werth Messtechnik

Always a Step Ahead with Quality

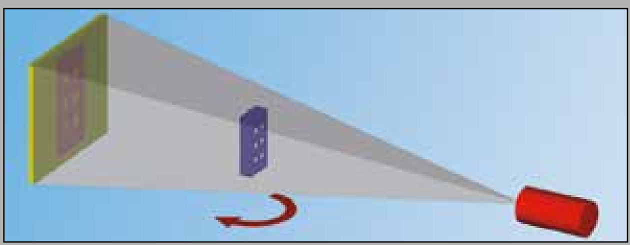
Coordinate Measuring Machines with Computed Tomography

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



The principle of computed tomography

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 MPE P and MPE E, conforms to VDI/VDE 2617-13, similar to standard coordinate measuring machines. Measurements on plastic parts, 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 work piece size and the precision required. The appropriate X-ray source is selected depending on the material and size of the work piece. In addition to metrology applications, all systems can also be used for non-destructive testing applications, such as detecting voids, cracks, and assembly errors.

Inspecting the material structure

With the TomoScope® 200, released in 2005, Werth presented the first machine developed specifically for coordinate measuring technology with computed tomography (with multisensors as an option). The X-ray sources available for this series have X-ray voltages of 130 kV, 150 kV, 190 kV, or 225 kV to allow the versatile use of the TomoScope® 200.

The Werth TomoCheck® HA 200 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

Multisensor Flexibility

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® HV Compact is designed to completely and precisely measure large volume parts with high densities (aluminum, steel, titanium, elastomers, hybrid plastics and ceramics).

As with all Werth coordinate measuring machines, the TomoScope® HV Compact also features forward-thinking modularity. Based on the application, these machines can be equipped with X-ray sources with voltages of 130 kV to 450 kV. To cover various applications, two X-ray sources can also be used in one system alternating automatically.


Werth TomoScope® 200


Werth TomoCheck® HA 200


Werth TomoScope® HV Compact


Werth TomoScope® HV 500


Werth TomoScope® HV 800

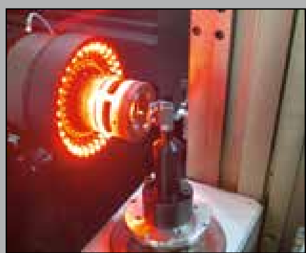
The TomoScope® HV 500 allows measurement of larger parts. This machine also has a larger distance between the X-ray source and the sensor for higher magnification. This reduces measurement deviations due to cone beam artifacts. The other technical parameters are the same as for the TomoScope® HV Compact. With the Werth TomoScope® HV 800, Werth Messtechnik GmbH offers the solution for measuring large volume components with lengths over one meter. Due to its high X-ray voltage of 450 kV, the TomoScope® HV 800 can also be used to measure vehicle engine components and other large workpieces that are difficult to penetrate.

Multisensors 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 pivot or a rotary-pivot joint with a sensor exchange interface.

If components 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.

Another important application is to save time by creating the datum of the workpiece using the high precision Werth Fiber Probe (patent) and then scan a 3D point cloud with the CT sensor related to this datum as opposed to scanning the entire workpiece.


Measuring with multisensors: Calibration of the component using the Werth Fiber Probe 3D-WFP prior to measuring with the X-ray sensor.


Measuring with multisensors: Diesel injectors: measurement setup with Werth Fiber Probe on the IP 40T sensor head.

Multisensors can also be used for reducing systematic measurement errors in tomography due to artifacts. Using Werth AutoCorrection (patent pending), these systematic deviations can be captured on master parts, then later automatically corrected during production measurements. For example, measurement of micro bores in steel parts can be done at a precision of better

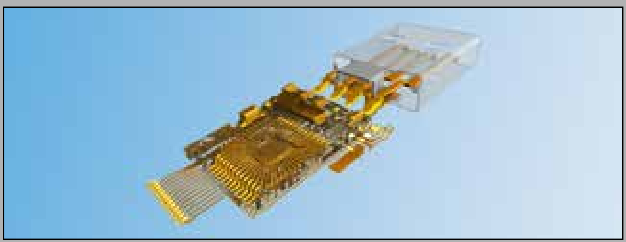
Speciality Measurement Methods

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 Guideline 2617 Part 13.

Special Methods for Special Applications

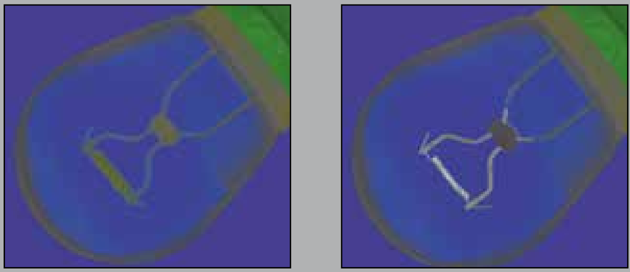
The methods which are described below can provide advantages in measurement uncertainty, resolution and measurement time for some specific applications.

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



Raster tomography for increasing resolution

- **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. The zones measured with different resolution can be combined into one point cloud and evaluated together (Multi-ROI-CT).



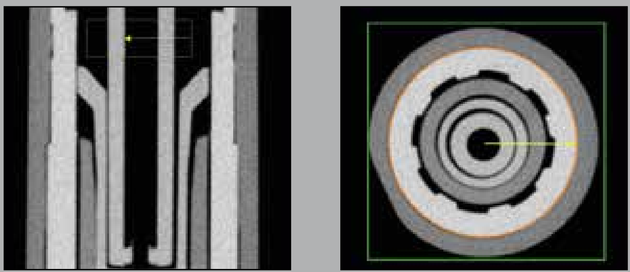
Car headlight coil: without ROI-CT (left); with ROI-CT (right)

- **Virtual Autocorrection:** By using the simulation method integrated in WinWerth, the difference between exact and artifact-afflicted measurement is determined after the measurement. The results of measurements (volume or point data) are corrected. Accurate measurement results are obtained even with workpiece geometries with difficult tomography behavior.

- **Half-sided CT:** Half-sided CT is used for tomographic imaging of large components 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 diameter range to be approximately doubled.

- **Multi-energy CT:** This option can be used to penetrate workpieces with large aspect ratios (long and thin parts) or assembled workpieces with different material densities.

- **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 section through the voxel volume of a ballpoint pen

- **Quick-CT:** With the Quick CT option, the tomography measurement is not performed over 360 degrees, but rather over approximately 180 degrees. This speeds up the tomography process by about a factor of two.

Analyzing Measured Data with WinWerth®

Uniform Measurement Software, Even for Computed Tomography

The WinWerth® software package, already used for multi-sensor 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 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 the exposure time, 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.

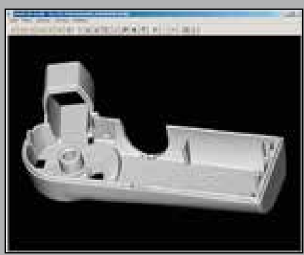
When the tomography process is started, any required qualification processing (such as dark/bright correction) is automatically carried out by the system. The tomography process then runs fully automatically. Since all parameter settings are saved for each part type, a fully automatic program in CNC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

Nearly Immediate Results

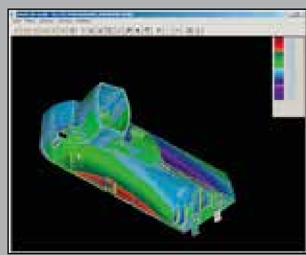
Following the completion of the tomography process and the 3D reconstruction that runs in parallel with it, the point cloud is automatically imported into the WinWerth® 3D CAD software. The evaluation of the individual inspection features can either be done directly on the measuring machine or off-line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

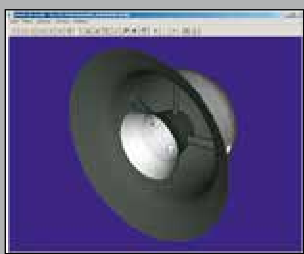
Due to the integrated software concept it is not necessary for the operator to switch between several software programs. The programs created on the TomoScope® measuring machines are compatible with purely tactile or other multisensor coordinate measuring machines from Werth Messtechnik.



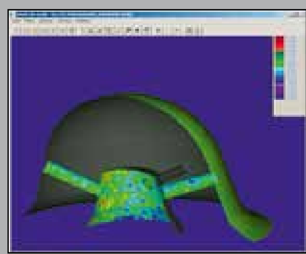
CAD model of an inhaler in Werth 3D module



Color coded plot of the deviation between inhaler and CAD model



Point cloud of an injection nozzle



Dimensional measurement also on inaccessible areas on the component

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