



Always a Step Ahead with Quality



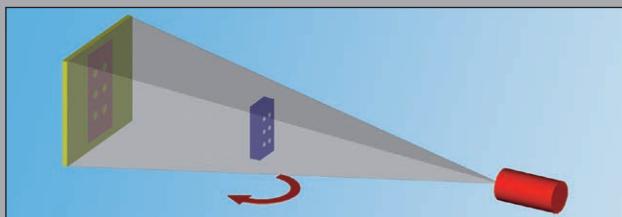
Coordinate Measuring Machines with Computed Tomography

Multisensor Coordinate Measuring Machines with Computed Tomography

Computed Tomography in Coordinate Measuring Machines – At the Touch of a Button

Tomography, based on X-rays and also known as computed tomography, or CT, was originally developed for medical applications. Since the 1990s, systems based on the CT principle have been used in industry for non-destructive material inspection only. In 2005, Werth presented the TomoScope®, the world's first coordinate measuring machine with integrated computed tomography. This created completely new possibilities for fast and precise measurement of workpieces. The complete measurement "at the touch of a button" became reality. Hundreds of thousands of measurement points are generated automatically.

They embody the workpiece geometry completely and accurately including internal geometries and undercuts. Since the very first prototypes, different machines have been developed for different fields of applications. Depending on the requirements, the emphasis is placed on highest resolution and accuracy, large measuring range or fast measurement. The machines supply a digital copy (voxel volume and point cloud) of the tomographed workpiece within a few minutes. The workpiece is placed on a rotary table and penetrated with X-rays. A matrix detector converts the X-ray image into a digital 2D image. The object is rotated through 360 degrees and many X-ray images are taken at precise rotary positions.



The principle of computed tomography

These images are then analyzed mathematically. A 3D reconstruction of the entire volume of the measured object is generated.

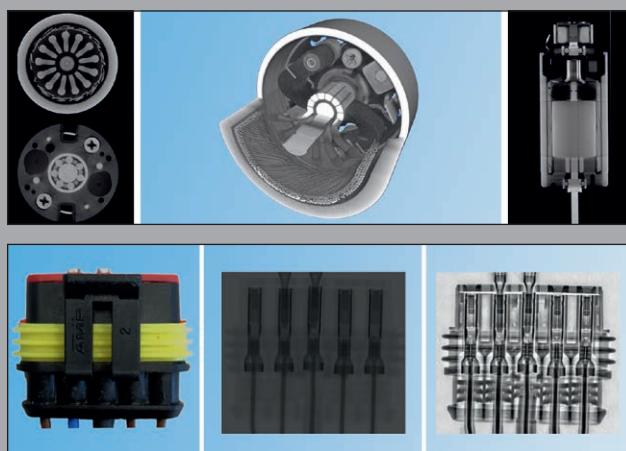
Complete Measurement and Inspection with Computed Tomography

The demand for more complete, more precise capture of workpiece geometry is only partially met by traditional

coordinate measuring machines. Modern Werth coordinate measuring machines with tomography sensor systems provide significant advantages. These systems are optimized for metrology applications to ensure high precision and reliability that were previously unobtainable with X-ray tomography. The key to this is the customization made possible by the use of the same mechanical and control components used in other coordinate measuring machines at Werth.

The specification for the maximum permissible probing and length measurement errors conforms to VDI/VDE 2617-13, similar to standard coordinate measuring machines. Measurements on plastic workpieces, for example, can be performed with the precision of a few microns. Software that fully integrates all functions required for automatic measurements provides measurement in full CNC mode. It also makes manual measurement as easy as possible.

Depending on the application, various machine types are available. Criteria for selecting suitable measuring machines are the maximum workpiece size and the precision required. The appropriate X-ray source is selected depending on the material and size of the workpiece. In addition to metrology applications, all systems can also be used for non-destructive testing applications, such as detecting voids, cracks, and assembly errors.



Inspection of the material structure and mounting position in the radiographic image and in the voxel volume

With the TomoScope® S, released in 2005, Werth presented the first machine developed specifically for coordinate measuring technology with computed tomography (with multisensor systems as an option). The X-ray sources available for this machines have X-ray voltages of 130 kV, 160 kV, 190 kV, or 225 kV to allow the versatile use of the TomoScope® S.

Multisensor Flexibility

With the TomoScope® XS, TomoScope technology is now available in a new compact format. The transmission tube – with a unique monoblock design – produces a small focal spot even at high X-ray power, so that rapid measurements can be performed at high resolution. The combination of „open“ and monoblock design allows an unlimited service life with long maintenance intervals and low operating costs. Due to the compact design and low weight it can be set up almost anywhere. Low acquisition and operating costs allow rapid amortization.

The Werth TomoCheck® S HA provides previously unmatched precision due to its granite base paired with high-precision mechanics and air bearing technology. The probing deviations of the X-ray sensor are minimized by a patented software process. With a special X-ray tube and a high resolution detector, it provides extremely high resolutions within less than one micron.

The Werth TomoScope® L is designed to completely and precisely measure large volume workpieces with high densities (aluminum, steel, titanium, elastomers, hybrid plastics and ceramics). As with all Werth coordinate measuring machines, the TomoScope® L also features forward-thinking modularity. Based on the application, these machines can be equipped with X-ray sources with voltages of 130 kV to 300 kV with transmission or reflexion target. To cover various applications, two X-ray sources can also be used in one system alternating automatically.



Werth TomoScope® XS



Werth TomoScope® S



Werth TomoCheck® S HA



Werth TomoScope® L



Werth TomoScope® XL



Werth TomoScope® XL NC

The TomoScope® XL allows measurement of large volume workpieces. This machine also has a larger distance between the X-ray source and the sensor for higher magnification. This reduces measurement deviations due to cone beam artifacts. The other technical parameters are the same as for the TomoScope® L. With the Werth TomoScope® XL NC, Werth Messtechnik GmbH offers the solution for measuring large volume workpieces with lengths over one meter. Due to its high X-ray voltage of 450 kV, the TomoScope® XL NC can also be used to measure for example vehicle engine components and other large workpieces that are difficult to penetrate.

Multisensor Systems and Computed Tomography

The basic mechanical design of the Werth tomography measuring machines relies on proven standard components which are also used in other Werth coordinate measuring machines. This ensures a high level of reliability, reproducibility and accuracy. Additional sensors can also be integrated. When computed tomography is combined with conventional sensors, such as touch probe systems, image processing, laser sensors, or the tactile-optical Werth Fiber Probe, it opens up another range of possibilities. These sensors can be mounted on a second independent axis, which prevents collisions. The sensors can be positioned outside of the working area when the tomography is running. The highest level of flexibility is provided when the multisensor axis is equipped with a tilt head or a rotary/tilt head with a sensor exchange interface.

If workpieces are difficult to measure due to their material composition, or if even more precise measurements are required, then partial areas or special features can be measured with a tactile or optical probe.

The integration of a loading system into the machine enables the automatic feeding of several identical or different workpieces within the machine measuring volume without additional set-up times or the need for additional radiation protection measures. The measuring machine remains closed during the whole measurement process and can be run in an unmanned shift.

Multisensor systems can also be used for reducing systematic measurement errors in tomography due to artifacts. Using Werth Autocorrection, these systematic deviations can be measured using master parts, and then later automatically corrected during production

Special Measurement Methods



Measuring with multisensor systems:
Calibration of the workpiece using
the Werth Fiber Probe 3D-WFP prior
to measuring with the X-ray sensor



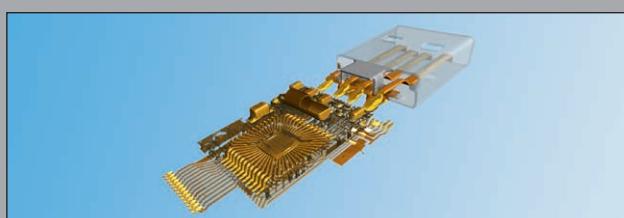
Coordinate measuring machine
with tomography sensors and
loading system

measurements. For example, measurement of micro bores in steel parts can be done at a precision of better than one micron, comparable to that of the Werth Fiber Probe. The measurements can be traced to the length standard of the German National Metrology Institute (Physikalisch Technische Bundesanstalt – PTB), while taking into account the actual workpiece properties. The best guarantee, for traceability of the measurement results, is given if the measuring instruments are calibrated by the Werth calibration laboratory which is certified by the German National Accreditation Body (Deutsche Akkreditierungsstelle – DAkkS) for tomography machines. The calibration is performed comparable to the VDI/VDE Guideline 2617 Part 13.

Special Methods for Special Applications

The methods which are described below can provide advantages in measurement uncertainty, resolution and measurement time for different applications.

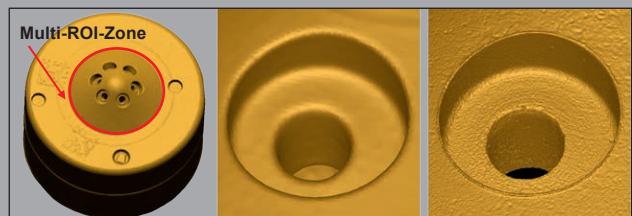
- **Raster Tomography:** Raster tomography can either increase the measurement range of the computed tomography sensor, or increase its resolution.



Raster tomography for increasing resolution

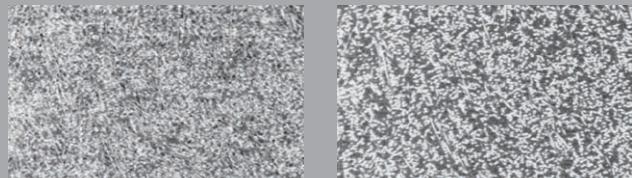
- **Multi ROI-CT:** One or more partial areas of a workpiece volume are measured with high resolution using ROI tomography (region of interest). It provides high resolution data in partial workpiece areas, saving measuring time when it is not required to scan the entire workpiece with high resolution. In combination with the patented Eccentric CT workpieces can be placed and measured

in any position on the rotary table or alternatively, virtual centers of rotation can be defined for tomography measurements outside the center of rotation. The zones measured with different resolution can be combined into one point cloud and evaluated together (Multi-ROI-CT).



Gasoline injection nozzle: complete nozzle (left), without ROI-CT (center),
with ROI-CT (right)

- **Drift Correction:** With the help of the drift correction, the drift (temperature-dependent position change of the focal spot or workpiece) can be corrected. This improves the measurement uncertainty for measurements on workpieces with small tolerances, as well as the ability to detect very small details when used for inspection tasks, for example the analysis of fiber structures.



Without Drift Correction

With Drift Correction

- **Multi-Spectra-CT:** With the multi-spectra CT, the artifacts occurring during the measurement of multi-material workpieces can be minimized. In this case, two CT measurements, whose spectrum is adapted to the respective material, are calculated to one volume.

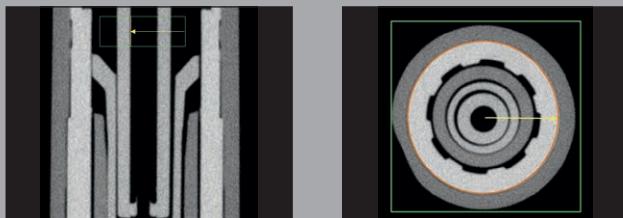


By combining several CT measurements (A and B) tuned to each specific material, artifacts are minimized (C and D)

- **Half-Sided CT:** Half-sided CT is used for tomographic imaging of large workpieces whose larger diameter cannot be captured completely by the detector. The center of the rotary axis is positioned at the edge of the field of view. Half-sided computed tomography allows the measurable workpiece diameter to be approximately doubled.

Analyzing Measured Data with WinWerth®

- **Volume-Cross-Section CT:** With this option, cross sections can be evaluated with the image processing sensor. All proven strategies of the Werth image processing software are available and can be used for accurate measurements.



Volume cross section through the voxel volume of a ballpoint pen

- **OnTheFly-CT:** With the OnTheFly-CT option, the measurement time with the X-ray tomography sensor can be significantly reduced by continuously rotating the machine axis.

Uniform Measurement Software, Even for Computed Tomography

The WinWerth® software package, already used for multisensor coordinate measuring technology in several thousand installations, also includes the functions for tomography. In addition to a simple menu for setting the tomography parameters, WinWerth® includes powerful functions for the real-time reconstruction of 3D data and automatic determination of measurement points at the material boundaries. The entire measurement, with computed tomography and other sensors, is completely and automatically controlled by WinWerth®.

To perform a tomography scan, the user must first select the appropriate settings for the X-ray source. This is done with the user interface in a similar manner to the light adjustments for optical sensors. To expand the dynamic range for low contrast objects, additional powerful tools are available. They can be used to increase image brightness and contrast or reduce noise in the images by filtering. Beam hardening filters, like copper or gold, can be automatically placed in front of the X-ray source by a software controlled filter changer.

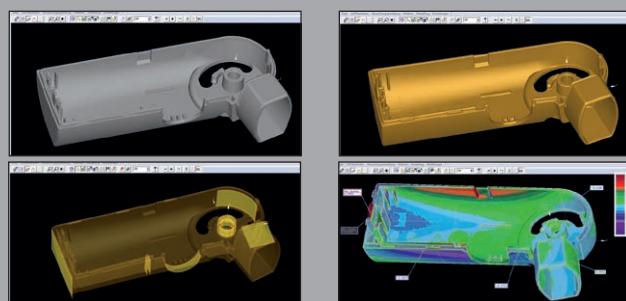
When the tomography process is started, any required qualification processing (such as dark/bright correction) is automatically carried out by the system. The tomography process then runs fully automatically. Since all parameter settings are saved for each part type, a fully automatic program in CNC mode can be created or repeated at any time.

Immediate Results

Following the completion of the tomography process and the 3D reconstruction that runs in parallel with it, the point cloud is automatically imported into the WinWerth® 3D CAD software. The evaluation of the individual inspection features can either be done directly on the measuring machine or offline based on the stored data (voxel volume, point cloud).

Measurement programs can be prepared in advance using CAD data. The extremely high data density provides the possibility to generate a color-coded presentation of deviations of the complete workpiece based on the CAD data in a few minutes. This procedure provides quick results and much more information content than columns of numerical values. The calculated deviation vectors can also be used for direct correction of finishing tools or plastic molds by changing the sign of the deviation data (patent). Regular geometric elements can be calculated from the measurement points and dimensions can be determined by simply clicking on the patches and selecting an element. Other metrology analyses, such as determining shape and position tolerances, can be done in a similar manner.

Due to the integrated software concept it is not necessary for the operator to switch between several software programs. The programs created on the TomoScope® measuring machines are compatible with purely tactile or other multisensor coordinate measuring machines from Werth Messtechnik.



Easy measurement of regular and freeform geometries (from CAD model to color-coded deviation plot)



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