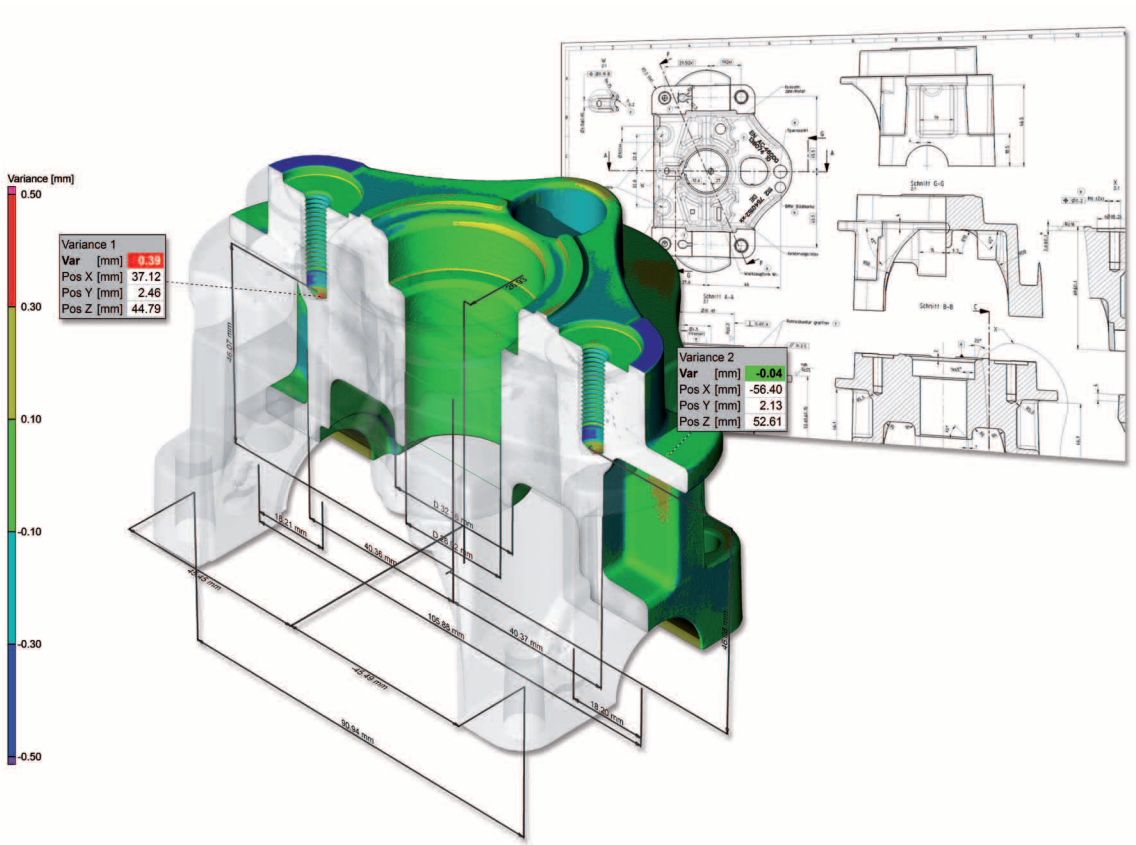
GE
Measurement & Control

Precision of 3D CT-Systems

Case studies to determination of the measurement accuracy referring to VDI standard 2630 and comparison with tactile CMMs



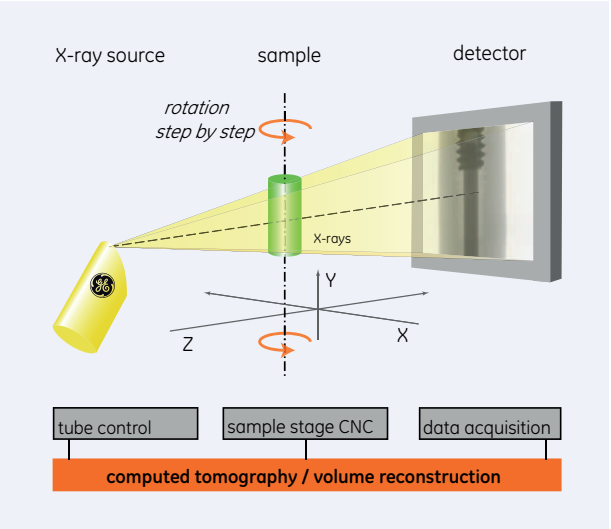
CMM Comparison Method

By contrast with conventional tactile coordinate measurement technique, a computed tomography (CT) 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?

For the first case study to demonstrate the measuring accuracy of the latest CT 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 with automatic beam hardening correction. The evaluation of the measured results was carried out using Polyworks/ Inspector™.

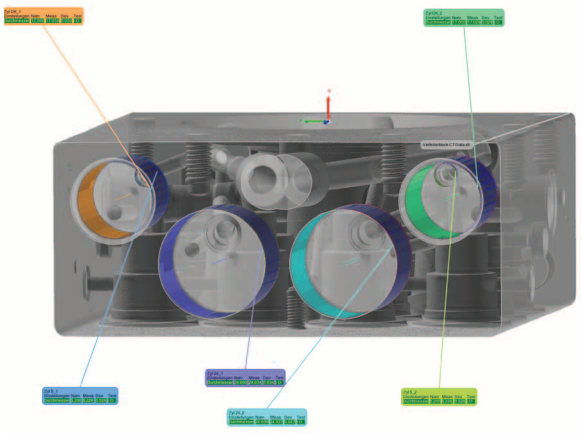
Measuring Complete Geometries



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.

Case study I: Comparison of Diameter, Distance and Angle Measurements



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

The table below shows as a comparison result that the maximum deviation between CT and CMM diameter measurements is 6 microns. Overall, 20 diameter features have been analyzed.

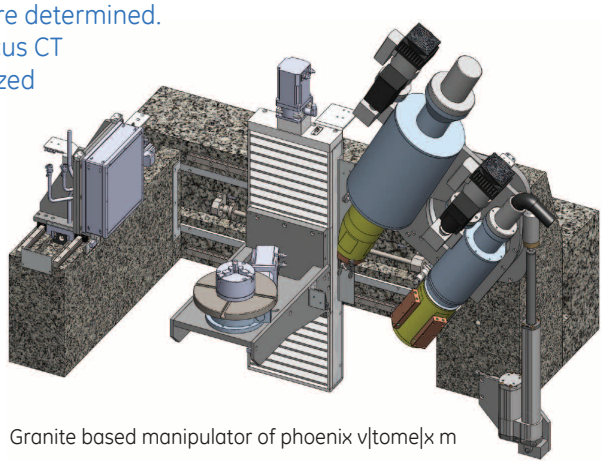
Feature	Ø [mm] Ref Q	Ø [mm] Ref P	Ø [mm] Ref M
Nom CAD	28.000	7.000	10.000
Tol+	0.06	0.1	0.06
Tol-	0.01	0	0
Meas. CT	28.035	7.055	10.037
Meas. CMM	28.034	7.054	10.035
Deviation CT - CMM	**0.001**	**0.001**	**0.002**

The other precision comparisons carried out revealed that the maximum deviation between CT and CMM of 12 measured distance features is 9 µm. Additionally, the deviation of six measured angles is between CT and CMM 0,13 degrees.

Case study II: Determination of Measuring Accuracy Referring to VDI guideline 2630

To verify the measurement accuracy in accordance to the VDI 2630 guidelines for CT in dimensional measurement, a series of CT scans has been performed in GE's class 3 measuring room at the application laboratory in Wunstorf, Germany. In the case studies, the sphere centre error and probing errors for size and form were determined.
The system used was the phoenix v|tome|x m, a versatile X-ray microfocus CT system for 3D metrology and analysis with up to 300 kV / 500 W. Optimized for long term stability and equipped with its specific 3D metrology package, the phoenix v|tome|x m includes all essential features for CT with extremely high accuracy and reproducibility:

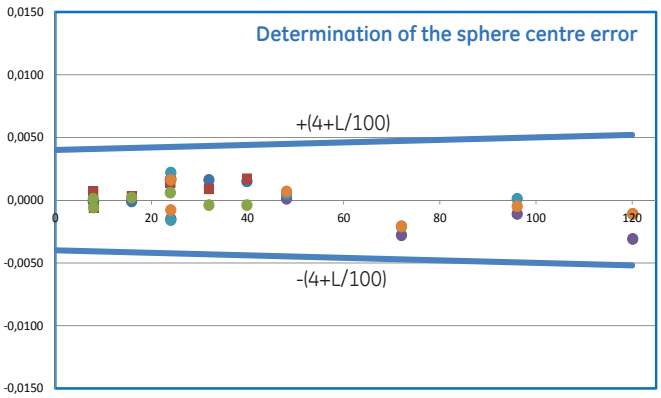
- Granite based manipulator
- High accuracy direct measuring system
- Water cooled GE proprietary X-ray tube
- Unique temperature stabilized high resolution GE digital detector array
- Temperature controlled X-ray protection cabinet
- Several tools for automated scan quality optimization



Granite based manipulator of phoenix v|tome|x m

Sphere Centre Error

As a result of the case study, a metrological performance of 4+L/100 µm for for sphere centre error could be achieved. The tests have been performed according to standard 2630 by using a calibrated ball arrangement backtraced to the German national standard.



X axis: centre-to-centre distance (mm), Y axis: deviation in mm

Probing Error PS and PF

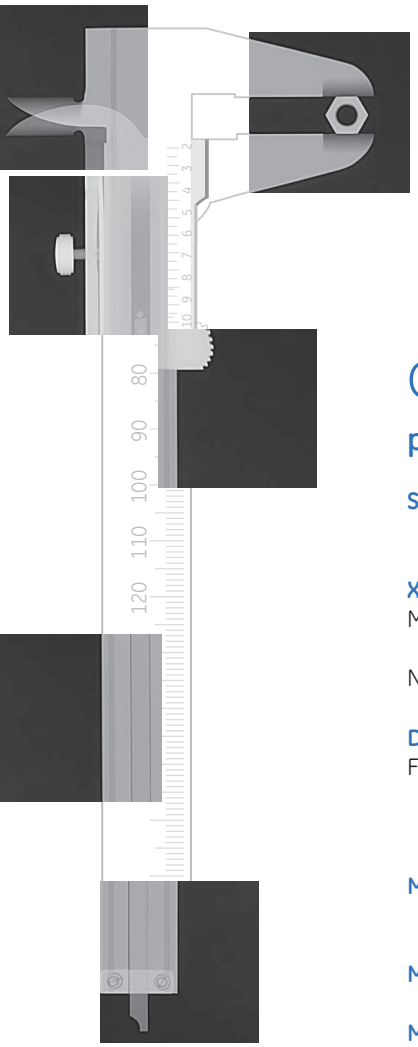
To determine the probing error size (PS) and form (PF), a special calibrated reference sample has been scanned and measured 3 times according to the standard.
As a result, a probing error size (PS) of 3 µm and a probing error form (PF) of 3 µm* could be determined.

Calibrated ball arrangement to measure the sphere centre error

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.
This could be verified by the accuracy case studies performed with GE's phoenix v|tome|x m CT system specially designed for high precision 3D metrology: in this case, an accuracy referring to VDI 2630 guideline of 4+L/100 µm for sphere distance deviation and a probing error of 3 µm for size and form each could be achieved.

* 90 % of the cumulated deviation determined with VG Studio MAX



CT-System

phoenix v|tome|x m metrology edition

System	Powerful versatile X-ray microfocus CT system for 3D metrology and analysis
X-ray tubes	
Microfocus	Up to 300 kV/500 W open design, unipolar for maximum magnification, min. voxel size down to 1 µm
Nanofocus option	Open 180 kV / 15 W high power nanofocus tube, min voxel size down to <1 micron
Detector	
Flat panel detector	Temperature stabilized digital GE DXR detector array, 200 µm pixel size, 2,000 x 2,000 pixels, 400 x 400 mm, dynamic range > 10,000 : 1, up to 30 frames per second
Manipulation	Granite based precision 5-axes manipulator with high accuracy direct measuring system
Maximum object size	Up to 500 mm Ø x 600 mm in height; 3D scanning area max. 290 mm Ø x 400 mm
Metrology package	Software / Calibration tool package for production oriented highly automated high-precision dimensional CT measurements compliant to the VDI 2630 standard with outstanding user friendly click&measure|CT software.
Measurement accuracy	4+L/100 µm referring to VDI 2630-1.3 guideline, measured as deviation of sphere distance in tomographic static mode SD (TS), method details referring to VDI 2630-1.3 guideline on request, valid only for phoenix v|tome|x m metrology edition

3D Metrology 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**
- **Measurement accuracy determinated referring to VDI standard 2630**
- **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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