Definition of an Aspheric Surface

PRECISION-OPTICAL ENGINEERING

DM 001

Application Note

The generic equation used to describe optical surface shapes takes the form of the determination of the sag Z of the surface at any point h, where h is the height from the optical axis.

An aspheric surface can be described numerically in many ways but for the purposes of optical design programmes and for manufacturing processes, it is best expressed as a numeric equation of two parts - firstly as a conic section departure from a sphere, then with further aspheric deviations according to higher polynomial terms, thus:

$$Z = \frac{ch^2}{1 + \sqrt{(1 - \varepsilon c^2 h^2)}} + A_4 h^4 + A_6 h^6 + A_8 h^8 + A_{10} h^{10} + A_{12} h^{12} + \ldots..$$

where:

c	is the curvature (= 1 / radius) of the base sphere (at the optical axis or vertex).
ε	is the 'conic constant' or measure of conic shape of the surface.
A_4, A_6, A_8, A_{10}, A_{12}	are the aspheric coefficients (ie. the 4th, 6th, 8th, 10th, 12th order aspheric deformations respectively). Note that only even powers appear because of axial symmetry. These coefficients are also sometimes referred to as A, B, C, D, E, etc.

This 'conic constant' ε is also related to other common ways of describing a conic section, thus:

$$\varepsilon = (1 + k) = (1 - e^2)$$

where k is the 'conic coefficient'
e is the 'eccentricity'

All these terms relate to the actual conic shape of the surface:

Surface	**Eccentricity e**	**Conic Coefficient k**	**Conic Constant ε**
Sphere	0	0	1
Parabola	1	-1	0
Prolate Spheroid (small end of ellipse)	< 1	-1 < k <0	< 1
Hyperbola	> 1	< -1	< 0
Oblate Spheroid (side of 2D ellipse, but not a 3D conic section)	-	> 0	> 1

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Clearly, if $A_4 = A_6 = A_8 = A_{10} = A_{12}$ etc. = 0 then the surface described is a pure conic. If also e = 0 then ε = 1 and the equation simplifies to that describing a sphere:

$$Z = \frac{ch^2}{1 + \sqrt{(1 - c^2h^2)}}$$

How to Specify an Aspheric Surface on a Manufacturing Drawing.

POE receives many manufacturing drawings that define an aspheric profile to an optical surface. Here we advise as to the 'preferred way' in which this information should be shown:

1/ Always quote the aspheric equation used. The one quoted above is most common, using either e, ε, or k to define conic departure from the base sphere curvature , c.

2/ Tabulate the aspheric coefficients A_4, A_6, A_8, etc. Take care to quote them with the right sign (+ or -) and the correct power in standard form ($A_8 = -3.115267 \times 10^{-12}$ for example).

3/ As a confirmatory cross-check POE would prefer to see a Sag Table quoting a range of values of Z versus h. This will enable us to confirm the equation used is correct and that the coefficients match up – ensuring a correct surface is machined. If a Sag Table is not offered, then POE will routinely ask for this to be provided, to enable a check to be performed prior to machining.

References:'Lens Design Fundamentals' by R.Kingslake (Addison Wesley 1982)
'Code V' Users Guide Notes for CON (conic) and ASP (aspheric) surface types.

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