Improved Inspection Software Helps Provide Optimum Gear Cutting Results

KLINGELNBERG MEASURING CENTERS ELIMINATE TRIAL-AND-ERROR WITH MODERN ANALYSIS TOOLS

Figure 1—The P26 Gear Measuring Center from Klingelnberg now offers advanced analysis software.

Improved software for assessing gear deviations is creating a new generation of more efficient gear cutting systems. Gear metrology and subsequent evaluation of test data play a crucial role in the gear manufacturing process. This is especially true if gear quality specifications are not met, or if a component fails to achieve the desired running behavior despite being within tolerances. Whereas modern gear measuring centers (Fig. 1) now achieve very high performances and possess a wide range of measurement and evaluation functions, analysis of gear variations and definition of suitable countermeasures still rely mainly on empirical know-how.

Relying on Empirical Data

Although a broad spectrum of remedial aids is stored in the machine control, gear know-how and the experience of qualified operators are often essential. This is particularly the case if the selected quality criteria or parameters (e.g. according to DIN 3962) do not sufficiently reflect the required component design. This frequently leads to systematic trial-and-error procedures, which may involve a whole series of iteration steps that often fail to obtain an optimum solution (Fig. 2). Klingelnberg has developed an analytical tool that supports detailed analysis of the diagrams (e.g. profile line and tooth trace, pitch and radial runout) to assist even the experienced specialist.

The aim of the new software is to support systematic solution-finding and to identify and quantify non-apparent influences. It provides four basic functions, which are described in more detail below.

Improvement through Comparison

When a gear is tested, the shape of the teeth is identified by means of profile and tooth trace measurements, usually on four teeth, and the position of all teeth is determined by pitch and radial runout measurements. With the aid of machine support and in some cases empirical know-how, the numerical quality values calculated from the variations are then converted into remedial steps. This procedure is usually reliable and simple. If it fails to produce the desired result, consideration of the variation curves themselves will be required.

In particular, the new software optimally supports the comparison of different test results. Figure 3 shows an example of profile measurements on two workpieces that have been profile ground on different machines. The profiles exhibit similar curves, and the calculated parameters are also the same. Only when they are shown together does it become apparent that the upper machine generates a much greater scatter of the profile form. Such a scatter could be due to a worn grinding spindle, for example. By contrast, the reproducibility of the profile on the lower grinding machine is very high. Its remaining waviness could be improved by optimizing the dressing process.

The potential offered by comparative curve displays is clear from this example. There are other application potentials in many other areas, such as the investigation of hardening distortions, tool wear, noise problems and production fluctuations, including capability testing of processes, machines and measuring devices.

Focusing on Tooth Thickness

Functionally, the tooth thickness of a gear describes the clearance in the installed state or the allowance for post processing. Geometrically, it represents a measurement that varies over the diameter. It can be measured directly by a gear inspection system or coordinate measuring machine, or indirectly in shop operation on the basis of the base tangent length or the two-ball dimension.

On gear measuring machines, the profile and tooth trace variations for various teeth are measured and presented as form variations in relation to the desired form, without the curves being related to one another in terms of their position. The pitch variations are also unrelated to the tooth thickness of the individual tooth.

With the aid of Klingelnberg's new analysis software, it is now possible to display all variation curves in the correct positions in relation to one another. The profile and tooth trace curves (Fig. 4) are now displaced horizontally in line with the existing pitch variations and are offset to the desired line by the amount of the base tangent length variations.

The pitch variations are likewise shifted vertically from the desired line by the amount of the base tangent length variations. The relationship of the form variations to the nominal

continued

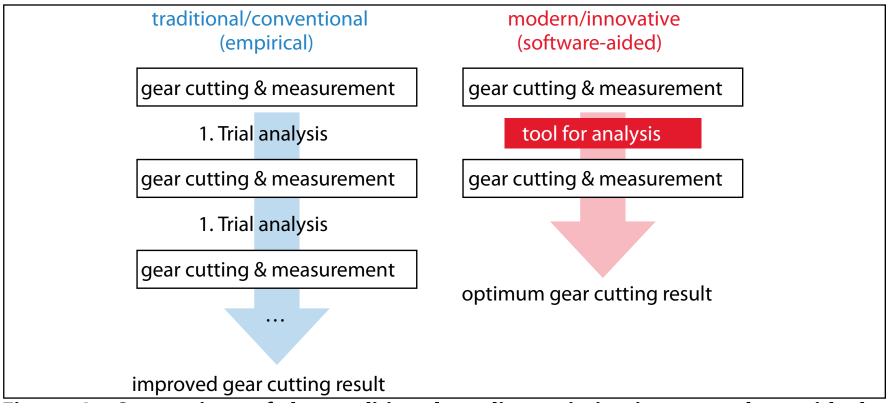

Figure 2—Comparison of the traditional quality optimization procedure with the procedure available using modern software.

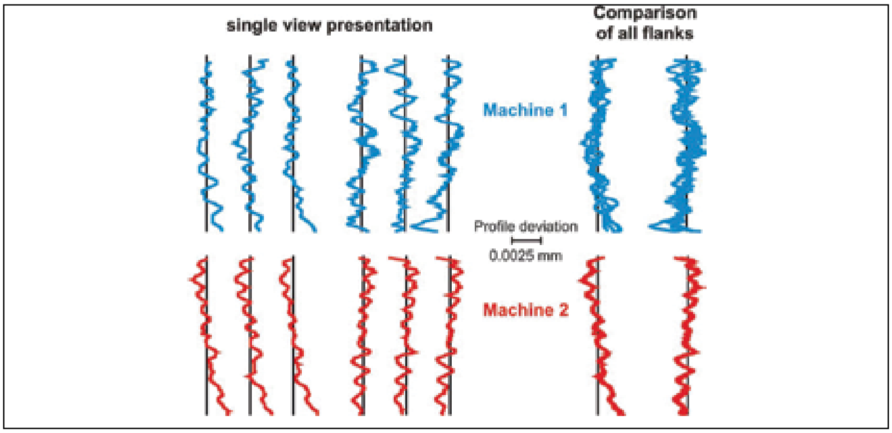

Figure 3—Klingelnberg analysis software allows side-by-side comparison of profile inspection traces.

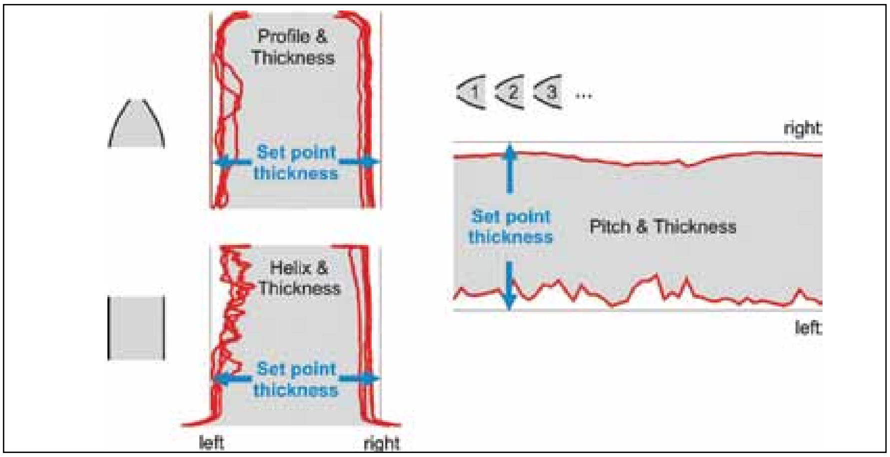

Figure 4—All variation curves are displayed in the correct positions relative to one another.

dimension can therefore be seen at a glance.

The material side is shown in grey for easier visualization. It is evident from the example that the gear is undersized in almost all areas.

Determining the Cause of Variations

Gears have a highly complex geometry, which must be manufactured with great accuracy. Disturbances that occur in the production process frequently affect several quality attributes at the same time, though in very different forms and sizes. Deducing the causes of a quality problem from the measured variations requires a great deal of experience, especially if the influences are superimposed. Here, the new analysis software acts in a supporting role, simulating the causes of variations very simply through their influence on the measured curves and qualitatively assigning existing variations in the measured results to their causes. The cause may usually be ascribed to clamping errors during the production process or during measurement.

Positional deviations occur when the center of the gear does not coincide with the desired axis of rotation in the installed state. Geometrically, variations in position are described as gear eccentricity or wobble, as shown in Figure 5. In the measured results, this leads to a variation in the profile and tooth trace direction and to sinusoidal variations in radial runout and pitch (Fig. 5, left).

On the one hand, the analysis software enables the user to visualize the effects of positional variations on gear quality. On the other hand, the clamping errors resulting from positional variations can be quantified and the measured values ironed out to rectify the respective defect rates (Fig. 5, right). In this optimum position, the remaining gear errors are clearly evident and can be analyzed and interpreted much more effectively.

Waviness Analysis for Low-Noise Gears

Another feature of the analysis software is waviness analysis. A frequency spectrum is calculated and displayed for each profile and tooth trace on the basis of measured variations (Fig. 6). The dominant frequency is plotted in the variation curve and expressed as a parameter in terms of amplitude and wave number. For purposes of further analysis, the variation curve is then rectified and the procedure repeated as necessary for further frequencies. The calculated frequencies can be plotted individually or as a mass curve, allowing comparison of compensating curves with real variation curves.

Figure 7 illustrates a first application of this new analysis option. Following installation of a new batch of ground gears, unacceptable noise behavior was noted in the gearbox. A comparison of measured values between the new batch and reference parts indicated the same frequencies in the profile, but higher amplitudes

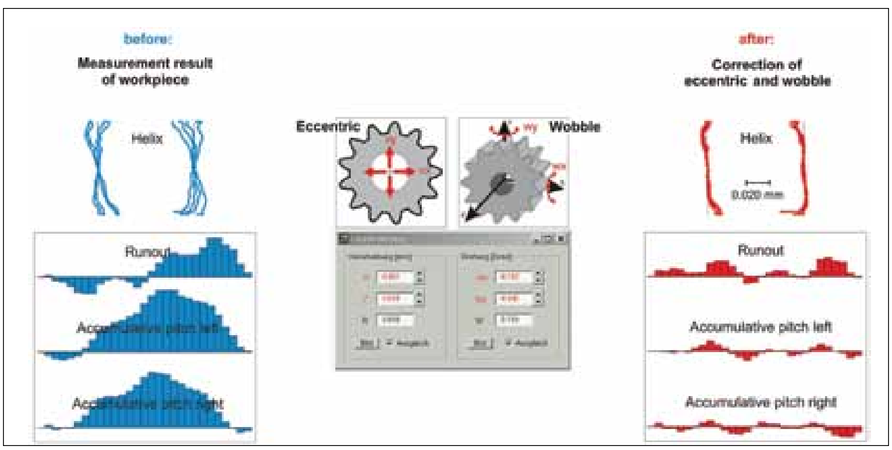

Figure 5—Software provides visualization of errors.

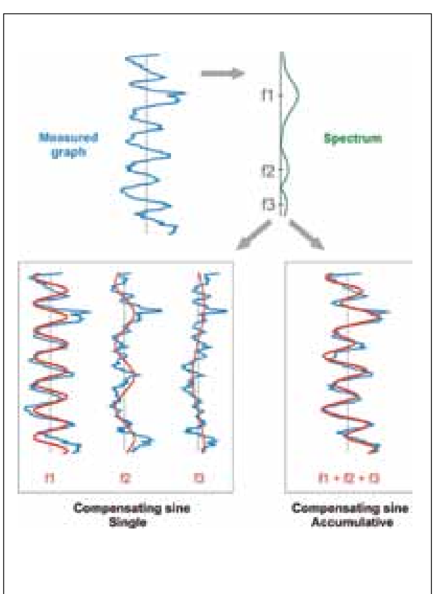

Figure 6—Waviness analysis allows a frequency spectrum to be calculated and displayed for each profile and tooth trace on the basis of measured variations.

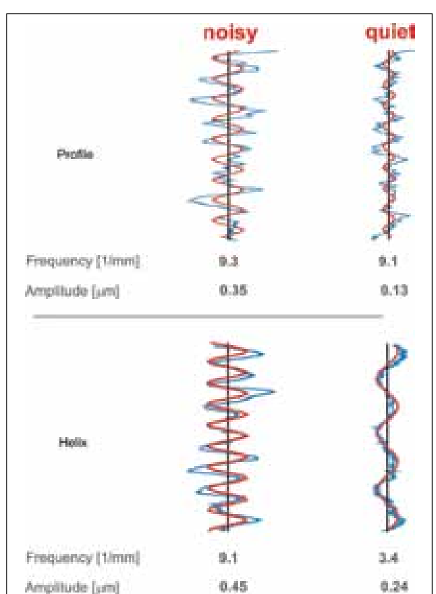

Figure 7—Example waviness analysis comparison between a noisy and quiet gear.

(approx. 0.2 μm), which could be attributed to altered dressing conditions for the grinding wheel. The tooth trace exhibits a change in frequency and amplitude caused by an increase in the feed rate during grinding.

Valuable Support

Modern gear metrology not only has to test gears as fast and reliably as possible, but must also support production in identifying the cause of errors. Klingelnberg's new variation analysis software is intended to bring users a step closer to this goal for a wide variety of problems and causes. Although the software cannot replace the necessary basic understanding of gear geometry and production experience, it can substantially support and simplify the process of troubleshooting.

For more information:

Liebherr Gear Technology, Inc.
1465 Woodland Drive
Saline, MI 48176-1259
Phone: (734) 429-7225
info.lgt@liebherr.com

Klingelnberg GmbH
Peterstrasse 45
D-42499 Hückeswagen
Germany
www.klingelnberg.com

Lube-Seal Solution

OPTIMIZES WIND APPLICATIONS

The Freudenberg Group embraces a natural synergy with the Lube&Seal package, jointly from Simrit and Klüber Lubrication, which combines the features of lubrication and sealing to benefit the greater system in wind turbine applications. The product integrates sealing lip systems and lubricants to create a more reliable tribological system.

"This is the first time we look at the lubrication and seals as an entire system instead of as individual components," says Tim Lomax, Simrit marketing communications director. "If, as in the past, each is regarded as completely independent of the other, one may be maximized at the expense of the other. For example, additives may be blended with a grease to give it certain lubrication properties with no regard as to how those additives affect the seal material. Certain additives

continued