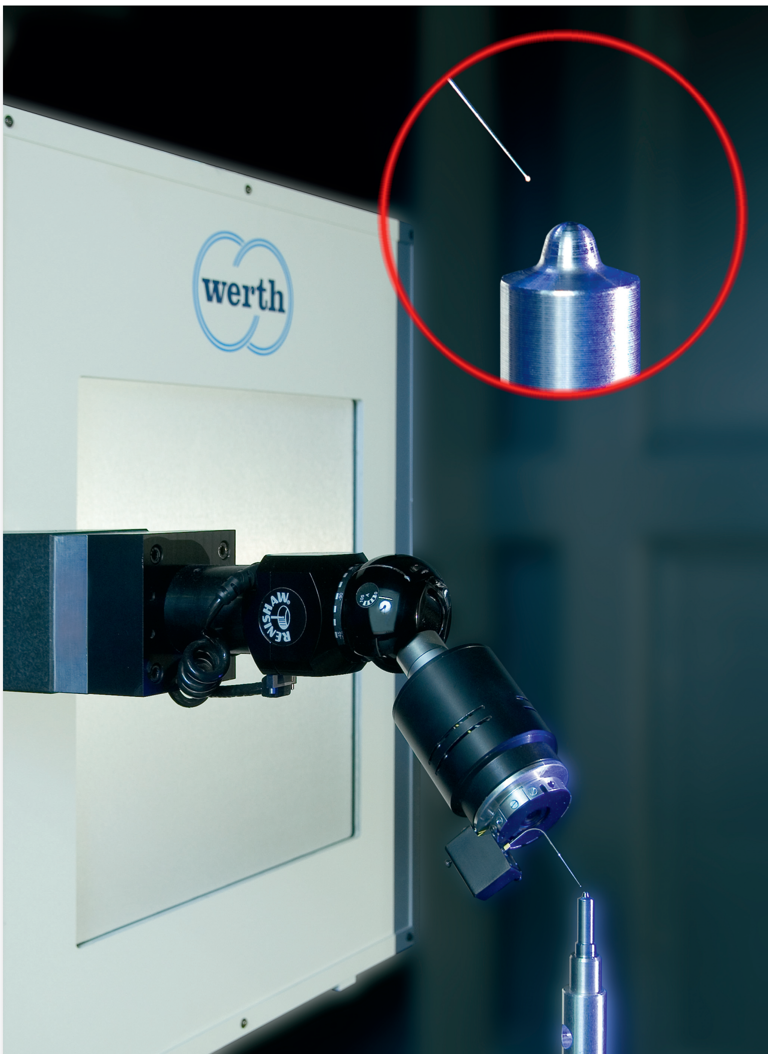
Quality Engineering

Multipoint Measurement in Coordinate Metrology



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Modern sensors enable workpiece geometry to be captured completely

Multipoint measurement in coordinate metrology

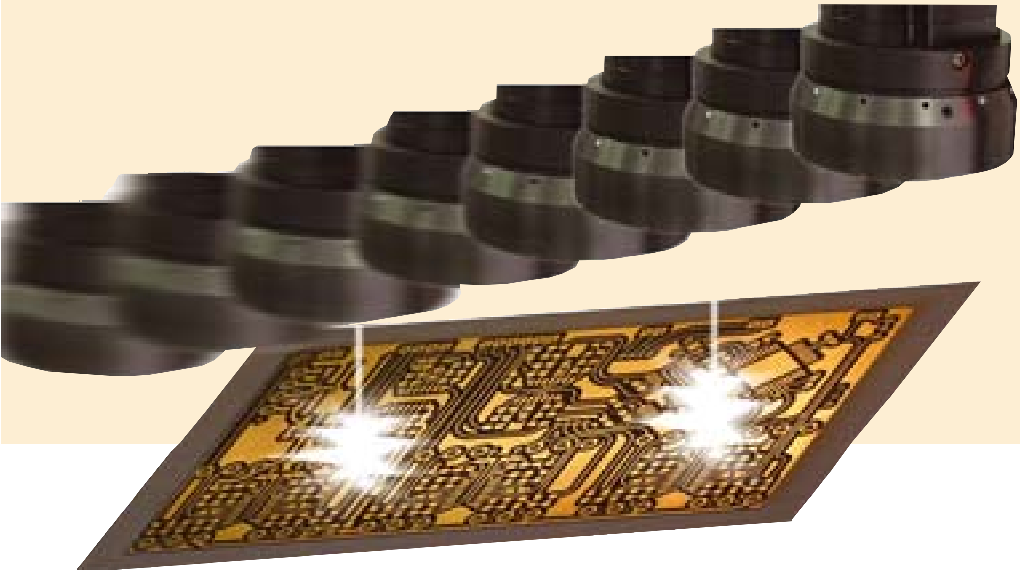

Fig. 1 OnTheFly – Highly advanced control technology enables the measuring machine to measure features precisely while in motion.

Modern coordinate measuring machines can be equipped with various sensors. In addition to tactile sensors, optical sensors are gaining more acceptance. Large quantities of measurement points on the material surface can be captured in a short period of time. This enables complete analysis of shapes, dimensions, and positions. Even more extensive potential is provided by completely capturing workpieces using computer tomography.

More and more, users of coordinate measuring machines are demanding that measured objects be captured as completely as possible. The reasons for this are partly found in the increasing complexity of the components that need to be checked using measurement technology. The use of free-form surfaces, for example in the design of components, is also increasing. For many functional parts, smaller and smaller geometric features occur as the result of miniaturization, which must be measured with higher resolution and precision. Shape deviations in such features are often found at similar orders of magnitude as the dimensional tolerance itself. If too few measurement points are captured, this can lead to measurement errors. Typical applications include the fields of plastic injection molding, microcomponent production for medical and automotive technology, sensor components, and cutting tools.

Two fundamental technical paths can be pursued to obtain the required large number of measurement points, multisensor CMMs and computer tomography. Multisensor coordinate measuring technology, the principles of which are well known, uses various optical and tactile sensors to enable measurement points to be captured at the highest level of precision. Optical sensors, in particular, allow large quantities of points to be gathered in a short time, so that features can be completely captured. Modern tactile sensors can also capture many measurement points due to the availability of scanning. This also applies to microprobes using the fiber probe principle. A newer method is the use of computer tomography in coordinate metrology. With this method, complete objects can be captured in a relatively short time. Precision in the lower micrometer range is also possible using a modern type of these machines.

Scan many points without contact using optical sensors

The optical sensor in most widespread use is image processing. In Werth coordinate measuring machines, image processing has traditionally been a central element. With over 20 years of experience in optical measurement, a solid foundation has been laid for reliability and precision.

This sensor type is very precise and fast. Flexible lighting, such as the Werth MultiRing, and reliable, precise image processing software that is also user-friendly, such as the AutoElement function, that automatically identifies geometric structures within the field of view, make measurements easier for the user. The new, patented OnTheFly technology (measurement in motion) has raised the combination of speed and precision to a new level. For example, measuring tens of features per second, including the repositioning of the measurement object is now possible (Fig. 1). With the use of OnTheFly raster scanning, complete objects can be digitized

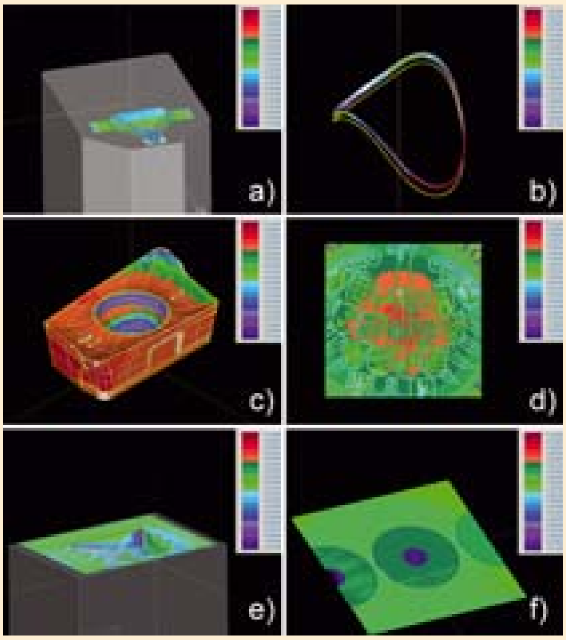

Fig. 2 Color-coded presentation of deviations of different workpieces measured by different sensors: a) micropunch tool measured with Werth 3D-Patch; b) cutting edge contour of a microcutting tool measured with Autofocus Scanning; c) surface topography of a cutting tool insert measured with the WLP laser distance sensor in scanning mode; d) embossing tool measured using the CFP chromatic distance sensor in scanning mode; e) micropunch tool and f) printer nozzle measured with the NFP confocal sensor

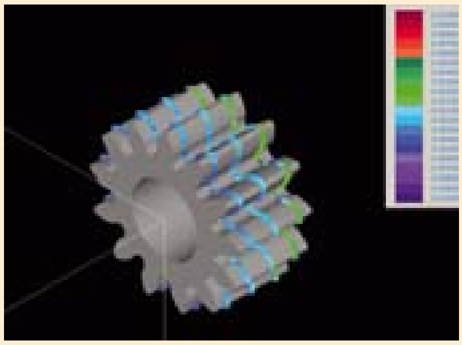

Fig. 3 Profile deviation of a microgear scanned with the Werth Fiber Probe

and measured with maximum resolution at previously unobtainable speeds.

Using the same hardware components, three dimensional geometric features can also be measured. Back in 1999, Werth presented a process based on the principle of focus variation. Using this Werth 3D-Patch and current image capturing technology, it is possible to capture several hundred surface points simultaneously in a few seconds. Radii and flatness of workpiece geometries, for example, can be measured entirely in a single pass.

This is particularly interesting for small geometric features. For larger workpieces, several such measurements can be taken at different locations on the workpiece, one after the other, so that point clouds can also be captured for larger areas of measured objects. (Fig. 2a) A similar method is used for measuring cutting edge contours (Fig. 2b).

For certain surface characteristics of the workpiece, other sensors are more suitable. These can, however, be more expensive or difficult to use under certain circumstances. For example, the surface topography of cutting tool inserts can be measured very well using the Werth laser probe (Fig. 2c). This sensor is fully integrated in the image processing beam path of the coordinate measuring machine, and therefore, is very easy to use. In scanning mode, many thousands of points can be captured in a few seconds. If the objects to be measured have strong reflective properties, such as optical functional surfaces, the chromatic distance sensor is more suitable (Fig. 2d). Complete capture of a surface of the measurement object in the submicron range can be obtained in scanning mode on the coordinate measuring machine.

The nanofocus probe, which measures surfaces in a similar way as the 3D Patch, allows the simultaneous capture of many measurement points in one measurement field of view (Fig. 2e, f). The use of a confocal beam path provides even greater precision and lower sensitivity to surface inclination. Flatness measurements at precisions in the 0.1 µm range are possible.

Fundamentally, the optical sensors listed above allow precision in the order of a few microns and sometimes much lower. When selecting the sensor for each case, the properties of the material surface of the object to be measured must be taken into consideration. Experience and competent advice by the manufacturer are particularly important in that case.

In order to design measuring machines to be flexible for various requirements, the use of several sensors in one measuring machine is sensible. The base equipment level includes image processing, combined with one or more distance sensors. These are complemented by tactile sensors and computer tomography.

Measure the smallest features at high precision using the Werth Fiber Probe

The principle of the Werth Fiber Probe is to measure the position of the contact sphere directly, or nearly directly, by using an optical sensor. This makes it possible to use a contact sphere and a probe pin that are arbitrarily small. This can be done only on a very limited basis with classic contact principles due to probe pin deflection and the associated degradation of the signal. Using the Werth Fiber Probe (with sphere diameters currently down to 20 µm), even the smallest features, such as flank faces of microgears, can be measured at high precision, even in scanning mode (Fig. 3).

By exciting the probe to vibrate on the order of a few microns, stick-slip effects are avoided and continuous point distribution is ensured. Comparisons to calibration values using other high precision measurement methods show deviations in the range of a mere 0.1 µm. The Werth Fiber Probe is thus suitable for the greatest precision requirements, such as spray hole measurement in diesel fuel injectors, or other measurement tasks with high precision shape and dimensional inspection of microfeatures. Calibration of workpieces and standards can also be done, or correction values for other sensors in multisensor coordinate metrology can be determined. This probe was developed in cooperation with the PTB (German National

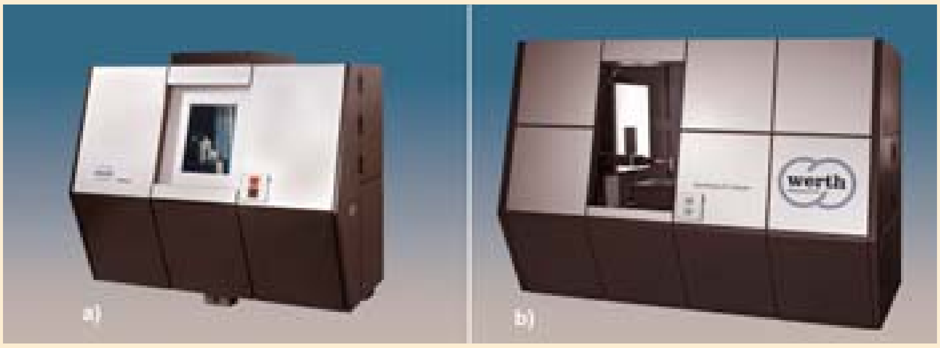

Fig. 4 Typical representatives of the Werth TomoScope series:
a) TomoScope 200,
b) TomoScope HV Compact

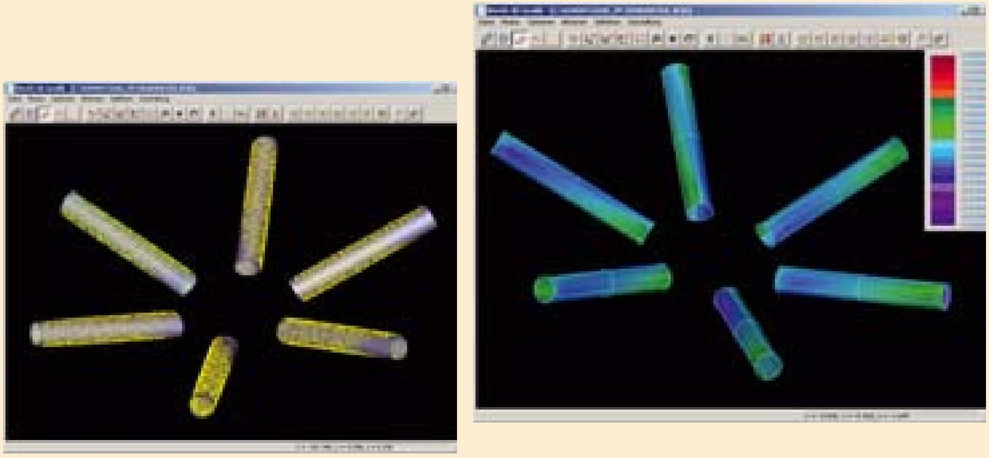

Fig. 5 Better than one micron precision: measuring diameter and shape of injection nozzles using computer tomography

Metrology Institute) and is used there to calibrate microstandards among other tasks. The Werth Fiber Probe is currently the microprobe in widest use around the world.

Measure completely and precisely using X-ray tomography

With the TomoScope, Werth presented the first coordinate measuring machine with computer tomography, optionally with multisensors, in 2005. Since then, it was developed into a series of machines to meet various requirements for workpiece size and material (Fig. 4).

They can be used, for example to measure plastic parts at a precision of a few microns, by capturing a large number of measurement points and determining the dimensions. Werth raster tomography makes it possible to adapt the measurement resolution to the requirements of the measured features while accommodating the overall size of the workpiece . Even small features on relatively large workpieces can be measured at high precision. The available data can be used directly for correcting the injection mold in the initial sample process.

If even more precision is needed for metal parts that are difficult to measure, then multisensors can help to reduce residual systematic measurement deviations. Using Werth AutoCorrection, such deviations can be captured on master parts and then automatically corrected in production measurements. This can be done at maximum precision with the combination of the Werth Fiber Probe and computer tomography (title image). For example, measurement of microbores in steel parts can be done at a precision of better than one micron, similar to that of the Werth Fiber Probe (Fig. 5).

Comprehensive measurement and analysis using a single software package

The comprehensive WinWerth software package provides ease of use for analysis and measurement with any and all sensors. This allows, for example, measurement sequences to be programmed in teach mode, with or without 2D or 3D CAD data and external CAQ inspection plans. This also enables user-friendly offline operation, and comparison of actual data to CAD models (Fig. 2,3,5).

Optimal solution using multisensors

The requirements for modern measurement technology that arise from current measurement tasks are no longer met by purely tactile measurements. High measurement point densities on individual features above all, or complete capture of entire components, can only be achieved at the required precision in combination with optical methods or tomography. The application examples shown make it clear that the selection of suitable sensors depends primarily on the measurement task, the existing component properties, especially surface finish or permeability, and the tolerances to be achieved. The optimal solution, however, is often found in the combined application of several sensors in a multisensor coordinate measuring machine, such as those available from Werth Messtechnik GmbH.

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