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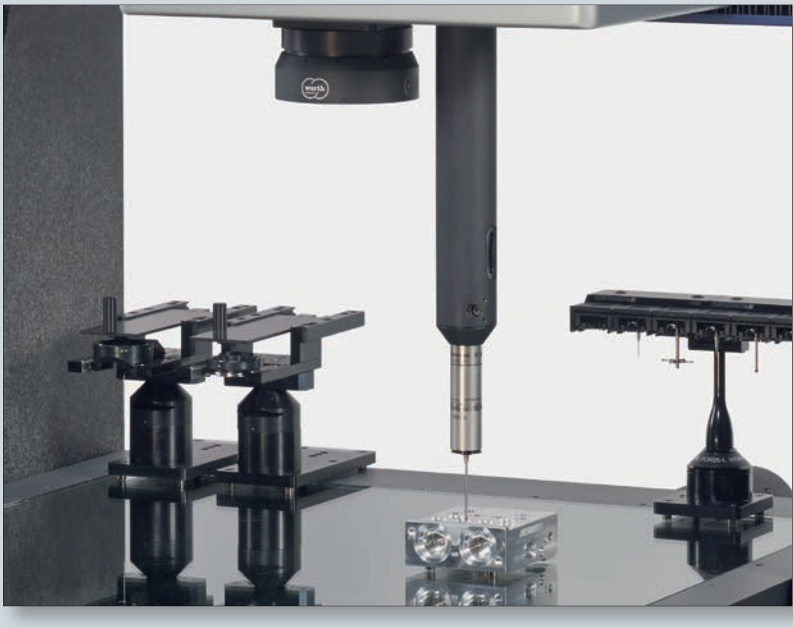
Multisensor Systems or X-Ray Tomography?

The Measurement Task Drives the Choice of Measuring Technology



Special reprint

Masthead
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Multisensor Systems or X-Ray Tomography?

The Measurement Task Drives the Choice of Measuring Technology

To use coordinate measuring technology effectively in quality assurance, a measuring machine of the correct accuracy class and size must be equipped with the right sensor or multisensor systems. It often makes sense to combine non-contact and tactile sensors. Whether a given sensor is suitable for a specific measurement task, however, depends on several different criteria.

Schirin Heidari Bateni

Multisensor systems combine various different measurement principles. One general distinction is between optical sensors, which use light as the primary signal carrier, and tactile sensors, where the signal is generated by contact between the workpiece and the sensor and transmitted mechanically from the stylus to a transducer. The rest of the signal processing takes place electronically. Tactile-optical sensors are a special case, where the information about the point of contact is first directly, or at least nearly directly, transmitted by an optical signal. Examples include the patented Werth Fiber Probe (WFP) and the Werth Contour Probe (WCP).

The integration of several sensor principles in one „multisensor" provides a num-

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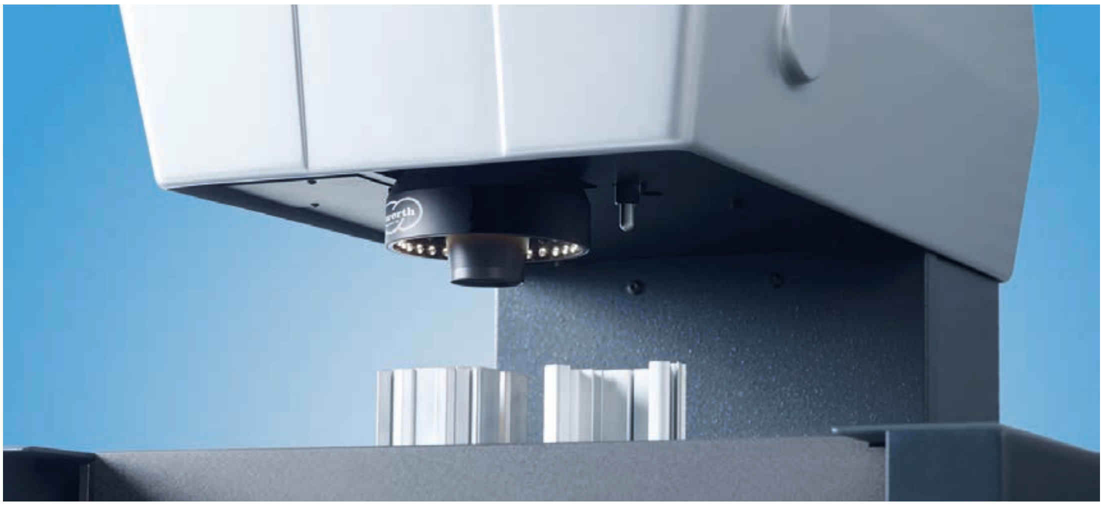

Figure 1. Optical 2D coordinate measuring machine with Raster Scanning for rapid evaluation „in the image“ (© Werth Messtechnik)

ber of benefits. For example, the Werth Zoom, also patented, integrates a laser distance sensor in the beam path of an image processing sensor. With the Werth Multisensor System interface, additional sensors can be placed in front of the beam path with zero offset. All of them act at nearly the same point in the coordinate measuring machine. This makes better use of the measuring range, as multisensor measurements are not limited by the offset between the sensors. Multisensor measurements are also more accurate, as the drift of the sensor offset is eliminated.

Integration of the laser distance sensor in the image processing beam path increases measuring speed, because little or no positioning motion is required when changing over. The image processing camera can also track the position of the laser spot on the workpiece surface, improving ergonomics.

Alternatively, different sensors can be spread over two independent sensor axes, only one of which is in the measuring range at a time. This prevents the sensors from interfering with each other while measuring (for example, a star probe and image processing probe head).

The ScopeCheck FB DZ, for example, is a multisensor coordinate measuring machine with two independent sensor axes so that each sensor can perform optimal measurements.

Flexible Measurements with Multisensor Systems

Depending on the workpiece geometry, different sensors will be more or less well suited for the measurement (Table 1). For fast, simple measurements of edges, holes, and surface structures, the image processing sensor is a good choice. With Raster Scanning HD, large regions can be captured quickly and automatically at high resolution. While the sensor is in motion, a patented method is used to capture images of the workpiece at the maximum camera frequency and then superimpose them into an overall image. This allows for evaluation „in the image“ with reduced measurement time and measurement uncertainty. Optical coordinate measuring machines for 2D measurements tasks, such as the QuickInspect MT with Raster Scanning HD, also support easy, function-based inspection using contour comparison (Figure 1).

A rapid, precise capturing of the surface topography is possible with the new Chromatic Focus Line Sensor (CFL), for example. This linear sensor projects a series of about 200 white light points onto the surface of the workpiece. Using a different focal plane for each wavelength, the distance between the sensor and workpiece is determined. The CFL captures about one million measurement points in three seconds. As an alternative, topography measurements can also be performed with focus variation sensors and confocal sensors.

In addition to chromatic focus sensors, contours and flatness are commonly measured with laser distance sensors. Using the Foucault principle, the laser beam is split on one side. The aperture of the optic acts as a triangulation triangle. As the distance to the focal plane varies, the position of the focal point on the workpiece surface also changes. This changes the position of the reflected signal on the photoelectric sensor. The distance between the sensor and the workpiece surface can be derived from this.

A small accessory unit on the Werth multisensor system can expand the coordi-

Figure 2. Modern machines with X-ray tomography sensors enable workpieces of various sizes and tolerance classes to be measured during production. Left: CT machine for measuring large workpieces with X-ray voltages up to 450 kV; right: compact, low-maintenance measuring machine with 160 kV X-ray for smaller plastic and metal components (© Werth Messtechnik)

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nate measuring machine to include contour and roughness measurements. In the Werth Contour Probe, the deflection of the contact stylus is detected by the laser distance sensor. Other sensors suitable for roughness measurements include the Werth Fiber Probe and interferometric or chromatic point sensors.

The 3D fiber probe is particularly well suited for measurements with tight tolerances and microgeometries. This tactile-optical micro-stylus uses the image processing sensor and an integrated distance sensor to determine the deflection of the probe sphere (as small as 20 µm) with high accuracy. Because the flexible shaft is used only for positioning, it can theoretically be arbitrarily small, and the contact force can be a hundred times lower than with conventional tactile-electrical probe systems.

The Werth Interferometer Probe (WIP) is also useful for highly accurate measurements of micro-geometries, for example, in otherwise inaccessible, deep holes. The interference signal between a light beam reflected at the workpiece surface and a reference beam is used to determine the distance to the workpiece surface. Depending on the characteristics of the workpiece surface, other optical sensors can be used, such as the image processing sensor, chromatic focus sensors, or confocal sensors.

Vertical surfaces and undercuts are inaccessible to optical sensors. Conventional tactile sensors are used here, as well as the fiber probe for micro-geometries and sensitive surfaces or when accuracy requirements are extremely high. Combinations of various sensors can be used to measure all geometries without repositioning the workpiece.

The suitability of the various sensors also depends on the condition of the workpiece. For example, the size of the geometries to be measured, the surface properties, and the sensitivity of the workpiece all play a role. Table 1 provides an overview of the various influencing factors. The flexibility of multisensor systems means that nearly any workpiece can be measured.

Measure Completely and Precisely with X-Ray Tomography

In X-ray tomography, simply referred to as computed tomography (CT), a workpiece placed between an X-ray source and detector is rotated as radiographic images are captured at many different rotational orientations. These are used to calculate (or reconstruct) a complete volume model of the workpiece. Using a patented subvoxeling method, WinWerth measurement software determines the measurement points at material transitions.

The first CT measuring machine developed especially for coordinate measuring technology, with optimal multisensor systems, was presented by Werth Messtechnik at the Control 2005 trade show in Sinsheim, Germany. Proven technologies from coordinate measuring technology were used to ensure the necessary accuracy. In the years that followed, the fields of X-ray components, software correction methods, and special measurement techniques experienced rapid advancement.

With computed tomography, all geometries can be measured to within a few microns, including undercuts and internal geometries. Werth Autocorrection – using a highly accurate sensor such as the Werth Fiber Probe for reference measurements – enables extremely low measurement uncertainties of about 0.5 µm when needed, for example to ensure measurement process capability for measuring

	Image processing	Focus variation sensor	Laser	Chromatic focus sensor	Interferometric point sensor	Confocal sensor	Touch-trigger probe	Fiber probe	Contour probe	X-ray tomography
Geometries										
Edges and 2D contours	X	(X)	(X)	(X)	(X)	(X)	0	(X)	0	0
3D contours and flatness	0	X	X	X	X	X	X	X	X	X
Surface topography	0	X	X	X	X	X	X	X	X	X
Micro-geometries	X	X	X	X	X	X	0	X	(X)	X
Vertical surfaces / undercuts	0	0	0	0	X	0	X	X	0	X
Internal geometries	0	0	0	0	0	0	0	0	0	X
Surface										
Sensitive / pliable	X	X	X	X	X	X	0	X	0	X
High-contrast	X	X	X	X	X	X	X	X	X	X
Low-contrast	0	0	X	X	X	X	X	X	X	X
Reflective	0	0	(X)	X	X	X	X	X	X	X
Transparent	0	0	0	X	0	X	X	X	X	X
Particularities										
High-accuracy measurement	X	(X)	(X)	X	X	X	X	X	X	(X)
Roughness measurement	0	(X)	(X)	(X)	X	X	0	(X)	X	(X)

Table 1. Suitability of various sensors for a given measurement task and workpiece characteristics; X: suitable; (X): limited suitability; 0: not suitable

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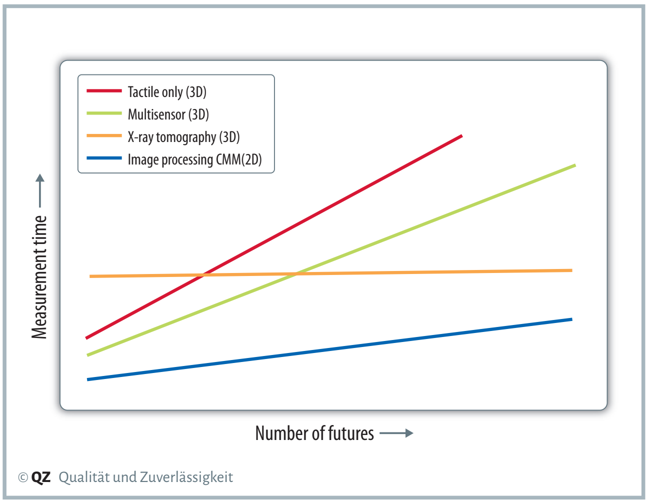

Figure 3. Measurement time as function of number of features – principle depiction for various types of sensors

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motor vehicle fuel injectors with tolerances of 5 µm.

A prerequisite for the use of CT is the radiographic permeability of the workpiece. This is made more difficult by highly absorbent materials and large radiographic lengths. Prerequisites for good measurement results with reasonable measurement times therefore include sufficient tube voltage and high resolution at high power. The resolution is substantially determined by the size of the focal point of the X-ray tubes.

X-ray tubes are differentiated between those with a reflection target and those with a transmission target. For the former, the X-rays are reflected by the target, and for the latter, the target is penetrated. With modern designs of transmission target tubes, the size of the focal spot increases less quickly as the power rises than for a reflection target tube, so the focal spot is smaller at a given power level. Transmission target tubes are therefore better suited for most measurement applications. Reflection target tubes are used for rapid measurements of workpieces with relatively wide tolerances.

CT Machines for Various Requirements

Various machine classes are available for different requirements for measuring range, resolution, measurement uncertainty, and measurement time. The span ranges from machines for measuring large engine blocks with tube voltages of 450 kV, to those for inline measurements on aluminum workpieces with a 30-second cycle times and tube power of over 1.5 kW, to compact machines like the TomoScope XS with high-performance, long-lasting, low-maintenance X-ray tubes (Figure 2). Combined with OnTheFly methods, this allows for short measurement times in sync with production lines. By continually rotating the machine axis, dead time for positioning the workpiece is eliminated.

One special feature of X-ray tomography is the ability to capture the installation orientation of individual parts in an assembly and dimensions of entire multi-material workpieces. Various software methods allow resolution to be increased or the measuring range to be extended. With Multi-ROI CT, only the interesting regions are measured at high resolution in order to reduce measurement time and data volume. Efficient mold correction in the injection-molding process shortens product development times.

The Measurement Task Determines the Sensor

The selection of suitable sensor systems must start with the measurement task and address its classification in the quality assurance concept. With multisensor systems, the total measurement time increases with the number of geometries to be measured. The image processing sensor, however, needs just a few second to measure many dimensions. Multi-dimensional distance sensors also capture a lot of points in a short time. Measuring the entire workpiece, however, may require slow tactile sensors. This often results in a relatively long total measurement time (Figure 3). Multisensor measurements are therefore particularly well suited for statistical process control (SPC) of relatively few dimensions, and for first article inspections with high accuracy requirements.

X-ray tomography allows the entire workpiece to be captured at the push of a button, with a nearly limitless number of geometrical characteristics, so the measurement time is virtually independent of the number of geometries to be measured (Figure 3). The CT sensor is therefore ideal for first article inspections or mold corrections. With rapid tomography scan methods, this sensor system can also be used for measurements during production. ■

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