Quasi absolute interferometric test for toroidal surfaces by using Combined Diffractive Optical Elements

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This study is a further extension of the work presented in the article B12 in this proceeding, where we proposed a three position quasi absolute test for aspherics by using Combined-Diffractive Optical Elements (Combo-DOEs) and discussed the design considerations of the Combo-DOE. We applied this procedure for the precise metrology of toroidal surfaces and compare the results with another scheme, where a combination of DOE and a spherical condenser has been used.

1 Introduction

A toroidal surface is a special case of an aspheric surface having two different curvatures perpendicular to each other. The industrial demand for such surfaces has increased because of their use in astigmatic systems like laser scanning devices and electronic printers. Testing of these surfaces in an absolute manner is more complicated than that of flats, spheres or even rotationally symmetric aspherics because of the reduced degree of symmetry.

The absolute measurement of torics requires several relative measurements, including measurements in a shifted as well as in a rotated position of the specimen with respect to the interferometer, and in addition a measurement with an absolutely calibrated sphere to know the deviation of the toric wavefront from the sphere [1]. To eliminate the influence of misalignment, the toric-spherical alignment function is also required to be determined. The necessity of these measurements makes this procedure quite involved.

Previously [2,3] a three position quasi absolute test for rotationally symmetric aspherics has been proposed by using Combo-DOE encoded with the aspheric wavefront as well as the best fit spherical wavefront with a slight linear offset. According to this proposal experiments were carried out demonstrating the validity of the procedure [4,5]. The calibration process works similar to the three position test for spheres as the additionally encoded spherical wavefront can be used for the cat's-eye measurement. These three positions are (1) an initial position, (2) a 180° rotated position of the aspheric under test, and (3) the cat's-eye position where a mirror has been placed at the focus of the spherical wavefront. For the first two positions, the aspheric wavefront has been used. This procedure is based on the assumption, termed as "quasi-condition", that the errors arising from substrate deviations and lithographic writing inaccuracies are identical for both wavefronts.

Another approach is to use a DOE, which generates a non-spherical reference wavefront from a spherical one (Fig.1). The spherical wavefront, which passes through the DOE in the 0^{th} order can be used for the calibration purpose. A drawback of using such a combination of a DOE and a spherical condenser is that it requires very strict alignment and positioning of the DOE with respect to the condenser.

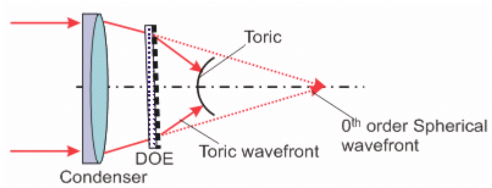

Fig. 1 *A DOE in combination with a spherical condenser, producing a reference toric wavefront while passing through the 1^{st} order of the DOE and a spherical wavefront using the 0^{th} order.*

In this paper we investigate the possibility of applying the quasi absolute approach to toroidal surfaces since they are invariant with respect to a rotation by 180° around the vertex normal. Another motivation to conduct this study is to explore the limits of the above mentioned quasi-condition, which is the basic assumption of this procedure. Here we present the first results of this effort and compare them with the approach of using a combination of a DOE and a spherical condenser.

2 Measurement Principle

A combined diffractive optical element has been employed to generate the toroidal as well as spherical wavefront simultaneously as illustrated in fig. 2. The spherical wavefront has been kept on-axis in contrast to the off-axis design as in the case of aspherics. The mean of the two principal radii of curvature of the toric has been chosen as the radius of curvature for the spherical wavefront, which is obviously quite different from the toric wavefront and therefore the diffraction orders can be separated easily.

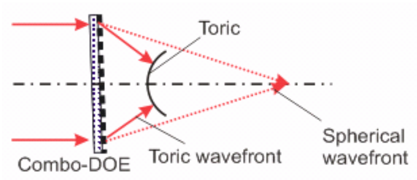

Fig. 2 *Measurement principle: Combo-DOE generating the toric as well as the spherical wavefront*

3 Representation of toric surface

The toric surface is represented by means of the angles β and ψ as depicted in fig. 3. The Cartesian coordinates x, y, and z in terms of the angles β and ψ are [5]:

$$x(\beta,\psi) = (R_x - R_y + R_y \cos\beta)\sin\psi$$
$$y(\beta,\psi) = R_y \sin\beta$$
$$z(\beta,\psi) = (R_x - R_y + R_y \cos\beta)\cos\psi - R_x$$

where the vertex of the toroid lies in the plane z=0. R_x and R_y are the radii of principal curvature.

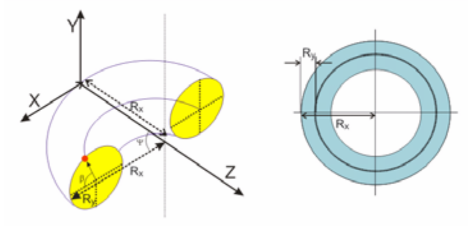

Fig. 3 *Representation of the tyre type toric surface in terms of the angles β and ψ*

4 First Results and Discussion

A phase-shifting Twyman-Green interferometric setup has been used. A tyre type toric with the principal radii of curvature 213.84 mm and 61.38 mm has been chosen as a test specimen. In our present experiment the DOE substrate is having thickness deviations of 3λ. Figure 4(a) shows the contour plot of the absolute deviations of the surface by using the quasi absolute test with Combo-DOE as described above. Figure 4(b) shows the same by using the combination of a DOE and spherical condenser. This DOE was supplied to us by AGFA Gevart AG, Munich. The contour line spacing is λ/50. The reproducibility of the three position test is λ/250.

Both results show a qualitative agreement, however indicating a difference of λ/15 as shown in fig. 4(c). As already mentioned, the substrate used for the Combo-DOE has strong surface deviations, likely causing this difference because of the fact that the substrate deviations affect the toric and spherical wavefronts differently.

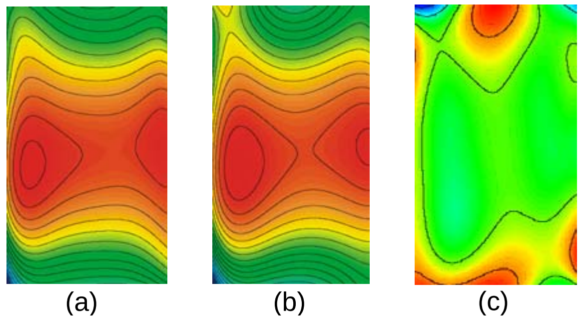

Fig. 4 *Absolute surface deviations by using (a) three position quasi absolute test with Combo-DOE, P-V; 0.3671λ (b) Combination of DOE and spherical condenser, P-V; 0.4078λ (c) The difference in the absolute surface deviations observed by both procedures; contour line spacing λ/50.*

5 Conclusion

We applied a three position quasi absolute test by using Combo-DOE, which was earlier proposed for aspherics, for the precise testing of toroidal surfaces. We have found that the results of this procedure are in qualitative agreement with another approach, where a combination of a DOE and a spherical condenser is used. However, it needs further investigations to find out the limitations due to the violation of the "quasi-condition" underlying the procedure.

References

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