Full 3D acquisition of cylinders and cones within a few seconds

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Injection nozzles (conical and cylindrical surface) and valve needles (conical surface) demand a fast and accurate measurement of the shape of the surface. Standard white-light interferometers are optimized to measure flat surfaces and cannot acquire the complete surface of cylindrical or conical object in one single measurement.

We modified our white-light interferometer to measure in cylindrical coordinates. For cylindrical objects a 90° conical mirror is use d to illuminate and to observe the measured object. For conical objects the angle of the conical mirror has to be properly adapted. To measure the inner surface, specifically the conical end of the injector nozzle hole, a conical micro-mirror was developed.

1 Basic Principle

The white-light interferometer (Coherence radar [1]) measures surfaces by scanning the temporal coherence function of the broadband light source. For each object point we record a correlogram. From the maximum of the correlogram the position of the corresponding object point along the z-axis can be found.

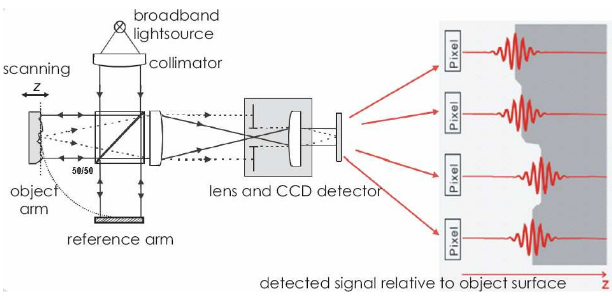

Fig. 1 *White-light interferometry – optimal for the measurement of a flat surface.*

The standard white-light interferometer is optimal for measuring flat surfaces (Fig. 1). To measure a conical or cylindrical surface we modified the illumination and observation in the object arm of the white-light interferometer [2].

With use of the proper conical mirror (Figs. 2 and 3) the illuminating rays are directed perpendicular to the measured surface. The conical mirror acts at the same time as an imaging device for the reflected rays [3].

This scheme has a significant advantage:

- incoming light is reflected directly back into the interferometer,

- we are measuring the whole surface of the object in one single measurement!

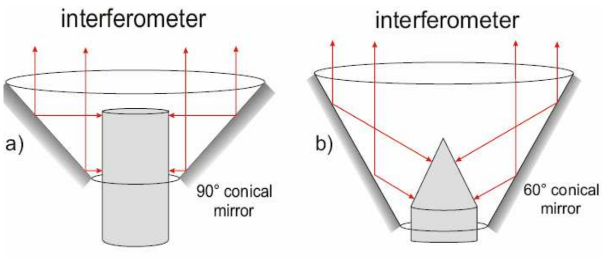

Fig. 2 *Conical mirror function. Measurement of a) cylindrical and b) conical object.*

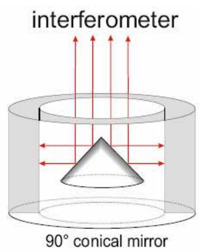

Fig. 3 *Measurement inside a cylindrical object.*

2 Adjustment model

Measurements using this scheme are highly sensitive to any adjustment error. Misadjustments are caused by error position of the conical mirror vs.

the interferometer and by error position of the measured object itself. Figure 3 displays the simplified adjustment model (two-dimensional cross-sections) for a cylindrical object. There are two major errors in the positioning of measured object:

1. shift against the optical axis,
2. tilt against the optical axis.

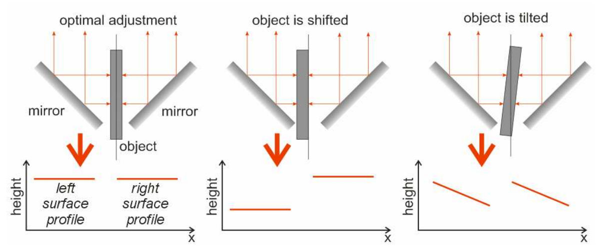

Fig. 4 *Simplified two-dimensional adjustment model.*

Our investigations reveal that it is possible to separate and eliminate these misadjustments from the measurement result as displayed in figure 4. Different heights of measured surface profiles are induced by lateral shift of the object (Fig. 4, centre). Tilt of the object causes tilt of measured height profiles under the same angle (Fig. 3. right). The same conclusions are also valid in a real three-dimensional adjustment.

3 Results

Figure 5 presents the measurement of the 60° inner-cylindrical surface of an injection nozzle. We used a 60° conical micro mirror with only 1.6 mm diameter, positioned at the bottom of the 40 mm deep nozzle.

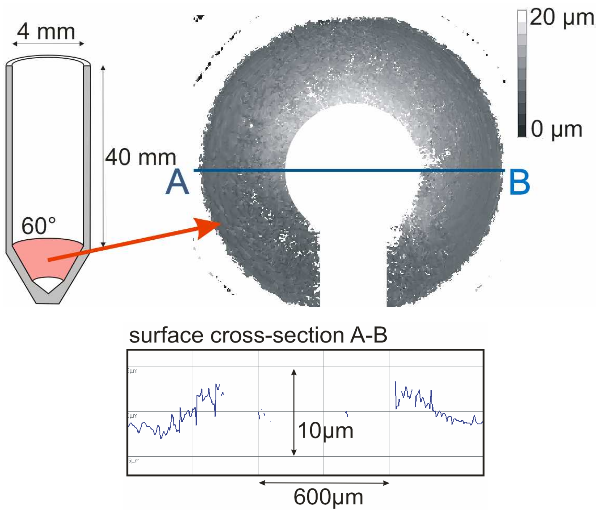

Fig. 5 *Measurement of the inner-conical surface.*

4 Conclusion

Experiments display that the alignment of the object and of the conical mirror is uncritical and sub-wavelength accuracy can be achieved. It should be noted that the imaging of an object surface via the conical mirror maintains high lateral resolution of object details. The measurement of the full surface is done in a few seconds.

5 References

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[3] B. Wiesner, A. Berger, R. Groß, O. Hybl, G. Häusler, „Faster and better white light interferometry", *Proceedings of ODIMAP V*, 216-221, October 2-4, Madrid (2006)