Practical Tip

HOW TO EXPAND THE APPLICATIONS OF X-RAY TOMOGRAPHY

Going Beyond the Limits

A choice must often be made between sufficient resolution and a large enough measurement range for X-ray tomography with coordinate measuring technology. Both are essentially dependent on the components of the coordinate measuring machine with X-ray detectors that is being used. Methods for increasing resolution expand the range of potential applications for X-ray tomography measuring machines beyond the limits of the machine components.

X-ray tomography is gaining significance in quality assurance due to its ability to measure workpieces quickly and completely. At first, industrial X-ray tomography machines were primarily used for the inspection of workpieces. Then in 2005 Werth Messtechnik from Giessen, Germany, presented the TomoScope, a machine designed especially for using X-ray tomography with coordinate measuring technology, with optional multisensor capability. Continuous improvements through the present day have made it possible to measure even microscopic features with tight tolerances on large workpieces.

Basic Principle of X-Ray Tomography

The basic principle of X-ray tomography is to capture many 2D radiographic images of the workpiece in different rotary positions. These are used to construct a digital 3D image of the workpiece by reverse projection (reconstruction). This is divided into small volume units (volume pixels – voxels) similar to pixels in photography. They represent the local absorption of X-rays and therefore the local density of the workpiece.

Resolution of tiny details requires voxel sizes considerably smaller than the details themselves (generally by a factor of 2 to 10). In order to generate them, the X-ray tubes must have a small focal spot. This can be achieved with low radiative power (only for small or easily penetrated workpieces) or by using special X-ray tubes. The machine mechanics must also meet the stringent requirements, of course (rotary axis, drift, etc.).

The voxel size also depends directly on the size of the pixels in the selected X-ray detector, taking the magnification factor and the image scale into consideration. A relatively high magnification is therefore necessary. Due to the available number of pixels in the detectors (the practical maximum is 4000 x 4000), this means that the measurement range is restricted. For a voxel size of one micrometer, for example, this results in a measurement range of about 40 mm, or even smaller for detectors with fewer pixels. By calculating the measurement points with a local subvoxel process (Werth patent), this ratio (voxel size to detail size) can be improved for metrological analysis. However, the basic requirement for an ideal coordinate measuring machine for high-precision measurements of large

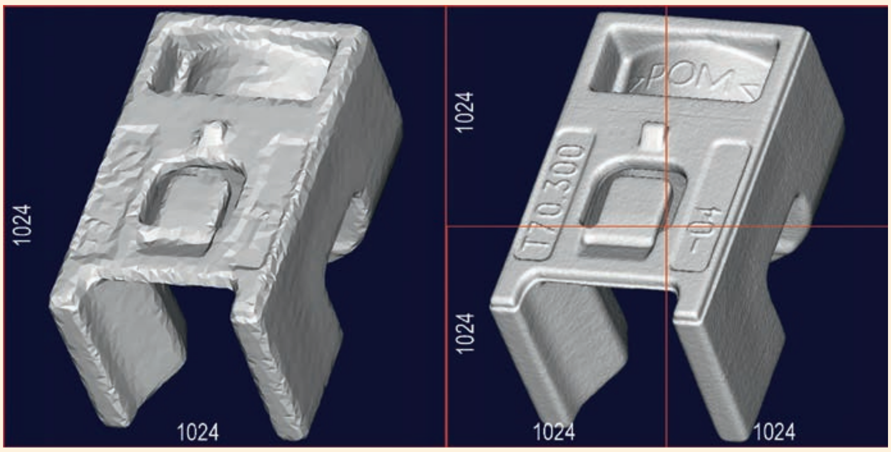

Figure 1. Point clouds (STL view) measured using tomography at low resolution (left) and using raster tomography at high resolution (right)

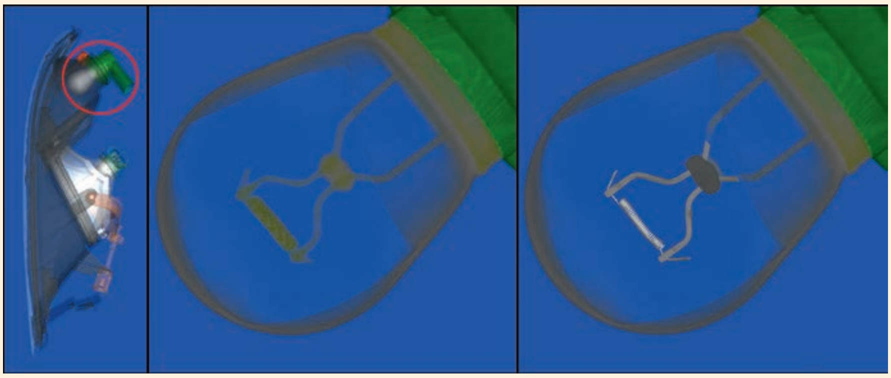

Figure 2. Voxel volumes of a car headlight: tomography at low resolution (left), partial view (middle), and high-resolution region-of-interest tomography of the luminous element (right)

workpieces – the smallest possible voxel size with the greatest measurement range – remains unchanged.

Any Desired Resolution with Raster Tomography

Particularly for workpieces with a lot of small features distributed throughout the measurement range, it makes sense to measure the entire workpiece at high resolution, that is, with a small voxel size. Raster tomography (patent pending) makes it possible to increase the ratio of the measurement range to the resolution, independent of the pixel count of the X-ray detector, for the entire workpiece. To do so, partial areas of the workpiece are tomographically scanned, one after the other, and joined together automatically (Figure 1).

The precision of the coordinate measuring machine allows the information from the different partial areas to be merged quickly into a single, high-resolution 3D volume of the entire workpiece. Using this method, it is possible to measure workpieces that are larger than the X-ray detector being used. A much more common application, however, is the complete measurement of workpieces using a voxel size (and therefore resolution) that is adapted to the feature size.

Concentration on the Essentials with Regional Tomography

If a workpiece has just a few features that need to be measured at high resolution because of their close tolerances or small size, this method can save measurement time and memory space. With regional tomography, also known as ROI tomography, one or more measurements are taken of small, interesting regions (Region of Interest – ROI) at high resolution, and the entire object is evaluated as a whole in an overview tomography scan (Figure 2).

Multi-ROI tomography, patented by Werth, allows the regions of interest to be selected anywhere within the measurement volume, without requiring each region of the workpiece to be centered separately on the rotary table. In this way, several regions can be measured one after the other at high resolution in a single setup. The partial measurements are collated into a single point cloud for evaluation. All of the features of the workpiece from the various measurements can thus be linked to each other. It is also possible to use the data from the overview tomography scan at low magnification to measure the features with less demanding tolerances at the same time.

Combining the two methods provides the greatest possible flexibility. Raster tomography can be used to measure workpieces that are larger than the measurement range of the detector would permit. Regions with small features and tight tolerances can then be tomographically scanned at high resolution using ROI or multi-ROI tomography. □

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