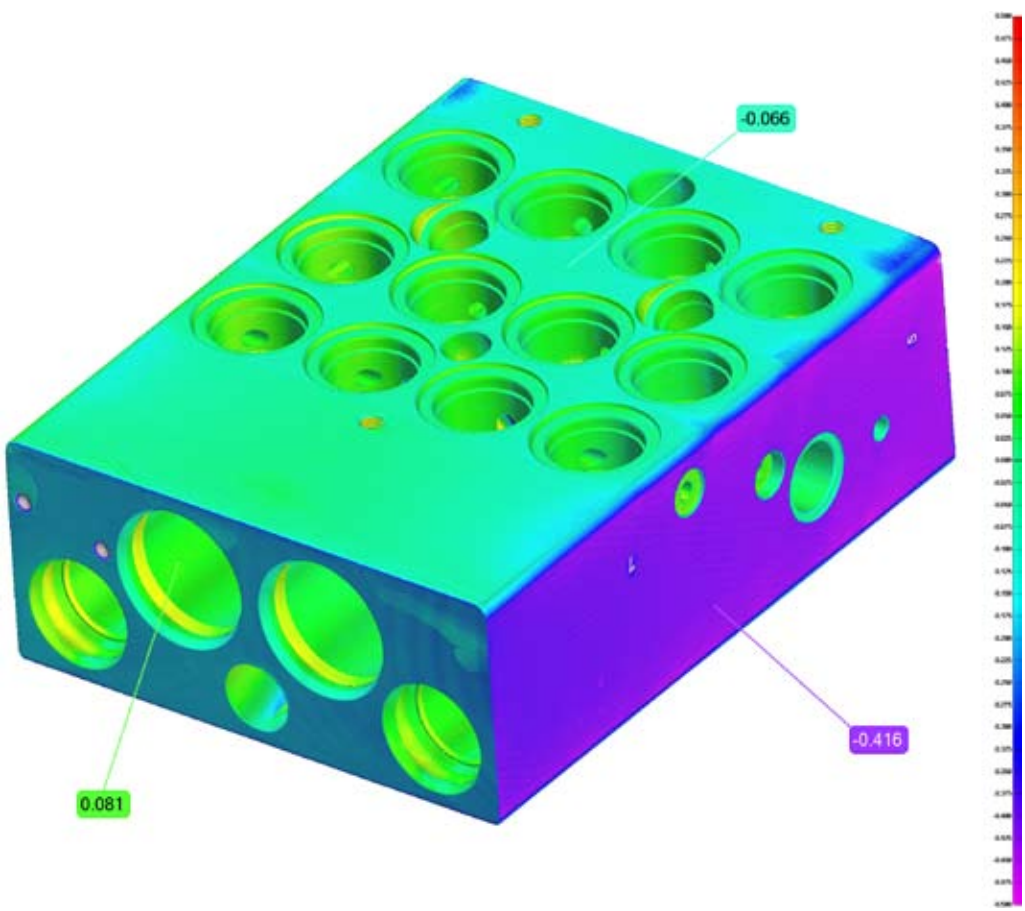
GE
Measurement & Control Solutions
phoenix|x-ray

Precision of 3D CT-Systems

Comparison of the measurement accuracy of phoenix|x-ray computed tomography systems with tactile coordinate measurement machines



GE imagination at work

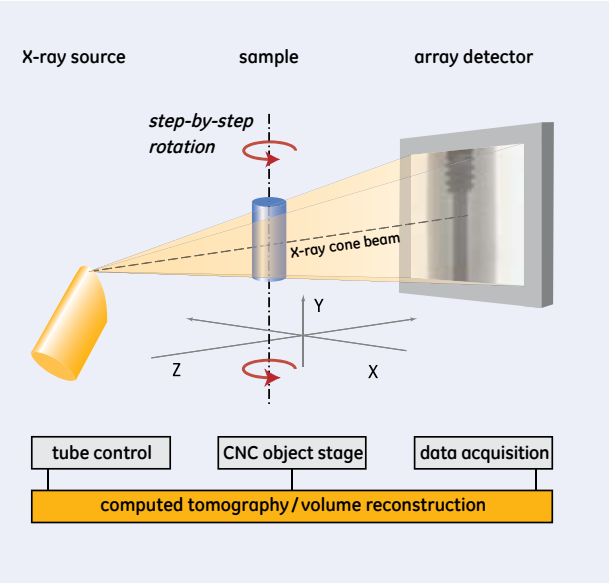
Method

By contrast with conventional tactile coordinate measurement technique, a computed tomography scan of an object acquires all surface points simultaneously - including all hidden features like undercuts which are not accessible non-destructively using other methods of measurement. Thanks to considerably faster scanning, reconstruction and evaluation possibilities, an examination report can be generated automatically in less than one hour. But how accurate are such measurements?

In order to demonstrate the measuring accuracy of the latest computed tomography systems and thus their suitability for use as a 3D coordinate measurement system, Continental AG in Frankfurt / Germany scanned an aluminum valve block with an edge length of 130 mm. Additionally, a reference measurement with a high-accuracy tactile 3D coordinate measurement technique was performed. For these measurements, a phoenix v|tome|x L computed tomography system from GE Sensing & Inspection Technologies and a Hexagon Metrology Leitz 3D PMM 8.6.6 coordinate measuring system were used.

The CT scans were made in an air conditioned full protection cabinet at 20.2°C workpiece environment temperature with a microfocus X-ray tube at 225 kV and 700 µA. The measured CT volume was optimized, using an automatic beam hardening correction. The evaluation of the measured results was carried out using Polyworks/ Inspector™.

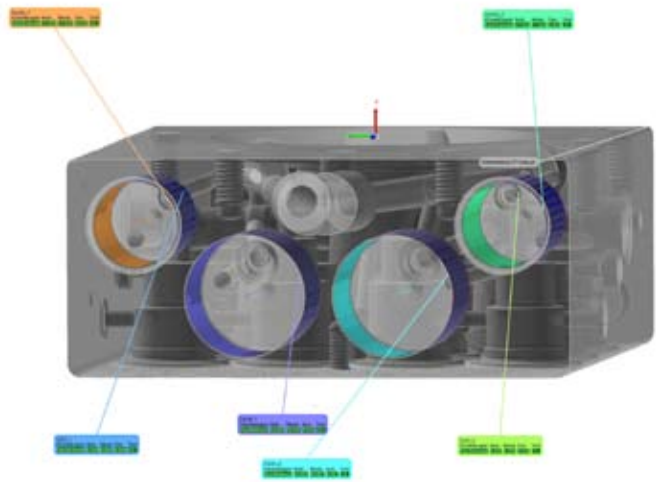
Measuring Complete Geometries



The CT scan acquires the entire geometry of the component by first generating a series of two-dimensional x-ray images while the workpiece is rotated in the X-ray beam. These projections contain information about the position and the density of all workpiece features which absorb radiation and serve as the basis for the numerical 3D reconstruction of the volume data record. All internal and external surfaces of the object are then extracted from this CT volume data.

The precision of the measured CT projection data is essential for the precision of all evaluations which follow. Nowadays, the entire automated process chain, from the scan to the generation of a final first sample examination report, can be performed in less than one hour.

Comparison of Diameter Measurements

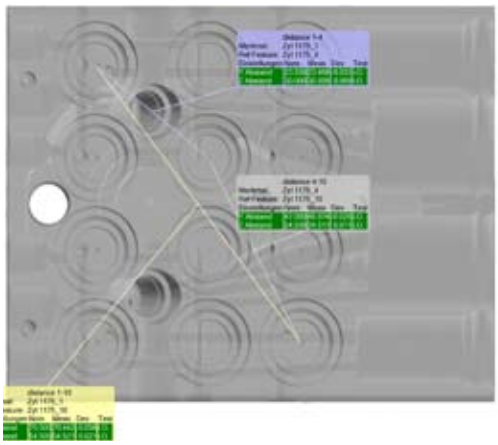


STL from CT-data of a valve block with ZX-cut and analysis of three features.

Feature	Ø [mm] Ref Q	Ø [mm] Ref P	Ø [mm] Ref M
Nom CAD	28.000	7.000	10.000
Tol+	0.06	0.1	0.06
Tol-	0.01	0	0
Meas. CT	28.035	7.055	10.037
Meas. CMM	28.034	7.054	10.035
Deviation CT - CMM	**0.001**	**0.001**	**0.002**

The maximum deviation between CT and CMM measurements is 6 µm. Overall, 20 diameter features have been analyzed.

Comparison of Distance Measurements

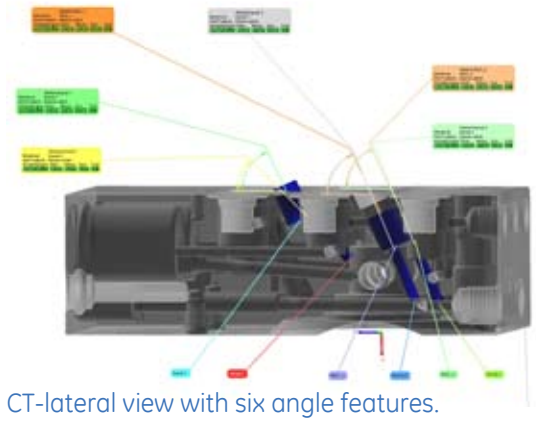


Top view of the valve block with three distance measurements.

Feature	Cyl. 1-4 y [mm]	Cyl. 1-4 z [mm]	Cyl. 1-10 y [mm]	Cyl. 1-10 z [mm]	Cyl. 4-10 y [mm]	Cyl. 4-10 z [mm]
Nom CAD	23.500	30.000	70.500	54.500	47.000	24.500
Tol+	0.1	0.1	0.1	0.1	0.1	0.1
Tol-	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1
Meas. CT	23.468	30.009	70.442	54.521	46.974	24.511
Meas. CMM	23.473	30.007	70.447	54.519	46.974	24.512
Deviation CT-CMM	-0.005	0.002	-0.005	0.002	0.000	-0.001

Extract of the measured 12 distance features. The maximum deviation between CT and CMM is 9 µm.

Comparison of Angle Measurements



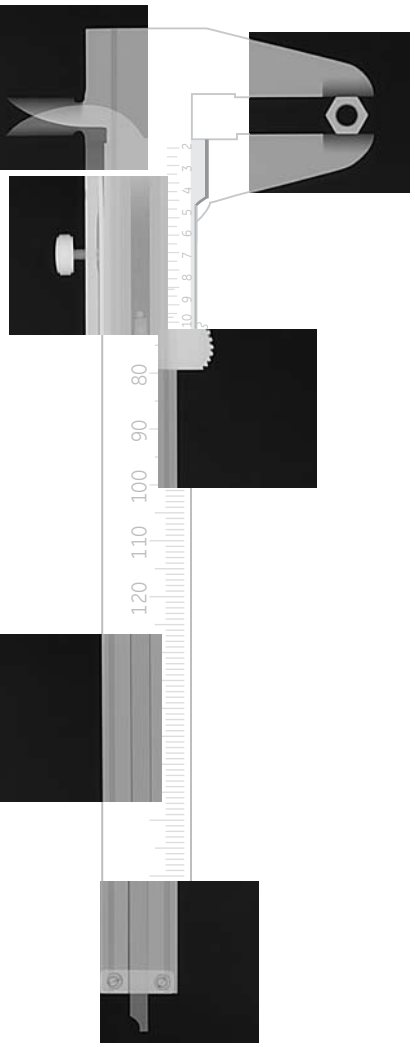
CT-lateral view with six angle features.

Feature	Angle CH 1	Angle CH 2	Angle NDD 1	Angle NDD 2	Angle CH 3	Angle CH 4
Nom CAD	65.00	45.00	65.00	65.00	68.00	68,00
Meas. CT	64.97	45.27	64.93	64.98	67.89	67.92
Meas. CMM	64.84	45.18	64.98	64.98	67.83	67.86
Deviation CT-CMM	0.13	0.09	-0.05	0.00	0.06	0.06

The deviation of the measured six angles is between CT and CMM 0,13 degrees.

Certified Precision

The comparison clearly demonstrates the excellent correlation between both, CMM and CT measurement methods. But this comparison does not show that, in general, every CT system offers such measurement accuracy because of differences in hardware and software components among various systems.
CT systems of the GE Sensing & Inspection Technologies phoenix|x-ray product line, designed for performing measurements, are based on high-quality X-ray tubes and detectors as well as precision manipulators ensuring stable acquisition conditions. Additionally certified test specimen for traceability to national standards and a broad range of modules for volume optimization and geometrical correct surface extraction are available. Only the interaction of these components ensures that the advantages of dimensional measurement with computed tomography can be combined with the precision of conventional coordinate measurement systems.



CT-System

phoenix v|tome|x L 450

System	3D/2D X-ray system with down to <2 µm voxel resolution and air conditioned full protection cabin
X-ray tubes	
Microfocus	up to 300 kV/500 W open design, unipolar for maximum magnification, detail detectability up to 1 µm
Minifocus	450 kV, different types available with up to 4.5 kW output
Detectors	
Flat panel detector	14/16 bit detector, ca. 40 x 40 cm active detector area, 200 or 400 µm pixel size
Multiline (optional)	Fully automatic collimator for scattered radiation-reduced CT scans without an additional line detector
Line detector (optional)	16 bit detector, 610 mm width, 400 µm pixel spacing, other types on request
Manipulation	6/8 granite-based axes
Maximum object size	1,250 mm height, 1000 mm diameter
Software	Metrology package for high-precision dimensional measurements with outstanding user friendly software. Automatic generation of first article inspection reports in less than one hour possible.
Back tracing	Test specimen (ruby spheres on CF-stick with DKD calibration certificate in different lengths)
Accuracy	
Sphere distance deviation	<1 µm in all directions. Determined using a special sphere plate with ca. 30 mm object diameter (±1.5 µm tolerance) calibrated by the German Metrology Institute.
Probing error size PS	2 µm + L/90 (L in mm). Determined via arrangements of the spherical elements (reference sample with DKD calibration certificate at different voxel sizes).

3D Measurements with CT - Your Advantages

- **Measurement of the complete internal and external workpiece geometry with one 3D-CT-scan**
- **Fast visual control of production quality by 3D CAD nom./act. comparison**
- **Reproducible precise measurement results comparable to established CMM technique**
- **Automatic generation of first-article-inspection reports in < 1 hour possible**
- **Additional benefit by non-destructive 3D failure analysis**
- **Significant reduction of inspection time and costs**

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