X-RAY TOMOGRAPHY - THE FUTURE OF COORDINATE MEASURING TECHNOLOGY

Trust in this technology needs to mature

In recent years, X-ray tomography has taken hold in the measurement labs of many companies. Recording data from the workpiece suddenly appears to be very simple and uncomplicated and the long-standing desire of metrologists to "measure without programming" has become a reality. But what exactly is a coordinate measuring machine with an X-ray tomography sensor and what is the current state of the art?

When the first coordinate measuring machines with tactile sensors were introduced a few decades ago, there was great uncertainty. Measuring down to a few micrometers in automatic mode? Despite violating the Abbe comparator principle, being more precise than a micrometer caliper or dial gage and universally applicable – these were at least the promises in the brochures. Soon it was learned that it was not quite so simple to determine workpiece dimensions. Measurement strategies, analysis algorithms, traceability and CNC programming of the machine were just a few of the challenges faced by users who previously checked their parts with manual instruments and gages. They first had to understand that coordinate measuring technology does not produce direct measured values, but is based on the analysis of the captured measurement points.

Uniformity of Stated Accuracy

As a successor to projectors and measuring microscopes, the introduction of image processing in the 1990s by Werth Messtechnik GmbH, Giessen, Germany, gave optical coordinate measuring technology a significant step forward. The machines with image processing sensors were superior to touch probes for many applications. Measurements were fast, non-contact, and provided a large quantity of measurement points in a short time.

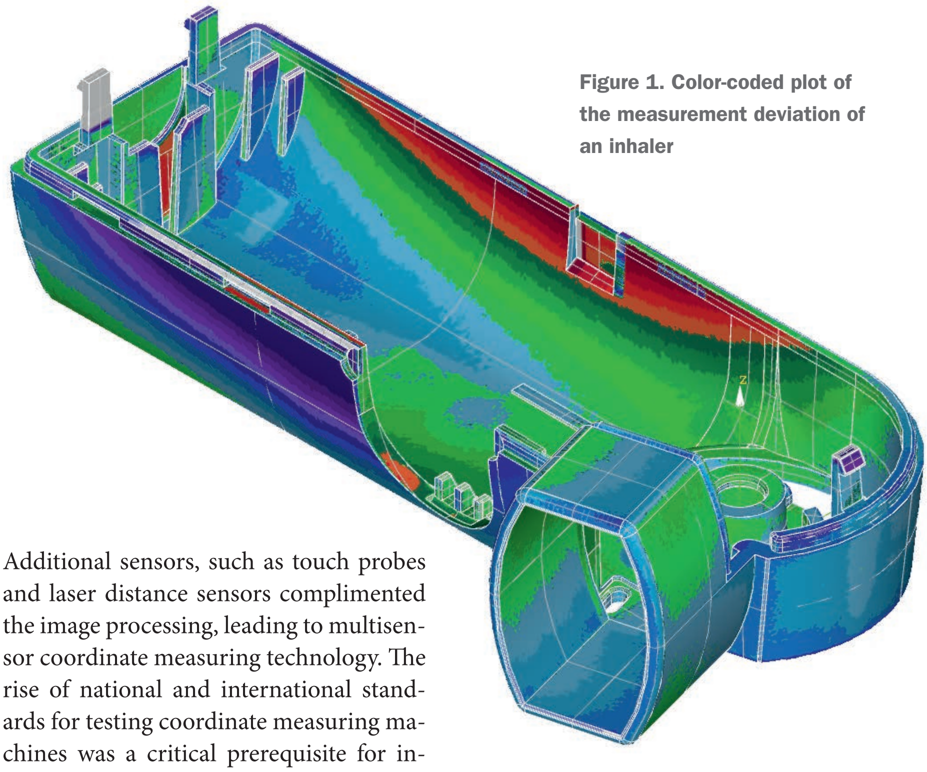

Figure 1. Color-coded plot of the measurement deviation of an inhaler

Additional sensors, such as touch probes and laser distance sensors complimented the image processing, leading to multisensor coordinate measuring technology. The rise of national and international standards for testing coordinate measuring machines was a critical prerequisite for increased trust in this technology.

A similar "revolution" in metrology began in 2005. At the Control trade show in Germany, Werth Messtechnik introduced the TomoScope, the world's first machine developed specifically for coordinate measuring technology with an X-ray tomography sensor, optionally available with multisensors (Figures 1 and 2). Complete and precise measurement at the push of a button had become reality.

Those first prototypes have since developed into a series of machines for various fields of application. Depending on the requirements, the focus can be on maximum resolution and precision, a large measurement area, or fast measurements. The machines provide a digital copy (voxel volume) of the scanned workpiece within a few minutes. Hundreds of thousands of measurement points are generated automatically. They embody the workpiece geometry completely and precisely.

The analysis of the individual inspection features can be done either directly in the measuring machine or afterward, using the saved data (voxel volume and point cloud). Measurement programs for this purpose can be prepared in advance using CAD data, so that the measurement results for hundreds of features are available shortly after the tomography scan. The extremely high density of the data provides the ability to quickly generate a color-coded deviation plot of the entire component relative to the CAD data.

This approach provides fast results with much more informational content than long columns of numbers. A very interesting feature for moldmakers is a patented procedure to make the correction of injection molding tools nearly automatic, using WinWerth tool correction software. The core question of trust in the new technology is one of precision. In principle, the same conditions must be met as for conventional coordinate measuring machines. First, the mechanics of the measuring machine must ensure the necessary reproducibility and precision.

Due to the basic principle of tomography, particular attention is given to the rotary axis. The other axes for adjusting the magnification, for raster tomography or for ROI tomography (region of interest) are also subject to stringent requirements (Figure 3). It is advantageous here to use proven components from conventional coordinate measuring technology. The technologies for CAA (computer aided accuracy) and temperature compensation methods also originated in conventional coordinate measuring technology.

Figure 2. The latest version of the first coordinate measuring machine with X-ray tomography presented in 2005 – optionally available with multisensors.

Another key area is the traceability of the measurement results. The software used to produce the results must also be included in this analysis. This dependency becomes clear in comparison to tactile coordinate measuring technology. There, calibrated standards are measured and the deviations of the measuring machine are determined. This information (e.g., sphere radius and position) are then used to automatically correct the results when the workpiece is measured.

Anyone can see that a tactile machine is no longer calibrated if, for example, the probe sphere diameter is changed without being measured again. The procedure for the algorithms for determining measurement points in machines with X-ray tomography is analogous.

A patented “edge detection” technique that is accurate to the “subvoxel” level is performed for every measurement point by the Werth software, which incorporates the calibration data of the machine and evaluates the local voxel amplitudes. When this procedure is repeated for every voxel at the material boundaries of the workpiece, a corresponding large amount of measurement points are generated. The resulting measurement point cloud is thus traceable and can be analyzed using appropriate software.

The raw data of an X-ray tomography scan can be sent for offline data analysis in addition to the measurement point cloud by data media, or via the Internet. However, it most be understood that when raw voxel data are used, the precise location of the measurement points is not included in that data. They can be precisely determined offline only if the necessary calibration and machine data are also transmitted. For offline work stations that use WinWerth software it is ensured that the results are also traceable.

Many other analysis software packages, independent of the type of machine, also measure in the voxel volume. Complete traceability for the results cannot be guaranteed, however, for the reasons listed above. The best guarantee of compliance with technical rules regarding traceability of measurement results is to have the measuring machines, including the analysis software, calibrated by a laboratory that is accredited by DAkkS for tomography machines. This is done in accordance with the applicable VDI guideline 2617 Sheet 13.

Metrology Milestones

New technologies require time to become established, especially in metrology. Trust in this technology needs to mature. Many systems are already proving their capability in everyday use. The use of X-ray tomography as a sensor in coordinate measuring machines is a milestone that is comparable to the introduction of tactile or optical coordinate measuring machines a few decades ago. □

Translated by Werth Messtechnik GmbH

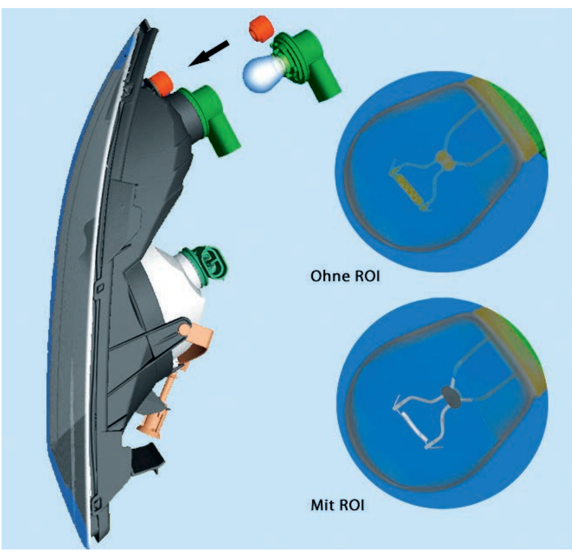

Figure 3. Segment CT using the example of an automotive headlight. The detail to be measured is in the middle of the workpiece. The ROI area can be selected which is much smaller than the workpiece diameter.

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