

**Figure 1. Measurement “in the image”**  
Lenses are available with fields of view from about 1 mm x 1 mm up to 240 mm x 180 mm with accuracies ranging from 0.3 to 10  $\mu\text{m}$ .

#### CAPABILITIES OF CMMS WITH IMAGE PROCESSING

## Measuring “in the image” and “on the image”

Various concepts can be used with coordinate measurement machines with image processing. But which approach is best for which measurement? This depends on the measurement task, the measurement uncertainty and the required measurement speed.

Machines where the camera is fixed with respect to the measured object, similar to the classical comparator, are suitable for measuring entire features within the field of view of the sensor, that is, “in the image.” Machines similar to the classical tool makers microscope can measure features that are larger than the sensor’s field of view by using mechanical axes (measuring table) to position the camera within the measurement volume, that is, measuring “on the image”.

#### Measurement “in the image”

In the simplest case, measurement “in the image” is performed using only the optics and a camera (e.g., a CCD or CMOS camera). Precision within the fixed field of view is determined primarily by the imaging scale (about 0.04 to 10 times magnification) of the optics, and thus by the size of the field of view (about 200 mm to 1 mm square). The larger the field of view, the lower the resolution and precision. For example, an object to be measured that

has a length of 100 mm, is projected onto the camera pixels by the optics. In the best case, there are a few thousand pixels per line.

The resulting resolution of about 100  $\mu\text{m}$  is improved by about a factor of 10 with subpixel interpolation to yield measuring uncertainties of about 10  $\mu\text{m}$ . For objects that are about 100 mm in size, this technique can be used to check tolerances in the range of 100  $\mu\text{m}$  (ratio of measurement uncertainty to tolerance of 10:1).

The low-magnification lenses required for large fields of view usually have a large depths of field due to economic considerations (limited space and thus a small aperture). This means that correctly focusing is difficult. The result is measurement deviations due to unknown magnification in the depth of field of “normal” lenses. Telecentric lenses provide constant magnification over a relatively large depth of field (telecentric range) and are therefore required for large fields of view. In addition, image processing provides features to support the user to find the correct focus.

A typical representative of the “in image” class of measurement machines is shown in Figure 1. If workpiece tolerances in the range of 10  $\mu\text{m}$  must be checked over a large measurement range, this machine concept is no longer sufficient. Ma-

chines that can measure “on the image” are then required.

### Measurement “on the image”

Measuring machines that measure “on the image” have the ability to move the workpiece or the camera on machine axes to capture individual geometric elements such as points, lines, or circles (Figure 2, left). The required precision is ensured in part by selecting optics with sufficiently high magnification. The sensor and workpiece position (for bridge type or X-Y table machines) are also captured by means of precise measuring machine axes, while correcting for geometric and temperature deviations. To link the geometric elements into features (such as distances or angles), the position of the captured element within the sensor coordinate system and the position of the sensor in the machine coordinate system are superimposed. The features’ locations and dimensions are computed by the measurement software.

An additional vertical measurement axis allows these machines to be used for three-dimensional workpiece measurement as well. The object surface is captured by the third axis, for example by using the image processing sensor as an autofocus sensor.

The disadvantage of measuring “on the image” is that the workpiece must be moved to the appropriate measurement positions. This is done manually by the operator or a measurement program is created to automatically move the machine

axes. However, the advantage is that high accuracies can be achieved even for large measurement ranges.

### Raster Scanning – Measuring “on the image” “in the image”

Raster scanning combines the advantages of both techniques. To allow large measurement ranges, images of the entire measured object are captured automatically at the various “on the image” positions and are assembled into one complete image. This overall image can then be evaluated “in the image” in a user-friendly way (Figure 2, right).

A particularly advantageous machine concept has the camera located in an encapsulated housing pointing up. The workpiece is located on a glass plate above the camera and is always in the focal plane. This means that it is not necessary to adjust the focus. For measurements using transmitted light, a light source is located above the workpiece. The special collimated transmitted light allows tall or round parts to be measured accurately, due to the lighting that is matched to the lens (apertures of both systems are identical).

### Measuring Accurately “in the image” and “on the image”

To evaluate the performance of coordinate measuring machines using image processing sensors, it is not enough to evaluate the reproducibility of measurement results. Measurements of calibrated standards (diameters and distances) must be used to establish comparability to nation-

al and international standards (traceability). The methods for testing the probing error and maximum permissible error are set forth in the international ISO standard 10360 Part 7 and the VDI/VDE-Directive 2617 Page 6.1 for measurements “in the image” and “on the image”, as well as for 2D and 3D measurement equipment.

Measuring machines that measure “in the image” are characterized by easy operation and ergonomics. Due to their ratio of precision to measurement range, however, they can be used only for a limited range and only for 2D measurement tasks. For most measurement tasks, the ratio between the tolerances and the overall part size requires measuring machines that measure “on the image”. □

► **Werth Messtechnik GmbH**  
**Dr.-Ing. Ingomar Schmidt**  
**Phone: +49 641 7938 0**  
**mail@werth.de**  
**www.werth.de**

*Translated by Werth Messtechnik GmbH*

**QZ-Praxistipps**  
**www.qz-online.de/656348**

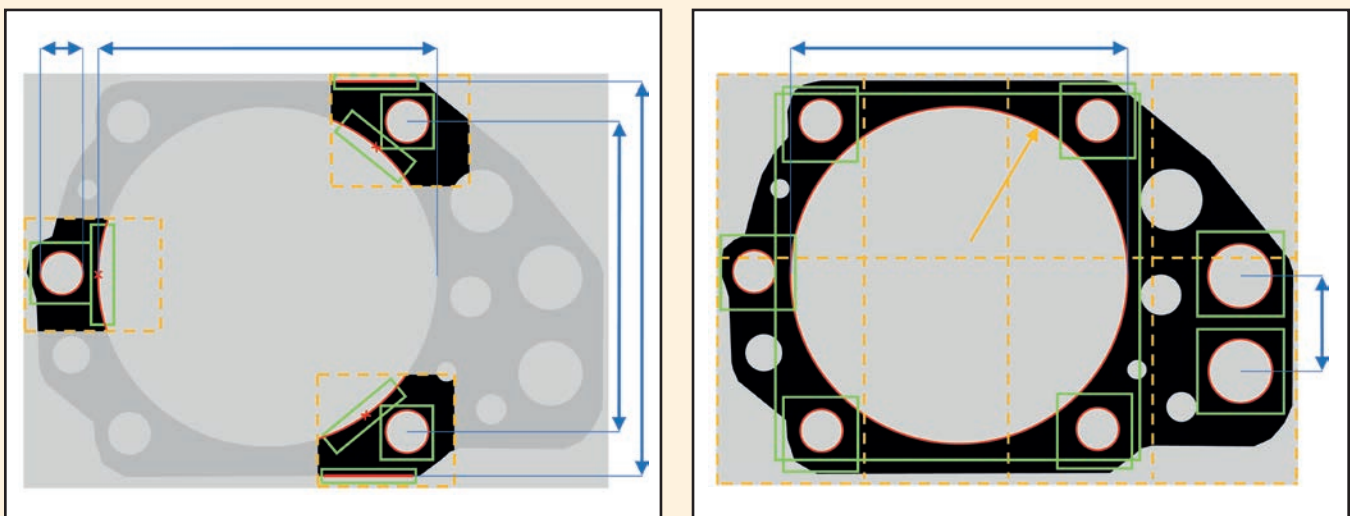


Figure 2. For measurements “on the image” (left), several randomly located image areas are measured individually (three yellow rectangles). For raster scanning (right), the entire object is captured by merging image areas (eight yellow rectangles). Windows (green rectangles) are positioned to select and measure contours and geometric elements (blue).