Contact Profilometry

Introduction: Contact profilometry is a technique for directly measuring the surface sag of an element. A mechanical probe is used to repeatedly sample points on the surface. These sag values in turn can be fit to a spherical and aspheric shape to recover the parameters of the surface.

Spherical Lens:

1. Measure a spherical surface with the spherometer and record its radius of curvature.
2. Measure the radius of the tip of the profilometer.
3. Mount the spherical surface on a translation stage. Align the surface under the profilometer until the highest point is under the tip. This point will serve as the origin for the measurements.
4. Translate the surface underneath the profilometer tip and record the relative sag values at various points along a profile.

Asphere Measurement:

5. Repeat steps 3 and 4 above for the aspheric surface. Getting the element level is more critical with the aspheric surface, so carefully align it prior to making measurements.

Fitting Spherical Surfaces

Calculate a set of N data points from your spherical measurement data $\{r_i, z_i\}$, where r is the lateral distance from the origin and z is the difference between the measured sag and the sag at the origin. For a sphere, the sag equation is

$$z = R - \sqrt{R^2 - r^2}$$

Rearranging gives

$$r^2 + z^2 = 2Rz$$

So we can estimate the radius of curvature R as

$$R = \frac{r_i^2 + z_i^2}{2z_i}$$

For each of the data points, estimate a value of R. How does the value measured with the spherometer compare to the estimates? How is the estimate affected when z gets small?

Fitting Conic Surfaces

Calculate a set of N data points from your aspherical measurement data $\{r_i, z_i\}$, where r is the lateral distance from the origin and z is the difference between the measured sag and the sag at the origin. For an asphere, the previous technique is generalized. The sag equation is

$$z = \left(R - \sqrt{R^2 - (K+1)r^2}\right) / (K+1)$$

Rearranging gives

$$(K+1)z^2 - 2Rz = -r^2$$

We can write a system of equations based on our measurements.

$$\begin{pmatrix} z_1^2 & -2z_1 \\ \vdots & \vdots \\ z_N^2 & -2z_N \end{pmatrix} \begin{pmatrix} K+1 \\ R \end{pmatrix} = \begin{pmatrix} -r_1^2 \\ \vdots \\ = r_N^2 \end{pmatrix}$$

If we let

$A = \begin{pmatrix} z_1^2 & -2z_1 \\ \vdots & \vdots \\ z_N^2 & -2z_N \end{pmatrix}$ and $C = \begin{pmatrix} -r_1^2 \\ \vdots \\ = r_N^2 \end{pmatrix}$, then the least squares solution to this system is

$$\begin{pmatrix} K+1 \\ R \end{pmatrix} = \left[A^T A\right]^{-1} A^T C$$

where superscript T denotes the transpose and superscript -1 represents the matrix inverse. What are the values of K and R based on your measurements? Again, points near the origin will cause problem, so you may want to exclude them in this analysis.

Other Questions

1. How does the radius of the profilometer tip affect your measurements?
2. What can be done to increase the accuracy of your measurements?