Measurement of aspheric surfaces with 3D-Deflectometry

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ABSTRACT

Using a high resolution two-dimensional angle sensor, 3D-Deflectometry determines the local slopes of an aspheric surface. The sensor scans the surface in spherical coordinates thus measuring the deviation from a reference sphere.

A new fault tolerant software algorithm transfers slope information into surface topography data simultaneously correcting for systematic errors of the instrument.

In this way various surface types can be characterized; convex and concave standard shapes as well as toric or even free form surfaces.

Keywords: Asphere, Aspheric surface topography, 3D-Measurement, 3D-Deflectometry

1. INTRODUCTION

In the production of aspheric surfaces, testing devices which provide fast and accurate measurement capabilities for the surface topography are badly needed. Already existing non contact measurement methods as interferometry or distance sensors are only sufficient up to a small degree of asphericity in their conventional way of application. Recently presented systems which expand the measurement capabilities of these methods by dividing the aspheric surfaces in segments which are successively scanned have the drawback of long measurement times and the need of data stitching. Thus measurements become extremely complex and measurement costs and time increase significantly.

Contrary to this 3D-Deflectometry provides very accurate results even for surface topographies with high asphericity in very short measurement times. No reference is needed and the measurement method is not limited to certain surface types. Convex and concave standard shapes as well as toric or even free form surfaces can be tested without the necessity of data stitching. There are also no constraints from surface materials as metal, glass or plastics.

2. MEASUREMENT PRINCIPLE AND SET UP

In deflectometry the local slopes of a surface under test are determined by scanning the surface with a laser beam and detecting the respective reflection angles. By integrating the slope data the topography can be reconstructed (Fig. 1). Since recording of the surface gradient is done in two dimensions a 3D-topography is obtained.

During measurements the sensor head is rotated around a horizontally arranged axis (θ-rotation in Fig. 2) thus predetermining a virtual reference sphere. The asphericity of the surface under test is measured as a deviation of the real surface topography from this basic sphere. In order to get access to the entire surface the test sample is rotated around a vertical axis which has to be aligned very carefully in respect to the sensor arm axis (φ-rotation in Fig. 2). During a typical measurement sequence with medium lateral resolution the sensor arm is stepped with $\Delta\theta \approx 0.2°$ while at each arm position approximately 750 sample points are recorded during one revolution of the sample.

The optical slope sensor consists of a diode laser which is focused onto the surface under test. A beam splitter redirects the reflected beam onto a 2-dimensional Position Sensitive Detector (PSD). Here angles are measured as deviations from a null position parallel as well as perpendicular to the scan direction of the sensor head.

The sensor head has a wavelength of 635 nm and a spot size of about 15 µm (FWHM) which defines the maximum lateral resolution of the instrument. The area of the PSD is 10 x 10 mm^2 resulting in a slope range of about ± 9° with an accuracy < 50 µrad. The reproducibility is < 1% and the measurement speed exceeds 400 Hz. Typical measurement times are less than 15 min.

The instrument in its desktop version is able to measure the surface topography of test samples with $Ø \leq 100$ mm and $R_{VRS} \leq 80$ mm - concave as well as convex - with a measurement resolution better than 50 nm.

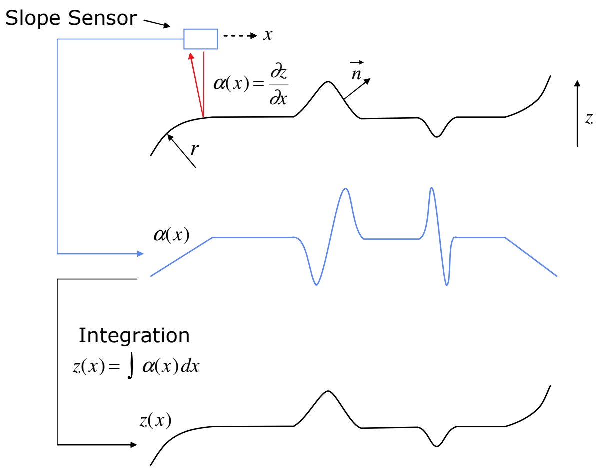

Fig. 1 By integration of the measured slope data the surface profile can be reconstructed.

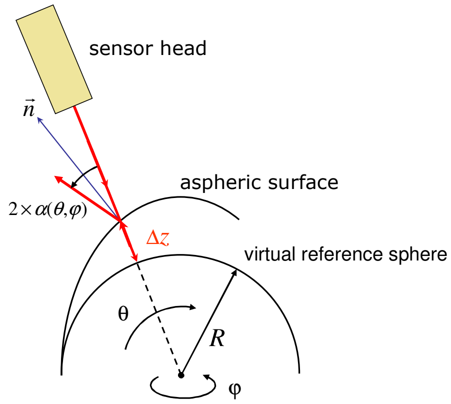

Fig. 2 Measurement of the asphericity as the deviation from a virtual reference sphere.

3. MEASUREMENT EXAMPLES

3.1 Measurement of a reference sphere

In Fig. 3 the cross section through a measured surface topography of a metal reference sphere (R = 6.99 mm) is shown. The surface was scanned with medium lateral resolution and the position of the sensor arm rotation axis was adjusted to the center of curvarture of the sphere. The maximum measured deviation from the spherical form (= asphericity) is about ± 20 nm (Peal-to-Valley).

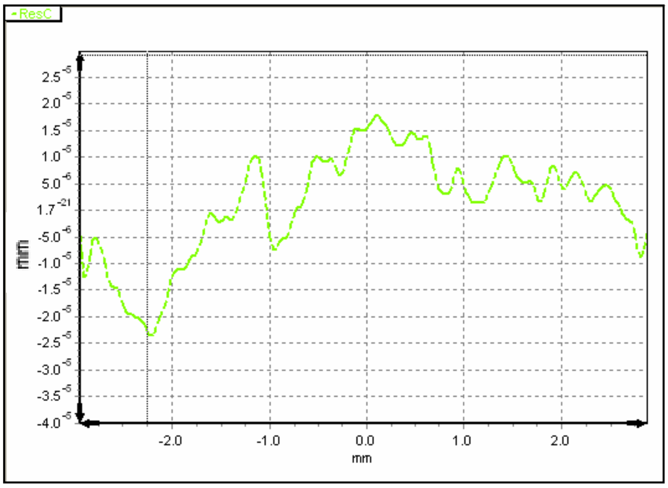

Fig. 3 Cross section of a reference sphere showing an asphericity of about ± 20 nm.

3.2 Measurement of an aspheric surface

Fig. 4 displays the measurement results of an aspheric surface in comparison to its design data. The profile of this sample is a combination of a spherical surface topography in the center part (r < 2 mm) and an aspheric part for r > 2 mm.

The surface was scanned with medium lateral resolution and the virtual reference sphere was set to match the radius of the central spherical part. The joint of the two different surface topographies can be seen clearly in the measurement results due to the medium lateral resolution. The quality of the measured profile at r = 2 mm can be improved by increasing the sample point density.

The deviation of the actual profile from the design data is (joint excluded) about ± 75 nm (Peal-to-Valley).

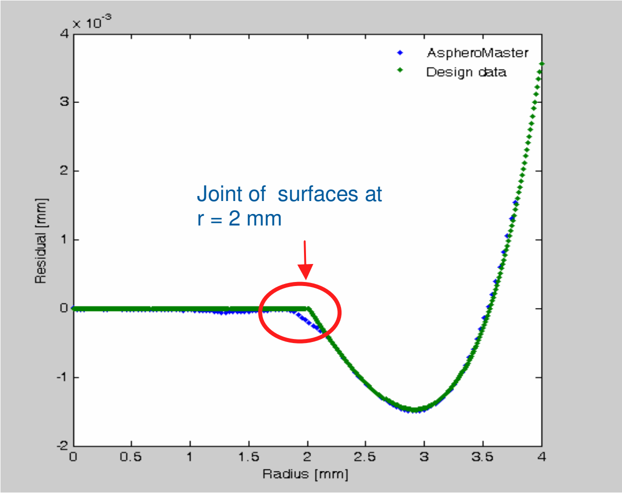

Fig. 4 The comparison of measurement- (blue) with design (green) asphericity shows a difference of about ± 75 nm (P.V)

Besides the above presented measurement examples further toric- and free form surfaces have been tested and analyzed thus showing the widespread potential of the instrument.

4. SUMMARY

By introducing 3D-Deflectometry a new measurement approach for aspheric surface topographies has been presented and measurement examples have been shown.

3D-Deflectometry allows for fast non contact measurements with high spatial resolution covering a large asphericity range. Standard spherical as well as free form topographies can be tested with a high accuracy while no additional reference is needed - thus providing a competitive alternative to conventional profiling instruments.