MIRROR COMPENSATOR FOR TESTING CONVEX SECONDARY

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The testing of convex secondary mirror of large telescope is known as a difficault thing, because it needs for a large mirror or lens. In USA, they used to use Hindle sphere for testing convex hyperboloids, and in West Germany as I know, they often use concave matrix probe for testing convex mirrors. In the case of Hindle method, the diameter of testing sphere always is about 2 or 3 times as the convex mirror under testing, in the later case, the matrix probe must has the same size as the convex mirror, further more, the probe itself needs another testing facilities. Some other methods had been suggested by R. Wilson, E, Gaviola and others but they have rarely been used in practice.

In fabrication of the convex secondary of 2.16 m telescope in China, we are using a different method. We use a concave ellipsoid as a compensator for testing it. The principle of this method is as following. (see fig. 1)

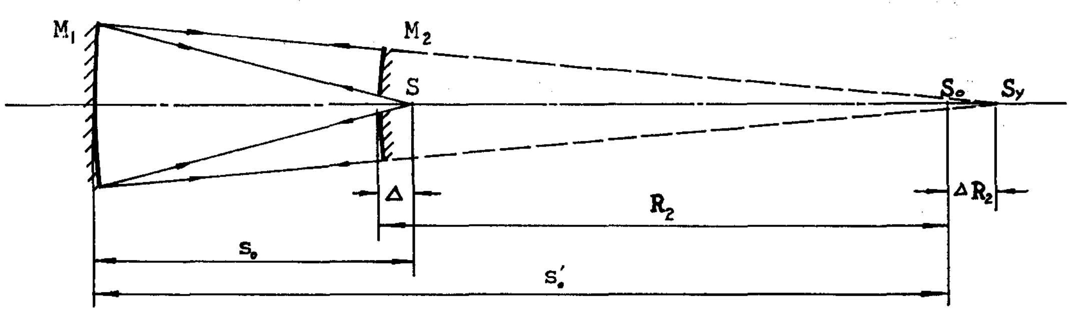

Fig. 1

M_1 Compensator, diameter = D_1, radious of curvature at vertex = R_1, eccentricity = e_1.

M_2 Convex secondary mirror, diameter = D_2, radious of curvature at vertex = R_2, eccentricity = e_2.

S_o Center of curvature at vertex of the convex secondary.

S_y Intersection point of marginal normal of convex secondary with optical axis.

S Light source and knife edge.

Light from a point source S at the axis of compensator is reflected by it and matchs the normals of the convex mirror under testing.

For determine the parameters of the compensator, we need only select the position of light source (Δ) and the ratio D_1/D_2 (α), the distance between

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two mirrors is defined by α consequently, because the diameter of the convex mirror is given. Evidently, α means how large the compensator is with respective to the convex secondary.

According to the theory of third order aberration, we derived the equation for determine the eccentricity of the compensator.

$$e_1^2 = \left(\frac{1}{\alpha}\frac{R_1}{R_2} \right)^3 \frac{e_2^2}{2\alpha} + \left(\frac{1}{\alpha}\frac{R_1}{R_2} - 1 \right)^2 \qquad (1)$$

On the other hand, from Gaussian optics we get

$$\frac{R_1}{R_2} = \frac{2\alpha}{1 + \alpha \frac{R_2}{S_0}} \qquad (2)$$

From fig. 1 we eassily know that

$$s_0 = R_2(\alpha - 1) + \Delta \qquad (3)$$

So that once α and Δ are given, the parameters of the compensator may be calculated by the above three equations immediately.

By analysing equation (1) we learn that the compensator must not be a sphere (e_1^2 must larger than zero) when $e_2^2 > 0$. Sets of calculation show that in general it is an ellipsoid for $e_2^2 > 0$.

The value of e_1^2 found by equation (1) is the first order approximation, we should make it precise by ray tracing, i.e. take the marginal normal of convex secondary as incident ray of compensator and calculate its point of intersection with the optical axis after reflecting by it. If this point is different from that of the paraxial normal ray, then we change the value of e_1^2 until they are precisely meet together.

After this, we should also calculate the zonal normal of convex mirror, i.e. take the 0.707 zone of marginal normal height and tracing its point of intersection with axis . If there is a small difference between the points of intersection of 0.707 zone and marginal zone, it does the residual aberration of this testing layout. If we note this axial aberration as $\Delta s'_{0.707}$, then the maximum surface aberration of convex secondary may be defined by the following formula:

$$E_{max} = 0.002604\, A^2\, \delta R_{0.707} \qquad (4)$$

in which

$$\delta R_{0.707} \approx \left(\frac{S'_0}{S_0} \right)^2 \cdot \Delta s'_{0.707} \quad , \qquad A = \frac{2 D_2}{R_2}$$

It should be noticed that equation (4) takes place just when we make a defocusing at point S with amount $\frac{3}{16}\Delta s'_{0.707}$.

Essencially, in this condition the surface error all over the diameter will take the form as shown in fig. 2.

Data from calculating a set of α with the same convex mirror show that the residual aberration depends upon α rapidly when $\alpha < 1.5$, and approxi-

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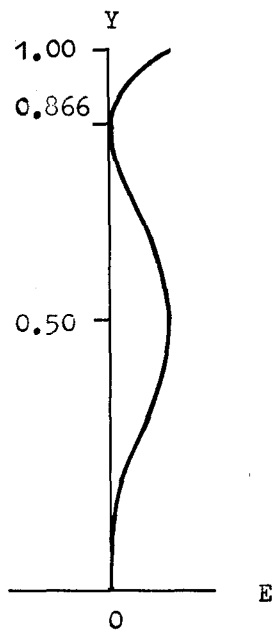

Fig. 2

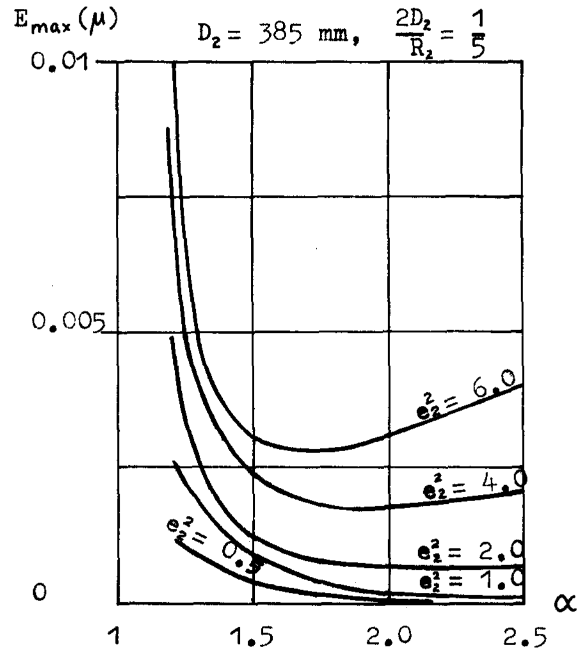

Fig. 3

mately does not depend on α when $\alpha > 1.5$. Fig. 3 shows the results of calculation.

The convex secondary of RC system of the Chinese 2.16 m telescope has $e_2^2 = 5.077526$ and $R_2 = 5797.5$ mm, its diameter is 720 mm. We take $\alpha = 1.6$, $\Delta = -200$ mm and find out the parameters of compensator to be $D_1 = 1152$ mm , $e_1^2 = 0.456278$, $R_1 = 4844.7$mm. The maximum residual surface error of convex secondary is found to be

$$E_{max} = \frac{\lambda}{25} \qquad (\lambda = 0.55\ \mu)$$

Refferences

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