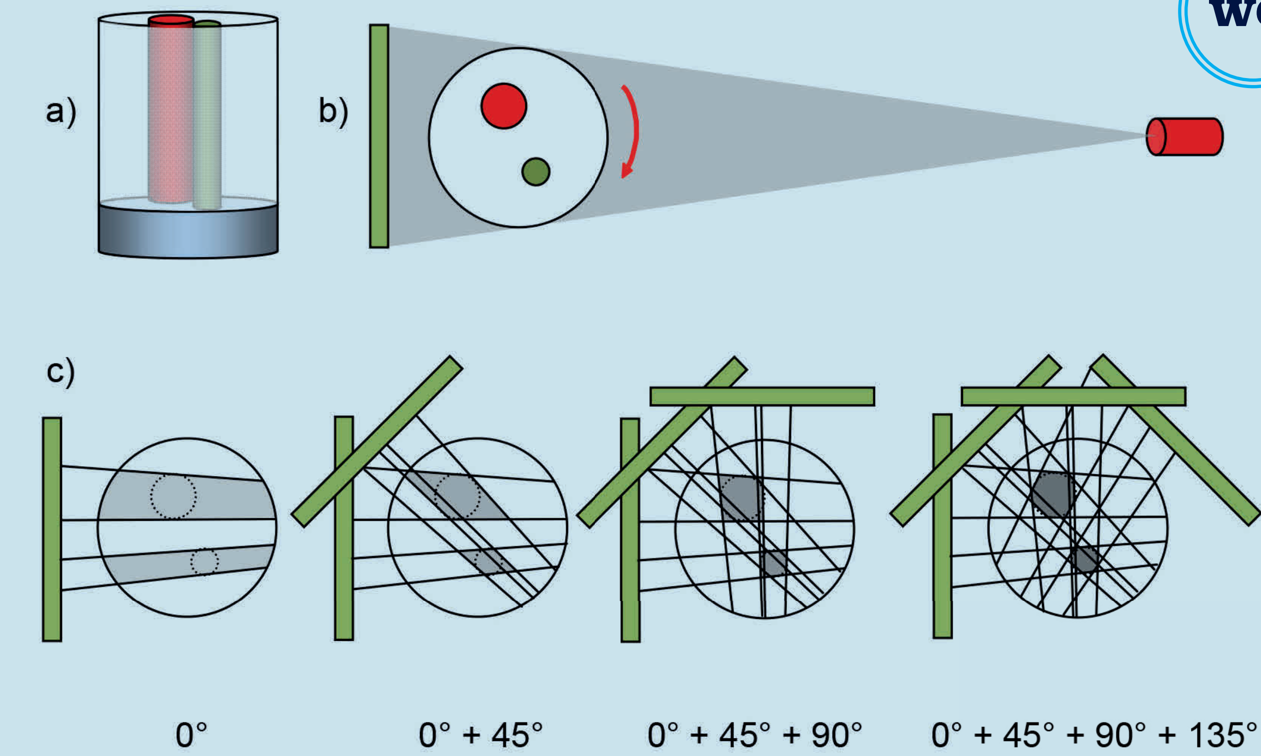

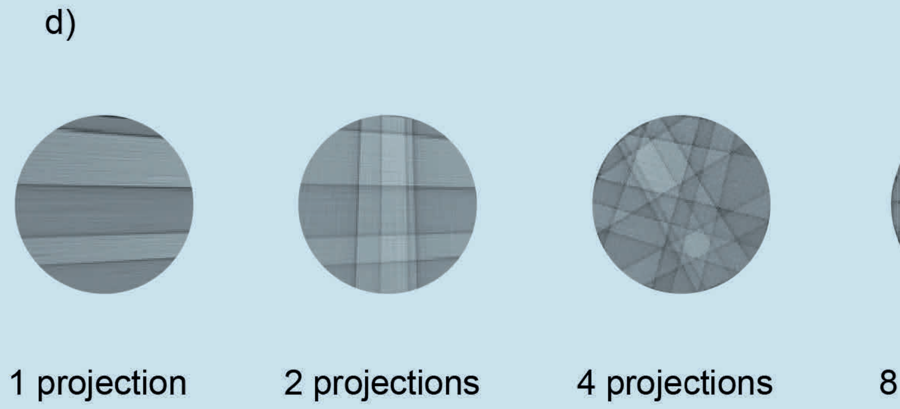

Special Print 02/2020

Measuring completely, outside and inside

X-ray tomography in coordinate metrology

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Measure completely, outside and inside

X-ray tomography in coordinate metrology

BASICS PART 3 Coordinate metrology mainly uses tactile and optical sensors and X-ray computed tomography. X-ray tomography machines differ in their base and components, such as X-ray source, axis of rotation, and detector, as well as in their software, and thus in their characteristics. A basic understanding is helpful for optimal use. Spatially extended objects, including their internal structures, can be measured completely.

Ralf Christoph, Hans Joachim Neumann, Schirin Heidari Bateni

For X-ray tomography, the ability of X-rays to penetrate objects is used. Starting from a point source, the X-rays pass through the measuring object and reach the X-ray sensor. Part of the radiation is absorbed on its way through the object. The longer the range of radiation is in the object, the less radiation escapes behind the object. Furthermore, the absorption depends on the type of material. By shifting the axis of rotation or the measuring object relative to the X-ray unit (source and sensor), the magnification and thus the resolution can be adjusted when a measuring object is detected.

In OnTheFly-CT, a few hundred to a few thousand of such two-dimensional radiographic images are taken one after another in different rotational positions of the object to be measured. Mathematical methods are used to calculate a volume model that completely describes the geometry and material distribution of the workpiece (Figure 1). In order to determine dimensions from the volume data, the exact position of the material transitions (e.g. from metal to air) is calculated from the amplitudes of the voxels (volumetric pixel: volume image point) in the surrounding area. By including the amplitude information, the achievable resolution of the edge location determination is significantly higher than that given by the center-to-center distance of the voxel raster (subvoxeling).

To determine dimensions from the measuring points created in this way, geometric elements such as straight lines, cylinders, or planes are calculated from point groups. The selection of the points is usually done with the help of a CAD model. From the geometry elements thus determined, the dimensions are calculated by linking them (e.g. the distance between two planes or circle centers) and compared with the nominal values.

X-ray tube influences resolution

The X-ray tubes used to generate X-rays are a core component of tomography measuring machines. X-rays are generated in an evacuated tube when a high-energy electron beam hits a metal target. The energy of

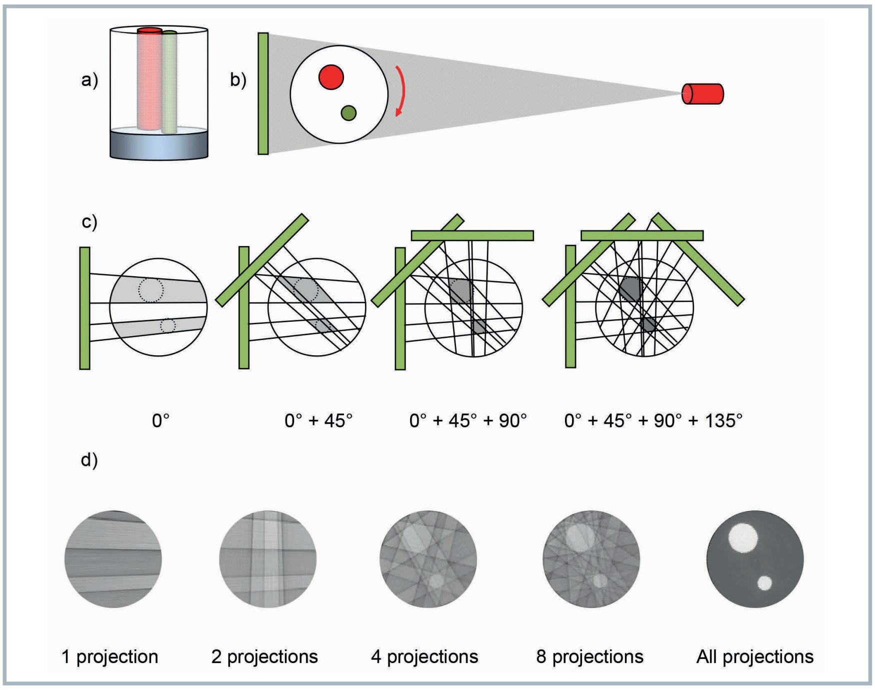

Fig. 1 Calculating volume data by back projection of the filtered radiographic images: a) Object, b) X-ray beam path in one section plane, c) Principle of stepwise back projection and superimposing, d) Result of reconstruction with different numbers of back projections for a real workpiece. (© Werth)

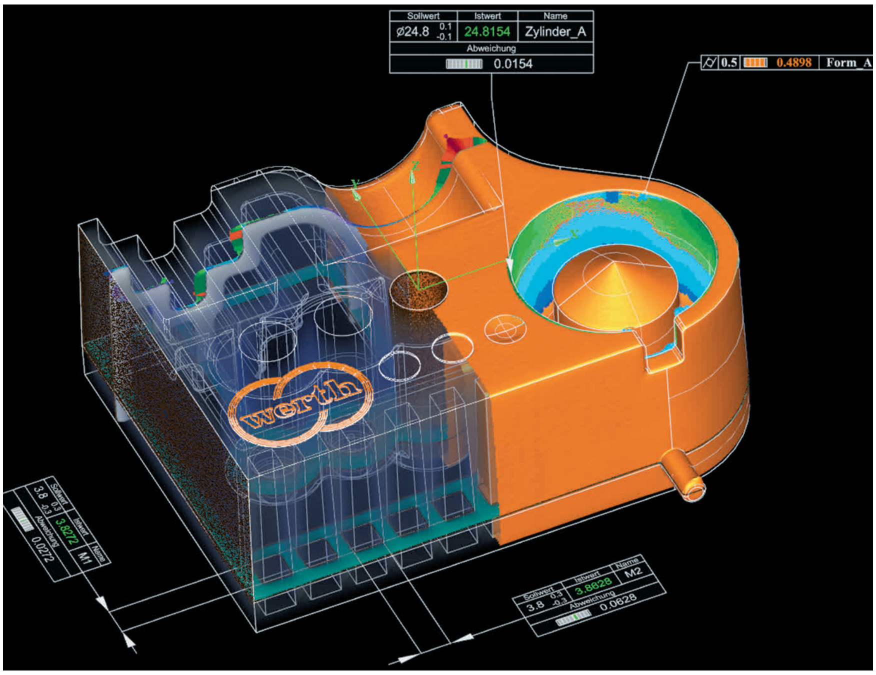

Figure 2. CAD model, CT volume data and measurement point cloud with measured geometric properties, color-coded deviation display from 3D target-1st comparison and 2D sections (© Werth)

the generated X-ray radiation depends on the voltage between the cathode and anode of the X-ray tube and on the target material. This is important for the selection of the X-ray tube, because for optimum measurement results the radiation energy must be matched to the material of the workpiece.

Basically, the targets of X-ray tubes are divided into reflection targets and transmission targets. The difference between the use of reflection and transmission targets is the available radiation power and thus the measurement time in connection with the minimum focal spot size that can be achieved.

In the reflection target, X-rays are reflected by the target. The disadvantage of reflection targets is that small focal spot sizes can only be achieved at very low power and thus a long measuring time (typically 5 µm at 5 W). In most cases, however, a higher maximum power is available, albeit at lower resolution, which is suitable for measuring large workpieces. Transmission targets are penetrated by X-rays. Here, a small focal spot can be achieved even at medium powers (typically 5 µm at 25 W) and most workpieces can be measured quickly with sufficient resolution.

Regular maintenance is required for open X-ray tubes; closed tubes must be replaced completely after a few years. Transmission target tubes in monoblock design combine the advantages of both designs with a long maintenance interval of typically 12 months and a technically unlimited lifetime.

Software tools for universal use

In addition to the method described above for determining geometric properties (dimensions) with the aid of CAD data, there are a number of other evaluation methods (Fig. 2). Geometric elements can be calculated from the point cloud without CAD data by an automatic segmentation function after defining a starting point. In the 3D nominal-actual comparison, the software calculates the distances of the individual measuring points to the CAD surface and displays them in color-coded form. The deviations of the actual geometry from the nominal geometry are thus visible at a glance. Data for the correction of injection molding tools, for example, are also calculated directly. Further methods are used to determine drawing dimensions in 2D views and sections using image processing or contour evaluation methods. Other software tools are used for the automatic identification of voids or inclusions in the measured object or of burrs and chips.

Raster CT allows the measuring range to be extended or the resolution for the entire workpiece to be increased by joining together several tomographed sections of the workpiece. The Eccentric ROI CT allows high-resolution measurements and linking of several sections of the workpiece. ■

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Masthead

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INFORMATION & SERVICE

ARTICLE SERIES

Extract from the specialist book „X-ray Tomography in Industrial Metrology“, for further information see literature reference.

LITERATURE REFERENCE

1 **Christoph, R.; Neumann, H.J.:** X-ray Tomography in Industrial Metrology. Third, revised edition: SZ Scala GmbH, Munich, 2017 („Die Bibliothek der Technik“, Volume 331).

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