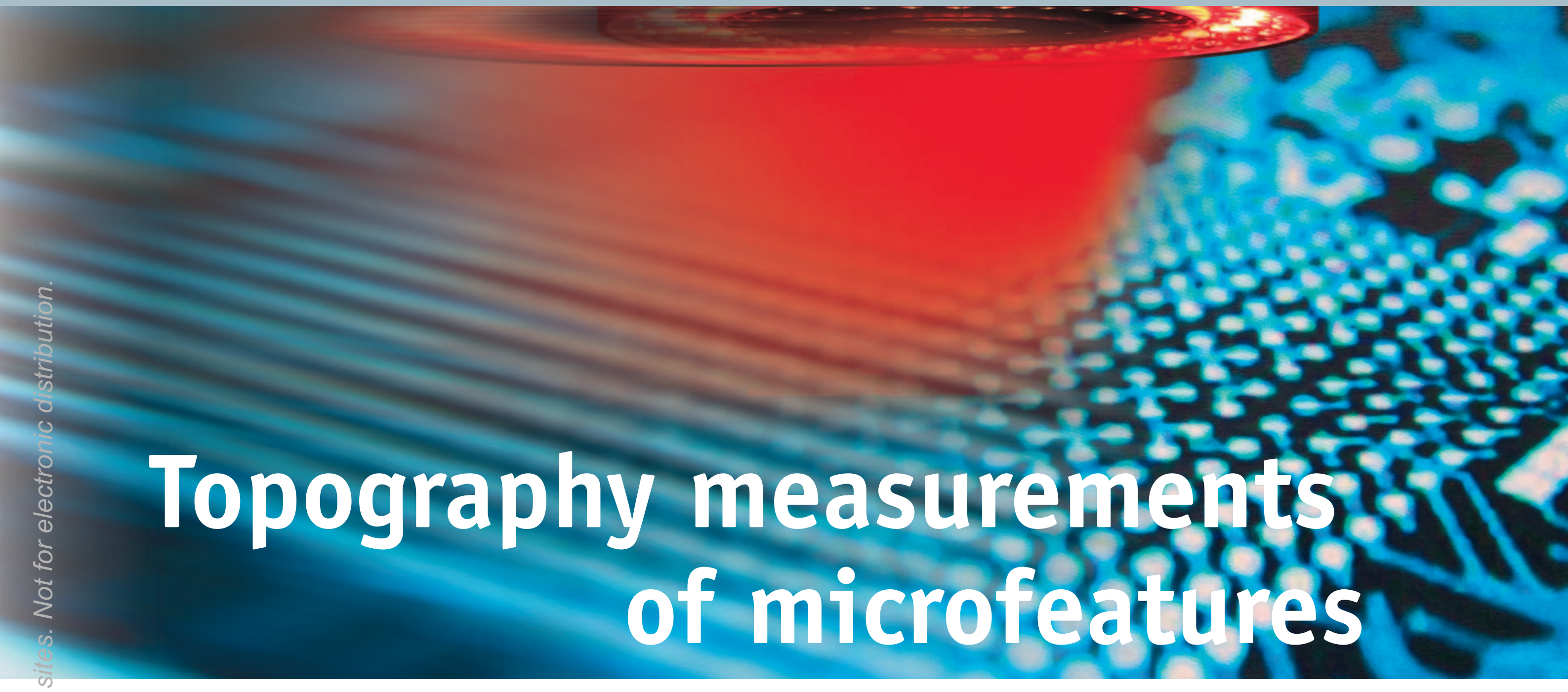


Topography measurements of microfeatures

3D POINT CLOUDS MEASURED BY OPTICAL SENSORS

Modern coordinate measuring machines can be equipped with a wide range of sensors. Besides the traditional tactile sensors, optical sensors are becoming increasingly popular. Using optical sensors, large numbers of points can be determined on the workpiece surface within a short period of time. This allows a complete evaluation of the shape, dimensions and position.

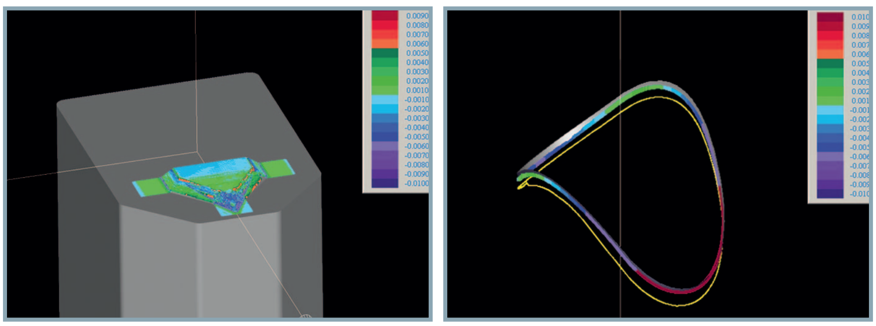
DETLEF FERGER

An increasing number of CMM (coordinate measuring machine) users are demanding that measurement objects be captured as completely as possible. This is due to the increasing complexity of the components that need to be dimensionally inspected. The use of free form surfaces for designing components is also becoming increasingly widespread. Additionally, as components continue to be miniaturized, the geometric features of many functional parts are becoming smaller and need to be measured with higher resolution and precision. Typical applications include the plastic injection industry, the production of microcomponents, sensor components for medical and automotive engineering and cutting tools.

The form deviations of these features are often of a similar order of magnitude as the part tolerances. If too few points are measured, this can lead to additional measurement deviations. Optical sensors in particular allow large numbers of points to be measured and features to be completely captured in the shortest possible time.

Non-contact scanning of many points

The most widespread optical sensor is the image processing sensor. It has traditionally been a central focus of Werth coordinate measuring machines. With more than 50 years' experience, a solid foundation for reliable and accurate optical measurement has been established at Werth. These sensors are extremely accurate and fast. Coupled with flexible lighting options, such as the Werth ›MultiRing‹, as well as the image processing software with accurate and easy-to-use features, such as the ›AutoElement‹ feature, measurement tasks can be made much easier for the user. With the new, patented ›OnTheFly‹ technology (measurements during axis movement), the combination of speed and accuracy has reached a new level. As a



1 **Color-coded presentation of deviations on different workpieces, measured using various sensors: a) microstamping tool, measured using the Werth 3D-Patch; b) cutting edge contour of a microcutting tool, measured using autofocus scanning**

result, it is now possible to measure ten or more features per second, including positioning of the measurement object.

Using ›on the fly‹ technology in combination with raster scanning, objects can be completely digitized and thus assessed with the highest resolution and unprecedented speed.

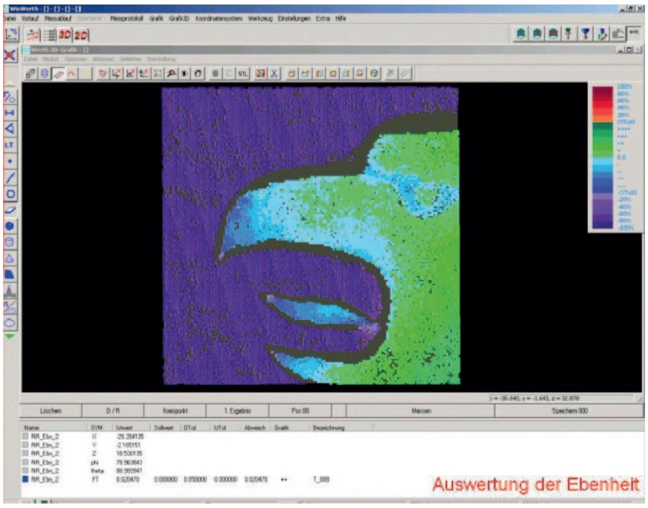
Topography measurement using autofocus

Using similar hardware components, three-dimensional geometric features can also be measured. Werth Messtechnik introduced a technique in 1999, based on the focus variation principle called the ›Werth 3D-Patch‹. Used in tandem with modern image acquisition technology, several hundred surface points can be captured simultaneously in one *z*-axis movement of the CMM in a matter of seconds.

With the 3D-Patch up to 250 000 surface profile measurement points are distributed in a freely definable dot matrix and captured within the measuring time of a conventional autofocus procedure. This data can then be evaluated using the powerful ›WinWerth‹ software. In this way, radii or the surface evenness of workpiece geometry can be measured completely in a single measurement operation. This is particularly useful for small geometric features.

For larger workpieces, several measurements of this type can be carried out in succession at different positions so that ›point clouds‹ can also be captured for larger measurement areas (**Figure 1a**). A similar technique is used to measure edge contours of cutting tools (**Figure 1b**). In many cases, the 3D-Patch feature is a very economical substitute for a 3D stripe projector or laser line sensor.

The technique works best on surfaces that lie normal to the optical axis. By integrating rotational and tilt axes, however, this limitation is easily overcome. Typical applications include the digitizing of smaller free-form surfaces, height determination of soldering points, the coplanarity of connector pads, embossing depths (**Figure 2**) as well as the spatial locations of extremely small surfaces (for example, locating tabs). This function is a valuable addition to almost any CMM.



2 Coin tool measurement using the 3D-Patch

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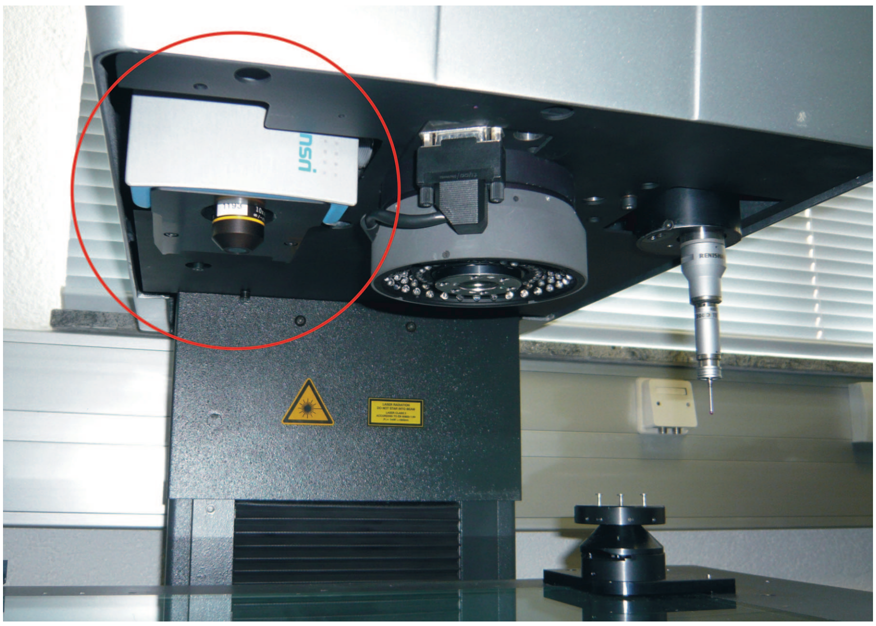
3D measurement of microstructures

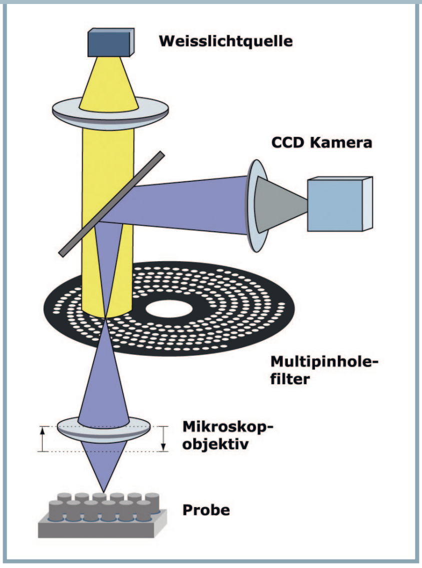
In addition to the existing range of sensors, Werth Messtechnik, in collaboration with NanoFocus, now offers the exclusive opportunity to perform high-precision measurements using a single profiling system via a non-contact confocal sensor. Even laminated microstructures can be easily captured in 3D using this sensor (**Figure 3**).

The sensor is suitable for use in both production and laboratory environments. The high-performance detector head with nanometer resolution provides reproduction of fine detail and high measuring speed. Besides analyzing the microgeometry in terms of shape, contour, flatness and roughness, this sensor can be used to evaluate the structural topographical features of modern functional surfaces.

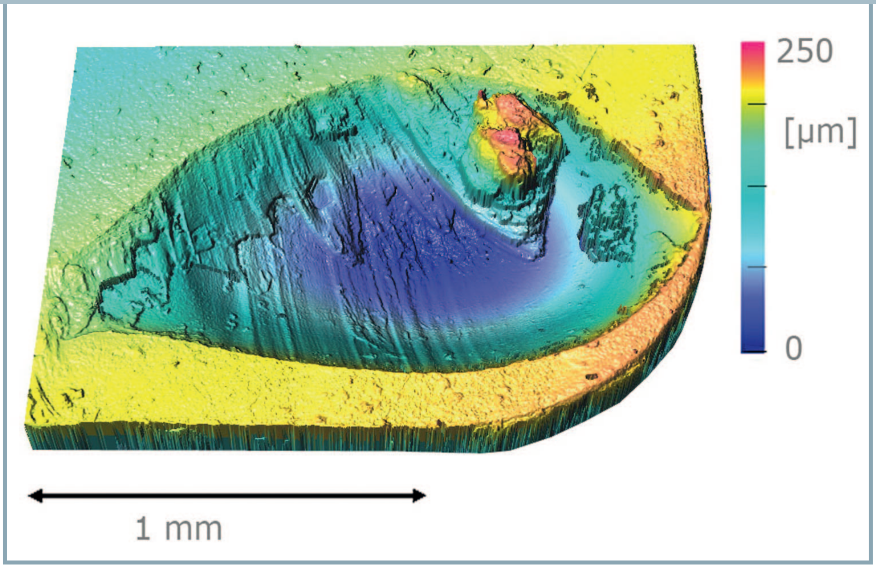
The 3D surface measuring system uses the depth-discrimination principal provided by confocal imaging. This measurement of surface structures, based on a fast ›multiple pinhole‹ technology with dynamic real-time synchronization developed by NanoFocus, determines the precise *xyz*-coordinates of a small ▶



3 Werth ›VideoCheck 400x200x200‹ with integrated NanoFocus sensor



4 Functional principle of the NanoFocusProbe



5 Color-coded presentation of pitting on a cutting disk

region around the extremely narrow focal plane of a precise microscope lens.

In conjunction with a fast *z*-movement of the focal plane through the surface of the measured object, the multiple pinhole set-up largely masks the light over the entire field of view while allowing the light from individual points to return in sequence (Figure 4). Utilizing a confocal approach, the maximum amount of reflected light is collected from any one point only when it lies exactly in the focal plane of the lens. Thus, by monitoring the light intensity of each point in relation to the *z*-position of the focal plane, its exact height can be determined. All points within the measuring field are captured using the real-time video performance of a CCD camera.

The advantage of the ›NanoFocusProbe‹ (NFP) is the inherently high vertical and lateral resolution. The lateral diffraction-limited resolution that is otherwise common in conventional microscopes is surpassed by the confocal approach. Additionally, even surfaces with steep slopes, complex structures, or transparent coatings can be measured. The NFP is used not only for the measurement of geometry, shape and roughness of microstructures, but also for radii of cutting tool edges and coating thicknesses. It is also typically used for inspecting the surface of medical engineering components, for example, dental implants, artificial joints, and stents. As the relatively small field of view of the sensor would otherwise only allow limited use, this can be extended to measurement objects of any size when integrated into a multisensor coordinate measurement system.

Workpieces can also be measured in combination with the image processing sensor. Utilizing a unified coordinate system, the confocal sensor can be rapidly and precisely positioned at the region of interest before initiating a more detailed measurement. The 3D point clouds can then be quickly and easily evaluated using the 3D ›WinWerth‹ measuring software and presented clearly using the integrated 3D CAD module. This is done either based on a breakdown into simple modelling geometries using, for example, classical measurement of lengths and angles, or by comparing profiles to the 3D CAD data and color-coding appropriately (Figure 5).

Using different optics, the performance parameters can be adjusted to the respective task in terms of accuracy and field of view. The available visual fields are between 1.6 x 1.6 and 0.16 x 0.16 mm^2 at an achievable maximum permissible error for probing (MPE P) of 0.6 to 2.9 µm.

Summary

Using the optical sensors described above, accuracy in the range of just a few micrometers – and, in some cases, far better – can be achieved. When choosing a suitable sensor, one needs to consider the material surface characteristics of the object to be measured. This is where the experience and professional advice of the manufacturer can be particularly important. To design CMMs with the flexibility to meet different requirements, it often makes sense to use several sensors within one measuring system. The key technologies include machine vision in conjunction with one or more distance sensors. These are complemented by tactile sensors and computer tomography.

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