# COMPLETE INSPECTION OF ROTATION SYMMETRICAL COMPONENTS ON ONE MACHINE

Gearing technology has extremely high requirements for a measuring machine: The machine must provide a high degree of measuring accuracy for continuous measured value recording (scanning) during profile and helix measurement on tooth flanks, and detect even the smallest deviations with a high point density. These tasks require a sophisticated combination of high-precision form and coordinate inspection. Klingelnberg Precision Measuring Centers have these characteristics, which enable our machines to perform a combination of various measurement tasks on rotation symmetrical components, typically done on several machines.

The main challenge in gear measurement is to combine high-precision path measurement, general form measurement and absolute 3D measurement on one machine, without making compromises in terms of accuracy. Absolute dimensions such as the tooth thickness and the tip circle diameter are required during gear teeth quality inspections, both of which are examples of coordinate measurement. However, at the same time it must also be ensured that form deviations such as profile and tooth trace deviations are kept within extremely tight limits. Furthermore, if noise behavior evaluations of the gear teeth are to be carried out based on the waviness in the profile, the demand for form measurement accuracy is even higher.

However, these measuring machine characteristics can be put to profitable use in more than just gear measurement. Klingelnberg Precision Measuring Centers are also capable of carrying out the majority of measurement tasks on shafts. This is true for both coordinate measurement and form measurement.

## Form measurement with self-developed technology

A key component of Klingelnberg machines is the continuously measuring 3D tracer head. For form measurement, the probe system must have ideal scanning properties. This requires extremely low measuring and deflection forces and low inertia in the probe system kinematics. A high sampling frequency and an optimum ratio between the deflection and measurement signal are also required. At the same time, however, the system must provide a robust, trouble-free measurement signal in all probing directions and be protected from damage due to collisions or improper operation. For this reason, Klingelnberg makes consistent use of a proprietary development that meets all precision and robustness requirements in the form of the M44 3D measurement system.

The workpiece rotational axis is another main component that is required for high quality form measurement on Klingelnberg Precision Measuring Centers. For form measurement, the circularity test accuracy for the workpiece rotational axis must be approximately 10 times greater than the tolerance of the component that is being measured. In the majority of cases air bearings are used in form testing machines, which provide extremely high circularity testing accuracy. However, these do not have the necessary robustness for shop-floor measurement, which has been the state of the art at Klingelnberg for many years. For this reason, Klingelnberg relies on a proprietary development with special precision rolling-body technology in this case. In order to achieve the necessary accuracy using this technology, the bearings are manufactured in-house by Klingelnberg.

## The "perfect shaft"

The result of all this effort is a measuring machine with outstanding characteristics, not just for gear measuring technology but also for general shaft measuring technology. The Klingelnberg philosophy is to measure not only the gear of a shaft, but also the entire shaft with all parameters to be measured, on a single measuring

# Compact

## All-in-one solution

No change-over, no machine changes: The Klingelnberg Precision Measuring Centers combine high-precision form, coordinate, and surface measurements – tasks that are traditionally carried out using several machines. Because these machines are "all-rounders", they can measure crankshafts and camshafts – and can also be used directly on the shop floor.

Behind the versatile Klingelnberg Precision Measuring Centers are proprietary technology and tool developments, which make shop-floor use of the machines possible in the first place.


Fig. 1: Precision Measuring Centers such as the P 40 make it possible to measure the entire shaft with all of the parameters to be measured.

Even components with no gear features can be measured with precision measuring centers such as the P 40.

machine. Developments in this area are now so advanced that many components that no longer include gearing components are measured on Klingelnberg Precision Measuring Centers (see also Figure 1).

Typical examples of these shaft measurement tasks are crankshafts and camshafts in engine manufacturing. A large quantity of geometrical measuring operations are needed for these components. In addition to coordinate and form measurement, the surface quality can also be tested directly in a single process.

## An in-depth look: Crankshaft ...

The main elements of a crankshaft are the main bearings and pin bearings, for which circularity and radial run-out are key factors as well as the geometry. The angular position of pin bearings is another quality criteria. The size, form and position are measured during testing of the bearing seats (see Figure 2a). The drive flange testing (see Figure 2b) focuses on position testing of the bore holes, as well as the angular position of the precision bore, e.g., in relation to the pin bearings or the gearing.  An angled probe, which can be inserted via an automatic probe change rack magazine, is used for this purpose.

## CRANKSHAFT MEASUREMENT ON A P 40

Fig. 2a: Measurement of bearing seats (dimension, form, and position)

Fig. 2b: Drive flange testing (measurement of bore hole and angular position); the automatic probe change rack can be seen in the background.

## ... and axial bearing seat

An axial bearing seat, for instance, requires different measurement tasks: measurement of the transition radius between the radial and axial bearing surface (see Figure 3a) on the one hand, and a roughness measurement on the axial bearing surface on the other hand (see Figure 3b). For the roughness measurement, a skid probe system is used, which is equipped with a probe needle with a tip radius of either 5 µm or 2 µm, depending on the task. This makes it possible to carry out standard-compliant roughness measurements directly on the precision measuring center.

## Roughness measurement

The roughness measurement is an integral component of the measuring procedure. Like a normal probe element, the roughness probe is adapted to fit the M44 3D measurement system via a standard adapter plate. This means that the roughness probe can be inserted via the automatic probe change rack. Klingelnberg has developed a special adapter for this purpose, with which the plug connector for the roughness probe is

MEASUREMENT TASKS ON A BEARING SEAT

Fig. 3a: Measurement of transition radius at the axial bearing seat

Fig. 3b: Roughness measurement on the axial bearing surface


Fig. 4a: Camshaft measurement

also inserted automatically. The roughness probe has an integrated motorized rotating mechanism, which automatically adjusts the probe direction based on the measurement task. Thanks to these prerequisites, various roughness measurements can be included in the automatic measuring cycle, and the entire component can be completely measured in a single operation. Another advantage of this procedure is the high degree of repeatability that can be achieved. Because the roughness probe is attached like a normal probe element on the 3D measurement system using the same axis motion, ensuring that roughness measurement recording always takes place in precisely the same location on the component. This ensures that precisely defined measurements are repeatable in the function-relevant area of the workpiece.

## Sprocket and cylindrical gear measurement

Of course, sprocket and cylindrical gear teeth can also be measured in a single clamping on the same measuring machine. Klingelnberg's many years of experience prove advantageous, specifically when it comes to measuring cylindrical gearing. The measurement software for cylindrical gears includes a number of evaluation options, which cover all of the relevant global standards (e.g., DIN, ISO,

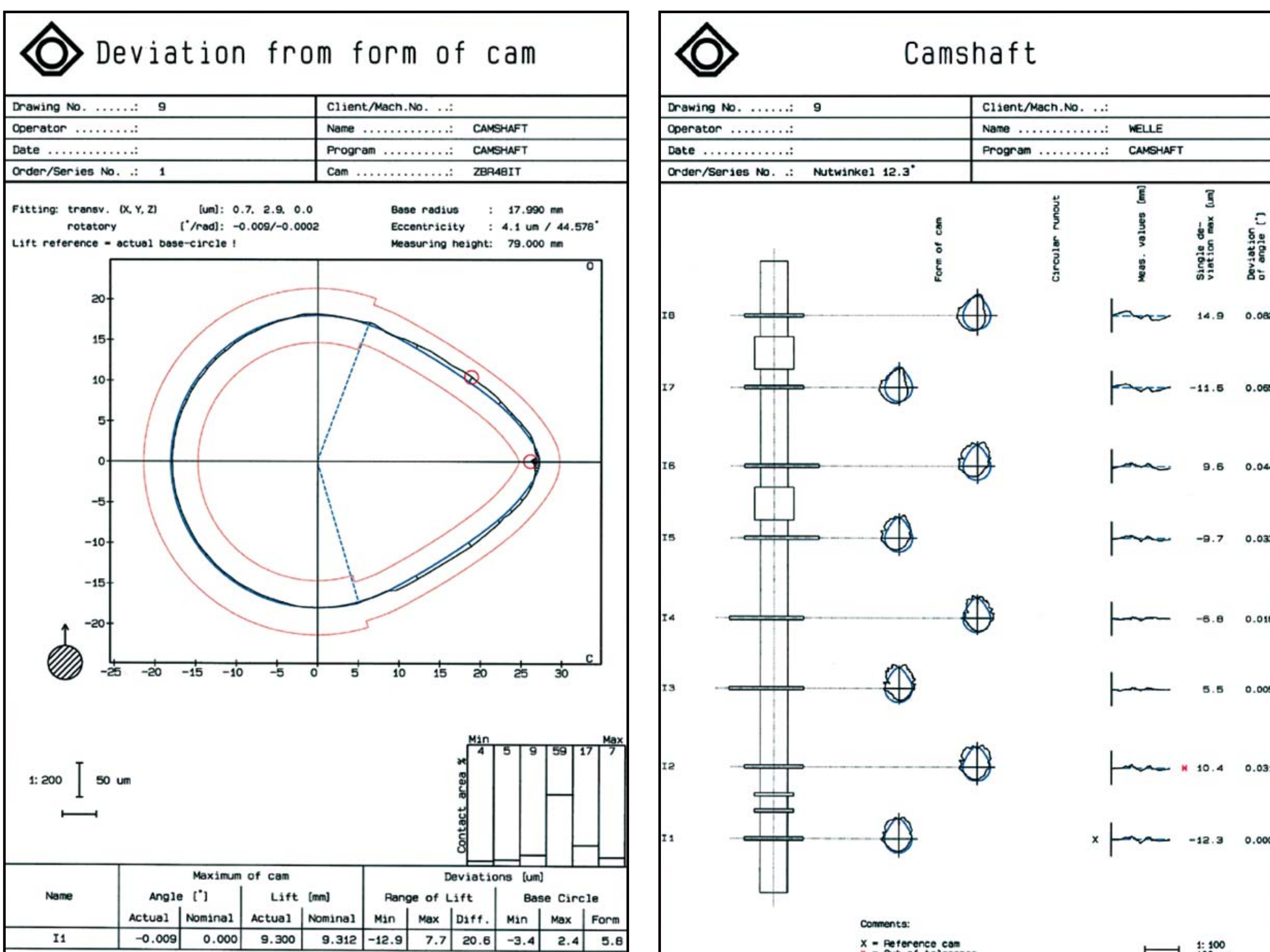


Fig. 4b: Camshaft measurement results: The measurement chart on the left shows the measurement tasks for the individual cam; alternatively, all cams can be displayed in an overview to obtain an general view of the entire component (measurement chart on the right).

AGMA). It also takes the factory standards of the majority of well-known gearing and gearbox manufacturers into account, which is of considerable benefit for the supplier industry in particular.

## Camshaft testing

Another feature of shaft measurement is camshaft testing. In this case, the nominal geometry of the cam is compared with the actual measuring result, i.e. the actual cam geometry (see Figure 4a/b). The user can choose whether to focus on the individual cam for the measurement task, or whether to have all cams displayed in an overview in order to obtain an general view of the entire component. As well as the cam shape, the relative positions of the high points of different cams can be evaluated when doing this, of course.

## Use on the shop floor

An extremely important aspect of the use of Klingelnberg Precision Measuring Centers is the beneficial temperature behavior of the machine, which is enhanced by effective temperature compensation. In many applications, measuring machines are used directly on the shop floor nowadays. Long distances to the measuring room and non-productive waiting times can therefore be avoided, particularly during first-part measurement and therefore release for production. Shop-floor use is made possible thanks to a suitable machine concept and the compensation of temperature effects. Consistent use of steel materials for the machine body has a positive effect here, since the machine components and the component to be measured have the identical temperature expansion coefficient. Moreover, residual error compensation is calculated on the basis of ambient, machine, and workpiece temperature measurements. This makes it possible for the measuring machines to be used in the shop-floor environment – removing the need for an air-conditioned measuring room in many cases. Shop-floor measurement is completed by the optionally available integrated vibration insulation (see Figure 1).

## Conclusion

Many components can be measured entirely on a Klingelnberg precision measuring center, particularly in drive train technology. The main advantage of this is the combination of form, coordinate, and surface measurement on a single measuring machine. This eliminates the need for machine and tool changes. And there is also the possibility of carrying out many measurement tasks directly in one automatic process. These characteristics for optimizing efficiency during the measurement of complex axially symmetrical components are enhanced by the possibility of measuring directly on the shop floor. ◆

## HIGHLIGHTS IN BRIEF

- Combination of form, coordinate, and surface measurement
- Measurement of complex, axially symmetrical components (e.g., crankshafts and camshafts)
- Many different measurement tasks in one automated process
- High degree of repeatability
- Measurement software covers all relevant global standards, as well as factory standards of well-known gearing and gearbox manufacturers
- Effective temperature compensation enables shop-floor use

Shop-floor manufacturing: Because of the the use of steel materials, the machine components and the component to be measured have the same temperature expansion coefficient.

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