Flexibility connected with high accuracy has led to a wide range of applications for coordinate measuring machines in dimensional measurement for production control, as well as for inspection in the laboratory. Multisensor coordinate measuring machines today feature both contact and non-contact sensors, thus combining the advantages of tactile and optical measurement in a single system. The operator can choose the sensor best suited to a given measuring task. He is not limited by single sensor types to a specific measuring strategy, and is therefore able to generate an optimised testing plan in one measuring run. The high measuring speed and the flexibility of multisensor coordinate measuring machines permit economical, near-production measurement.

Machine selection based on specification and part size

The modular design principle of the Werth coordinate measuring machines can accommodate different application needs, and therefore different measuring ranges and accuracy requirements, as well as environmental conditions, can be considered. The Werth Scope-Check series was designed for cost effective quality control in the shop floor environment. The machines in the Werth Video-Check series (Fig. 1) readily meet higher demands for accuracy. Intelligent solutions in mechanical design are the basis of the outstanding characteristics of this machine, with performance superior to any in this class world-wide. Solutions to the most complex measuring tasks are provided with the incorporation of rotary or rotary/tilting axes. With the combination of super high resolution linear scales and 3-D error compensation, measuring uncertainties down to 0.5 µm are provided. The Werth Inspector FQ series of machines was designed for fast production control. The modern drive system, based on linear motors, makes it possible to reach up to five positions per second and to measure several geometry elements at each position.

Sensor configuration based on feature type

The sensors must be selected based on conditions in and around the work-piece, the touch sensitivity of the object, the size of the features to be measured, the requirements of the measurement plan, and the number of measured points. Thus, the selection of the sensor or sensors basically depends on the measuring task at hand. In order to perform complex measuring jobs, it is usually necessary to use different sensors for a single measuring run (Fig. 2).

Optical sensors

Image processing sensor

The basic configuration of each multisensor coordinate measuring machine includes an image processing sensor system that is tailor made for metrology and is perfectly suited for fully automatic mea-
measurement of complicated work-pieces, even in poor contrast, in transmitted and in reflected light. Special grey-scale image processing filter methods reduce the influence of dirt particles, for example upon the measuring result. Telecentric lenses are recommended as the preferred choice of optics for precision measurements. From an application point of view, it makes sense to combine high and low magnifications. The greatest flexibility can be achieved using a zoom lens system. An ideal solution for many standard measuring tasks is the Werth-Zoom (Fig. 3). The design principle (patent pending) is based upon linear guide-ways and provides highly repeatable and stable measurement. Another unique feature of this zoom is that both the working distance and the magnification can be adjusted automatically. Measurement into the depth of work-pieces up to 200 mm is possible. It is also possible to search work-pieces with a large field of view and to measure big parts with a large working distance without the risk of a collision. Further advantages are to measure large turned parts or to use a combination of vertical and horizontal lenses, for measurements in different views.

The use of visual sensors usually requires reflected-light as well as transmitted-light illumination. A multi-segmented ringlight is ideal for most applications. The Werth MultiRing illuminator (patent pending) provides maximum contrast (Fig. 4). A defined pre-selection of the illumination angle is provided by quadrant choice. The incidence angle is programmable over a wide range.

**Autofocus**

Measurements in the Z-axis are done with the image processing sensor using the integrated fast autofocus. Precision in the submicron range is obtainable, depending on the lens depth of field. When compared with a laser sensor, autofocus offers the fundamental advantage of being relatively unaffected by material surfaces.

**Laser**

Laser distance sensors are well suited for the rapid measurement of the flatness of work-pieces as well for the measurement of low slope freeform surfaces. Optimal results can be achieved with laser sensors which function according to the Foucault principle. To optimise the practical use, a Foucault laser sensor of this type is integrated in the beam path of an image processing sensor.

**Tactile sensors**

All tactile sensors function on the principle of mechanical contact with the work-piece. A distinction is made here between touch trigger and measuring probing systems. The touch trigger probe therefore belongs to the basic configuration of a modern multisensor coordinate measuring machine. In contrast with touch trigger probes, measuring tactile probes have integrated path measuring systems. Therefore, a continuous evaluation is provided in 3-D scanning. Higher point densities and positioning speeds allow economic operation during the measurement of freeform surfaces. These probes may also be equipped with rotary/tilt devices and probe stylus changers in order to increase flexibility.

**Measuring tactile-optical sensor**

The use of ultra-modern glass fiber technology made it possible to develop the patented Werth Fiber Probe (Fig. 5). Measuring the smallest 3D micro features (i.e., sphere radius from 12–250 µm) opened up completely new applications. Due to the extremely low probing force, measurement of rubber and plastic parts can be made by contact. The gap between optical and traditional contact probing is therefore closed. If a high precision coordinate measuring machine is used, the probing deviation may be smaller than 0.5 µm. Also, the measurement of gages and high precision tools is now in reach.

**Outlook**

The share of multisensor coordinate measuring machines on the total metrology market has significantly increased in recent years. Due to the growing flexibility of these machines, they perform tasks that have heretofore been the domain of conventional systems in the areas of form, roughness, and one-dimensional length. One of the major tasks for the coming years will be to increase the accuracy, the measuring speed, and the ergonomic structure of the corresponding software modules.

An ever increasing number of activities will be transferred from the operator to the computer based on the existing CAD data interface. The environment and the interaction between software and the sensor systems will become more intelligent and powerful, and will increasingly reduce the number of operating errors. Future software packages featuring “artificial intelligence” will define measurement plans based on CAD models, and prompt the user to enter subjective answers to specific questions (for example, the required reference coordinate systems).

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**Fig. 5: Working principle of Werth Fiber Probe;**

- a) 2-D measuring set-up
- b) 3-D measuring set-up with second camera

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