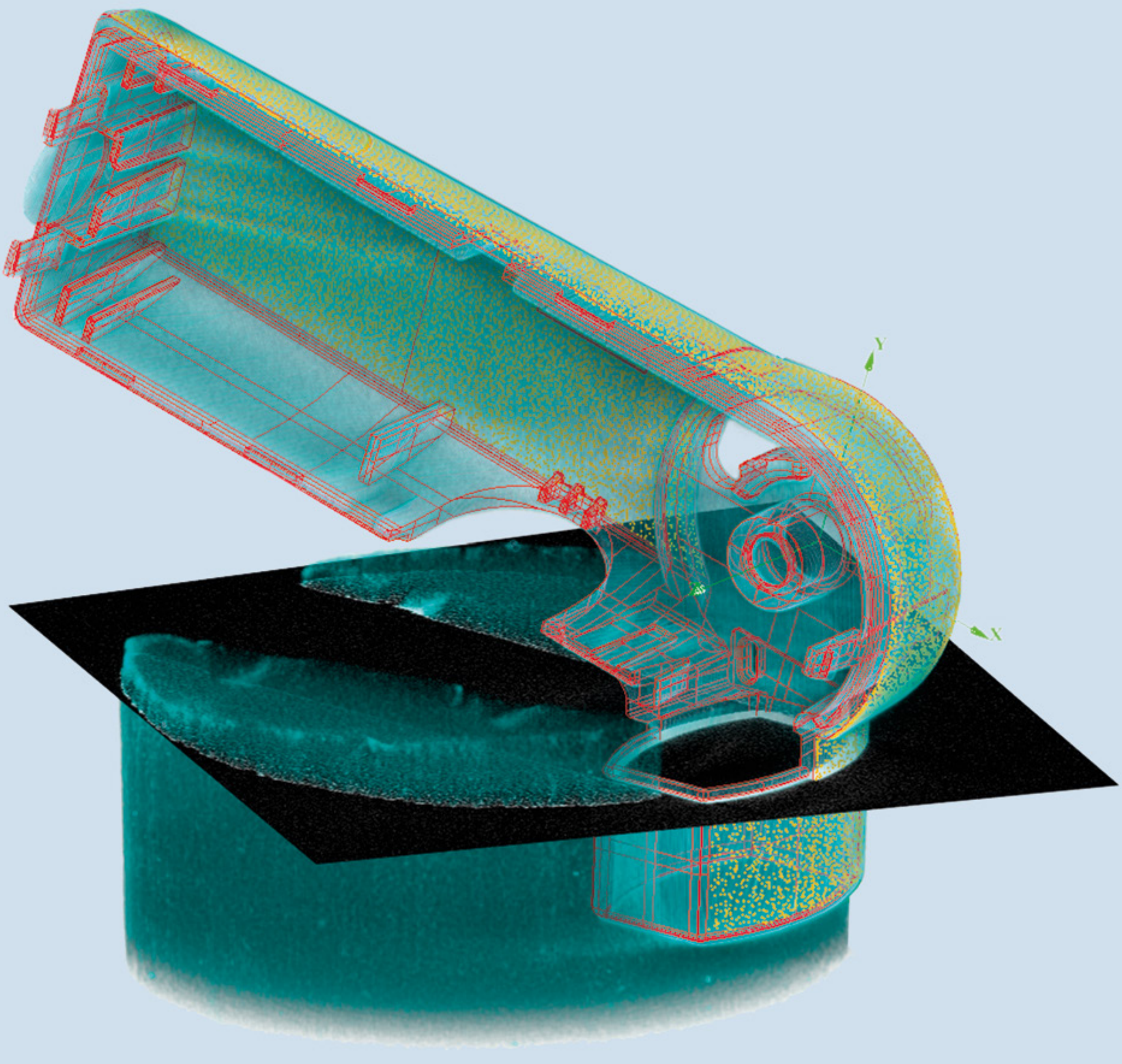
Multisensor

Issue 2018

Always a Step Ahead Through Innovation

ScopeCheck® FB DZ | WinWerth® 8.42 | Werth Interferometer Probe



Title

WinWerth® 3D Graphics with Volume Rendering:
CAD model (red lines), voxel volume (green)
and measurement point cloud (yellow)

The new ScopeCheck® FB DZ version enables easy multisensor measurements without restrictions.

Always a Step Ahead Through Innovation

Every year, we look forward to presenting you with new ideas and solutions in our latest edition of the “Multisensor.” This year’s edition provides information on product innovations, an interesting application report, the latest news from our group and from our foreign trade partners, as well as an article on multisensor system developments over the past 25 years.

Innovation is not just defined as the constant expansion and development of our product lines; rather it is also the early identification of new development trends. Our success over the past 25 years is based both on integrating customer’s needs into the development of our product lines and on close cooperation with leading research institutes. We would like to express our gratitude for the trust that has been placed in us and for the pleasant, long-term collaboration.

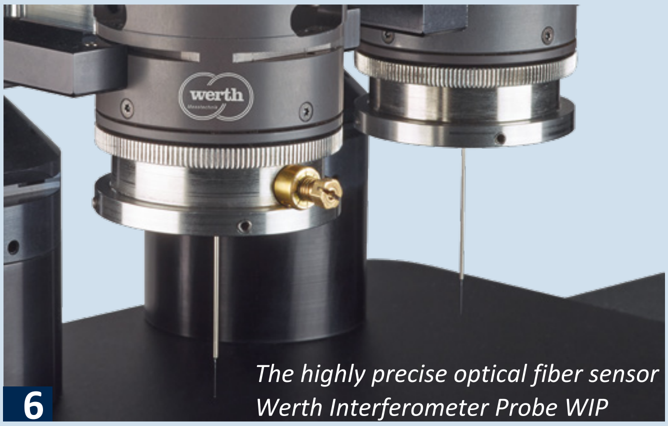
Efficient metrology helps our customers maintain their competitive edge. The versatility of multisensor technology is the solution to just about any dimensional measurement task you may have. The modular design of our coordinate measuring machines provides a technical edge, ensuring that your company is in the position to meet the increased challenges the future will bring. X-ray tomography accelerates first article inspection and injection mold correction efficiency over the entirety of the product development process. X-ray tomography applications for easily penetrable materials, such as plastic, will soon be a must-have for manufacturers to maintain their competitiveness. Our TomoScope® XS is the optimal measuring machine for this purpose.

This year, we are introducing a more compact version of the ScopeCheck® FB DZ product line with larger measuring ranges and two independent sensor axes, making measurements in production monitoring even more flexible. The optical distance sensor, the Werth Interferometer Probe (WIP), is particularly suited for non-contact measurements of hard-to-access and sensitive geometries. With the WIP/RS, for example the roundness of holes or shafts can be measured with minimal measurement errors of about 100 nanometers.

The FormCorrect functionality in the new 8.42 version of our WinWerth® measuring software generates a corrected CAD model for the compensation of geometrical errors on the basis of X-ray tomography measurement data. Time-consuming reverse engineering is no longer necessary and the number of corrective iterations for injection mold development or additive manufacturing is minimized. Test plan preparation is now possible on the basis of PMI data. Dimensions provided by the design engineer, including nominal values and tolerances, can be taken directly from 3D CAD models.

We invite you to get to know the wide-ranging possibilities of our 3D coordinate measuring machines!

Dr. Ralf Christoph
President and Owner
Werth Messtechnik GmbH



The highly precise optical fiber sensor Werth Interferometer Probe WIP

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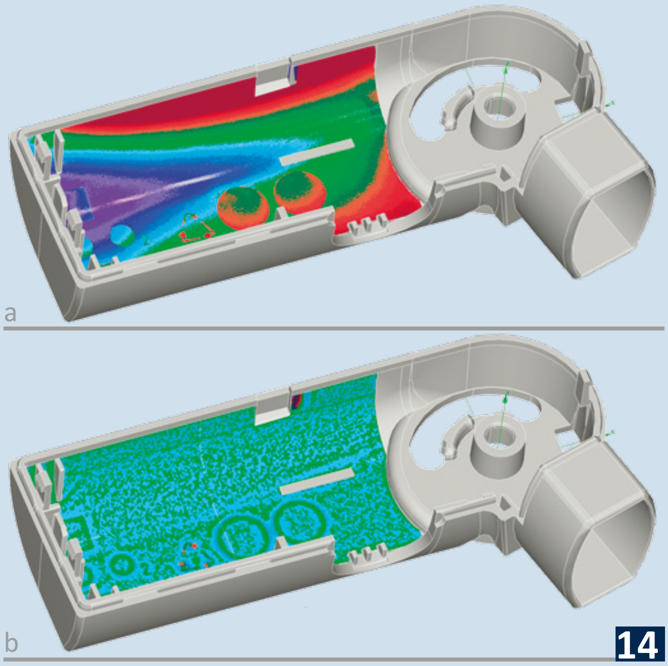

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Using WinWerth® FormCorrect with its high precision, the deviations of the plastic injection molding workpiece (a) are often corrected in only one iteration (b).

As the diversity and complexity of workpieces increases, measurement tasks can often no longer be addressed with just one sensor.

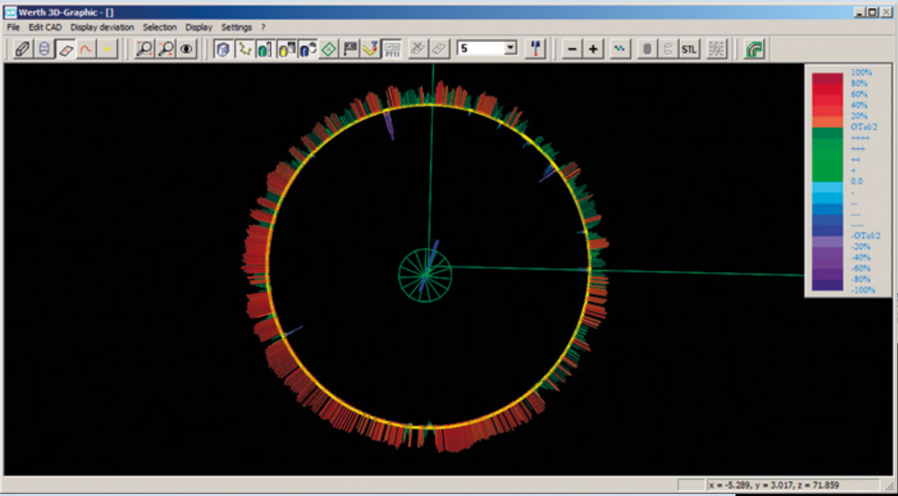
Contents

WinWerth® 8.42 – Many New Functions

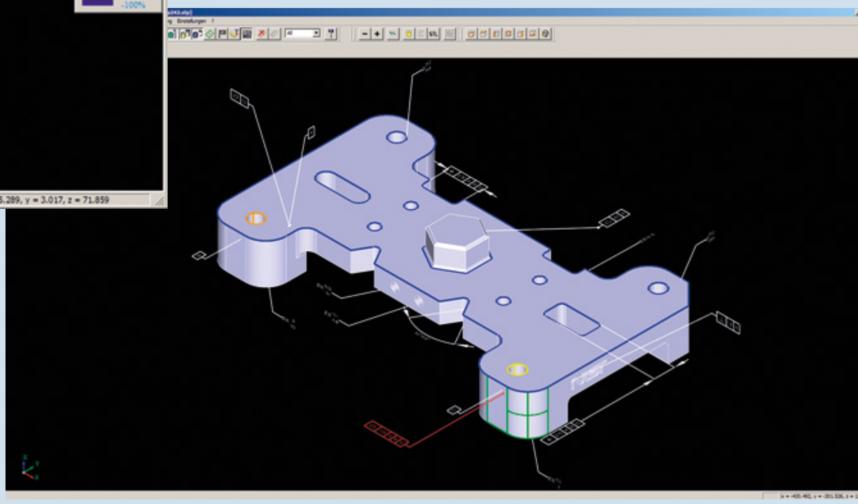
The WinWerth® 8.42 measurement software offers a variety of new functions for multisensor systems and X-ray tomography. For coordinate measuring machines with multisensor technology, in addition to PMI supported measuring (see below), 2D-CAD-Online® and 2D-CAD-Offline® have been integrated into the 3D graphic. The range of functions is dependent on the individual data of the used 2D or 3D CAD model (see p. 13).

The new feature FormCorrect accelerates product development processes based on X-ray tomography data (see p. 14-15). Volume Patch Selection provides for the measurement of multi-material workpieces with high lateral resolution all the way up to the outer edges of the workpiece (see p. 22). In addition to depicting CAD models and measurement point clouds, the 3D module now allows to depict voxel volumes in the same coordinate system (see p. 23).

Many other details, such as an improved display of geometrical characteristics in the 3D graphic (see p. 22), the automatic recognition of the geometrical feature when clicking on the CAD model, and color-coded deviation plots with adjustable spike width for improved orientation, increase the user-friendliness.



Color-coded plot of runout error

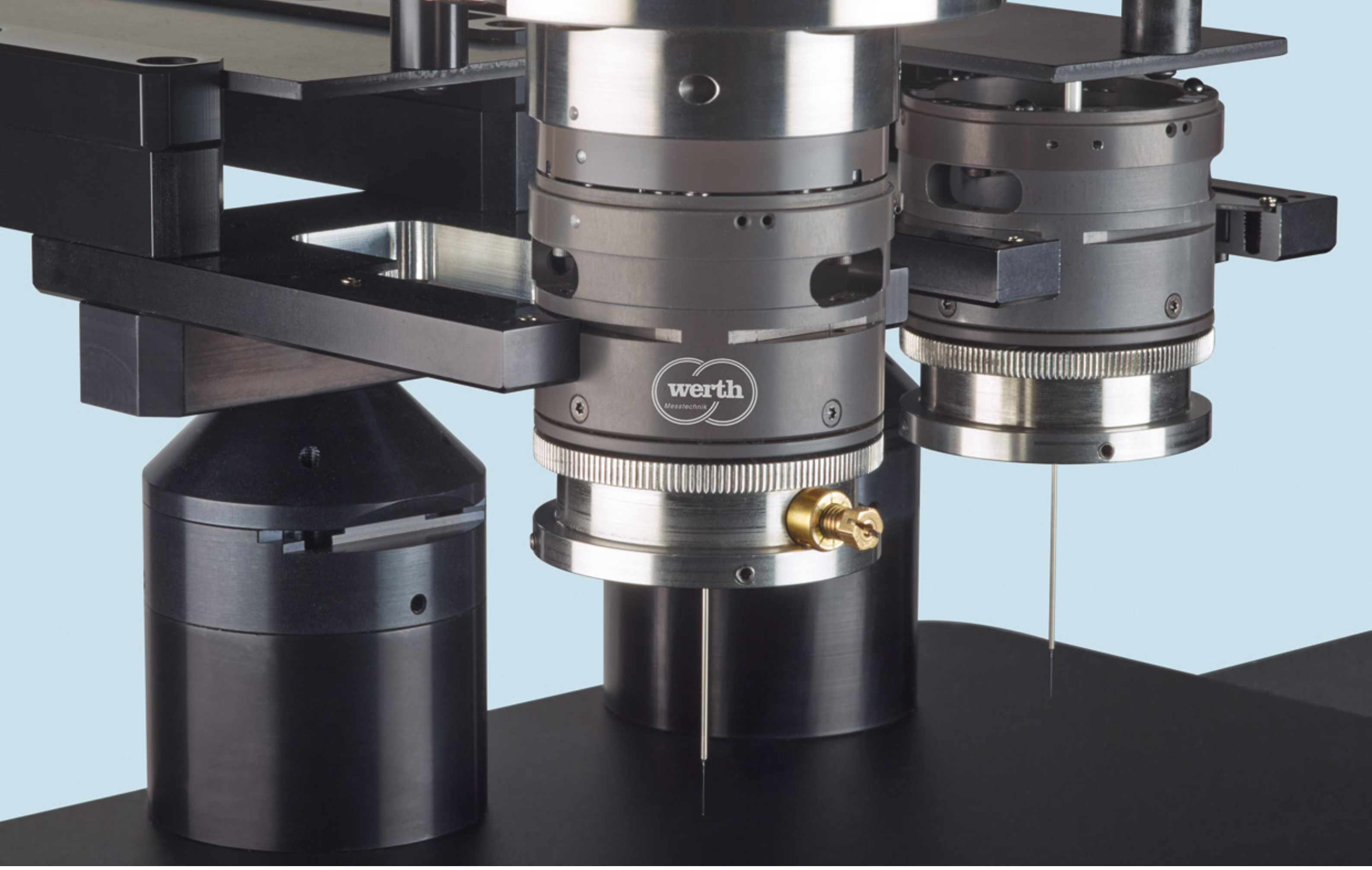


By clicking on the geometrical characteristic, the elements that must be measured are color-coded, for example with a blue border.

Measuring Made Simple with PMI Support

Many CAD systems now offer the option of integrating PMI data (Product and Manufacturing Information). The resulting CAD data sets contain, in addition to geometric descriptions of the CAD elements, the dimensioning provided by the design engineer, including tolerances and datum elements. This information now forms an ideal framework for the creation of a measurement sequence using the WinWerth® measurement software. By clicking on the desired geometrical characteristic, all geometrical features needed for the measurement are color-coded. For measuring with the automatic scan path and point distribution, the user can click on the geometrical elements one after the other, and if required, modify the probing strategy, as well as measure immediately in the CAD-Online® mode. After the measuring has been completed, the nominal values and tolerances can be transferred directly from the PMI data into the measurement report and modified manually.

By overlaying the CAD model, PMI color coding and the display of the elements that have already been measured, additional work steps can be recognized easily. With PMI, the tolerated elements can be identified at a glance. Searching for the datum elements in the drawing is no longer required. This simplifies the interpretation of the task at hand and minimizes transmission errors at the same time.



Werth Interferometer Probe (WIP) – the measuring probe is a long, light-conducting glass fiber with a standard diameter of 125 µm.

If the Standard Fails – Highly Precise Optical Measurements of the Smallest Features

With conventional optical sensors, narrow and deep features, such as air gaps on electric motors or the roundness of fine injection nozzles, are often not measurable. Laser distance sensors, chromatic focus sensors and confocal sensors fail as a result of the lens' aperture, and oftentimes the working distance is too small. With the Werth Interferometer Probe (WIP), a highly precise optical fiber sensor is now available that measures via interference.

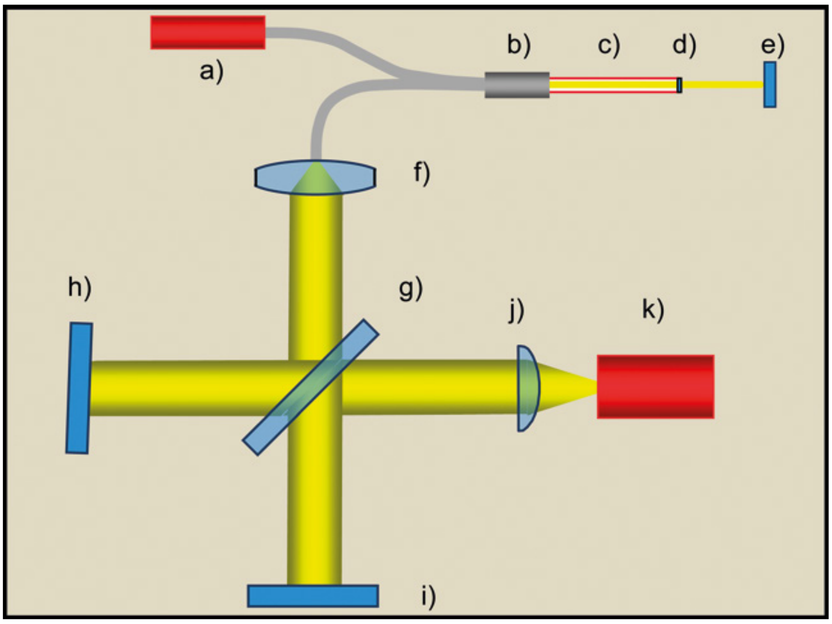
Function Principle

The WIP uses the physical effect of interference to determine the distance between the end of the optical fiber and the workpiece surface. The reference beam is reflected by the optical fiber's end, and the measuring beam is created through the reflection from the surface of the workpiece and is superimposed with the reference beam. The light is generated using a superluminescent diode (SLD). This provides for a highly precise interferometric measurement of the position of the workpiece surface. At the same time a beat signal is generated through the different SLD wavelengths. Since this beat signal has a significantly greater wavelength than light, the sensor's measuring range is increased to technically useful distances.

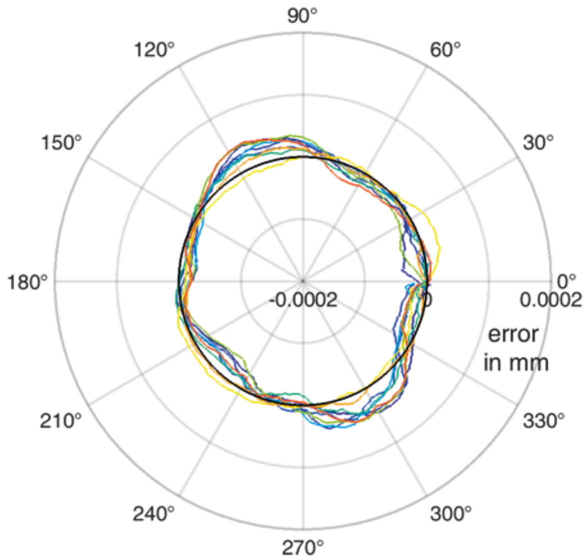
The evaluation interferometer splits the light beam with the beat signal into two beam paths of differing path lengths. This balances the path length difference of both light beams so that they are able to interfere. By tilting one of the two mirrors, the axial location information of the beams (depending on the position of the workpiece surface) is converted into information for lateral evaluation. Depending on the position on the mirror at which the beam is reflected, different lateral intensities arise, producing interference patterns. These are captured by means of a camera, and then the distance between the reference surface and the workpiece surface is derived.

Different Probe Geometries

The measuring probe is a light-conducting glass fiber with a standard diameter of 125 µm, smaller probes are available. By guiding the fiber in a metal tube,



Principle of the interferometer point sensor (WIP): a) superluminescent diode, b) fiber coupler, c) probe, d) probe exit and reference surface, e) workpiece surface, f) collimator lens, g) beam splitter, h) mirror 1, tilted, i) mirror 2, j) cylinder lens, k) line camera



Roundness measurements with minimal measurement errors of about 100 nm

very long probes can be produced for larger immersion depths. The probe geometry can be manufactured for the individual requirements of the measuring task, for example straight or L-shaped probes are available. The angle of the probe determines the exit angle of the measuring beam between 0° and 90°. Probes with 90° angles are used for the measuring of the circumferential surface of small holes, for example.

Highly Precise Roundness Measuring with the WIP/RS

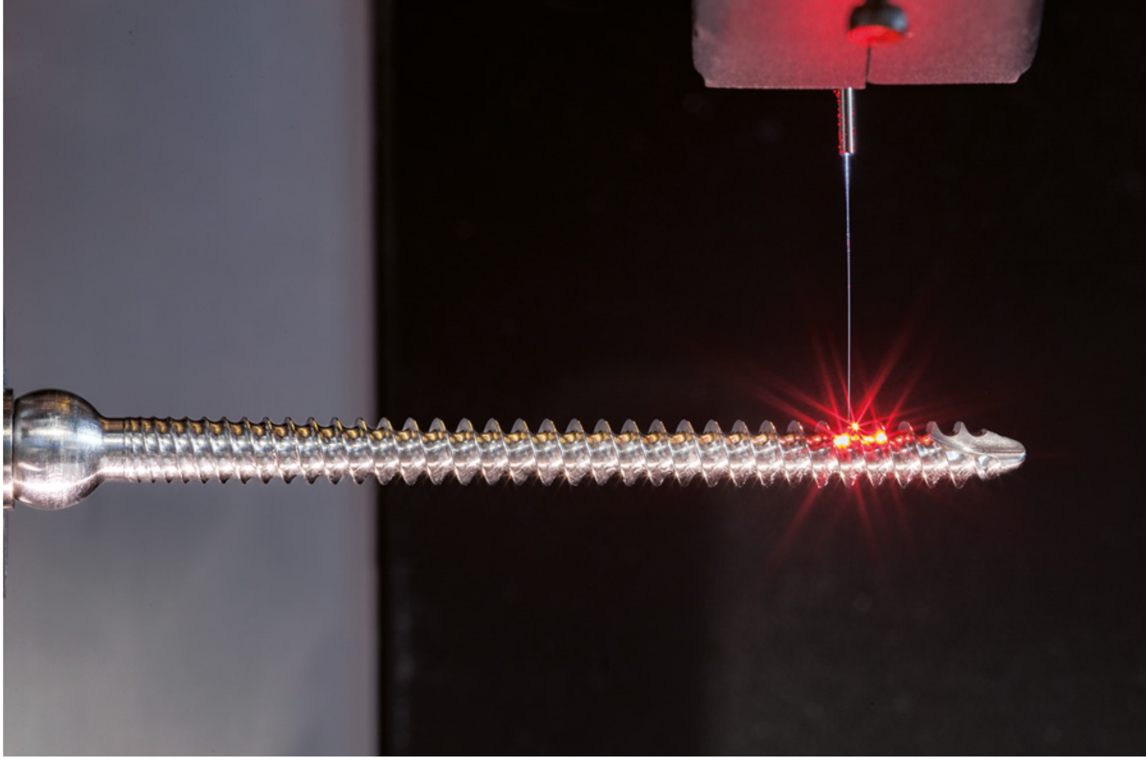
The WIP/RS provides for a highly precise roundness measurement with a rotating probe. The probe is rotated only through the movement of the highly accurate sensor rotary axis. The user can move the probe from a middle position to an outer position and adjust the desired radius of the cylindrical geometrical element. This functionality allows one to perform roundness measurements with measurement deviations of approx. 100 nm. Alternatively, the probe can be moved during the rotation with the Cartesian axes of the coordinate measuring machine on a circular path to measure larger geometrical features.

The Werth Interferometer Probe (WIP) provides for measurements with tight tolerances in deep holes and narrow slits with long measuring probes. This functionality provides for the ability to measure a cone seat in a fuel injector nozzle at a depth of more than 10 mm exactly to the sub-micrometer. Another example is the ability to measure the flatness of deep, sensitive bearings in a gear housing. This sensor is also suited for non-contact roughness measurements. In this case, the precision advantage of the process is of particular significance when compared to the triangulation or focus variation processes.

Multisensor Metrology for Surgical Instruments and Implants

For the Good of the Patient

No other industry is subject to as much regulation or high customer expectations as the field of medical technology. In order to meet all of the quality requirements, Gebr. Brasseler uses the latest measurement technology, which feeds the company‘s digital process chain on the software side. By networking with CAD, CAM, and CAQ, the medical technology manufacturer is able to produce top quality and still get to market quickly.



Measuring with the Werth Fiber Probe® (WFP) a thread on a pedicle screw for stabilizing vertebral bodies

Gebr. Brasseler is an international medical technology company with over 1,000 employees at its headquarters and main production facility in Lemgo, Germany. For over 90 years, the brand name Komet has stood for high-quality dental drills. With these rotating instruments and other dental tools, the company became a global leader in innovation and quality. From this strong position, Gebr. Brasseler developed Komet Medical, a division that manufactures rotating instruments, saw blades, immobilization and navigation pins, and other products for orthopedics, ENT, and neurosurgery, in the 1990s. Starting in the fourth quarter of 2017, the scope of manufacturing technology has expanded to include the spinal implant product group. Komet Medical will only be a contract manufacturer in this area, however.

While Komet Medical branded products are sold as catalog items by distributors all over the world, the division, which has been managed as a separate business unit since 2013, is also a production partner for numerous PLMs (private label manufacturers). Jens Haverkamp, General Manager of Komet Medical, explains, “For some PLMs, we now deliver complete sterile-packaged products bearing their label. This is a sign that our quality is truly first-class and that customers trust our entire process chain.”

No wonder, as Brasseler works according to a comprehensive quality management system certified to the EN ISO 9001 and EN ISO 13485 standards. Regulatory requirements, however, have grown tremendously in recent years. In order to reliably meet all the specifications, the development process often takes up to a year, starting with a risk analysis per DIN EN ISO 14791. “This places tremendous pressure on project and product management,” says Jens Haverkamp. “Ultimately, product launch times should be as soon as possible for cost reasons.”

Optimized Processes Under Industry 4.0

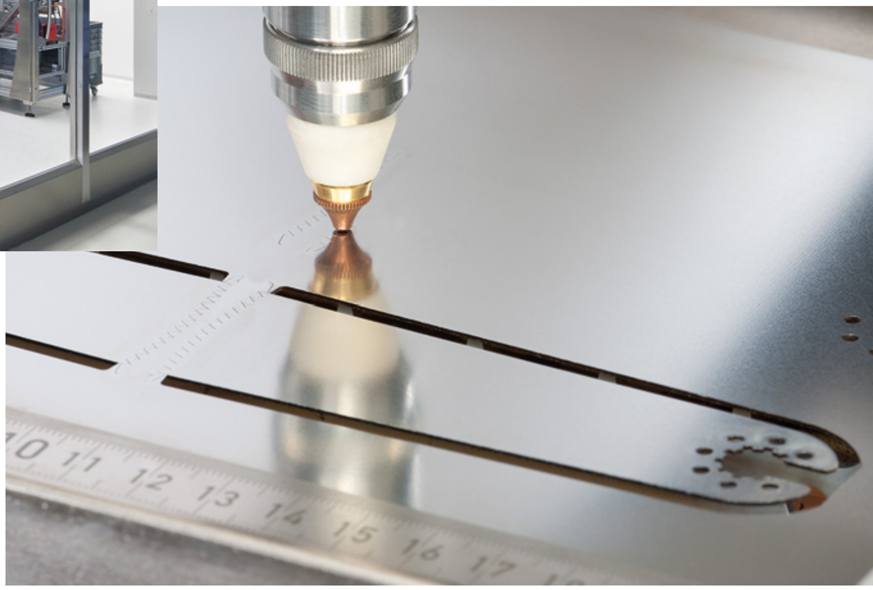
Gebr. Brasseler reacted several years ago and optimized the entire process, from product development to shipment of finished parts. The term Industry 4.0, familiar throughout Germany, describes production that is self-organized and monitored to the greatest extent possible. Investments in new hardware and software were combined with the development of optimized design methods and digital data flows.

The optimization process also included quality assurance and metrology, which in Jens Haverkamp’s view will take over a large portion of the manufacturing process in the future (Figure 1). “In order to meet all the specifications, we need traceable and reproducible processes at all times. This can only work with high-precision metrology that covers the entire process and is integrated in our digital network.”

For a long time now, Brasseler has partnered with Werth Messtechnik, a leading company in coordinate measuring technology with optical sensors, multisensor systems, and X-ray tomography. Many ScopeCheck®

Demonstrable high quality is critical to the continued market success of Komet Medical saw blades.

Using modern metrology, even the strict requirements for the medical industry are met.



and VideoCheck® multisensor coordinate measuring machines are in use in the Lemgo facility. Jens Haverkamp explains why, “Multisensor systems are indispensable, especially for our rotating and oscillating instruments. In order to capture various different features, we need optical image processing sensors and lasers, as well as various probes.”

Komet Medical, where such sophisticated instruments as the high-speed drills for neurosurgery and the new spinal implants are produced, uses the Werth VideoCheck® FB DZ, a high-precision multisensor coordinate measuring machine with a fixed bridge design and air-bearing technology. In order to use sensors flexibly, it also has a rotary/tilt axis, in addition to the three linear axes. Besides an image processing sensor with a fixed magnification, the patented Werth Zoom is equipped with an integrated Werth Laser Probe (WLP) optical distance sensor. The Werth Fiber Probe® (WFP), also patented, makes it possible to measure extremely small geometries with high tactile accuracy. Metrologists at Komet Medical use it to check a pedicle screw that helps to stabilize vertebral bodies. To find the core diameter of a twist drill, they use the patented Werth Contour Probe (WCP). The tactile-optical WCP can be used to perform profile and roughness measurements as well.

Axel Pieper, Group Lead for Quality Engineering, explains, “We derive the need for measurement systems from the required measurement tasks in each case. When highly accurate measurements or multisensor systems are required, we typically use Werth VideoCheck® or ScopeCheck® machines for both process-integrated measurements and final inspections.” For the saw blades product group (Figure 2), which has entirely different measurement tasks, the quality assurance team at Komet Medical uses the latest machines in the Werth FlatScope series. “The Werth FlatScope was the only measurement device that was able to meet our requirements,” says Axel Pieper.

Besides the Technology, the Overall Concept is Critical

At Brasseler, the required measuring equipment is always discussed with the team (Figure 3). For new acquisitions, the decision is made unbiasedly using defined key factors, one of which is a suitable overall concept. Quality expert Pieper explains, “The measuring machines and their software need to be able to be integrated in our structures, including the digital ones. For example, we need to have the superstructure of a software system with an offline programming option. It also has to be able to exchange data with our various systems.”

This is because the decision-makers at Gebr. Brasseler have designed the process chain to be completely digital in order to reduce time to market. A 3D volume

Jens Haverkamp (left) and Axel Pieper agree, „We need reliable, long-term partners like Werth Messtechnik to provide quality products, which can be integrated into our digital network."

model is created in the CAD system, from which the NC programs required for machining are derived in the CAM system. In parallel, the volume model is used to program the measurement sequence offline in the WinWerth® software. The measurement technicians at Komet Medical are thus able to create a measurement program for a new product before a single workpiece has come off the machine. Offline programming thus speeds up production starts and keeps the measuring machine free for other tasks.

The WinWerth® measurement software includes a CAD as well as a CAQ interface. Werth Messtechnik has a special projects department that takes care of customer-specific interface adaptations. "The data exchange with CAQ software means that we can use part of the measurement program to create the inspection plan. It defines the inspection sequence, when each feature is measured, and at what frequency the inspection needs to be performed. The dimensions and tolerances are taken from the measurement program," explains Pieper.

When the programs support process-integrated measurement, the measurement results flow directly into a modern CAQ/SPC software system that performs statistical analysis and gives appropriate feedback. The result is a data bundle that extends across all process stages. Axel Pieper sums it up, "In the end we benefit from faster processes and increased reliability. Manual entry is completely eliminated as a potential source of errors."

Data Exchange Defines the Future

Komet Medical General Manager Jens Haverkamp considers this cooperation with Werth Messtechnik to be the way of the future. "We need reliable, long-term partners like Werth to provide quality products, which can be integrated into our digital network." He especially prizes the willingness of his metrology partner to work closely with Brasseler as an end user, as well as with grinding system manufacturers and CAQ software providers.

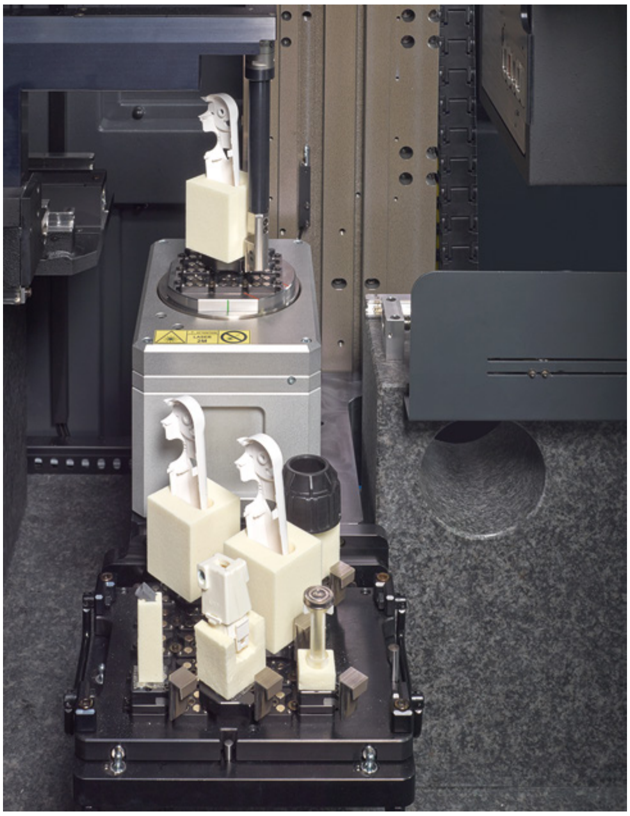
Cross-company partnerships will increase in the future, in his opinion. The reason for this, in Haverkamp's view, is that projects take much longer due to regulatory requirements, especially with large partners in medical technology. This produces close partnerships that last many years and often lead to identical measurement technologies being purchased and used. "Unlike in previous times, data exchange is often much more open, which strengthens both partners in the end," asserts Haverkamp confidently. For him and for Komet, this already means, "Our customers know what machines we work with and what we measure. We share measurement programs with our project partners in order to reduce costs and also build a secure basis to guarantee that measurements are correct." This eliminates incorrect measurement strategies, so the measured values and results can be discussed immediately.

New Workpiece Changing System for TomoScope®

The workpiece changer for the TomoScope® line automatically feeds workpieces into the machine for optimal usage. The workpiece carriers are located in the device, so measurement sequences can be run during unattended shifts without having to make special radiation protection precautions.

There are several gripper types for the different workpiece carriers. The new version of the changing system allows for the positioning of the differently sized workpiece carriers anywhere on the pallet without having to calibrate the position each time. The system has been converted from a pneumatic to a mechanical one, and, as such, requires no maintenance and has less downtime.

The user friendliness of the system is much improved by the graphic depiction in the WinWerth® 8.42 measuring software. Another new functionality is the ability to use several loaded pallets. This shortens the set-up times significantly. Additional time savings can be achieved by using the loop function for the quick teaching of series measurements.



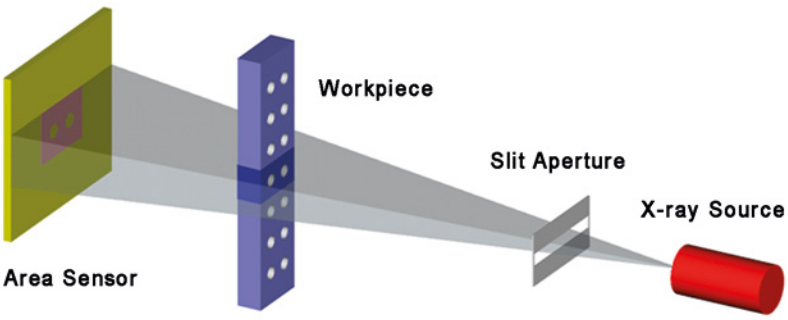
Positioning of workpiece carriers is now possible anywhere on the pallet without calibration.

Reducing Cone Beam and Scattered Radiation Artifacts

When measuring workpieces with high radiographic length or high material density, such as cylinder heads or turbine blades, scattered radiation and cone beam artifacts often occur. They make inspection tasks more difficult and increase measurement uncertainty when capturing geometric properties. Some features on workpieces that are hard to penetrate are thus difficult or impossible to measure.

These interference effects can now be greatly reduced for Werth CT coordinate measuring machines, with the use of scattered radiation artifact reduction (SAR), a special aperture in the X-ray beam path, and a corresponding operating mode for raster tomography. When the aperture is used in raster mode, only part of the workpiece is exposed, which reduces the proportion of scattered radiation. The matching detector region is chosen automatically. Alternatively, the height of the active detector area can be adjusted and the planar detector can be used like a line-sensor. Limiting the detector range reduces cone beam artifacts as well.

With flexible adjustment of the line width, an optimal compromise between measurement time and quality of the measurement results can be achieved. The flexibility of the coordinate measuring machine is increased, eliminating the need for a separate investment in a line sensor, as the area sensor can incorporate this function when needed. SAR scattered radiation artifact reduction allows highly accurate measurements of the entire workpiece, with reduced artifacts even for workpieces that have always been difficult to measure.



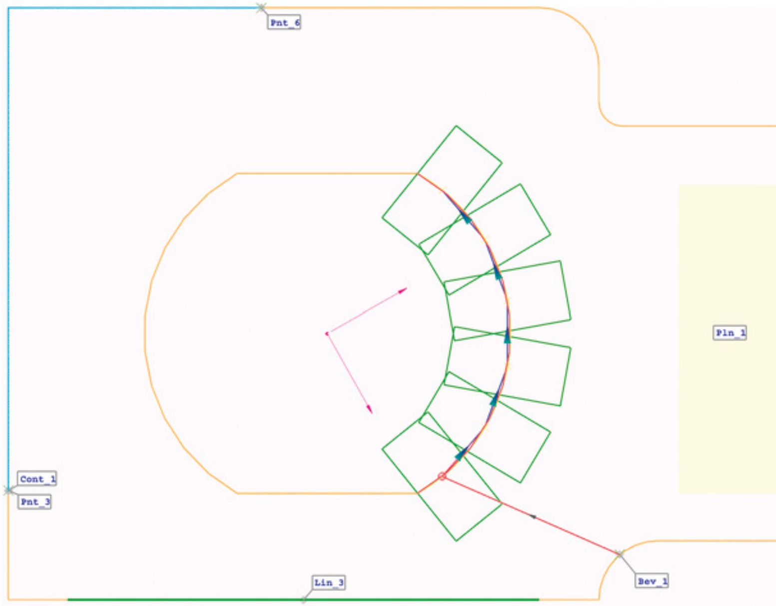
SAR Scattered Radiation Artifact Reduction with slit aperture and Raster Tomography

Aligning and Teaching with Just a Mouse Click

Creating measurement programs with 2D-CAD-Online® or 2D-CAD-Offline® is as simple as can be. These two options allow easy CAD-based measurements of 2D contours using the most appropriate sensor. The controls are integrated in the 3D graphic of the WinWerth® software program. The functions available depend on the 2D or 3D CAD model, and the previously separate 2D CAD view has been eliminated.

The Raster Scanning HD (patented) and AutoAlign options are now available for CAD-based measurements for the first time. This makes it much easier to align the coordinate systems of the CAD model and the workpiece. When the CAD element is clicked, WinWerth® automatically recognizes the nominal element and creates the point distribution. In addition to lines, circles, points, and planes, contours can also be scanned, and now it is possible to measure edge breaks completely automatically in conformance with standards.

The terms 2D-CAD-Online® and 2D-CAD-Offline® were coined by Werth Messtechnik in 1996. Using 2D-CAD-Offline®, the measurement program can be created offline, away from the machine, with the nominal data (CAD), before the first workpiece is produced. This also means that the coordinate measuring machine is not tied up for programming and is available for other tasks. With 2D-CAD-Online®, in contrast, the user can control the machine axes and sensors using CAD data in order to create programs quickly without manual positioning.

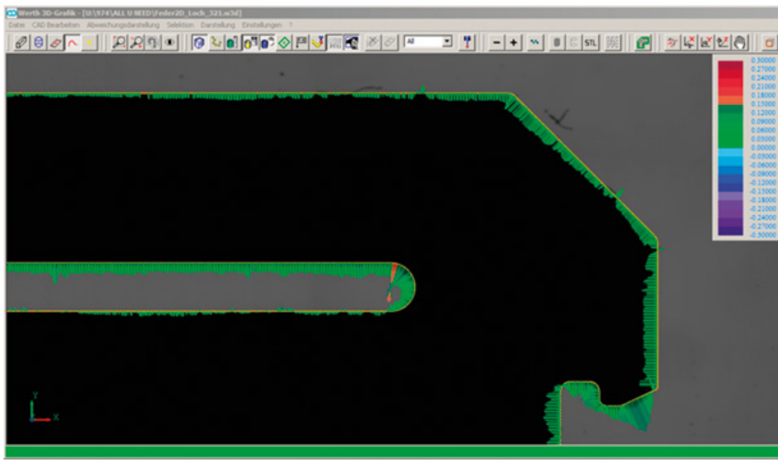


With 2D-CAD-Online®, various geometrical features can be measured directly by clicking the Werth 3D graphic.

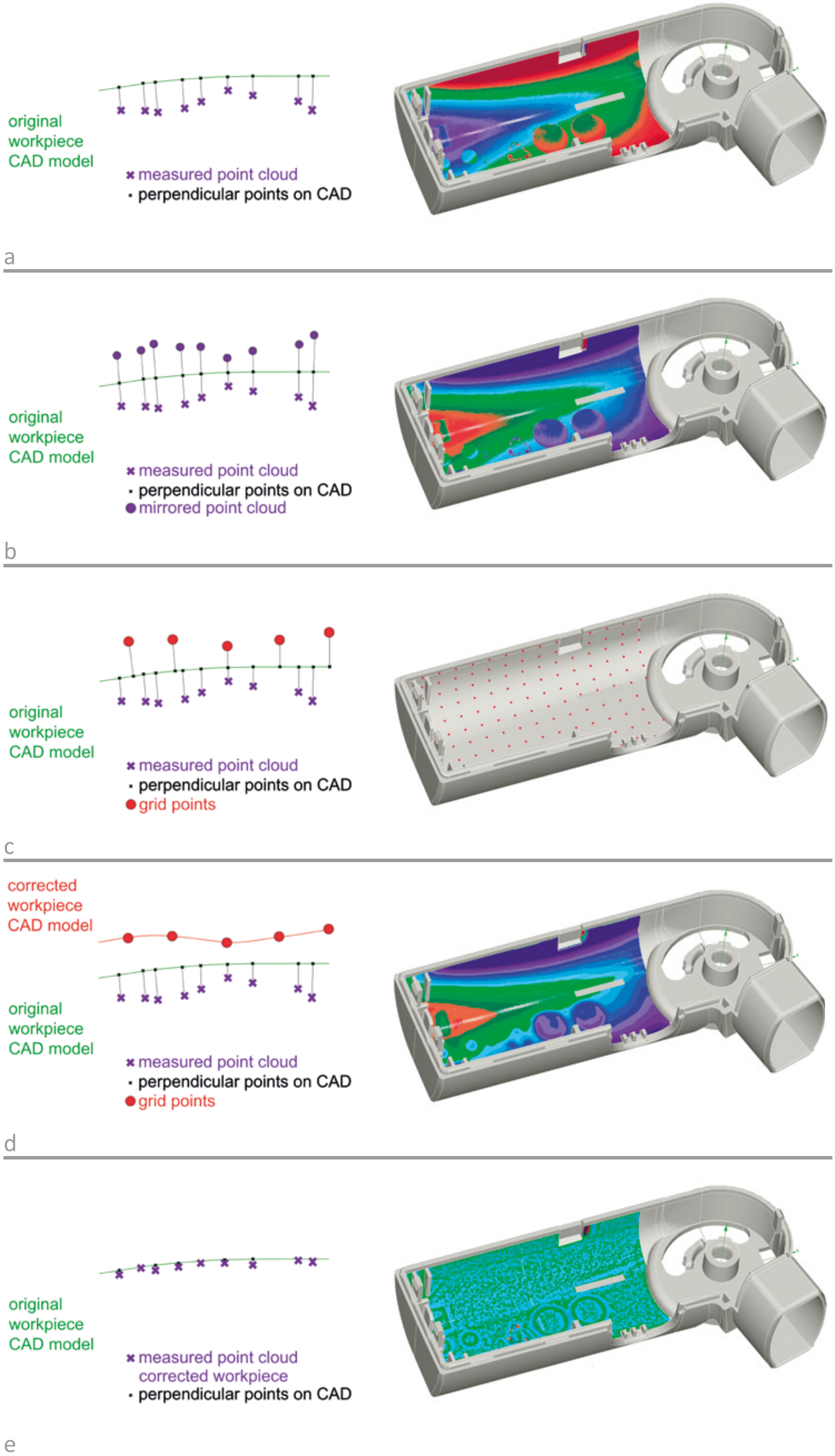
WinWerth® Profile Projector Function

The patented Raster Scanning HD method can be used to capture an entire workpiece automatically at high resolution. A new function also makes it possible to overlay this raster image with the 2D CAD model in DXF format within the Werth 3D graphic. The software thus takes on the function of a profile projector. The actual condition in the raster image can be visually compared to the nominal condition from the 2D CAD model. This allows a rapid visual check of the extent or presence of various geometries. Problem areas can be zoomed in on quickly, as the image has very high digital resolution.

The 3D BestFit, 3D SurfCompare and the Contour element options also allow BestFit analysis with a color-coded deviation plot. Local deviations between the measured data and the CAD model can be inspected using the mouse cursor. The deviations can also be displayed with flags, and the least and greatest deviation are detected automatically.



A raster image superimposed on a DXF file, with color-coded deviation plot from contour comparison



The functional principle (left) and WinWerth® FormCorrect results: a) deviation between measuring data generated using a Werth TomoScope® and the workpiece CAD model, b) deviations mirrored at the surface of the workpiece CAD model, c) automatically determined grid points to calculate the corrected surface, d) deviations of the corrected surface to the original workpiece CAD model, this is equivalent to the corrections of the mold, e) remaining deviations after correction of the mold CAD model, modification of the mold and new manufacturing

WinWerth® FormCorrect – a New 3D Correction Process for Workpieces

Plastic injection molding tools or nominal data for 3D printers are created on the basis of workpiece geometry. Even though complex manufacturing process simulations are used, process-related systematic geometrical deviations occur. This is caused by manufacturing parameter deviations, insufficient shrinkage process simulations, nonhomogeneous mold injections, as well as nonhomogeneous cooling processes. FormCorrect can change the plastic injection mold or the CAD model for the 3D printing process, such that the finished workpieces are within the defined tolerance range.

Reduction of Product Development Time

Until now, corrections performed on plastic injection molds were largely done manually. To accomplish this, the deviation between nominal and actual is determined by measuring the test workpiece. The correction is performed by manually inputting data into the CAD/CAM system or relatively costly correction respectively recreation of the CAD model with reverse engineering software.

With FormCorrect, the exact workpiece geometry is achieved by a mostly automatic correction of the CAD model. The deviations between the original CAD model and the test workpiece measurement data are directly determined by the WinWerth® measurement software and mirrored at the CAD model surface. Using this data, WinWerth® generates a corrected CAD model, with which systematic manufacturing deviations are compensated. On this basis, a preview of the remaining deviations of a corrected workpiece is now possible. Extensive reverse engineering, which requires expert qualifications, is no longer needed.

The geometric changes can be realized both in the workpiece CAD model and in the mold CAD model. Using the corrected workpiece CAD model, a new simulation of the manufacturing process is performed, and a data set for the workpiece rework is generated. The simulation parameters used here are the same ones used in the creation of the first sample workpiece. Due to its high precision, FormCorrect often requires only one corrective iteration, which in turn results in a significant reduction in development process costs.

WinWerth® Advantages

Through the integration into WinWerth®, the changes to the CAD model can be realized on the basis of the standard alignment process. The coordinate systems can, for example, be set via reference elements either with the help of multi-point alignment (MPA) or by using a Gaussian adjustment. With this, FormCorrect can be used with a variety of application specific alignments, which correspond to the functional and manufacturing-related specifications. The option of a largely fully automated correction process reduces operator influence and increases user-friendliness. The result is a corrected CAD model that is compatible with practically all existing CAD/CAM systems. The implementation of a new CAD/CAM software is no longer necessary.

Flexible, Efficient, and Exact

In contrast to common reverse engineering, the application is now much simpler. Based on a color-coded deviation depiction between nominal and actual, the user can simply click on the areas that are to be corrected in the CAD model. FormCorrect is able to calculate individual surfaces that are mathematically unlimited or limited by curved edges. The transitions between different surfaces can be automatically calculated now, and the corrected surfaces can be adjusted into the entire CAD model.

Measurement data is the basis of FormCorrect. This data is best generated using Werth TomoScope® machines to capture the workpiece geometry. Through the use of X-ray tomography, the entire workpiece can be captured, and the CAD model can be corrected using this information. The high measurement point density enables high-resolution correction. The high-precision and traceability of the measurements ensure excellent product quality that is achieved with a reasonable investment of time and effort.

From Tactile Systems to Coordinate Metrology with Optics, X-ray Tomography and Multisensor Systems

25 Years of Rapid Development in Coordinate Metrology

It‘s hard to imagine a modern quality assurance approach that does not use coordinate measuring machines with multisensor systems. This has not always been the case; rather, it is the result of rapid developments over the last 25 years. This technology is now suitable for a wide variety of measurement tasks that are the outcome of increased automation and tougher requirements for measuring speed and precision.

Figure 2: The image processing sensor – seen here with the patented Werth Zoom with variable working distance and lighting angle – is one of the fastest and most accurate sensors.

Figure 1: In 1987, Werth Messtechnik presented the first multisensor coordinate measuring machine, the Inspector®.

In the 1980s, coordinate metrology was dominated by tactile machines. The sensors for similar optical measuring machines were not yet available. The first solutions came about in the late 1970s when Dr. Siegfried Werth developed the Werth „Tastauge," [1] a punctiform optoelectronic fiber sensor for measuring projectors (comparators). The use of CCD cameras for coordinate metrology was also being investigated [2]. It was still some time, however, before functional measuring machines with image processing sensors were developed. The first machines with CCD cameras and image processing were available by the end of the 1980s. Examples are the Inspector® from Werth [3] (Figure 1) as well as similar machines from other companies. High prices and often inadequate performance kept these machines from widespread use, and they were not able to penetrate the market.

Introduction of Digital Image Processing

PC technology in the early 1990s, with the first frame grabbers, was powerful enough to automate optical coordinate measuring machines. With a management buy-out in 1993, now 25 years ago, business autonomy was reclaimed and Werth Messtechnik was the first European manufacturer to introduce a coordinate measuring machine with image processing based on PC technology, the VideoCheck® [4]. It enabled automatic measurement using incident light and measurements in 3D with autofocus points. The decision by Werth to embrace image processing on the PC and Windows operating system platform was considered a mistake by many experts at the time. Today this solution is the standard.

In the following years, image processing sensor development continued to advance. The patented Werth Zoom (Figure 2) made it possible for users to adjust not only the magnification but also the working distance for different measurement tasks. The MultiRing® can be used to adjust the lighting angle over a wide range to meet the requirements of the workpiece for reliable measurements.

Even after 20 years of image processing in coordinate metrology, revolutionary developments are still possible today. For example, the Raster Scanning HD process presented in 2016 enables previously unknown measuring speeds while increasing accuracy. To do so, images of the workpiece are recorded at the maximum camera frequency while in motion and are superimposed by a patented method to form an overall image (Figure 3). Large areas are captured quickly at high resolution. This method makes it possible, for example, to completely capture a 7-inch wafer at a very high magnification within a measurement time of just 2 minutes. An image with 256 megapixels is produced, from which the geometric properties of the wafer can be determined. Another application is the measurement of complete cutting edge geometries on hob-cutters. It is possible to measure 32 teeth in a row within 1.5 seconds and analyze them „in the image."

From Image Processing to Multisensor Systems

As the diversity and complexity of workpieces increases, measurement tasks can often no longer be addressed with just one sensor. Multisensor coordinate measuring

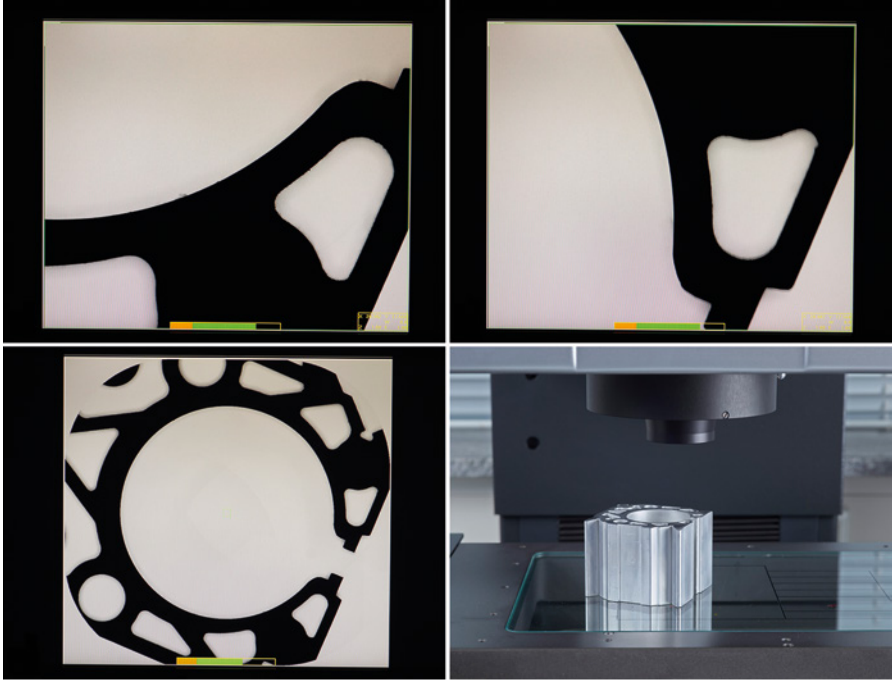


Figure 3: Raster Scanning HD (patented) provides high-resolution images in seconds.

Figure 4: The patented Werth Laser Probe is integrated in the beam path of the Werth Zoom image processing sensor.

machines are created by integrating various sensors in one measuring machine, each allowing individual adaptation to a specific task. Because all of the sensors measure in the same workpiece coordinate system, the measurement results can be linked together in any combination.

With the success of image processing, an obvious next step was to integrated such sensors in tactile coordinate measuring machines as an alternative, resulting in multisensor coordinate measuring machines (such as the VP1 video probe system) [5]. These solutions were not very successful on the market, however, because the image processing sensors had to be very compact. This placed limitations on the performance and flexibility of the imaging optics and lighting systems. Another approach to multisensor systems equipped the image processing sensor with an integrated laser distance sensor [3] (Figure 4). This was a purely optical multisensor coordinate measuring machine at first, allowing faster 3D measurements than had been possible with the autofocus function of the image processing sensor alone.

The use of a combination of optical and tactile-electrical sensors was successfully advanced by Werth Messtechnik starting in 1993, as the already established Renishaw probe system was integrated in the compact optical VideoCheck® coordinate measuring machines [4]. Soon tactile scanning operation modes made rapid measurements of contours possible with high point density, combined with 2D image processing measurements and laser scanning in 3D.

Cooperation between medium-sized companies and universities and other research institutions is particularly well advanced in Germany. Cooperative efforts between Werth Messtechnik and the Physikalisch-Technische Bundesanstalt (PTB – the German National Institute of Metrology) in 1998 resulted in a tactile-optical micro-stylus [6]. This patented measurement principle uses the flexible glass fiber solely for positioning the probe sphere, which can be as small as 20 µm in diameter. The deflection of the sphere is measured optically by an image processing sensor. This principle results in lower probing force, higher accuracy, and improved robustness, particularly in comparison with conventional micro-styli (Figure 5). The 3D Werth Fiber Probe® was developed from the original 2D principle in 2011 [7]. It can use practically all measurement methods familiar from conventional tactile probes, such as single point probing and scanning.

Over the following years, the spectrum of optical distance sensors in particular was expanded. The laser distance sensors mentioned above were supplemented by chromatic focus sensors for measuring surface contours and flatness on reflective surfaces. That sensor

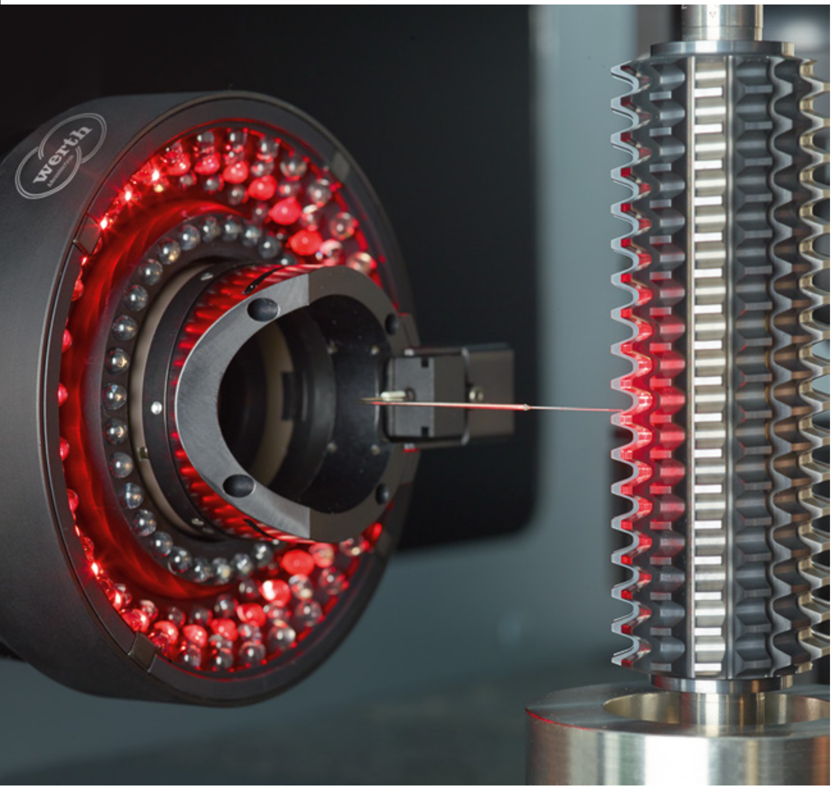


Figure 5: The Werth Fiber Probe®, or WFP (patented), with a probe sphere as small as 20 µm in diameter, is the most accurate micro-stylus on the market.

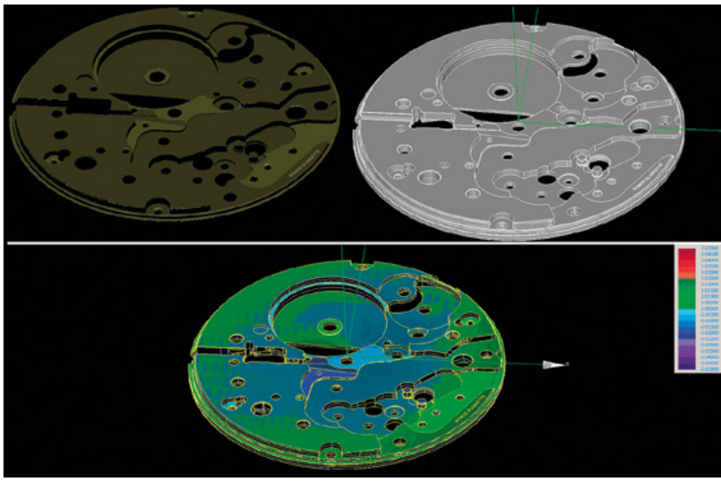


Figure 6: Optical distance sensors provide a 3D point cloud of the workpiece surface (top left), which enables a target-to-actual comparison with the CAD model (top right) in addition to dimensional measurements, along with a color-coded deviation plot (bottom).

determines the distance to the workpiece surface based on the different focal planes of the colors that make up white light, so it is often simplifying referred to as a white-light sensor.

Area sensors that use the focus variation principle, such as the Werth 3D Patch, or confocal sensors, such as the Nano Focus Probe (NFP) [8] capture surface topographies with high point density to determine roughness, shape, and other geometric properties. With both measurement principles, one 3D measurement point is determined for each pixel in the camera. To do so, the sensor is moved perpendicular to the workpiece surface while the contrast (for focus variation sensors) or image brightness (for confocal sensors) is evaluated to determine the distance to the workpiece surface.

Line sensors are used to rapidly measure relatively large areas of the workpiece surface. The Laser Line Probe (LLP) and now, since 2017, the Chromatic Focus Line Sensor (CFL) are available (Figure 6). The CFL combines high measuring speed with high accuracy in an unprecedented manner.

The various aforementioned measurement principles differ in potential accuracy and primarily in their dependence on the contrast, reflective behavior and inclination angle of the workpiece surface.

Specifications using uniform scales and certified calibrations allow objective comparison of the performance of various coordinate measuring machines, ensuring traceable measurements. In 2004 the first calibration lab of the DKD (Deutscher Kalibrierdienst – German Calibration Service) accredited to ISO 17025 for optical and multisensor coordinate measuring machines opened at Werth. The Werth DAkkS lab (Deutsche Akkreditierungsstelle – German Accreditation Body) is currently the only one that is also accredited for the calibration of coordinate measuring machines with X-ray tomography. This ensures that users can perform workpiece inspections using DAkkS-calibrated measuring equipment, as required by IATF 16949.

A New Sensor: X-ray Computed Tomography

The first experiments for introducing computed tomography (CT) to coordinate metrology took place in the early 2000s. Unfortunately, the process was still much too imprecise, with measurement deviations in the range of tenths of millimeters. One early solution was the Werth Autocorrection method, wherein a master part is measured using an accurate sensor and the deviations from the CT measurement are used to correct subsequent CT measurements of additional workpieces. This method and the use of proven components from multisensor coordinate measuring machines enabled Werth Messtechnik to create the TomoScope®

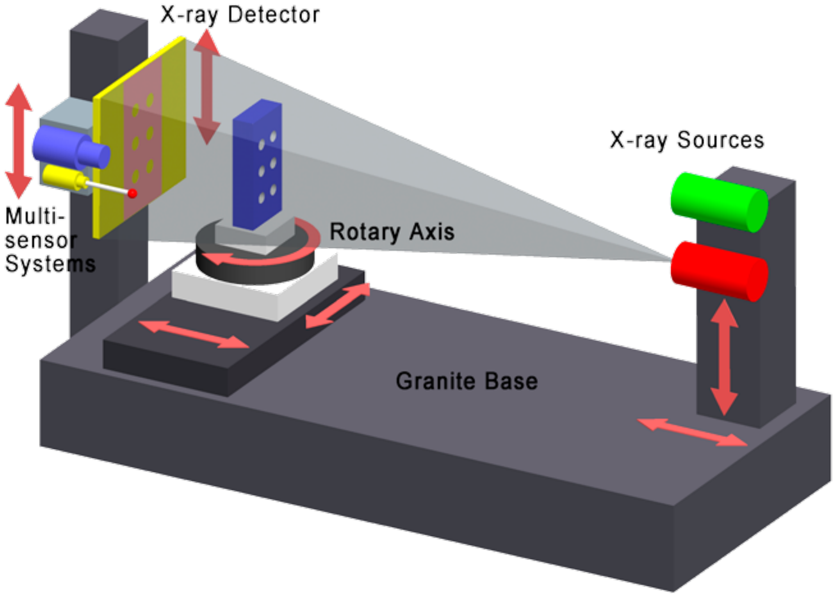


Figure 7: In X-ray tomography, the entire workpiece volume is reconstructed from radiographic images in various rotational orientations.

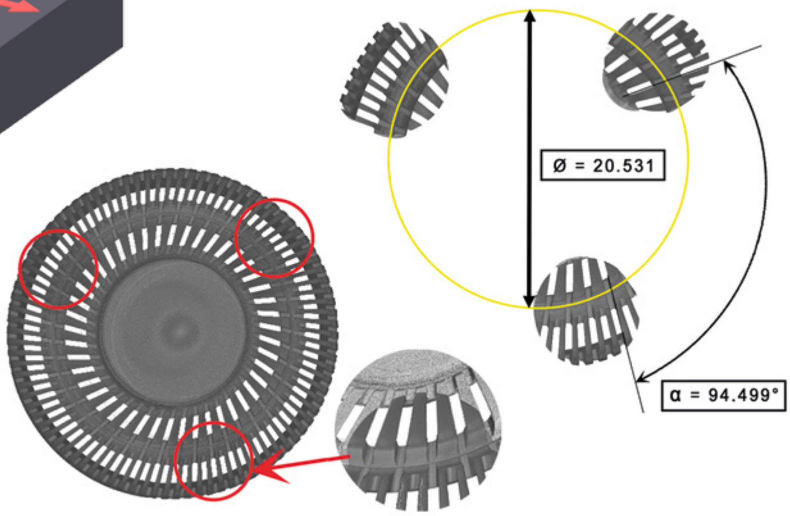


Figure 8: Using Multi-ROI CT, only the regions of interest are measured at high resolution, reducing measurement time and data volume.

200 in 2005, the first machine with X-ray tomography developed especially for coordinate metrology, with optional multisensor systems [9]. This machine already had specifications and measurement uncertainties comparable to conventional coordinate metrology. „Measure completely and accurately“ was the new motto, as now for the first time all of the areas of the workpiece that were difficult to access, including internal geometries, were able to be captured (Figure 7).

The field of X-ray tomography in particular is seeing rapid advancements. A series of software correction methods are now available, so that sufficiently precise CT measurements are usually possible without Autocorrection. With Autocorrection, the measurement process is even suitable for holes in motor vehicle fuel injectors with tolerances of 5 µm. One example of the many new developments in recent years is the Werth Multi-ROI CT (ROI – Region of Interest), which enables high-resolution measurements of any desired partial region of the workpiece by Eccentric tomography. With this method, the 3D point cloud of the workpiece from a low-resolution overview measurement is merged with high-resolution measurements of the regions of interest (Figure 8).

The Future of Multisensor Coordinate Metrology

The future points to increased integration. One example of this is the Werth Multisensor System, with conventional stylus systems, the fiber probe, and/or the contour probe, and accessories such as angle optics and ancillary lenses placed directly in the image processing beam path with an integrated laser distance sensor (Figure 9). The distribution of sensors on two independent axes, of which only the currently active sensor approaches the workpiece, also increases flexibility and operator convenience.

Measurement technology is increasingly being integrated in production processes. Functions such as the OnTheFly operating mode, wherein measurements can be performed with the image processing sensor while the machine axes are moving, allow high throughput. In the CT field, machines with monoblock transmission target tubes (Figure 10) can be used for rapid measurements at high accuracy [10]. Similar to the image processing sensor, OnTheFly CT can increase measuring speed by up to ten times for some applications.

Optical and tactile multisensor coordinate measuring machines will continue to dominate the area of production monitoring, as they are faster than CT machines when just a few dimensions need to be checked. Conventional probe systems that were around at the beginning of automation in metrology will never go away, as optical sensors cannot reach every element or capture every surface. For fast, flexible measurements, a combination of optical and tactile sensors is the solution.

The advantages of CT over conventional coordinate measuring machines, though, lie in the complete

Figure 9: The Werth Multisensor System enables multisensor systems to be integrated in the coordinate measuring machine with zero offset.

Figure 10: Modern machines with X-ray tomography sensors combine the advantages of transmission target tubes with a compact form factor and low maintenance costs.

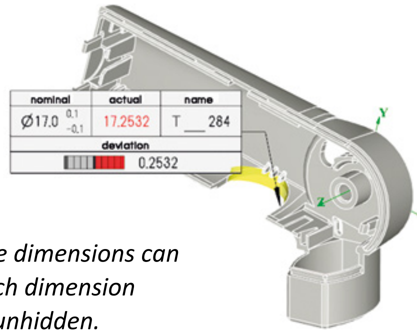
capture of the workpiece, enabling rapid first article inspection, for example, or efficient tool correction for plastic injection molding, thus accelerating product development. Because the measurement time is not affected by the number of dimensions, computed tomography is being used more frequently for production monitoring as well, mainly for workpieces with many inspection dimensions.

Werth was still skeptical 25 years ago as to whether it would ever be possible to measure substantially more accurately than one micrometer. Today, improving accuracy still remains a development goal, and machines and sensors with measurement errors less than 100 nm are in development at Werth.

[1] WECKENMANN, A., Hrsg., 2012. Koordinatenmesstechnik: Flexible Strategien für funktions- und fertigungsgerechtes Prüfen. 2., fully revised edition. Munich: Carl Hanser Verlag. ISBN 978-3-446-40739-8
[2] WOSCHNI, H.-G. and R. CHRISTOPH and A. REINSCH, 1983. Verfahren zur Bestimmung der fotometrischen Mitte einer optisch wirksamen Struktur. DD, Patent specification WP 201500. 20.07.1983
[3] WERTH MESSTECHNIK GMBH, 1987. Der Werth-Inspector stellt sich vor: Meßzeitverkürzung durch parallel processing. Gießen: Werth Messtechnik GmbH
[4] GREBE, Wolfgang, 1993. Fertigungsnahe Qualitätskontrolle. In: Microtecnic. 47 (2), S. 8-9. ISSN 0026-2854
[5] RENISHAW PLC, 1998. Firmenprofil. Bristol: Renishaw plc
[6] CHRISTOPH, R. and E. TRAPET and H. SCHWENKE, 1998. Koordinatenmessgerät mit tastelement und dieses vermessenden optischen sensor. Application: 10.06.1998. WO, Patent specification PCT/EP1998/003526. 17.12.1998
[7] HOPP, B. and U. NEUSCHAEFER-RUBE and J. VOIGTSBERGER, 2016. Messen von Mikrogeometrien mit dem Fasertaster. In: Mikroproduktion. 14 (2), pp. 64-67. ISSN 1614-4538
[8] FERGER, D., 2009. Konfokaler Sensor bereichert die Multisensorik. In: Mikroproduktion. 7 (3). ISSN 1614-4538
[9] CHRISTOPH, R. and W. Rauh, 2005. Vollständig und genau messen: Tomografie im Multisensor-Koordinatenmessgerät. In: Quality Engineering. 24 (6), pp. 28-30. ISSN 1436-2457
[10] HEIDARI BATENI, S., 2017. Messen wie im Flug: Koordinatenmesstechnik mit Computertomografie auf dem Vormarsch. In: Quality Engineering. 36 (3), pp. 24-27. ISSN 1436-2457

New Display of Geometrical Characteristics in the WinWerth® 3D Graphic

WinWerth® 8.42 now offers the functionality of a more comprehensive and clearer display of geometrical characteristics in the 3D graphic. The display of the geometrical characteristics is now based on the ISO-Norm 16792. The actual values are color-coded. Green highlights represent measurements within the tolerances; red highlights show that the measured value of the feature is outside of the tolerances. The reference lines allow one to easily assign the measured values to the respective features.



The displays of the dimensions can be edited, and each dimension can be hidden or unhidden.

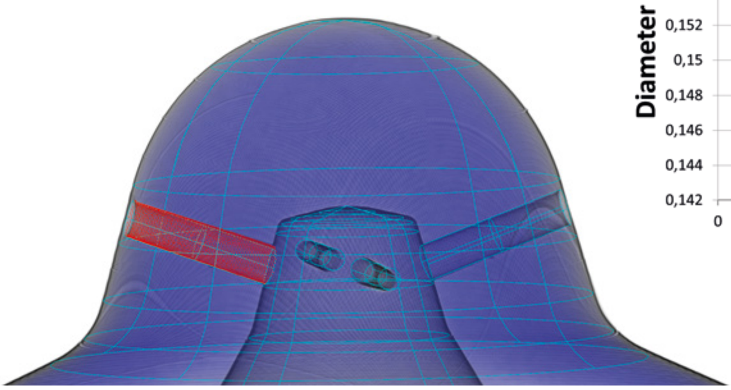
New Measuring Strategy for CT Data – Volume Patch Selection

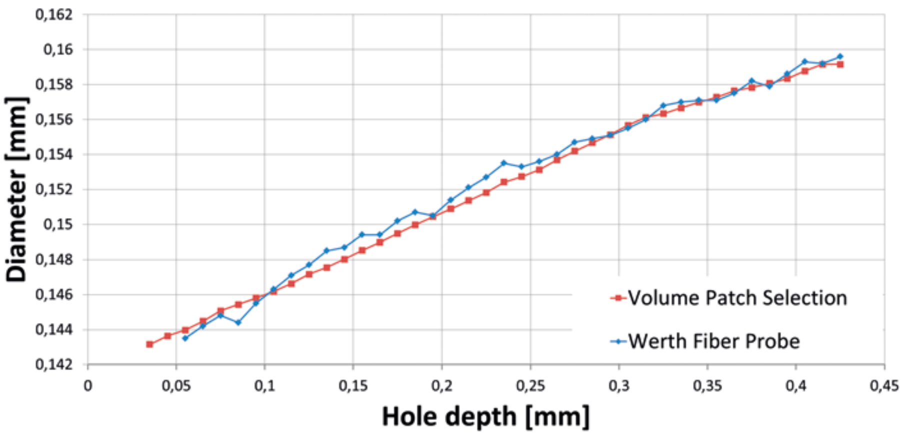
With computed tomography, the complete workpiece geometry is captured with one single measurement. To determine the measurement points in the entire voxel volume, at Werth the material transitions are calculated using a patented subvoxeling process. Using this process, it is sometimes difficult to differentiate between the individual materials in multi-material workpieces. The grayscale values of the background can also differ due to CT artifacts. For this reason, precise measurement points of such material transitions have at times been calculated with only limited success up until now.

The new Volume Patch Selection provides for very exact multi-material measurements and measurements of high-density workpieces. The process provides a higher lateral resolution compared to the previous one, especially for the measurements of fine structures on the edge of the workpiece. A further advantage is the larger artifact tolerance. With the CAD model and the voxel volume as source elements, measuring points are calculated for local points of interest. Using the new volume rendering (see page 23) that is now integrated into the WinWerth® 3D module, the operation can be perfectly visualized using the voxel volume. This leads to improved measurement results, so that workpieces with even tighter tolerances can be measured. For some workpieces, this is the first time that area based point calculation is even possible.

With multi-material workpieces, such as metal-plastic components, it is now possible to analyze 3D standard geometries of the material transition between plastic and air, without having to calculate the artifact-rich measurement cloud of the low-contrast plastic separately. For fuel injector components with tightly toleranced geometrical characteristics in the nozzle hole, the new process increases the lateral resolution and makes accurate measuring of the outermost edge of the workpiece possible.

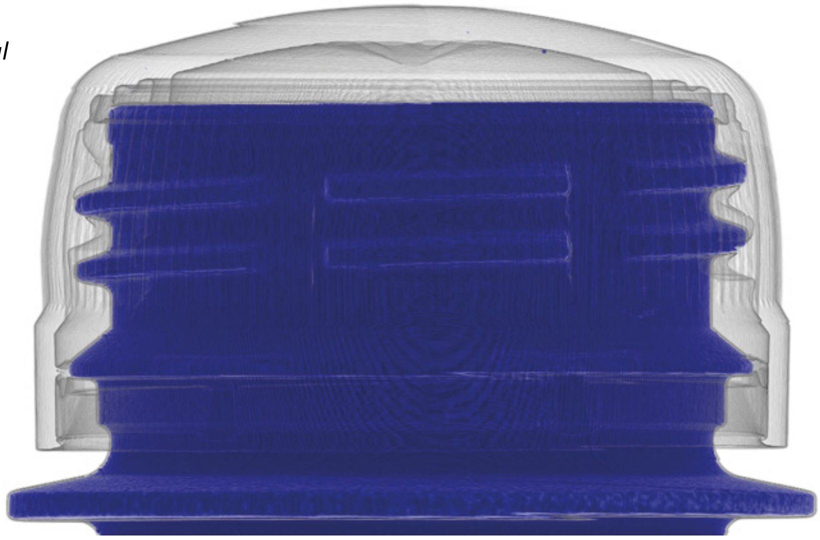
The measuring points (red), generated through Volume Patch Selection, can be displayed simultaneously with the voxel volume (blue) through volume rendering.

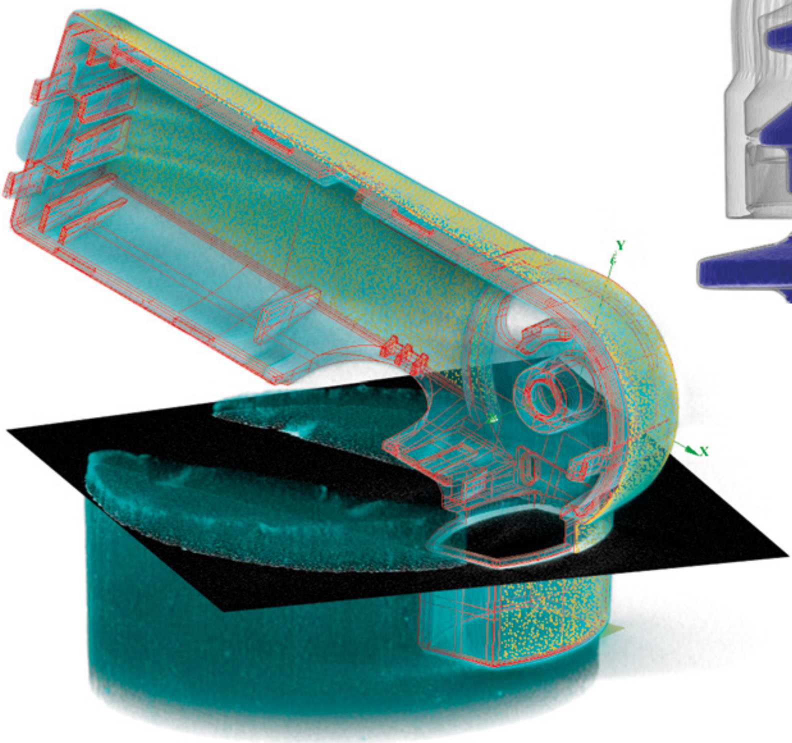




With Volume Patch Selection, the diameter of the spray hole can be measured precisely during the entire progress, as you can see from the comparison to the Werth Fiber Probe®.

Multi-material assembly with the less dense material being transparent





The WinWerth® 3D graphic depiction options include: CAD model (red lines), voxel volume (green) and measurement point cloud (yellow).

WinWerth® 3D Graphic with Volume Rendering

The depiction of volumetric data is now integrated into the WinWerth® measuring software's 3D module. Three different views can be used at the same time and can be unhidden or hidden. This provides the option to show the entire volume, i.e. all voxels with their respective grayscale values. In the depiction of the "ISO-Surface", only voxels with the selected grayscale value are displayed. 2D cross sections can also be depicted by selecting the cross-section plane. All variants can be rotated three-dimensionally and can be analyzed from all sides. The CAD model, voxel volume and measurement point cloud are superimposed in the same coordinate system. They are easy to visualize, and the data is easy to analyze using color and transparency settings.

The histogram function provides the option to choose the grayscale area to be depicted. For example, only the more dense material can be analyzed with multi-material workpieces. The transparency setting can be adjusted for the depicted grayscale interval. This provides a high degree of flexibility, which, for instance, allows for the inspection of assemblies. A multitude of depiction options are available. For a clearer picture, the grayscale can be depicted using a color scale. Through variation of the transfer curves in any number of subintervals, grayscale and color ranges can be spread out to increase the contrast.

The compact ScopeCheck® FB DZ is perfect for multisensor measurements without restrictions.

ScopeCheck® FB DZ – Multisensor Technology Now Even More Flexible

The ScopeCheck® FB DZ product line offers compact devices with large measuring ranges. A large combined measurement range can be achieved for Multisensor measurements, as for the smallest machine it is 425 mm x 500 mm x 350 mm with an image processing sensor and a conventional probe. For measurements with only one sensor, the smallest machine offers an expanded measuring range of up to 530 mm x 500 mm x 350 mm. Larger measuring ranges are for example 1130 mm x 650 mm x 350 mm in size.

The design of the new Scope-Check® FB DZ version is much more compact. As compared to the previous model, the machine is heightwise 130 mm lower and lengthwise 250 mm shorter, while still covering the same measurement range. Even though the new machine weight has been reduced by approx. 400 kg, it is sturdier, and the ambient vibration responsiveness is much improved.

The ScopeCheck® FB DZ can be loaded from all four sides, and the accessibility is improved even more with the extendable measuring table. With the new transmitted light concept, the glass table and transmitted light unit are easy to disassemble for the measurement of heavy workpieces, and the workpieces can be mounted directly on the measurement table.

Two Sensor Axes In Place Of Two Coordinate Measuring Machines

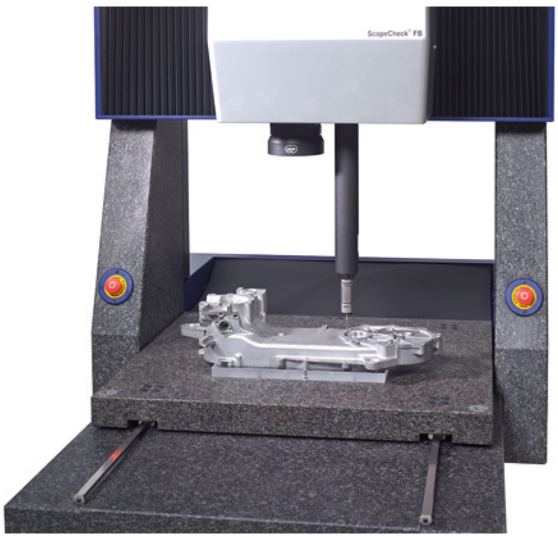
The machine can optionally be equipped with two independent sensor axes. Both optical and tactile measurements as well as an optimal combination of both measurement principles are possible. During measurements with one sensor, the second axis remains in the park position outside of the measuring range. This ensures that the geometries of the workpiece can be accessed from all sides without the risk of collision. In combination with the thin probing ram, this allows for lowering of the sensor into a large workpiece. If the machine is only equipped with one sensor axis, the second axis can be added later onsite if found to be necessary.

With the Werth Multisensor System, a wide variety of sensors can be attached to each sensor axis. These sensors are attached with a magnet coupling – without offsetting the sensors - at the same position in front of the beam path of the image processing sensor. To be able to automatically set up different sensors, the retracting axis for changing racks is now also available for the ScopeCheck® FB DZ. The changing rack is only moved from its park position into the measuring range via the coordinate measuring machine axes when the sensors are being changed. After the change it returns to its park position outside of the measuring range. The benefit here is that the entire measurement range may be used to measure workpieces.

Multisensor Technology for Any Type of Application

The basic ScopeCheck® FB DZ configuration includes the proven zoom optics. Optionally, the machine can be equipped with the patented Werth Zoom. The Werth Zoom not only allows the user the choice of magnification, but the working distance can also be adjusted to achieve collision-free measurements in deep holes or of cylindrical workpieces with large diameters. With the MultiRing®, different light angles of incidence can be set, for instance, to optimize the contrast of flat edges with a short working distance and an extremely small angle.

The entire spectrum of modern multisensor technology can be used with the ScopeCheck® FB DZ. The laser distance sensor, Werth Laser Probe (WLP), is integrated into the beam path of the image processing sensor. The Laser Line Probe (LLP) can be used with a rotary/tilt head to be able to measure large workpieces from all sides. The patented Werth Fiber Probe® (WFP) and Werth Contour Probe (WCP) tactile-optical sensors can also be used with the ScopeCheck® FB DZ. The WCP enables standard-compliant roughness measurements in workpiece coordinates without a preferred direction. The patented micro-probe WFP®, equipped with a small probe sphere (diameter down to 20 µm) and flexible shaft, achieves probing forces that are up to 100 times smaller than for conventional tactile-electrical probes. These properties make the micro-probe WFP® well suited for 3D measurements of micro-geometries and sensitive surfaces.

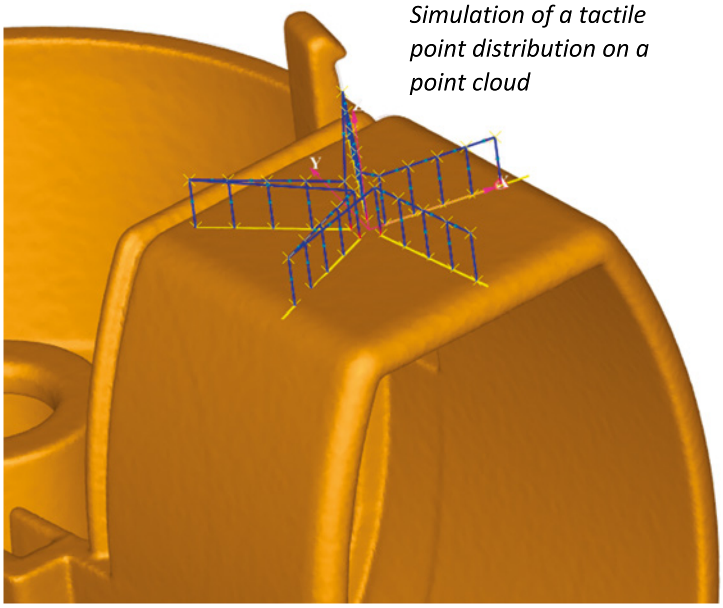


With the new transmitted light concept, heavy workpieces can be measured directly on the measuring table.

Tactile Measurement Strategy on Point Clouds

The new Measuring Spot Sensor simulates a tactile scan path or point distribution on a point cloud. The measurement points or scan paths, as is the case of tactile sensors, are automatically distributed on the selected geometrical features using the WinWerth® measurement software. The nominal element can be defined via patch selection or through the entry of the parameters. Depending on the geometrical feature, a multitude of distribution strategies are available based on helical, circular, and cylindrical surface lines; raster; stars, spirals, boundary curves and polylines. The scan path and point distribution can be tested and edited online during the interactive measuring using the coordinate measuring device or offline at a workstation in the office away from the machine; in the case of online use it can be applied directly.

Existing measurement programs with automatically created scan path and point distribution can now be used for the analysis of point clouds and vice versa. With the help of this new function, for example, point clouds of gears can be evaluated with the Werth GearMeasure program.



Simulation of a tactile point distribution on a point cloud

High Precision for Quick Measurements Under Continuous Motion

A quick "in the image" measurement in the field of view of the image processing sensor has the same advantages for large workpieces as it does for small, however the measurement precision is not as high as it could be due to the limited magnification when measuring with a large field of view. Raster Scanning HD makes it possible to quickly capture a complete image of a large area with high precision.

This process is unparalleled in the market: the image processing sensor takes high frequency images of moving workpieces without any loss of precision. The individual images taken by the camera during the measurement process are superimposed using a patented re-sampling process to create one overall image. To accomplish this, WinWerth® starts by creating a pixel raster the size of the final image. The grayscale values for the individual pixels are calculated using the neighboring pixel amplitudes of all overlapping images. This creates an extremely high resolution overall image of the selected measurement area with up to 4000 megapixels (4 gigapixels). In addition to the software correction of the machine geometry and optics, positioning uncertainty is minimized though the superimposition of images from different locations.

On the one hand, Raster Scanning HD attains a large degree of precision through high magnification measuring, and averaging over several images improves the signal-noise ratio. On the other hand, the continuous movement of the sensor provides for high measurement speeds.

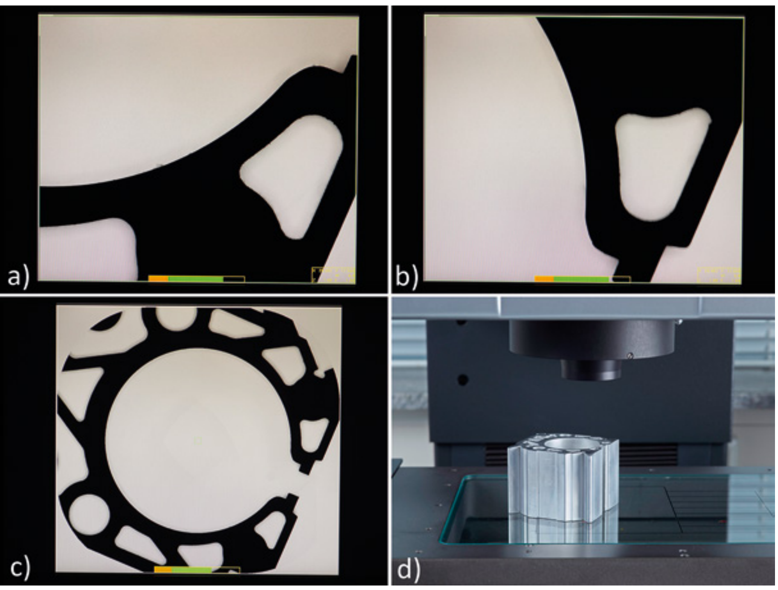


Image details at the start a), and end b) of a predefined circular path, overall image c) and workpiece d)

Promoting Science and Technology

During the annual Werth Technology Days, the Dr.-Ing. Siegfried Werth Foundation once again recognized scientific work in the field of dimensional metrology. According to Axel Hoffmann, from the University of Applied Sciences in Frankfurt, Germany, the Technology Day in Giessen was “a very successful event. The presentations were high-quality, entertaining, and understandable, and they impressively demonstrated the current state of the art in metrology.”

To promote young talent, Werth Messtechnik GmbH and 11 other companies from the central Hessen region will finance a professorship for optics and optical technologies at the TH Mittelhessen University of Applied Sciences (THM), beginning in 2018.

Prize awards at the Werth Technology Day: from left, Mr. Peter Hornberger, University of Applied Sciences in Deggendorf, Germany; awardee Anton Sigl; Mr. Arno Fink, Chairman of the Board of the Werth Foundation; awardee Dr. Marc Fischer; Dr. Rainer Tutsch, Braunschweig University of Technology in Braunschweig, Germany; Dr. Ralf Christoph, president and owner of Werth Messtechnik GmbH

Thomas Burgstaller, Managing Director of Werth Messtechnik Austria

Werth Messtechnik Austria

The founding of Werth Messtechnik Austria in 2017 represents an important step in the further optimization of customer service. The subsidiary will handle all aspects of sales, service, and applications and will maintain contact with the headquarters in Germany.

New Partner in Turkey

INSTRO Co., Ltd., which was founded in 2013, specializes in the manufacture and distribution of precision measurement devices. The company has offices in Istanbul and Ankara and assumed the sales and service activities for Werth coordinate measuring machines in October 2017.

Barış Odabaşı, Managing Director of INSTRO Co., Ltd., with Werth Area Sales Manager Tobias Schröder (right)

Innovation Prize for TomoScope® XS

At the end of 2017, the 59th International Engineering Fair MSV was held in Brno, the Czech Republic, with over 1600 exhibitors from 32 countries. The Werth TomoScope® XS received the gold medal from MSV in the category of Innovation in Automation. The prize was awarded in the presence of many important representatives from the worlds of business and politics.

The TomoScope® XS uniquely combines the benefits of various classes of machines.

Credits

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