Integration of Optical Sensor into UPMC

[1]D. Ewert, [1]L. Autschbach, [1]H. Wang, [1]R. Grau, [2]H. Thiess, Y. Yuan
[1]*Carl Zeiss Jena GmbH, Oberkochen; Germany*
[2]*Carl Zeiss Laser Optics GmbH, Oberkochen, Germany*

d.ewert@zeiss.de

Abstract

Today's optic industry shows a sure trend towards more precise optical surfaces, leaving regular geometries and introducing more and more complicated freeforms. One of the greatest challenges is metrology for validation and close-loop processes. On the one hand coordinate measurement machines (CMM) are able to measure freeform surfaces. Since they need to touch the work-piece with a probe point by point, CMMs are quite slow and the amount of measure points is limited. Another disadvantage is that by touching delicate surfaces get damaged. For regular geometries (like spheres or planes) optical metrology methods are common. They are a lot faster and at the same time allow a higher density of measure points. On the other hand optical metrology for freeform surfaces is very difficult to put into effect and usually is not very flexible (e.g. CGH).

To overcome the disadvantages of both types of metrology, a combined measurement device was developed. This development was done only for internal Zeiss (freeform-) projects and has no commercial background like standard available measurement technique from Zeiss IMT e.g. Presented in this paper are the combined measurement system, the measurement possibilities, material perception and the achieved measuring range, accuracy as well as its repeatability. The paper ends with an outlook for further needs and development tasks.

1 The coordinate measurement machine

As basis for the measurement system a highly tuned UPMC Ultra CMM from ZEISS was used. The UPMC itself has a measurement range of 850mm x 1200mm x 600mm and has an active scanning system with probe head correction. Further specifications are summarized in Table 1.

Table 1: UPMC Ultra CMM Specifications

Form Measurement Error	< 0.2µm + L / 1000
Probing Method	single point and scanning
Scanning Unit Resolution	0.005µm
Measuring Forces	intermediate steps of 1mN (50mN – 400m N)
Max No. of data points	24.000 pts in 16h (single point)
Probe Weight	up to 0.6kg
Work-Piece Weight	up to 1000kg

The goal of integrating an optical sensor onto the UPMC was to achieve high speed with v > 250mm/min, high data volume with several million points per scan in 3d, various range of reflectivity from 4% - 100% and a high flexibility for plane as well as complex 3D surfaces. Several optical sensors were tested regarding sensitivity to stray light, to different types of material from plastic to metal forms, to different surface qualities Ra = 2000nm to Ra = 1nm and angle dependencies < 20°.

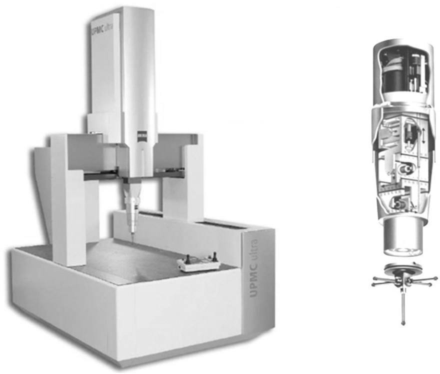

Figure 1: UPMC Ultra CMM with active scanning system (schematic right)

2 Adaption of optical sensor on UPMC

To use the sensor on the UPMC it was attached to a probe mount. With a probe the work-piece position is acquired. According to this position a scan track is programmed. While the CMM executes this scan track, the sensor software gives the measurement points. An accuracy of < 3µm was achieved. Within 4 hours a 3d surface was successfully measured in scanning-mode with up to 1.5 million points. Scanning speeds of > 1000mm/min were successfully performed.

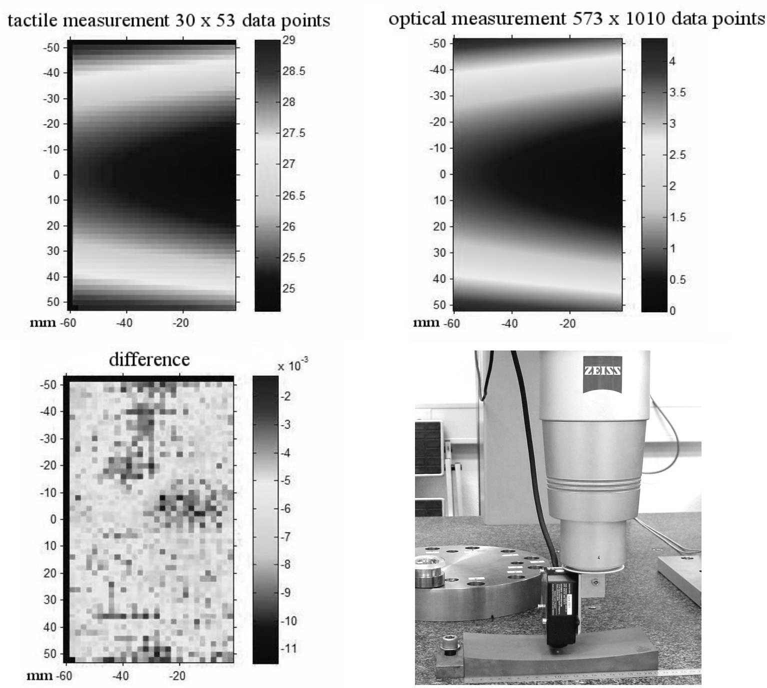

Figure 2: Comparison of tactile measurement and optical measurement. The difference is less than 3µm over a measuring field of 100x60mm.

3 Tests with the optical sensor

As sensor a monochromatic confocal sensor was chosen. This sensor has a high resolution of 2µm lateral and 10nm in z-direction and is able to measure both reflective, as well as non reflective and rough surfaces. Thus this sensor enables a broad variety of measurement tasks. In comparison to a stylus probe there are a few limitations. This particular sensor is only able to measure angle deviations to the optical normal of ±20°. No under angle measurements are possible.

3.1 Material Perception and Measuring Range

The sensor has a measurement range in z-direction of 0.6mm. Different materials were tested to verify this range (ground glass, polished glass, ground ceramic, brushed metal, moulded plastic). For this experiment the distance between sample and sensor was manually adjusted. All tested materials were perceived by the sensor over nearly the whole measurement range (ca. 0.59mm). This is a great advantage over other optical sensors of which some failed to measure the ceramic surface, some couldn't measure the brushed metal and some couldn't handle the plastic.

3.2 Measuring Accuracy and Repeatability

Two samples were chosen to figure out the measuring accuracy and repeatability of the sensor. A polished glass asphere and a ground ceramic sample were measured in tactile mode on the UPMC and with the optical sensor manually on a second reference setup. The achieved data points were adjusted, aligned and fitted to the UPMC measurement.

Table 2: Measuring accuracy and repeatability tested on two different samples.

	mean deviation [µm]	standard deviation [µm]
polished glass asphere	0,63	0,11
ground ceramic sample	0,83	0,52

In this comparison of the data the mean deviation of the sensor points to the UPMC points were calculated, as well as the standard deviation of several repeated measurements of the same line. The results are shown in Table 2. As expected the measurements on the polished glass asphere are with an accuracy of 0.63µm about 24% more accurate than those on the ground ceramic sample and it also shows a better repeatability. This deviation could be caused by scattered light, or by the smoothing effect of the probe-ball on rough surfaces (of the reference measurement).

4 Summary and outlook

To provide the possibility of form- and material-independent, fast and contact-less measurements suitable optical sensors were tested for implementation on a high-precision CMM. A monochromatic confocal sensor was chosen, which is able to perform measurements on all chosen materials. An accuracy of < 3µm was achieved at a high speed of > 1000 mm/min and a high data volume of > 1 Mio. data points.

For further developments a direct connection of the sensor to the CMM-Interface is planned, as well as an adapter for increased measuring angle. In this way measurements will be easier to perform, higher scanning speeds are expected at increased precision and a greater topographical flexibility should be achieved.