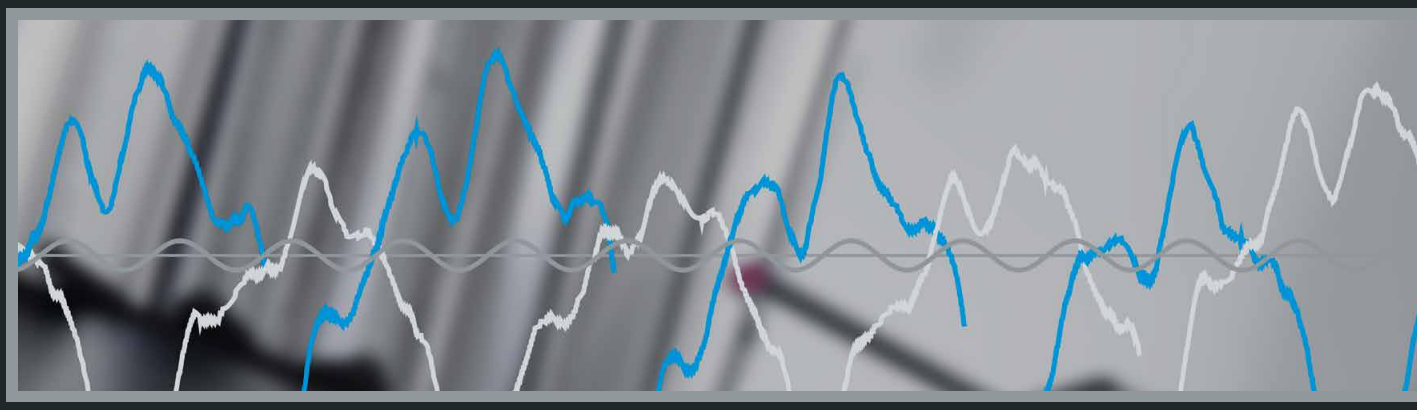


KLINGELNBERG DEVIATION ANALYSIS

PRECISION MEASURING CENTERS - SOFTWARE

KLINGELNBERG

Sustainable Quality Management of Drive Elements

Stringent precision requirements for gear measurements and the increasing complexity of drive components call for two things: the best measuring technology available and a machine and software concept optimized for these applications. That's why leading manufacturers put their trust in Klingelnberg precision measuring centers – not only the most widely used standard in the industry, but also the reference for metrology institutes.

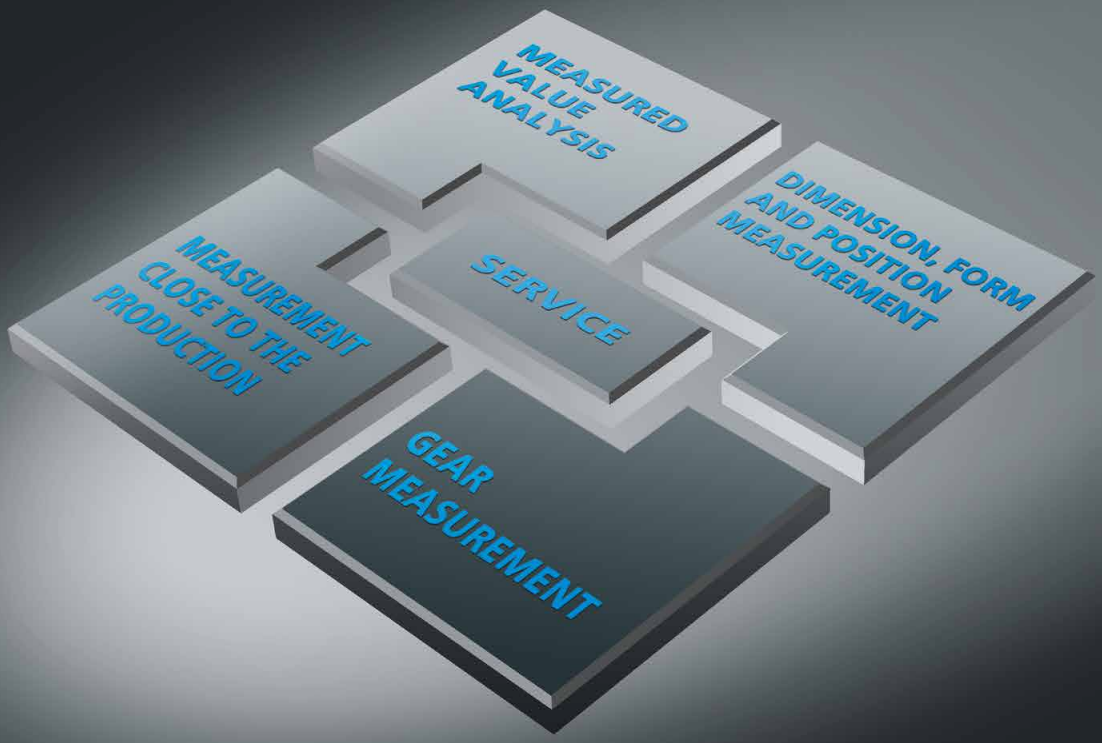
Klingelnberg (P-series) precision measuring centers today are capable of performing most of the measurement tasks that are relevant for a future-oriented, efficient production process in a wide range of industries. Users in the automotive and commercial-vehicle industries, the aerospace and aeronautical engineering industry, and the wind power industry rely on this technology, which replaces up to six different conventional measuring devices. This allows the following measurement tasks to be fully automated in a single setup:

- Gear measurement
- Optical measurement
- General coordinate measurement
- Form and position measurement
- Roughness measurement
- Contour measurement

The modular concept used in the P-series offers measuring devices in just the right size and a broad range of applications, providing the utmost accuracy:

- Measuring centers for workpieces up to 3,800 mm in diameter and up to 20,000 kg in weight
- Gear measurements starting from module 0.1 mm

P 26 – workpiece diameter range to 260 mm



Close to the Market and to User Requirements

- First-class machine quality guarantees reliable quality assurance over the long term
- Robust measuring machine technology with low maintenance and calibration requirements
- High measuring accuracy as a basis for testing drive components of the highest quality
- Machine design suitable for use on the production floor
- Simple, easy operation of the measuring centers for all applications
- Continuous development of evaluation standards according to the specifications of industry and standards associations
- Comprehensive service offering: fast, skilled, worldwide

Easy Identification of Complex Relationships

Due to stringent requirements for comfort, lightweight construction and cost-effective production, gears must meet increasingly precise accuracy specifications down to the microstructure. This is particularly true for drive systems in area of electromobility. To help its customers successfully master this challenging situation, Klingelnberg offers a software tool with the capability to analyze many different aspects of the measurement results performed on P-machines. This analysis tool offers a range of options for displaying and evaluating deviations in such a way that the causes of problems can easily be identified and corrections made.

Surface waves as small as 100 nanometers can be a source of noise in gears. Klingelnberg precision measuring centers are able to measure these microstructures, but they can only be made visible through wave analysis. This allows noise-producing effects to be detected and remedied in the gear production stages – not just during the final inspection of the finished gears. Klingelnberg gear analysis reliably indicates waviness, thereby enabling precise process monitoring and control.

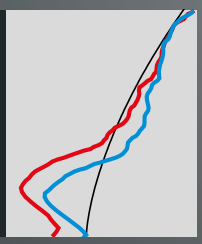
High-precision gear production is an extremely dynamic process in which multiple-thread grinding worms mesh with the workpiece. It is an extremely complex process, and the impact minimal deviations can have on the tool or in the setup is unclear. That is why Klingelnberg offers its customers evaluation software and simulations that make it possible to accurately simulate and predict influences emerging during the production process. Simulations and calculations performed in advance make the production process more precise and more robust.

- Comparison of workpieces and tools
- Optimization of noise behavior
- Simulation and prediction of influences during the production process
- Determination of the causes of deviation

Deviation Analysis
Software Module Overview

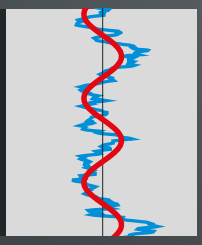
VIEW

Basic module for visual process monitoring by means of stored measurement diagrams



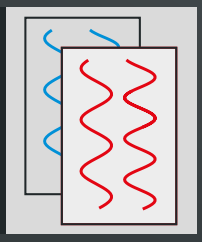
OPTIMIZE & WAVE

Software for fast, automatic waviness evaluation after the measurement



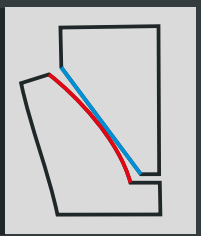
WAVE PRODUCTION

Software for automatic waviness evaluation during the measurement



PRODUCE

Add-on module for simulation of deviations during hobbing and generation grinding



VIEW

Basic Module for Easy Comparison of Measurement Curves

The View basic software module provides every basic function needed for the graphical display of deviations measured with the KLINGELNBERG precision measuring center. All additional add-on modules build on these functions.

A central element is the comparison of deviation curves. With a click of the mouse, the deviation curves in the profile and tooth trace are superimposed and displayed in a graph, making form variations easy to detect. Up to twelve different measurements can be compared in this way so that the influence of parameter and tool changes can be quickly assessed as can the stability of the production machines.

Since gears today are often crowned for correction purposes, a curve comparison is not always meaningful. By eliminating the actual crowning and the actual angular deviation, however, it is possible to identify the form variation hidden below. The display can be enlarged to such an extent that even small wave-like structures become visible. Deviations from topography measurements are color-coded, making it easy to identify and classify three-dimensional patterns on the tooth surface.

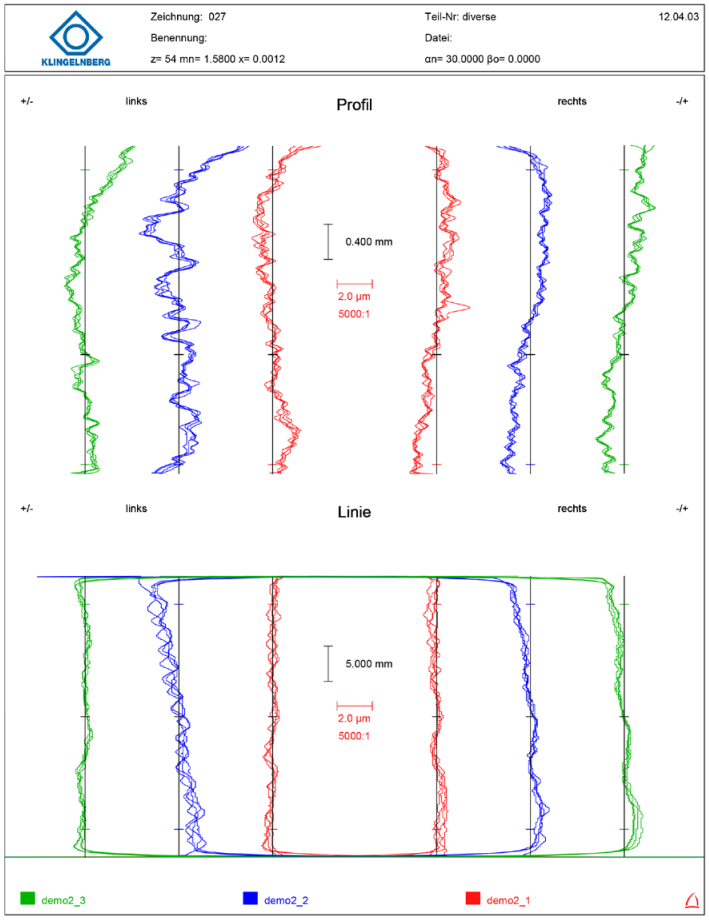
The form and tooth thickness display shows the deviation curves with reference to their nominal tooth thickness. Allowance and backlash can thus easily be assessed.
If the external and internal gear measurements are loaded for a spline, the resulting backlash can be evaluated as well as the fit.

View analysis at a glance:

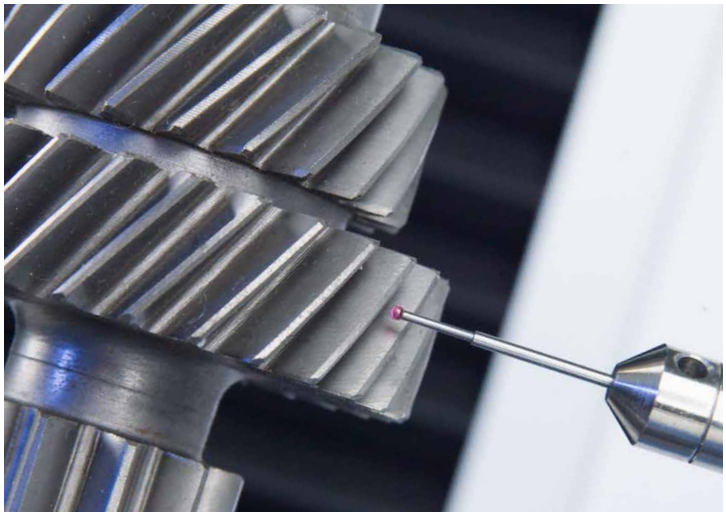
- Easy comparison of deviation curves
- Immediate detection of process changes
- Representation of form and tooth thickness
- Troubleshooting in the problem area: fit and backlash
- Display of deviation curves without crowning
- Pattern identification with color-coded topography

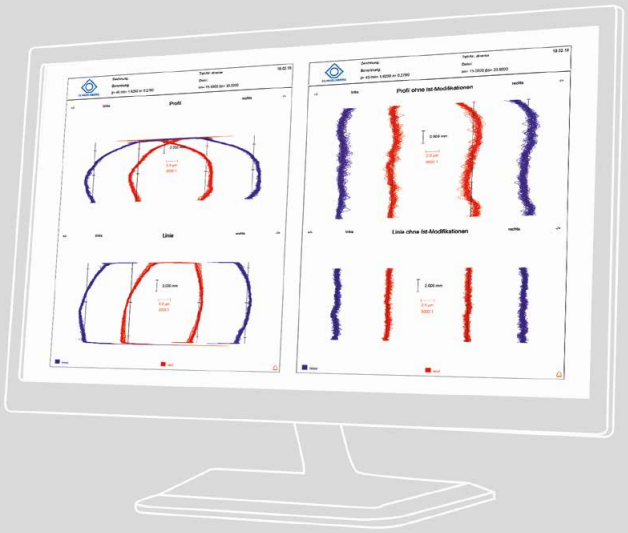
A direct comparison of the tool and workpiece is therefore possible for injection-molded gears.

The software is easy to use and intuitive. Free-positioning toolboxes contain frequently used features, and standard evaluations can be performed automatically.

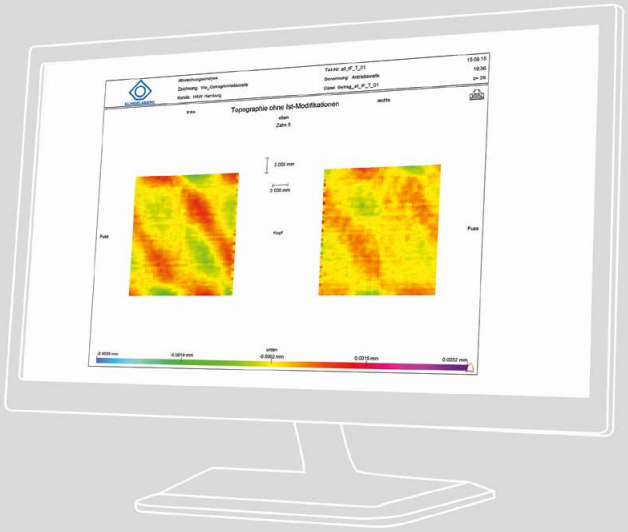


A comparison of deviation curves from three workpieces clearly shows the systematic changes in form due to process parameter variation.

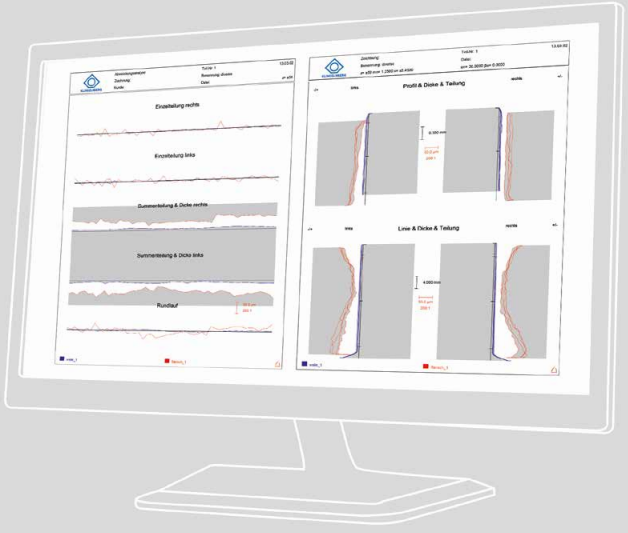




The wave-like form is only visible after the actual modifications (crowing and angle) have been eliminated.



The color-coded display of topography deviations makes it easy to evaluate complex deviation patterns.



Form representation including tooth thickness makes the fitting clearance between the external and internal gear visible.

OPTIMIZE & WAVE

Simulation and Reliable Correction of Gear Deviations

The add-on software module Optimize & Wave makes high-precision identification of gear surface waviness extremely easy. At the same time, typical errors on the gear teeth can be simulated and corrections calculated for improved production.

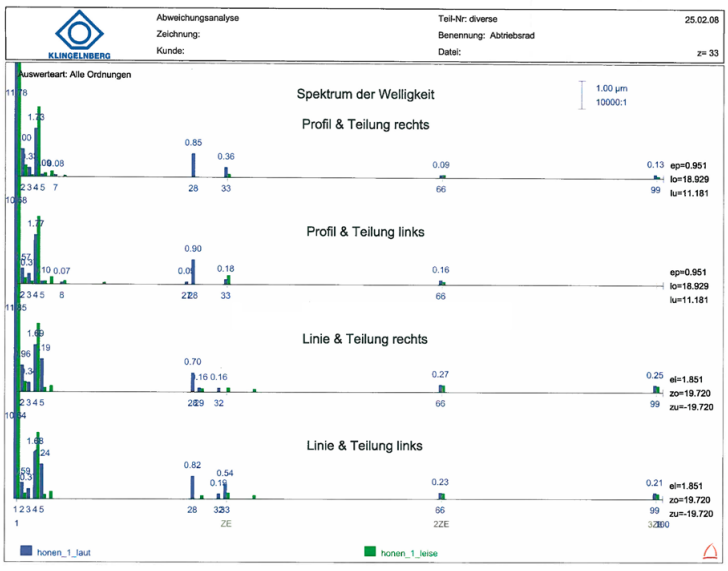
The Optimize & Wave module performs a wave analysis of all measured teeth. It does so by joining measuring points to form a closed curve based on their angle of rotation. This is then used to calculate an order spectrum by means of compensatory sine functions. The orders refer to a revolution of the gear and provide an extremely precise description of the periodic deviations of the surface. If multiple intersections are measured, the helix angle of the wave can be calculated for every order. This provides important information about the effect of the wave in the gear unit and the way in which waves develop during production. The topographical display makes it possible to evaluate complex patterns.

For a better understanding of wave structures and how various orders are superimposed, waves can be simulated with all of the parameters. An analysis of these ideal curves without interference from form deviations reveals interactions and influences on the analysis. If the structure of a gear surface is reliably recorded, the existing noise orders can be identified and simulated. When the noise problems are known, it is possible to define tolerance curves for the order spectrum. Orders that exceed the tolerance are highlighted. For a more extensive comparison of test series, the waviness indicators can be exported and processed in Microsoft Excel.

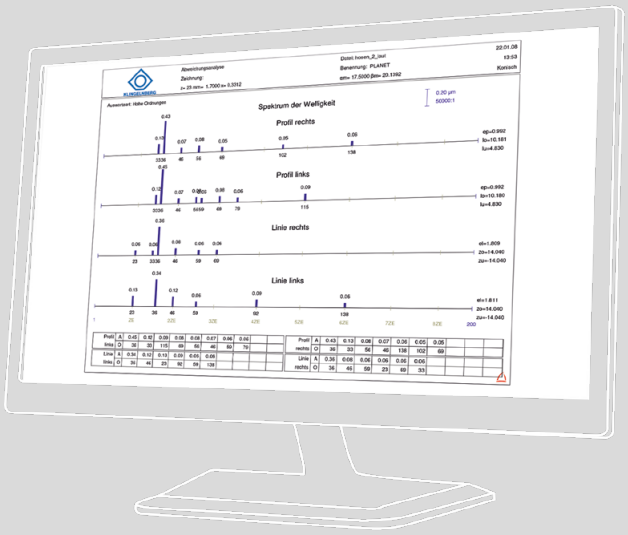
Optimize & Wave analysis at glance:

- Waviness calculation of all teeth over the rotation angle
- Display of waviness curves and order spectra
- Simulation of waviness
- Comparison against tolerance curves
- Export of indicators to Microsoft Excel
- Simulation and calculation of eccentric and wobble
- Optimization of pressure angle, helix angle, module and tooth thickness
- Influence of temperature changes

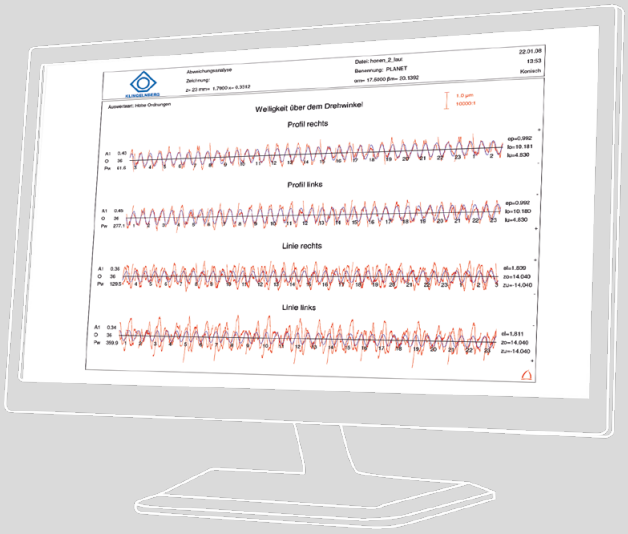
The functions in Optimize & Wave allow typical gear deviations to be simulated and corrected. Position errors, temperature effects and geometric parameters such as pressure angle and helix angle can be changed with a click of the mouse. These influences can thus be eliminated incrementally in the measurement curves, or correction values can be calculated automatically. A copy function makes it possible to clearly document individual corrective steps and their effect.



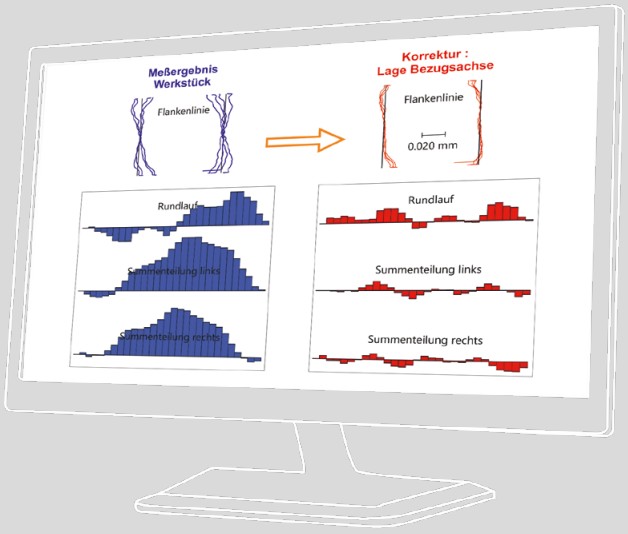
Comparing spectra of two gears.



The order spectrum of a loud gear teeth.



The combined display of deviation curves for a loud gear teeth.



Correction of eccentric and wobble.

Wave Production: The Revolution in Waviness Analysis

With the expanded, fully automatic waviness analysis of profile and tooth trace measurements and pitch measurement, waviness can now be detected reliably and precisely based on standard measurements.

The Wave Production software installed on the measuring instruments performs an automatic waviness analysis in conjunction with the measurement and evaluation software on the precision measuring centers and evaluates the results according to tolerances.

With the new version of Wave Production, it is now possible to perform an exact waviness calculation from a standard measurement expanded by just a few teeth. The high quality of the waviness analysis itself is based on enhanced measuring options within the Klingelnberg GINA evaluation software, and obtained by performing further measurements on adjacent teeth around the first tooth. This measurement series is game-changing in terms of the accuracy of the analysis, which could previously be achieved only by measuring all teeth.

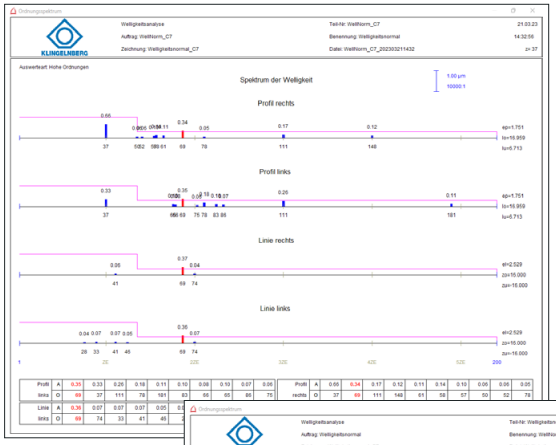
A salient feature of this new option is that despite the additionally measured teeth, only the standard measuring sheet with four measured teeth is output. Consequently, charts in the usual and recognized format are available for reporting. In-process measurement enables a timely response in cases such as noise-producing structures forming on the tooth surface due to tool wear. This saves a great deal of time and opens up a whole new range of possibilities for quality assurance of gears with extremely high surface and noise behavior requirements.

To detect further low-frequency orders, an order spectrum is also calculated for the pitch measurement. In addition, the 6s characteristic and the waviness indicator w derived from it make it possible to evaluate deviation curves for the presence of periodic components. The evaluation can be output in different formats and degrees of detail: as a PDF document or hard copy, or limited only to cases in which the results are out of tolerance.
Adjusted tolerance curves for critical orders describe the permissible amplitudes on the tooth flanks. If these are defined for a gear,

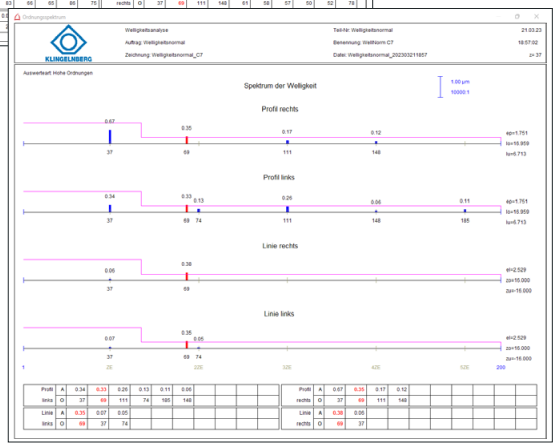
Expanded Waviness Analysis at a Glance:

- Automatic waviness calculation based on the profile and tooth trace of a standard measurement expanded by just a few teeth
- Waviness evaluation of the standard pitch measurement
- Definition of 6s characteristic value and waviness indicator w
- Easy setting of the output scope, and memory and output types
- Comparison with modifiable tolerance curves as well as OK / NOK - Evaluation
- Interface to Q-DAS qs-STAT statistics program

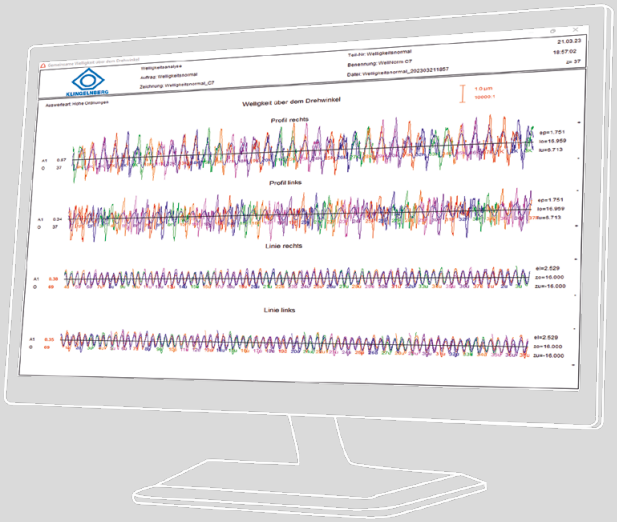
an automatic test and evaluation can be run during production. Numerical and optical control indicators allow early intervention in the production process.



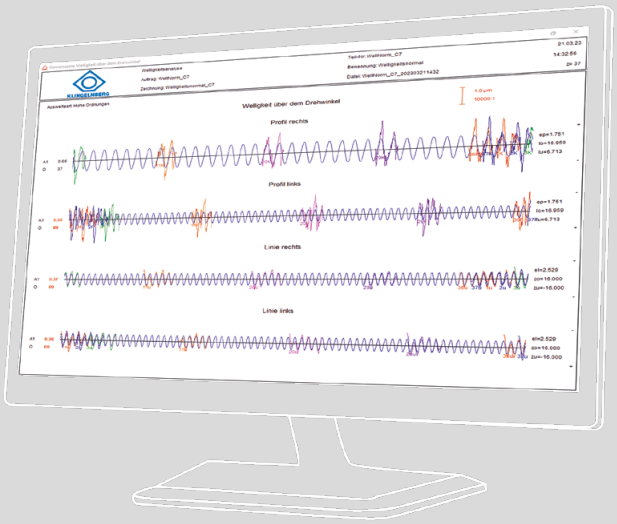
Analysis of the spectrum of waviness using the all-tooth measurement



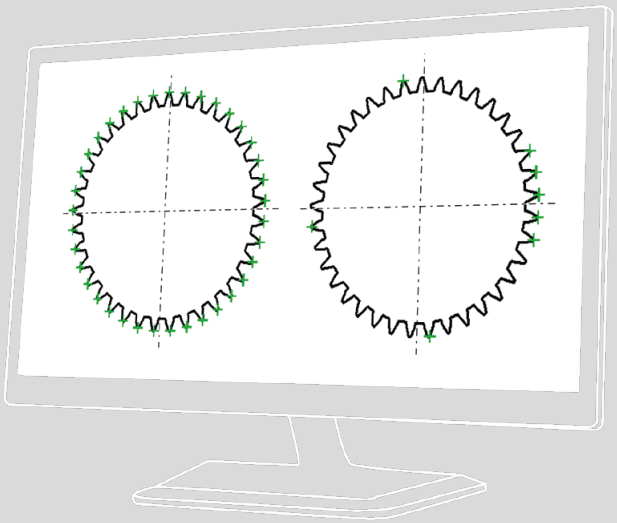
Analysis of the spectrum of waviness using the extended standard measurement (4+4)



Evaluation of profile, flank and pitch using all-tooth measurement



Evaluation of profile, flank and pitch using the extended standard measurement (4+4)



Schematic view of the all-tooth measurement (left) and the extended standard measurement 4+4 (right)

PRODUCE

Add-on Module for Simulation of Deviations During Hobbing and Generating Grinding

The software add-on module Produce is a powerful tool for troubleshooting, designing and optimizing generating production processes.

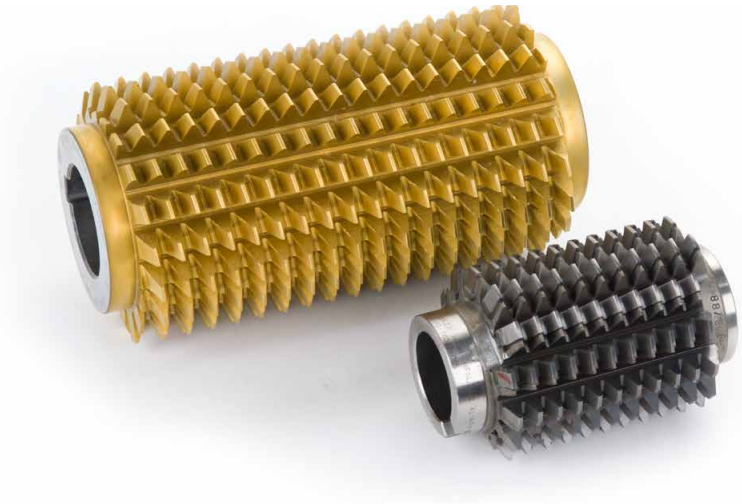
Produce enables an extremely precise simulation and easy-to-read display of workpiece deviations caused by hobbing and generation grinding. Tool edges, including protuberance and tooth tip chamfer, are modeled and moved based on the machine tool kinematics. Process parameters such as axial feed and tool parameters such as the number of starts can easily be changed. The calculation is quick and accurate, and the graphical comparison shows the changes. Since the results of this simulation are treated like the results of a measurement, all of the display and comparison functions in the basic module are available.

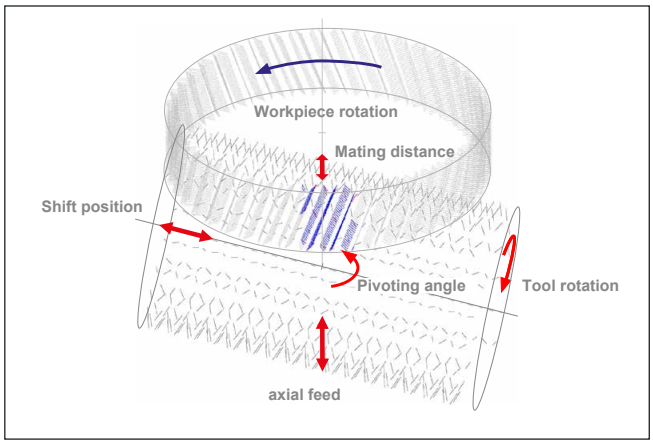
In addition to error-free machining with an accurate tool, typical tool and clamping errors can also be simulated: a tool can have lead deviations or axial displacement of the starts and can be set up with an eccentric or wobble.

A highlight is the processing of results of a hob measurement. Using the measured deviations, the user is able to predict the quality of the workpieces that the measured hob can produce. From a protuberance calculation in the profile cross section that takes

Produce analysis at a glance:

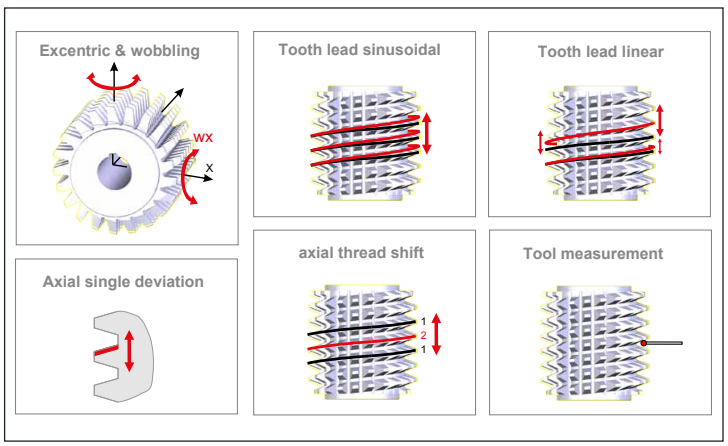
- Simulation of typical errors during hobbing and generating grinding
- Easy comparison of measurement against simulation
- Quick search for the cause of deviations
- Process modification with just one click
- Optimization of production processes



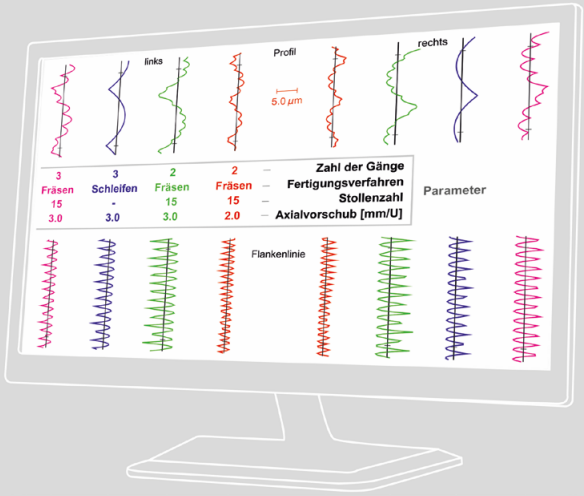


Movement capabilities between tool edges and the workpiece surface in the simulation.

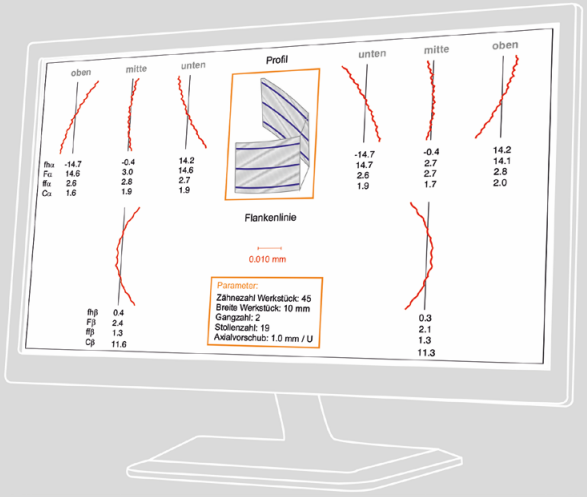
only seconds to compute, to a detailed look at the topography of a tooth, the influences of production are extremely easy to examine. By specifying the number of intersection curves and teeth to be calculated, the operator can control the scope of the calculation. In connection with the Wave add-on module, it is possible to perform a waviness calculation with the simulation results in order to obtain information about the cause of noise problems.



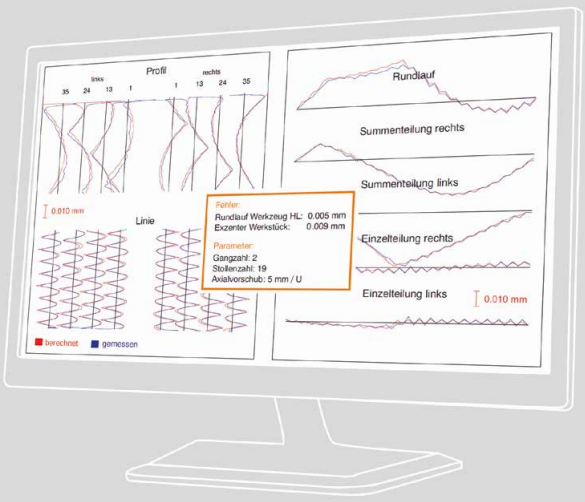
Tool and clamping error that can be processed in the simulation.



The influence of tool and process parameters is easily identifiable.



A twist can be calculated at individual intersections.



A comparison of the workpiece with the simulation of a wobbling hob shows a very good correspondence.

Drive Components with Guaranteed Quality Ensure Optimal Performance

For hundreds of years, gears have been a necessity around the world. In the past, function and service life were the only criteria that counted, but today, gears are expected to perform at the highest levels in every sector. Noise emissions are increasingly becoming the focus of attention, and a service life of several hundred thousand kilometers is standard today in passenger cars as well as commercial vehicles.

Comparing the output to be transmitted by passenger cars and commercial vehicles with that of earlier vehicles, the increase in performance and torque is striking. Yet gear dimensions have scarcely changed. The technological progress in this area is evident. Klingelnberg stands for this technological know-how and always has an expert solution to offer throughout the entire gear cutting chain. With manufacturing and process monitoring and optimization, the portfolio of products and services covers the full range: from the design stages to surface measurement.

Automotive

Cylindrical gears are used in manual and automatic transmissions in motor vehicles. Due to increasing requirements, these drives must be able to transmit outputs of more than 300 kW in some cases. The components must be efficient, smooth running and require low maintenance. Reproducible quality in series manufacturing with the shortest possible production times are the key requirements in this industry. Lower noise emissions are also increasingly expected. With the Wave Production software, Klingelnberg offers a solution for process control.

Electromobility

Due to the extremely high input speed of the electric motor, the transmission behind it is subjected to different stresses than transmissions in combustion engines. In addition, the lack of masking noise from the combustion engine and the exhaust gas system makes the acoustic design of the transmission more difficult. Accordingly, this shifts the focus to the surface structure. Klingelnberg is setting the standard in this area with fully automatic roughness measurement and process-independent waviness analysis for pinpointing interference frequencies and orders.

Gear Manufacturers/Suppliers

Contract gear manufacturers in particular have to be able to react flexibly to market conditions on a daily basis and produce a whole host of different gear components. From standard solutions to high-tech applications – Klingelnberg offers its customers tailor-made machine designs and comprehensive engineering solutions and services. Klingelnberg surface measurement and evaluation solutions enhance the reliability of the production process.

Aviation

Cylindrical gears used in airplanes must meet the highest quality standards in terms of pitch and concentricity (DIN 1-3). Just as important are other geometrical features such as surface finish, root geometry, rotational errors, high strength and low weight. Frequently used in this industry are specialty materials, which place extreme demands on tools and processes. Various additional evaluations in the analysis software ensure a reliable product.

Railroad Gears

In the area of railway transmissions, there are a number of different applications in which cylindrical gears are used. These include drive trains in rail vehicles, among others. These special gear units must meet specific requirements, such as noise minimization, maximum power transmission and durability. High speeds and large moving masses call for robust gears. The analysis software can also be used for large gears.

Industrial Gear Units

Industrial gear units place considerable demands on the reliability of the toothed gears. The gears for these sectors are often produced by companies specializing in small batch sizes and a variety of products. These individual small to large-scale production operations do not allow for time-consuming preliminary runs or test runs. Processes must be reliable and controllable. With this analysis software, Klingelnberg offers its customers an entire toolbox of support, starting with the tool and process design phases.

KLINGELNBERG Service

The KLINGELNBERG Group is a world leader in the development and manufacture of machines for bevel gear and cylindrical gear production, and precision measuring centers for gearing and axially symmetrical components, as well as the production of customized high-precision drive components. In addition to the headquarters in Zurich, Switzerland, further development and production facilities are located in Hückeswagen and Ettlingen, Germany.

The company also maintains a presence with Sales and Service offices and numerous marketing agents. On this basis, Klingelnberg offers users a comprehensive range of services for all aspects of toothed gear design, manufacturing, and quality inspection. The spectrum includes technical consulting, on-site machine acceptance, operator and software training as well as maintenance contracts.

KLINGELNBERG Solutions

Klingelnberg solutions are used in the automotive, commercial vehicle, and aviation industries, as well as in shipbuilding, the wind power industry, and the general transmission manufacturing industry. With numerous R&D engineers around the globe and over 200 registered patents, the company consistently demonstrates its capacity for innovation.

EN 05/2023 - Subject to technical modifications without notice.

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