NEW HYBRID TECHNOLOGY FOR TACTILE AND OPTICAL MEASURING TECHNOLOGY

The demands placed on gear measuring technology are extremely high: Accuracies in the nanometer range on the one hand, and on the other, short measuring times with a higher information density. In late 2018, Klingelnberg will launch a new hybrid technology that combines all the advantages of both tactile and optical measuring technology.

The desire for contact-free, fast and complete measurement of gear geometry is at least as old as CNC-controlled gear measuring technology itself, which Klingelnberg introduced in 1985. Inspired by the possibilities now suddenly offered by CNC technology, back then, Klingelnberg had a vision of not only revolutionizing the motion sequences of the measuring machine, but also of finding a way to do without contact sensing of components.

Intensive research as early as the 1990s

At the start of the 1990s, Klingelnberg therefore played a significant part in the first research project on optical gear measurement at the Fraunhofer Institute for Production Technology (IPT) in Aachen, Germany. A team of experts equipped a Klingelnberg PNC33 with a laser triangulation sensor for this project. As it was already known that shading of the laser beam in the direction of the detector posed a problem during gear measurement, the laser triangulation sensor was equipped with two offset detectors. This ensured that at least one of the two detectors received a signal at all times, regardless of the helix angle of the gear. The sensor had been developed by Gesellschaft für Messtechnik mbH (GFM in Aachen) with Fraunhofer IPT, in close cooperation with Klingelnberg.

Reflectivity stands in the way of a solution

Looking back, it is remarkable how far along the notions of optical gear measurement had already come. Despite this, however, measurements with usable results could still only be performed on an entirely free-cut tooth. Disappointingly, the challenging reflectivity of the gear surface, combined with the unfavorable contact conditions, did not produce a viable solution, despite two years of intensive research.

Since that first research project at the Fraunhofer Institute, optical metrology has evolved significantly. Many measurement methods have only now become practicable, thanks to technical improvements in detectors and the high performance of computer-assisted processing of measurement data. Other measurement methods have been added. And with new technologies, it has also been possible to develop new sensors. Klingelnberg has taken a keen interest and has actively supported these developments through ongoing work in testing. This involved various optical measurement methods and sensors, in research projects conducted either on its own premises or at development partners' sites.

High standards for measuring accuracy

Given that the standards for gear measurement are extraordinarily high, however, it will likely be quite some time before the problem is solved. In particular, the required measuring accuracy has been extremely challenging for Klingelnberg. To compare, some ten years ago, "µm" was still considered the measure of all things; yet today's standards for measuring accuracy are now given in nanometers. To perform a ripple analysis (Gravel), for example, minute geometric deviations of approximately 50–100 nanometers are recorded during sampling.

Light reflections and angle ratios – a challenge

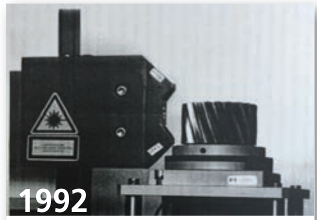
Likewise, optical measured value acquisition is also extremely challenging due to the surface quality of the gear teeth. It is now possible to reliably mass-pro-

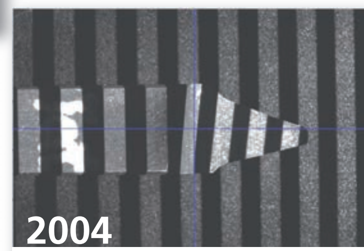
Compact

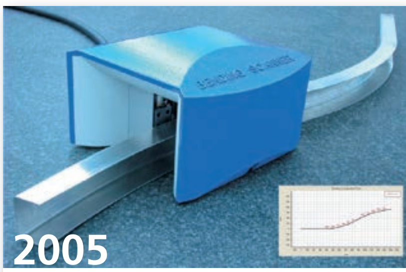
The vision: Optical measurement

At the start of the 1990s, Klingelnberg played a significant part in the first research project on optical gear measurement at the Fraunhofer Institute for Production Technology (IPT) in Aachen, Germany, and has since been actively involved in developing new technologies in this area. At EMO Hanover 2011, Klingelnberg presented its first optical measurement system, which underwent extensive further development in the following years to significantly improve data rates and signal quality.

Fig. 1: A timeline of developments in optical metrology


1992
Dual triangulation laser sensor, test setup


2004
Tool measurement with fringe pattern projection

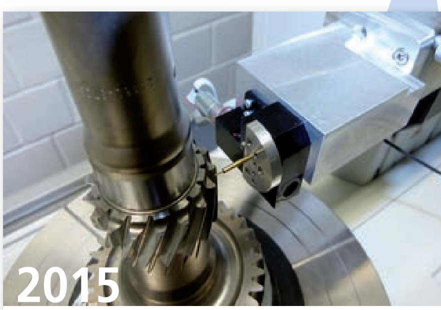

2005
Optical measurement of bent parts

1990

2000

2005


2011
Optical tooth-edge measurement with white light sensor


2015
Gear tooth measurement with interferometric fiber-optic sensor

2010


2017
Triangulation laser sensor

2015


2018
Fast optical scanning sensor

2018

duce surfaces with roughnesses of Rz < 1 µm. Since these flat, shiny surfaces have a mirror-like effect, the proportion of diffuse reflection is extremely small due to physical constraints. The greatest portion of the light reflects in one defined direction according to the law stating that the angle of incidence is equal to the angle of reflection. Independently of the optical measurement method, the detectors within the sensor only generate a signal when a portion of the light is reflected in the direction of the sensor. This requires a diffuse reflection, that is, a certain scattering of the reflected light. Combined with the unfavorable angle ratios of the tooth surface, relative to the sensor, the mirroring effect results not only in a further reduction of the detected light, but also in multiple reflections within the tooth space.

On the whole, it is clear that the gear geometry and surface pose a great challenge for optical measuring technology in conjunction with the required accuracies.

2015: Fiber-optic sensor improves accuracy

However, the situation can be improved, thanks to a sensor system that is inserted into the tooth spaces. This became evident in 2015 in the Opto-Gear research project by Forschungsvereinigung Antriebstechnik e.V. (FVA). An interferometric fiber-optic sensor was inserted into the tooth space and guided over the tooth surface at a short, even distance. The accuracies that can be attained in this way are comparable to those of tactile measurement. Yet because the motion sequences are executed in a manner similar to that of tactile measurement, no noteworthy advantage could be achieved. Truly rapid sampling with a large number of measuring points and, ideally, complete acquisition of the complete geometry was not possible with this approach.

> The required standard for optical measuring: Attaining a significant gain in speed over tactile measuring.

Cost advantage through reduced measurement time

Traditionally, however, Klingelnberg has always held itself to an extremely high standard of developing breakthrough innovations. It was therefore clear that optical measurement of gear teeth had to provide significant gains in speed in any case, since an economic advantage can only be achieved if, for example, the measurement time is reduced while the measuring point density stays the same. Alternatively, the measuring point density (and thus the informational content) could be significantly increased, provided that this did not entail disproportionately long measurement times.

Initial solution from Klingelnberg in 2011

The optical measurement system presented by Klingelnberg at EMO Hanover in 2011 was developed in line with this standard. Constrained by the measured data rates that were possible in 2011, however, the economic advantage was not entirely adequate to justify the additional cost for the optical sensor system. Since 2011, Klingelnberg has achieved significant improvements in data rates and signal quality through extensive efforts in ongoing development; the company has therefore decided to present a new optical measurement solution.

Combining optical and tactile measurement

Numerous studies and many years of experience with a range of optical measurement methods led to the realization at Klingelnberg that tactile measurement cannot be fully replaced by optical measurement methods. Essentially, it became clear that the two systems had to be combined – forming a hybrid solution. In order to combine the advantages of tactile and optical measurement in a hybrid system of this type in the best possible way, there is one basic prerequisite: The system must allow for an extremely rapid changeover from one measurement method to the other, since the total measurement time can only be reduced through this optimal combination of the two technologies.

The advantage of rapid sampling by the optical sensor is combined with the flexibility and extremely high accuracy of the 3D NANOSCAN tactile sensor system. This ensures that the new, highly appealing potential of optical measurement can be utilized without compromising the measuring accuracy.

APPLICATION EXAMPLES

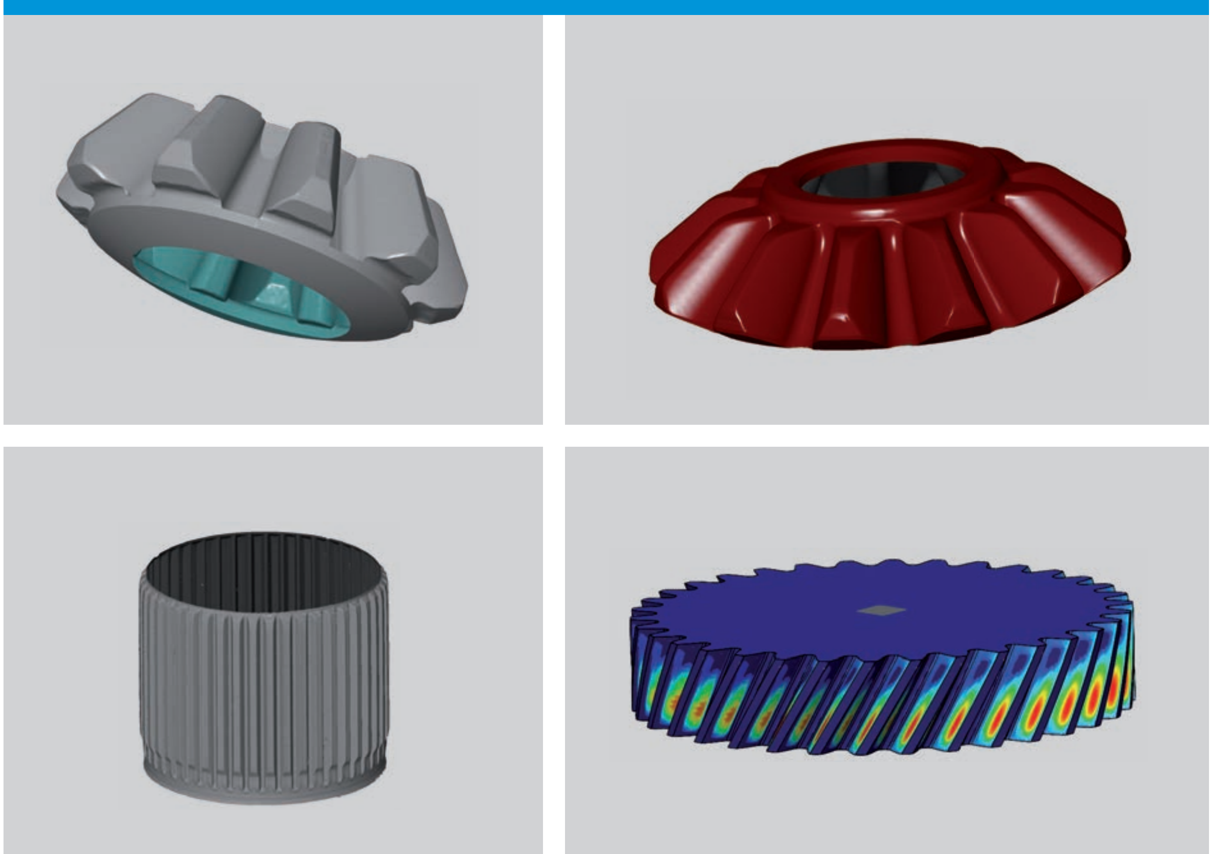


Fig. 2: Differential bevel gear (top left), flat side shaft bevel gear (top right), spline (bottom left), cylindrical gear (bottom right)

Rapid scanning with high point density

The hybrid system is designed so that the optical sensors can be adapted in a variety of ways. Klingelnberg avoided committing to one sensor principle only. The current stage of development uses a very fast scanning sensor. This allows for any number of axially symmetrical components to be digitized through rapid scanning with an extremely high point density, using a very simple measurement sequence. The optical sensor is guided along the outside contour of the component via the CNC axes. For a cylindrical gear, for example, this is a linear movement in the vertical direction. During this time, the component rotates at up to 1.5 revolutions per second. Through this combined motion, a point cloud with an extremely high point density of 0.5 million points per minute is recorded.

Multiple scans capture complex components

Multiple scans can be joined together to ensure optimal tracing conditions. For example, the left and right flanks of a gear tooth can be traced using two

BEST CASE: HYBRID TECHNOLOGY

Years of experience with various optical measurement methods has shown that tactile measurement cannot be fully replaced by an optical measurement method. That is why Klingelnberg has opted for a hybrid solution combining the best of both measurement types. The basic prerequisite for such a system is an extremely rapid changeover from one method to the other.

Fig. 3: Optical measuring

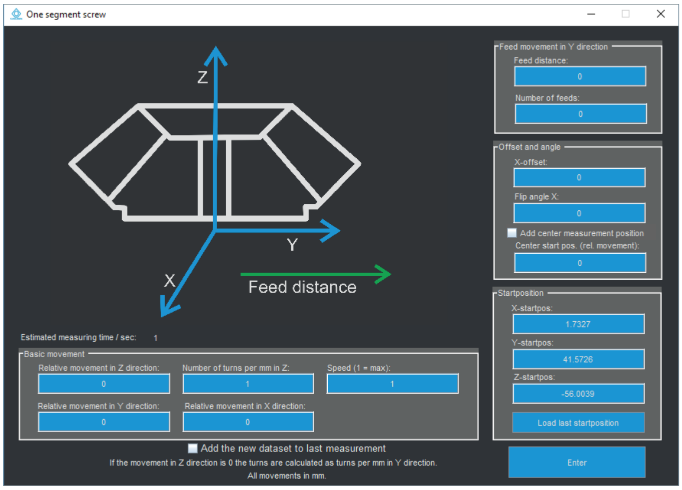


Fig. 4: Data entry for the measurement sequence

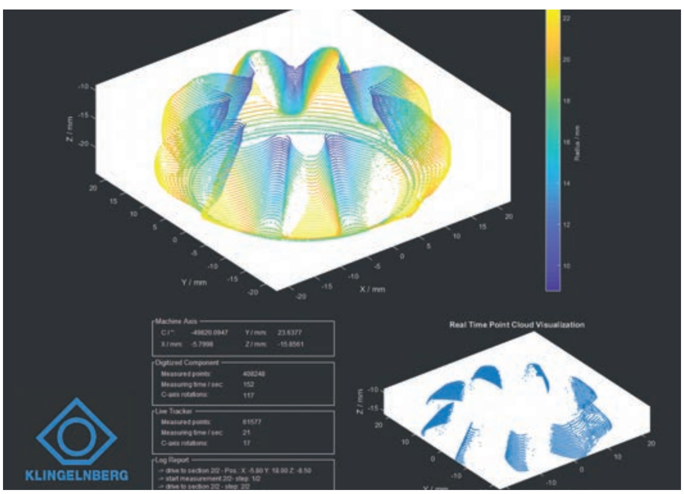


Fig. 5: Online display of sampling

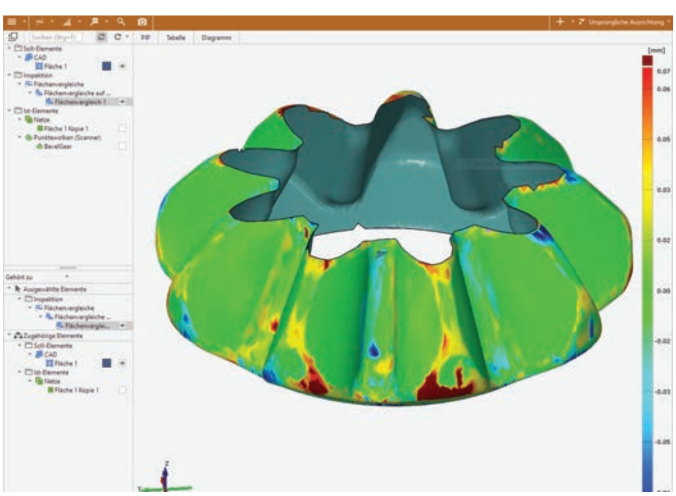


Fig. 6: Evaluation in the GOM software: Comparison of actual and target values using a false-color image

scans from different directions. This feature can also be used to expand the measuring range on the component, regardless of the actual measurement range of the sensor. Even complex component geometries can be seamlessly traced. This is done by performing multiple scans on different radii and joining these according to the onion skin principle.

Fast and flexible sampling

A further advantage is that a measurement sequence can be programmed without having to enter gear tooth data or other component parameters. The scanning motions are easily defined by interpolation points using the teaching function. As a result, it takes just minutes to prepare for sampling, and the recording can be used in a variety of ways.

During the scan itself, the point cloud is displayed on the screen as it emerges. For multiple scans, the existing point clouds are added to step-by-step. High accuracy of the machine axes is a basic prerequisite for using this measurement method. At such high scanning rates, this is the only way that sensor values can be combined with machine coordinates at the required level of accuracy.

Measured values incorporated into the CAD evaluation

Right after sampling is complete, the entire point cloud is available and is converted to an .stl file using a special compatible algorithm for this measurement method. This .stl file contains all of the information about the component geometry obtained during the sampling and can easily be further processed with CAD-based evaluation software.

Klingelnberg uses and recommends an evaluation software from GOM for this purpose. This is an extremely comprehensive, well-established software program designed specifically for the evaluation of measured data acquired through optical scanning.

Hybrid technology unlocks potential

Optical measurement is a new, extremely powerful option for the precision measuring centers P 26 through P 100L. Available beginning in late 2018, this option includes the HIGHSPEED OPTOSCAN optical sensor with a rapid change feed unit, the software for sampling and visualizing the measured point cloud, and the GOM-3D evaluation software. A retrofit solution for machines built in 2012 or later will also soon be available. ◆

AT A GLANCE

- Hybrid system with rapid changeover between tactile and optical measurement
- Extremely fast sampling with high point density
- Simple handling and operation
- Optical measurement of highly polished gearing
- Digitization of complex axially symmetrical components
- "Optical measurement" option also available as a retrofit kit

OPTICAL METROLOGY – THE VIDEO

This video provides essential information about optical measurement:

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