scattering. This higher spread is clearly due to a higher out-of-roundness level of the clamping fixture on the C2 axis. Once the clamping fixture was clocked into the correct position, the process became stable and identical for both work spindles as of workpiece 4,000. It is essential to point out that even the blue dots up to workpiece 4,000 were still within an acceptable pre-machining tolerance.

The application of the process monitoring system has significant economic benefits. As well as monitoring geometric inconsistencies, for example, detecting grinding burns is of paramount importance to ensure stable production conditions. Grinding burns must be avoided at all costs. Therefore, one of the most common strategies to avoid thermal damage is to reduce feed rates as the thresholds of thermal damage are not precisely known. However, if the grinding intensities are calibrated on components that have been ground and proved to be free of thermal damage, the process can be optimized with higher feed rates and lower shifting rates. This process optimization leads to shorter grinding cycle times and an increased tool life for both grinding wheels and diamond rolls, all of which translates into better process economics.

The Reishauer process monitoring system shows that even the most sophisticated grinding process can be made transparent and controllable. This level of transparency and control not only carries economic benefits but can also offer the zero-error production that is demanded by grinding process end users. ⦿