Probing Behaviour of a Micro CMM

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Introduction

Miniaturization has an enormous potential for increasing our quality of life by packing more functionality into a smaller volume. For the realization of this potential however, it is important that the miniature components in question can be manufactured reliably. This in turn requires traceable 3D measurements. For these complex 3D micro-parts, a new generation of CMMs, so called micro coordinate measuring machine (micro-CMM) have arisen. One of those is the F25 microCMM which was developed by ZEISS in cooperation with our institute and the Eindhoven University of Technology. We have reported before on the traceability of our F25[1] and shown how we characterized the geometrical machine errors and determined the uncertainty. Here we will present our work done on evaluating the probing behavior of the tactile probe of our F25 for the case of static probing. We will discuss and explain the observed effects and estimate the contribution to the uncertainty of our F25.

1 The F25 microCMM

The F25 has an aluminum platform which can move in x and y direction on a granite table using air-bearings, see figure 1. The z-axis carrying the probe system is suspended in this platform and can move in the z direction. The measuring volume is 100 × 100 × 100 mm. The position of the platform and the pinole is measured by line scales. More detailed information can be found in refs [1,2].

Figure 1: The F25 micro-CMM

The tactile probe consist of a passive stylus, with probe tips of 300 or 120 micrometers, connected to a 6.5 mm x 6.5 mm silicon chip membrane with integrated piezo-resistive elements [3].

2 Static probing measurements

To investigate the static probing behaviour of our F25 we have carried out several MPE_P tests. This means probing a sphere with 25 points similar to the ISO 10360-5 probing acceptance test, see figure 2. Different size spheres (1 mm, 4 m, 6.35 mm and 8 mm) and different probes with sphere diameters of 0.12 and 0.3 mm were used. The average MPE_P value, being the difference between the measured maximum and minimum radii, of 14 measurements was 189 nm with a standard deviation of 60 nm. All values but one comply with the manufactures specification of < 250 nm. Further the values found are similar to the ones found by Z.X. Chao et.al. [4]. In that article the main contribution to the MPE_P value was said to come from the form deviation of the probing sphere. Below we will show that another contribution is even more important.

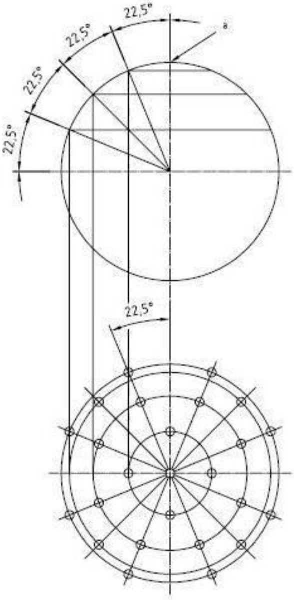

Figure 2: Probing points according to ISO 10365-5

Looking more closely at the 25 individual data points, see figure 3a, we see that the measurement results where we have rotated the reference sphere in steps of 90 degrees are highly comparable. So the form deviation of the reference sphere is not the main contribution. This is to be expected since the roundness of the reference spheres is typically 40 nm. Comparing data on different artifacts and with different probes, see figure 3b, the same pattern is still clearly visible. Since it is highly unlikely that all the probing spheres have an almost identical form deviation, there must be another cause. The only common factor is the silicon chip membrane to which the stylus is attached. These membranes are produced on wafers by a well reproducible process. Therefore it is likely that they exhibit similar behavior.

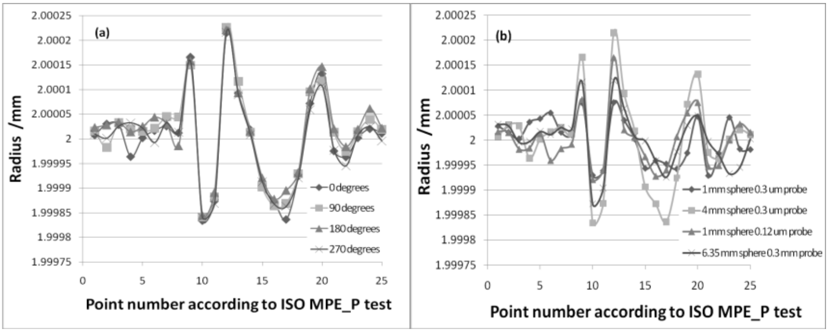

Figure 3: (a) MPE_P test on a 4 mm sphere at different rotations. (b) MPE_P test on different spheres with different probes

To investigate this further we measured 668 points on a 6.35 mm sphere. For this we increased the number of points on the circles of the MPE_P test, see figure 2, and added additional circles in between. So measurements at 9 heights instead of 5 heights were obtained. Again a very repeatable pattern was observed. The radius deviations as function of the azimuth and the z-coordinate (height) are plotted in figure 4. It can be clearly seen that the variation in this deviation on a particular circle depends on the height and the maximum variation is found at a height of 0.8 mm. In the next section we will give an explanation for this observed effect.

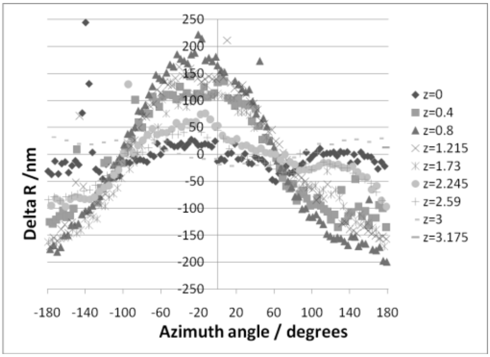

Figure 4: Radius deviation as function of azimuth and height on the reference sphere.

3 Discussion and conclusions

It was shown that the signals from sensing elements of the F25 boss probe are depended on the deflection in the other directions, see ref [5]. There are several possible reasons for this; such as the large anisotropy of the stiffness between x,y and z, possible crosstalk between the piezo-resistive sensors and the stress distribution. For example: when sensing in x and z simultaneous there is additional stress on the x element compared to the situation where there is no z deflection. Since the sensitivity coefficients in x and y are somewhat different also their z dependency will be different. This explains the observed ellipse when measuring a circle above the equator. The maximum deviation is observed at 22.5 degrees. The deviations are systematic and reproducible. The current probe calibration takes points at three different heights (on top, on the equator and in-between) does not or at least not fully correct for these deviations. To reduce the uncertainty contribution of the probe a more extensive probe calibration is needed to better correct for these deviations.

The extended MPE_P test with a few hundred points gives a similar MPE_P value. Therefore the standard MPE_P test is a sufficiently good estimate of the probe uncertainty of the F25 tactile probe.

The uncertainty of the F25 for 3D measurements of small objects (< 10 mm) will be dominated by the MPE_P value. A possible way to partly compensate for it is taking an additional measurement at 90 degrees rotated and then averaging the measurement data. When doing only planar like 2D measurements with the F25 the uncertainty is significantly better and estimated to be about 50 nm.

Acknowledgments

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References:

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