practical tip

MEASURING WORKPIECE SURFACES WITH OPTICAL SENSORS

Comparison of distance sensors

There are a great many contact and non-contact sensors for measuring workpiece surfaces. Depending on the measurement task and the surface properties, a suitable sensor is selected. The greatest flexibility comes with different sensors in a single measuring machine.

For surface measurements, dimensions (distance, radius, angle), geometric tolerancing (position, flatness, roundness) and surface parameters (roughness) of regular geometric elements (planes, spheres, cylinders) or free-form surfaces measuring points are captured. Optical sensors work with non-contact, which means that even sensitive workpieces and small features can be measured. The measurement points are captured very quickly, or many points can even be captured at once. Applications include production inspection of various workpieces, such as injection molded parts, optical functional surfaces, flexible sheet metal parts, and components for micromechanics (implants, watches).

Optical sensors can be distinguished on the basis of their measurement direction as lateral measurement sensors (measuring orthogonally to the optical axis, such as image processing) and axial or distance sensors (measuring along the optical axis). Distance sensors are distinguished between pointwise and area measurement sensors (Figure 2).

Pointwise distance measurement sensors

Distance measurment sensors capture measurement points individually on the workpiece surface. Suitable sensors are used for scanning during motion relative to the workpiece, capturing several hundred to thousands of points per second, even spread over large areas of the workpiece.

In the classical autofocus method, the distance between the workpiece surface and the sensor is determined by evaluating the contrast at various distances while moving the focal plane through the surface of the workpiece. The maximum contrast is found when the workpiece surface is directly in the focal plane. The sensitivity is influenced by the depth of field of the objective (the range along the optical axis in which a sharp image is generated), which in turn is dependent on the numerical aperture (opening angle) of the objective.

Objectives with a high numerical aperture have shallow depths of field and thus enable more precise measurements. With integrated grid projection, workpieces that have no surface structure under normal lighting can also be measured. Autofocus is used to measure individual points, such as to determine heights or the spatial location of surfaces.

Distance sensors with triangulation project a light beam (typically a laser beam) at an angle to the optical axis onto the workpiece. The location of the measurement point is determined from the location of the reflected beam on a camera, using the angular relationships (the triangle of the light source, surface point, and sensor). The sensors commonly used in automation with projection angles of some 10 degrees have relatively large measurement uncertainties, depending on the surface angle and structure. Sensors that use the Foucault principle (such as the Werth Laser Probe WLP) use the much smaller aperture

Figure 1. High-resolution area measurement with 3D Patch: Meshed view of the measured surface (top), color-coded deviation plot to the CAD model (bottom)

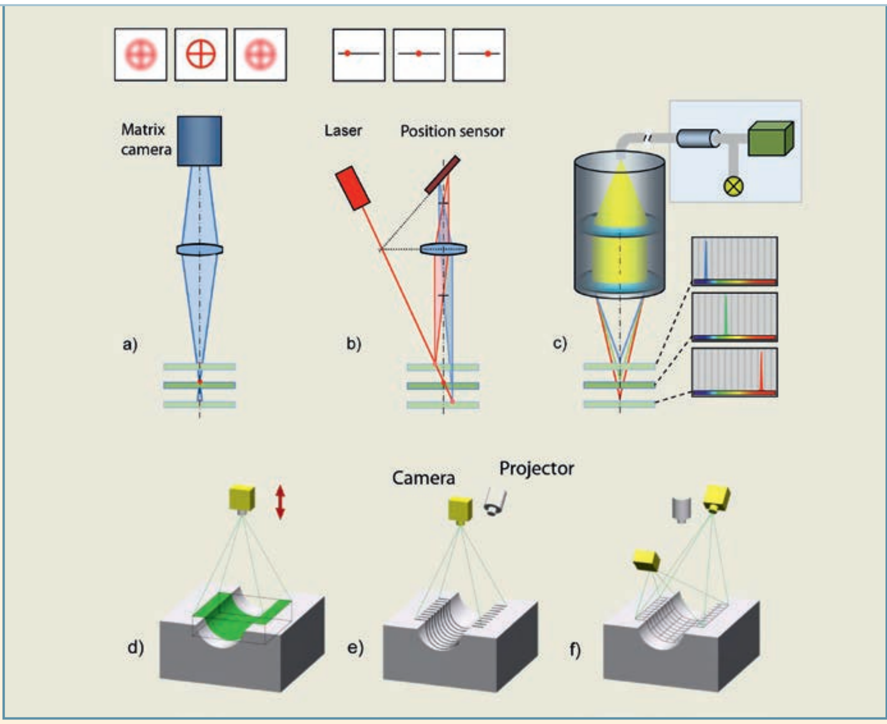

Figure 2. Overview of optical distance sensors. Pointwise distance measurement sensors: a) Autofocus, b) Triangulation, c) Chromatic methods. Area distance measurement sensors: d) Focus variation, e) Fringe projection, f) Photogrammetry

angle as the beam passes through the imaging optics and allow workpiece surface angles of up to 80°. If the sensor is integrated in the beam path of an image processing sensor, it is possible to switch between the two sensors and the laser probing can be observed without any mechanical motion. Foucault sensors are used for contour and flatness measurements with precision in the micrometer range, such as on sealing surfaces or tools (cutting and clearance angles, edge radii). The advantage relative to autofocus sensors is especially fast scanning.

The imaging error of optics known as chromatic aberration is deliberately exploited in chromatic focus sensors (such as the Werth Chromatic Focus Probe CFP). With special optics different colors of the light used for point illumination result in very different working distances. When white light is used, precise distance measurements are possible by determining which wavelength is in focus on the workpiece surface. This also allows high-precision measurement of even highly reflective surfaces at less workpiece angle (limited by the numerical aperture of the objective), such as on optical surfaces or for layer thickness measurements.

The advantage that distance sensors with the Foucault and chromatic principles have in common is the ability to scan measurement points over large linear regions of the workpiece at a high frequency, such as for measuring straightness or radii.

Area distance measurement sensors

With area distance sensors several thousand measurement points are typically recorded at once. This allows closed surface regions to be captured with a high point density. When the autofocus method is used for several groups of image points or for every image point of the camera in parallel, a simple and fast three-dimensional measurement is taken. Such focus variation methods (such as the Werth 3D-Patch), as well as the single point autofocus method, can be implemented at low cost using image processing sensor hardware that is generally already present. For example, fillets on tool blades or the complete topography of workpiece regions can be measured in this way. Special lighting and image capturing methods (grid projection, variation of the amount of light captured) are used if the workpiece surface structure does not generate sufficient contrast or if great local variations in reflection are present (flat or inclined surfaces).

Under certain conditions, roughness parameters can also be determined. The comparability of measurement results to tactile measurements should, however, be verified and correlated experimentally using sample workpieces.

Analyzing brightness progression while traveling vertically through the measurement range when using confocal sensors (such as the Werth Nano Focus Probe NFP) provides complete independence from the surface contrast. Reflective surfaces and even roughness can be measured in this way. Severely angled surfaces can be measured only at a short working distance or with very specialized objectives (with high numerical aperture). The measurement deviations that can be achieved are in the range of tenths of micrometers. Typical application examples include measuring the entire geometry of inserts for stamping tools or coin embossing punches.

With suitable coordinate measuring machines, several regions captured with focus variation or confocal sensors can be combined with high precision and without using error-prone "stitching" methods (combining using surface features) and can be analyzed together.

For measurement tasks with low precision requirements, such as in car body applications, pattern projection methods can be used. The pattern projected on the workpiece is analyzed by triangulation. In classical fringe projection, the geometry of the pattern and the imaging beam path (magnification, imaging errors) affect the precision that can be achieved. Photogrammetric sensors capture the workpiece surface from different directions with two cameras and are more robust with respect to brightness differences and surface defects.

In cooperation with the coordinate measuring machine manufacturer, the right optical distance sensor can be selected for many measurement tasks. Together with image processing and tactile sensors, the optimal multisensor coordinate measuring machine can be configured for the application. □

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Translated by Werth Messtechnik GmbH

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This article can be found online:
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