COMPLETE MEASUREMENT ON THE SHOP FLOOR

How are productivity increases achieved? By combining as many different process steps as possible on a single machine. And what's true for production facilities is also a key aspect of measuring technology. The P series precision measuring centers cover a broad range of measurement tasks – and can be used directly on the shop floor. These same properties were the main focus – and underwent further improvement – during the development of the two latest additions, the new P 65 and the P 16 G.

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The way to significantly increase productivity in production, particularly with respect to tooling and processing times, is to integrate different process steps on a single machine. The same can also be achieved in measuring technology: Consolidating different measurement tasks on a single machine increases the likelihood that the entire process can be realized in an automated sequence. This saves tooling and rechucking time on a measuring machine and reduces processing time. Klingelnberg Precision Measuring Centers systematically follow this approach: By combining various measurement tasks from the areas of coordinate and gear measurement in conjunction with form and roughness measurement, it is possible to execute all tasks in an automated sequence, even for end-of-line testing of shaft-type components.

The P machine: all-in-one solution

In addition to gear measurement, Klingelnberg Precision Measuring Centers feature a host of other measurement tasks. The special design with three high-precision linear axes and the precision rotary table provide ideal conditions for additional applications. The bearing arrangement of the precision rotary table has a radial spindle deviation of under 0.2 µm (optional) thus providing suitable accuracy for form testing. It also features a high-precision probing system that is optimally suited to the requirements of gear, form and coordinate measurement.

Thus the prerequisites are met for performing almost all measurement tasks on axially symmetrical components – at any point in the process chain (see Fig. 1). The blank can be fully measured with all relevant features, even before gear cutting takes place. Both dimensional and geometrical measurement tasks can be integrated here. Of course, the same also applies to machining form elements after heat treatment and before hard finishing of the gearing.

In addition to conventional gear measurement, the tools used in the process can

HIGHLIGHTS IN BRIEF

Special features of the P machines include:

- Three high-precision linear axes
- Precision rotary table
- Optional: 0.2 µm radial spindle deviation
- 3D nanoscan probing system capable of high-precision measurement
- Ambience Neutral Technology
- Optional adaptable, fully automatic roughness probing system
- Optional integrated vibration isolation

P machines cover the following measurement tasks:

- Gear measurement
- Form measurement
- Coordinate measurement
- Roughness measurement

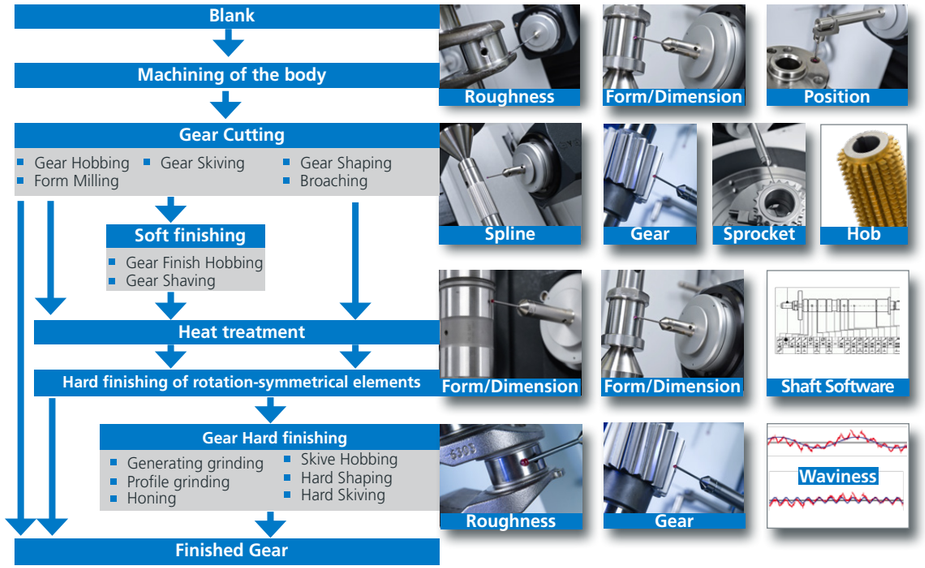

Fig. 1: Measurement examples along the process chain of gear manufacturing

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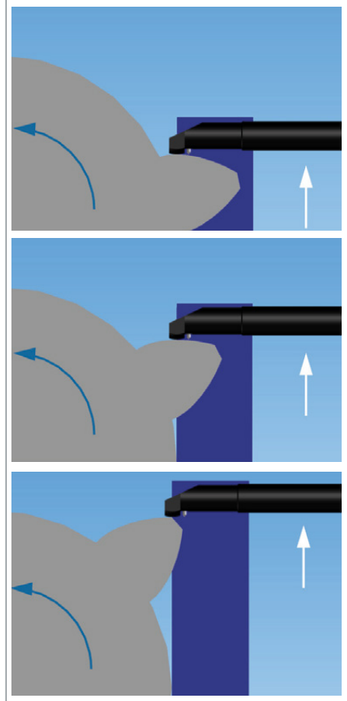
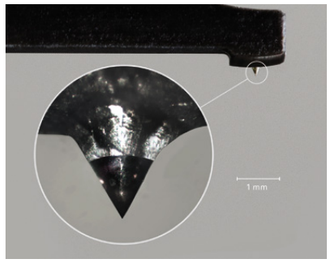
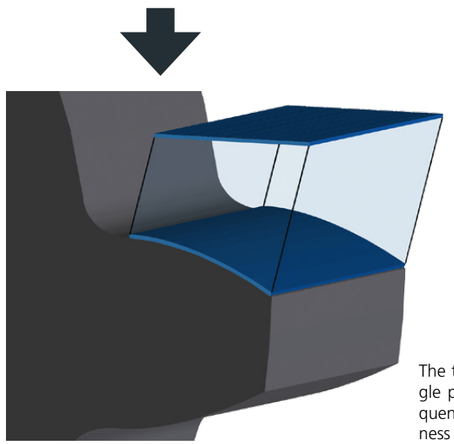
ROUGHNESS MEASUREMENT ON ONE TOOTH FLANK (GENERATING)



Automatic changing of the roughness probing system, including automated plug-in process.



The skid radius is 1,000 times larger than the tip radius of the diamond needle.



The tooth flank is projected in a single plane due to the generating sequence of movements during roughness measurement.

Fig. 2: Roughness measurement

also be measured. And hard finishing is followed by a waviness measurement on the tooth flanks. This highly precise measurement of waviness is possible because form measurement capability is an essential component of the P series. With the right "deviation analysis" evaluation software, noise phenomena such as so-called ghost frequencies can be analyzed, and important information for their prevention can be gleaned.

Unique feature: roughness measurement with skid scanning system

Roughness measurement on a Klingelnberg Precision Measuring Center offers several advantages. The measuring device's high-precision axes are available for positioning the roughness probe system. (See Fig. 2.) Thus measurement can always take place in exactly the same place. Moreover, roughness measurement can be integrated into the measuring run. When used with an automatic probe change rack, tooling and set-up times are completely eliminated.

Klingelnberg uses a skid scanning system for roughness measurement. Thus the reference plane for the measuring result is the component surface, not the machine feed axis. The skid itself has a large radius so that measuring results cannot be distorted by the reference plane. The skid and stylus are swivel-mounted. The unit is automatically swiveled into the measuring position and is controlled by the measurement software. In this way, both tooth flanks of a gearing can be measured with a probe, without manual retooling. What's more, geometrical elements such as the shaft on which the toothed gear sits can also be measured directly in the same clamping. This design allows different gearings and bearing seats on a component to be tested in a single clamping. The usual parameters for roughness measurement are output in this process.

On Klingelnberg Precision Measuring Centers, roughness measurement on involute tooth flanks is always performed in a generative process, where the C and X axis execute a coupled movement, the same as in gear measurement. Thus the curved tooth flank is transformed into a plane relative to the probing system, whereby the stylus is always perpendicular to the measured surface (see Fig. 2).

P 65: premiere for the new design

In the new P 65, the tried and tested technology of the P machines was further developed specifically to meet the strict requirements for measuring accuracy in complete measurement of axially symmetrical precision parts. Beyond the technical functions, ease of operation and ergonomics are gaining importance, not only in processing machines but also in measuring machines. For this reason, Klingelnberg has thoroughly overhauled and standardized the design and ergonomics of its product range. The P 65 is the first machine in which function, design and ergonomics have been brought in line with the new standards (see Fig. 3).

Klingelnberg 3D nanoscan probing system

In addition to gear measurement, increasing importance is also being given to coordinate and form measurement tasks in complete measurement processes on P series machines. The probing system plays a significant part here. Many measurement tasks require a 3D system that has the same properties in all coordinate directions with respect to accuracy, dynamics and scanning behavior – while also ensuring a broad linear measuring range for parallel deflection. For high-precision form measurement tasks, additional properties such as minimal contact force and maximum resolution are required. And with gear measurement, one thing is especially important: the ability to selectively influence the direction of deflection.

To fulfill these different, demanding tasks, Klingelnberg has developed special kinematics for use in the patented 3D probing system. A unique feature of this kinematics is the low moving mass, which is also identical in all three coordinate directions. This results in a loss-free, highly dynamic transfer of the probe sphere deflection to the integrated length measuring systems. With a resolution of less than 0.004 µm, these length measuring systems operate with the same optical inferential measurement method as the systems in the measuring axes. Thanks to the highly dynamic signal processing specifically suited to this method, all measurement systems, including the 3D probing system, are read and further processed synchronously.

Fig. 3: Ergonomics and ease of operation were further improved in the new P 65, in addition to the technical properties. The most salient feature is the new design.

Compact

First machine in new design

As with production machines, the ease of operation and ergonomics aspects play increasingly important roles in measuring machines as well.

The P 65 is the first precision measuring center in which the new design has been implemented.

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Compact

The new P 65

The new design of the P 65 offers much more than "just" eye appeal: improved thermal isolation, optional integrated vibration isolation and more efficient handling thanks to optimized ergonomics. Thus the new precision measuring center is even better suited for direct shop floor use.

The combination of this kinematic design, the high-precision measurement systems and the real-time signal processing ensures a linear, hysteresis-free transmission behavior, which is required in particular for dynamic, high-resolution 3D scanning. Thus even the finest deviations in form in the nanometer range can also be measured; these are relevant for gear noise analyses, for example, but also for a number of form measurement tasks.

Ambience Neutral Technology

For over ten years, Klingelnberg customers have successfully made use of the capability of performing measurements directly on the shop floor with the P series. Development of the new P 65 was systematically aimed at further improving the properties required for this. As such, the new machine paneling now fully covers the entire machine. This results in improved thermal isolation of the machine components relevant for the machine geometry from the ambient temperature.

To isolate the machine from ground vibrations, Klingelnberg has implemented in the P 65 the integrated vibration isolation system already in use for a number of years in the P 26 and P 40 machines. Extensive FE calculations made it possible to design the machine structure so that the installation on three air springs (three-point bearing system) that is optimal for column machines could now also be used for the P 65. Thanks to this type of vibration isolation, the new P 65 no longer requires a sophisticated vibration-isolated platform – and ergonomics have been significantly improved at the same time (see Fig. 5).

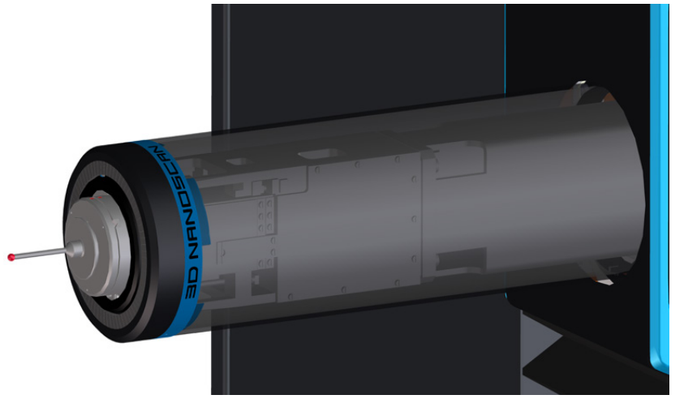

Fig. 4: With its unique properties, the Klingelnberg 3D nanoscan probing system provides the functionality of a multisensor system. In addition to gear and coordinate measurement, high-resolution form measurement tasks can be executed irrespective of the probe direction. The Klingelnberg roughness measurement system is also extremely easy to adapt.

Improved ergonomics

As part of the new design, the machine ergonomics were also optimized: The new placement of the counter support and the container provide better access to the workpiece axis (see Fig. 6). This improves handling during workpiece loading and unloading, as well as clamping and fixing. Thanks to an optimized axial positioning mechanism, precise alignment of the workpiece is no longer necessary. This eliminates the previously required pneumatic table lift.

Optimal complete measurement on the shop floor

In sum, the new P 65 is the optimal solution for measuring axially symmetrical components. In recent years, a multitude of different measurement tasks have been successfully integrated into one precision measuring center, thereby combining various measuring devices in a single machine. Shop floor measurements are a further key aspect for increasing economic efficiency.

P 16 G a replacement for gauges

Today gauges for quality inspection of individual process steps are used in many places in the production environment. These can be implemented directly in the production machine without restrictions. They are characterized by extreme robustness and "built-in temperature compensation". If the gauge is made of a material with the same thermal expansion coefficient as the workpiece and has the same temperature, any thermal influence on the test result is ruled out. In addition, testing is extremely easy and can be carried out directly by the machine tool operator.

Fig. 5: For over 10 years, Klingelnberg precision measuring centers have been successfully operated on the shop floor using the 3-point vibration isolation system developed by Klingelnberg. The integrated system familiar from the P 26 and P 40 has been implemented in the new P 65.

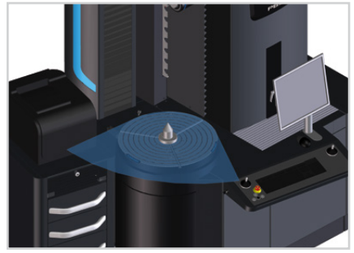

Fig. 6: C axis accessibility was significantly improved to achieve optimal workpiece loading. The loading angle was increased by over 50 % compared with the old P 65.

Fig. 7: On the shop floor, the machines are typically operated while standing. For optimal ergonomics, the motorized operator console height adjustment is now an available option for the P 65.

Major disadvantages of gauges are that they must be individually adapted to the component and test task, they are extremely expensive, and they require long delivery times. This poses a significant challenge for production managers, particularly when drawings are modified. In addition, documentation of the test result is merely qualitative in nature and cannot be used for process control purposes. It would thus be desirable to have a measuring device that has the benefits of a gauge – without the drawbacks.

In general, all measurement tasks on axially symmetrical components can be performed on a Klingelnberg Precision Measuring Center. In addition to precise linear axes, this requires a high-precision rotary table with an extremely small radial spindle deviation. In conjunction with the 3D nanoscan probing system, dimensions can be measured and form testing tasks can also be performed.

Precision measuring centers from Klingelnberg are used as a reference around the world, not just by countless customers, but also by renowned metrology institutes.

And the measuring device can be used in the immediate production environment. This is made possible by the necessary robustness combined with temperature compensation and vibration isolation. Like all measuring devices from Klingelnberg, the P 16 G also comes equipped with Ambience Neutral Technology, the high-precision rotary table and the 3D nanoscan probing system.

Much more flexible than gauges

"Typical" measurement tasks on a P 16 G include, for example, testing of diameters, clearances and lengths, positions with respect to a reference, and many other positions (see also Fig. 8). These can be realized as measurement tasks on a coordinate

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The new P 16 G

The P 16 G measuring machine is designed for disk-shaped components and short shafts and can be used directly on the shop floor, just like gauges. The entire range of typical measurement tasks for gauges can be realized on this machine – with the advantage of far greater flexibility. Thus any number of different components can be tested, and slight changes to the measuring run are all that's required to adapt to geometry modifications.

measuring machine. The flexibility of this measuring device cannot be compared with that of a gauge, as it allows any number of different components to be tested – all that's required is to create an appropriate measurement program. Adaptations to geometrical modifications of existing components frequently call for just slight changes to the measuring run.

Improved process control

The P 16 G (see Fig. 9) is a measuring machine designed for disk-shaped components and short shafts of the type frequently found in the automotive industry, for example. Shop floor measurements significantly improve process control. Statistical evaluation of measured values can pinpoint trends in the early stages – making it possible to intervene before the first component is found to be out-of-tolerance and subsequently rejected.

An additional essential factor in the production environment, which naturally lacks trained measurement technicians: The measuring machine is operated by the operator. With this factor in mind, Klingelnberg developed its "EasyStart" software. This system effectively separates the creation of the measurement program from the measurement itself. The operator locates the measurement program on the start screen and launches it directly, with a click of the mouse. The process can be simplified even further by using a barcode scanner in conjunction with a barcode on the component.

Potential savings in quality assurance

The precision and robustness of the measuring devices in Klingelnberg's P series opens up a notable potential for savings in quality assurance. By using a P 16 G to replace gauges on the shop floor, the high cost of gauges can be eliminated and lengthy replacement times – which can occur when drawings are modified, for example – can be avoided. In addition, the P 16 G makes it possible to use statistical process control directly on the production machine, while also ensuring the traceability of components from the shop floor.

"Fit" for Industry 4.0 with the P series

The ability to execute a broad range of measurement tasks directly on the shop floor, complete with easy handling and virtually seamless digital documentation – in developing its precision measuring centers, Klingelnberg is systematically pursuing the goal of opening savings potential in quality assurance. The new P 65 and the P 16 G are two examples from Klingelnberg of innovative solutions for Industry 4.0. ◆

Fig. 9: A P 16 G can operate multiple production machines, replacing gauges

SAMPLE MEASUREMENT ON A P 16 G

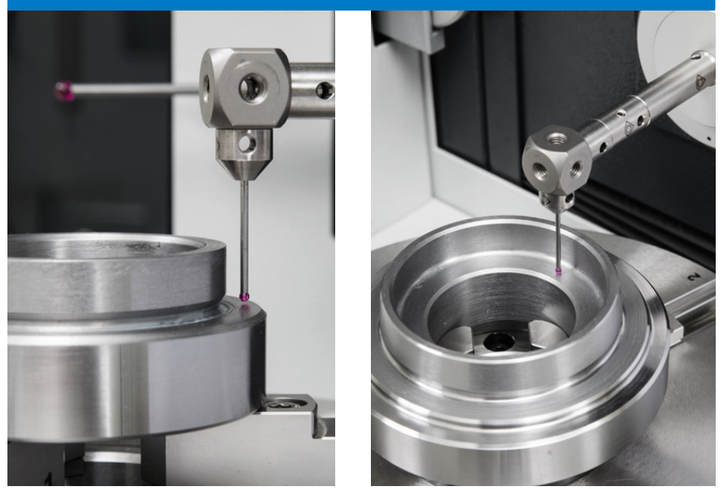

Fig. 8: As an alternative to the gauge, a precision measuring machine can be used directly on the shop floor.

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