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Computed tomography in coordinate metrology

Werth Messtechnik GmbH

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PRACTICAL TIP For precise measurements with X-ray computed tomography (CT), Autocorrection based on a reference measurement with a different sensor was initially necessary. In recent years, the measurement uncertainty has been considerably reduced by improving the machine components and software. Today the measurement accuracy even of compact coordinate measuring machines with CT is similar to machines with conventional sensor technology.

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For measurement with computed tomography, radiographic images are taken in different rotational positions of the workpiece and the complete volume of the workpiece is reconstructed. Until the beginning of the millennium, the field of application of CT was limited to medicine and material inspection; measurement deviations were still in the tenth of a millimeter range. In 2005, the Werth TomoScope was introduced as the first coordinate measuring machine with a CT sensor, optionally with additional sensors, whose specification corresponded to that of conventional coordinate measuring machines.

Solutions from the coordinate metrology

Proven components and principles from coordinate measuring technology such as the mechanical design, high-precision coordinate axes, air bearing technology at least for the rotary axis, correction of the machine geometry, measuring software and concepts for traceability led to a new generation of machines. In order to determine the position of the measuring points at the material transitions with higher spatial resolution, the amplitudes of the voxels located in the vicinity are taken into account using a subvoxeling method patented for Werth.

In the early years, the patented Werth Autocorrection (in which a master part is measured with a more accurate sensor in order to then use the deviations from the CT measurement to correct the CT series measurement on additional workpieces) was essential to achieve a sufficient ratio between measurement uncertainty and workpiece tolerance. Thus, the measurement of workpieces with tolerances in the single-digit micrometer range was already reasonably possible in 2005. Similar to conventional coordinate measuring machines, CT machines achieved a specification and measurement uncertainty of a few micrometers.

Increased accuracy through X-ray components and software

Today, almost all workpieces are measured with sufficient accuracy without any additional sensors. Modern transmission target tubes enable high performance with good

Fig. 1. Today, even compact machines with computed tomography achieve the same high accuracy as conventional coordinate measuring machines. (© Werth Messtechnik)

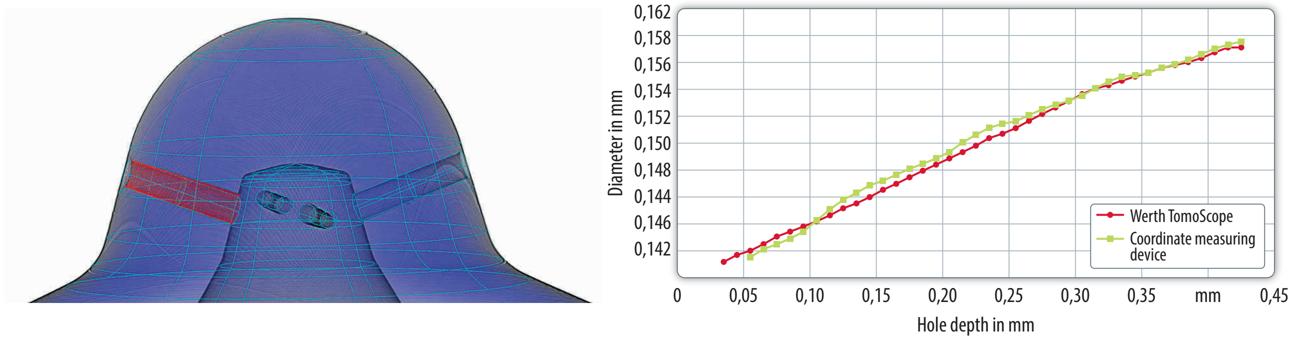

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Fig. 2. **Comparison measurement of the diameter of a fuel injection nozzle with computed tomography and high-precision fiber probe (a); display of measured volume and measuring point cloud in the area of the spray .** (© Werth Messtechnik)

resolution. Thus even micro geometries can be measured in a short time with good reproducibility. With the Werth 300 kV transmission target tubes with 80 W maximum power, even thick-walled metal parts or assemblies made of highly absorbent materials can be penetrated due to the high X-ray voltage. Even at 80 W power, the focal spots are only 10 micrometers small. In combination with modern detectors, which have a high number of pixels and therefore enable a finer 3D voxel grid, high structural resolutions can be achieved.

Software correction methods (for example for artifact correction and temperature compensation as well as for geometry and drift correction) allow a further increase in accuracy. Empirical Artifact Correction (EAC) uses a reference measurement and determines a material-dependent correction of the measurement. This can also be used to correct further measurements, for example in series production.

Virtual Autocorrection (VAK) is used for scattered-beam artifact reduction. By simulation on the CAD model or the measurement result of a workpiece, the resulting scattered radiation can be determined and the measurements corrected. Deviations from the ideal machine geometry and from the calibration state are also recorded and automatically corrected during each measurement.

In modern machines, temperature correction of the scales and the workpiece should be standard. Using the workpiece temperature and the corresponding coefficient of thermal expansion, the measurement results are calculated for a reference temperature of usually 20 °C. Some instruments can be equipped with an active climate control system so that the measuring volume does not deviate more than ±1 K from the reference temperature.

Measurement with resolution and measuring range as required

In addition to the correction methods, intelligent procedures are available to increase the resolution and extend the measuring range: With raster CT, radiographic images of different areas of the workpiece are recorded one after the other and combined for evaluation.

Excentric Tomography allows the workpiece to be placed anywhere on the rotary table. Tomography is then performed around a virtual axis of rotation in the center of the region of interest (ROI). Based on this method, selected parts of the workpiece can be measured in high resolution and a final point cloud with different structural resolutions can be calculated (Multi-ROI CT).

OnTheFly CT reduces measuring time and increases reproducibility eliminating the dead time for positioning the workpiece by continuously turning the rotary axis. The prerequisite for sufficiently sharp images is a very short exposure time. Many radiographic images must be acquired. A very fast reconstruction software is absolutely necessary for real-time operation.

Applications from automotive to medical implants

The opportunity to measure the workpiece completely, outer and inner geometries, with good accuracy results in many applications for coordinate measuring technology with X-ray tomography. Plastic injection molding workpieces, micro gears for the automotive and aerospace industry, micro lenses with tolerances down to 10 µm as well as stents for cardiac and vascular therapy are just a few examples. Measurements like that can also be performed with compact machines such as the TomoScope XS Plus (Fig. 1). For quite some time, acceleration voltages of up to 300 kV have been used to measure large metal parts such as water jet nozzles with tolerances down to several 10 µm. Werth Autocorrection is also still used to reduce systematic measurement errors down to fractions of a micrometer for tolerances in the single-digit micrometer range, such as those of fuel injectors, for example with a Fiber Probe (Fig. 2).

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Masthead

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