euspen's 17th International Conference & Exhibition, Hannover, DE, May 2017
www.euspen.eu

Recent results of micro geometry measurements using Werth 3D Fibre Probe

Jakob Schlie[1], Michael Neugebauer[1]

[1]*Physikalisch-Technische Bundesanstalt (PTB), 38116 Braunschweig, Germany*

Jakob.Schlie@ptb.de

Abstract
Measurements and calibrations of high precision micro geometries or soft materials are becoming more and more necessary in modern industrial processes. In this paper, the results of measurements of micro calottes using a Werth VideoCheck UA CMM equipped with a 3D fibre probe are shown. The fibre probe enables measurements with probing forces less than 0.1 mN and the use of stylus tips down to 25 µm.
The results using probes with 100 µm and 250 µm tip diameters show that the measurements of the calottes coincide with the reference values of Zeiss F25 with respect to the stated uncertainties. The results also meet the expectation that high precision measurements of even smaller objects are possible using fibre probes with tip diameters down to 25 µm.

Fibre probe, micro CMM, probing force, micro geometries

1. Introduction

Objects with high precision micro geometries like micro gears or watch parts are becoming more and more established in everyday life. Furthermore, micro geometries like calottes [1, 2] or small balls on thin non-metal shafts [3] are needed for the calibration of the emerging industry using (micro) CT systems. Especially for soft materials like plastics, additive manufactured parts (3D printing), or thin structures/mountings, the tactile calibration possibilities with probing forces less than 0.5 mN are strongly limited [4].

In this paper, the opportunities using the 3D fibre probe are shown. It allows tactile measurements with probing forces less than 0.1 mN and the use of probes with tip diameters down to 25 µm. The working principle of the 3D fibre probe is briefly described and some results of measurements of micro calottes are reported.

2. Working principle of the 3D fibre probe

A Werth VideoCheck UA multi-sensor CMM equipped with a 3D single-sphere fibre probe was used for the investigations. The working principle of the probe is shown in figure 1. An optical glass fibre with a glass sphere tip is mounted on a leaf spring. The tip is placed in the focal plane of the imaging optic and is illuminated by LED light. In addition, a mirror is mounted on the upper end of the fibre slightly above the spring. The position of the tip in x- and y-direction is measured on the CCD sensor by image correlation techniques. The z-position is determined by a laser distance sensor which measures the change of the mirror position. The spring and the glass fibre are selected to have nearly isotropic compliance to achieve similar probing forces in all directions.

In contrast to conventional tips, the fibre probe tips are manufactured by melting a glass fibre and therefore the tip form is often slightly drop-shaped. The form deviations of the tip, therefore, are determined at a high precision reference sphere and corrected.

More detailed information about the fibre probe can be found for instance in [5].

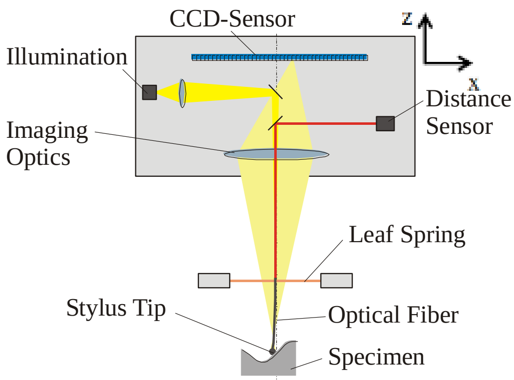

Figure 1. Working principle of the 3D single-sphere fibre probe [5]

3. Test objects and test procedure

Firstly, reference spheres of diameters of 2 mm, 6.35 mm and 10 mm with form deviations of much less than 0.1 µm were used. The spheres were measured with twenty-five points according to ISO 10360-5 [6], respectively. From these measurements the respective parameters P_{Size} (size error) and P_{Form} (form error) were estimated.

Secondly, a micro calotte cube made of titanium as shown in figure 2 was measured. The micro calottes have a radius of 0.4 mm and were manufactured by EDM. Therefore, the form deviations of the calottes are relatively large within about 5 µm to 8 µm. Because the probes are calibrated using imperfect spheres, some systematic errors cannot be tested with the aid of spheres, e.g. the probe sphere diameter. For this reason, an inverse geometric element like the micro calottes is used for the test. An equidistant pattern of points is applied with a spacing of about 100 µm, resulting in 115 points overall.

The test objects were calibrated with the aid of a micro-CMM F25 [7] using a micro-probe with a tip diameter of 300 µm and a probing force of approx. 1 mN. The tests with the 3D fibre probe were carried out using two different probes with nominal tip diameters of 100 µm and 250 µm. A least-squares sphere was fitted into the points measured at the objects, respectively, and no filtering or outlier removing was applied.

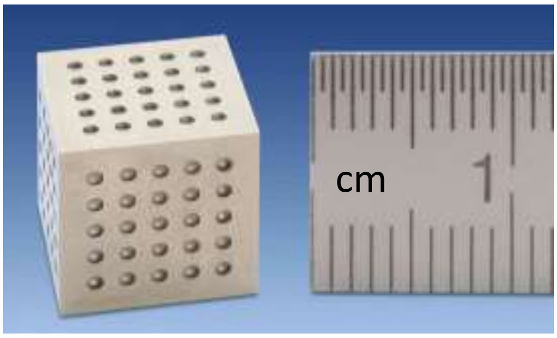

Figure 2. Micro calotte cube with an edge length of 10 mm with 25 calottes of 400 µm radius on three faces each (PTB)

Figure 3 shows a microscope height image of the measured calotte no. 1. At a height of around 150 µm, moulds from probing with a conventional CMM with a much higher probing force in a former measurement can be seen.

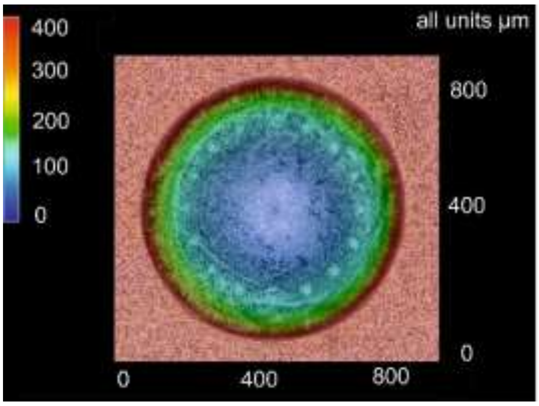

Figure 3. Microscope height image of calotte no. 1

4. Results

Table 1 shows the results of the measurements of the spheres. For the 2 mm sphere, which is of the same size as the calibration sphere for the probe, both the size error (P_{Size}) and the form error (P_{Form}) are below 0.2 µm. For the measurements at the larger spheres the deviations are higher. This is probably caused by shadowing effects. These effects depend amongst others things on the tip size and the shaft geometry and are to be investigated in the future.

Table 1. Results of the measurements of the reference spheres

CMM (Probe diameter)	UA (254 µm)	UA (106 µm)
2 mm sphere	Value in µm	
P_{Size}	+0.08	+0.19
P_{Form}	0.06	0.18
6.35 mm sphere		
P_{Size}	+0.07	+0.20
P_{Form}	0.58	0.31
10 mm sphere		
P_{Size}	+0.24	+0.24
P_{Form}	0.81	0.43

Table 2 shows the results of the measurements of three micro calottes. The deviations from the reference values are below 0.4 µm for radii (ΔR) and below 0.1 µm for the centre distances (ΔL), respectively. The form deviations are in the same magnitude as the calibrated form deviations of about 6 µm.

The uncertainties of the fibre probe measurements with the 254 µm probe for the reference sphere diameter were roughly estimated to be 0.3 µm for ∅ 2 mm to about 0.6 µm for ∅ 10 mm. Due to the much larger form deviations of the micro calottes the uncertainty of radii considerably increases to about 1 µm.

Table 2. Results of measurements of the three micro calottes

CMM (Probe diameter)	UA (254 µm)	UA (106 µm)
Parameter	Deviation from reference value in µm	
ΔR 1	-0.18	0.35
ΔR 2	-0.18	0.25
ΔR 3	-0.24	0.28
ΔL 1-2	-0.06	0.00
ΔL 1-3	0.02	-0.02
ΔL 2-3	0.09	0.09

5. Summary and outlook

In section 2, the working principle of the 3D fibre probe was described. The combination of tip diameters down to 25 µm and probing forces below 0.1 mN makes the fibre probe a useful technique for the measurement of small and soft micro geometries. In section 3, the procedure for the measurements and the test objects was described. The results in section 4 show that the fibre probe allows to determine the measurands within the calibration uncertainty. The measurement uncertainties for the calibrations were estimated by the analytical approach and roughly estimated for the fibre probe, whereas for the future, PTB plans to implement the VCMM for the fibre probe by the end of 2017.

The main uncertainty contributions for measurements with the 3D single-sphere fibre probe used are firstly, shadowing effects and, secondly, thermal drift effects. Part of the next investigations, therefore will be the testing of 3D dual-sphere fibre probes to reduce the influence of shadowing [5] as well as to reduce the influence of thermal drift effects with appropriate methods. Moreover, 3D fibre probes with a much smaller diameter down to 25 µm will be tested.

References

[1] Neugebauer M, Hilpert U, Bartscher M, Gerwien N, Kunz S, Neumann F, Goebbels J, Weidemann G 2007 Ein geometrisches Normal zur Prüfung von Röntgen-Mikrocomputer-tomographiemesssystemen *Technisches Messen* **74** 11

[2] Hermanek P, Carmignato S 2016. Case Studies in Nondestructive Testing and Evaluation, http://dx.doi.org/10.1016/j.csndt.2016.05.003

[3] Bartscher M, Illemann J, Neuschaefer-Rube U, Case Studies in Nondestructive Testing and Evaluation, http://dx.doi.org/10.1016/j.csndt.2016.04.001

[4] Thalmann R, Meli F, Küng A 2016 State of the Art of Tactile Micro Coordinate Metrology *Appl. Sci.* **6(5)** 150

[5] Neuschaefer-Rube U, Bremer H, Hopp B and Christoph R 2014 Japan. Recent Developments of the 3D Fibre Probe *Proc. 11th Laser Metrology for Precision Measurement and Inspection in Industry*

[6] ISO 10360-5:2010

[7] Neugebauer M: Precision size and form measurement with a micro-CMM F25. *IXth International Scientific Conference Coordinate Measuring Technique, 2010, Bielsko-Biała, Polen*