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How to Select the Right X-Ray Tomography Coordinate Measuring Machine

The Whole Is Greater Than the Sum of Its Parts

Special reprint

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How to Select the Right X-Ray Tomography Coordinate Measuring Machine

The Whole Is Greater Than the Sum of Its Parts

PRACTICAL TIP Apart from a high accuracy, the resolution available as well as the required measurement time and measuring range are crucial to solve measurement tasks using coordinate measuring machines with X-ray tomography. A modular design enables the selection of X-ray tubes and detectors, the base machine as well as the software. In this way, the machines can individually be adapted to specific requirements.

Raoul Christoph

WHEN MEASURING with X-ray tomography, workpieces are exposed in various rotational orientations, radiographic images are captured, and a volume data set is reconstructed from them. The 3D point cloud determined from this describes the entire surface of the workpiece or interesting partial regions enabling the accurate measurement of all internal and external geometries.

The Right Sensor Systems for the Measurement Task

As a first step, X-ray tubes must be selected such that the maximum acceleration voltage is sufficient for generating X-ray radiation with the energy needed to penetrate the workpiece. For highly absorbent materials and long radiographic lengths higher acceleration voltages are required. The X-ray radiation is generated when the electron beam accelerated by the voltage impacts on a target.

Tubes with a reflection target typically allow a higher maximum power output. However, the focal spot size, which is critical to the structural resolution that can be achieved (also known as spatial resolution, describing detail detectability), increases as the power of these tubes increases (Figure 1). At a power level of 80 W, for example, the focal spot is typically 80 µm in size, and at 250 W, it is even about 250 µm in size. In order to achieve resolutions that are useful for metrology, the power of the tube and therefore the brightness of the X-ray images must be greatly reduced. Thus, long measurement times are required for reproducible measurement results. Tubes with reflection targets are therefore recommended only for measuring larger workpieces with wide tolerances in the range of tenths of millimeters or low requirements for measurement speed.

Modern tubes with a transmission target allow for smaller focal spots in principle (greater structural resolution) as well as higher power levels for small focal spot sizes and therefore more precise or rapid measurements. For example, the focal spot size at a power level of 80 W is only about 16 µm, which is five times better than the tubes with reflection targets for the same power level.

The use of transmission target tubes and the determination of surface points using a patented subvoxeling method allow for rapid measurements with low measurement deviations of 1 µm and lower. Even for production monitoring of motor vehicle fuel injectors, with tolerances of less than 5 µm, the measurement process capability is ensured at a measurement time of a few minutes. With a maximum acceleration voltage of 300 kV at this time, such tubes are also suitable for relatively large workpieces and materials that are difficult to scan with computed tomography.

Tubes in monoblock design with a transmission target allow for great reductions in

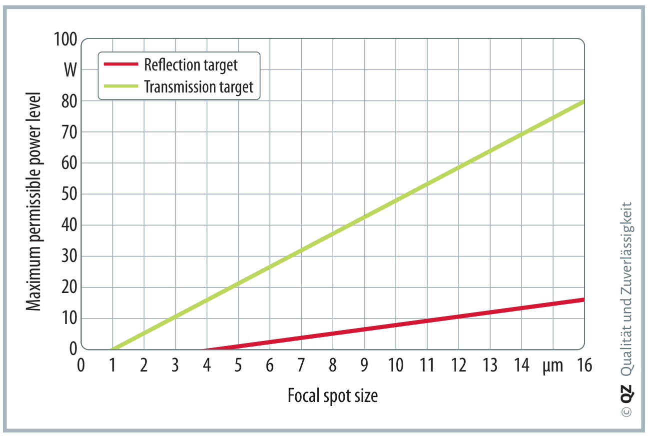

Figure 1. Maximum permissible power level as a function of the desired resolution (focal spot size) for tubes with transmission (green) and reflection (red) targets, for the range critical to coordinate measuring technology (© Werth)

maintenance and purchasing costs, at very good resolution and performance, by integrating tube, high-voltage generator, and vacuum generation in a single unit. Such tubes are currently available with up to 160 kV acceleration voltage and combine the advantages of various conventional tubes.

The X-ray detector must have sufficient radiation resistance for the X-ray tubes used. The interplay of the number and size of pixels with the machine geometry and focal spot size determines the structural resolution for a measurement. The maximum measuring range for a measurement "in the image" depends on the surface area of the detector. In this context, a high pixel count results in a high resolution, but also larger quantities of data and longer calculation times.

For large workpieces with low resolution requirements, large detectors with relatively large pixels are thus sufficient. If a high resolution is required for small workpieces, selecting a detector with a small pixel size and high pixel count makes sense in order to keep the machine compact in size. In any case, the selection of the X-ray detector should be coordinated with the manufacturer to suit the requirements of the measurement tasks to be addressed.

Mechanics and Software Are Also Critical

In 2005, Werth Messtechnik combined the design principles from coordinate measuring technology and X-ray sensor systems to create the first machine with X-ray tomography sensors specially conceived for use in coordinate measuring technology, with optional multisensor system capability (product information). In addition to a solid granite base, today these machines include precision guideways, air-bearing rotary axes, temperature and 3D-geometry correction, and many other processes. Magnifications calibrated for long-term stability ensure traceability of measurement results and save time. Today, DAkkS calibration also guarantees that the machines work within their specifications.

To many companies, the possibility to set up compact machines at nearly any location and at moderate prices is attractive (Figure 2). In combination with monoblock transmission tubes, the machines nevertheless have very high performance. In contrast, larger machines have larger measuring ranges, as well as higher structural resolution, even for larger workpieces, due to their higher maximum magnification. These machines can be equipped with more powerful X-ray tubes or two different X-ray tubes at the same time.

Figure 2. Compact machines can be set up nearly anywhere: a flexible measuring machine for large workpieces (left) and a compact machine with transmission tubes and monoblock design (right) (© Werth)

A consistent software concept, from the assessment of radiographic images to the determination of geometrical characteristics (dimensions, etc.) allows for the complete automation of the measurement process, up to the automatic correction of CAD models for moldmaking and reliable traceability of measurement results.

To reduce measurement uncertainty, various methods are used for subvoxeling, correcting artifacts that arise from the interaction of X-rays with the workpiece, and correcting temperature-induced drift. Dual-Spectra Tomography enables reliable measurements of multi-material workpieces. With additional specialized measurement methods, such as raster tomography and eccentric multiple ROI tomography, the measuring range can be extended or the resolution increased. Real-time reconstruction of the workpiece volume in parallel with image capture and OnTheFly CT reduce measurement time.

Technology Offers a Variety of Potential Applications

The ability to combine various base machine sizes with X-ray tubes and detectors having different properties results in a wide variety of applications for coordinate measuring machines with X-ray sensors. These range from relatively large engine blocks, to complex plastic and plastic/metal composite parts, to high-precision fuel injectors for engines.

Working together with the manufacturer, the optimal machine for the application can be put together from a wide range of potential combinations. In this process, the requirements for measuring range, resolution, measurement uncertainty, and measurement time for the workpieces to be measured must be considered. ■

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