Q-Type Forbes Aspheres for Diamond-Turning

EEO is now accepting drawings for diamond-turning using the Q-type Forbes bases

- EEO has developed capabilities to create diamond-turning sag tables directly from Forbes coefficients
- Profilometer scans can be analyzed directly using Forbes coefficients
- Surfaces can contain QCON and QBFS forms with any number of coefficients

- Forbes Aspheres provide optical designers with control that is difficult and time-consuming to replicate using standard even aspheres
  - More easily screen undesired design forms[1]
  - Reduce final system sensitivity[2]
  - Forbes bases are orthogonal, so the designer can change the number of terms without affecting the surface sag[3]
  - Drawings require 1/3 the number of significant digits[4]
  - Coefficients can be meaningfully toleranced[5]

Certified System AS 9100 QMI-SAI Global ISO 13485

Bases now accepted by EEO

Q^{BFS} (mild):

$$sag(\rho) = \frac{\rho^2 Curv}{1+\sqrt{(1-\rho^2 Curv^2)}} + \frac{\left(\frac{\rho}{\rho_{max}}\right)^2\left(1-\left(\frac{\rho}{\rho_{max}}\right)^2\right)}{\sqrt{(1-\rho^2 Curv^2)}}\sum_{m=1}^{M} a_j Q_m^{bfs}\left(\frac{\rho}{\rho_{max}}\right)^2$$

Q^{CON} (strong):

$$sag(\rho) = \frac{\rho^2 Curv}{1+\sqrt{(1-(1+K)\rho^2 Curv^2)}} + \left(\frac{\rho}{\rho_{max}}\right)^4 \sum_{m=1}^{M} a_j Q_m^{con}\left(\frac{\rho}{\rho_{max}}\right)^2$$

Traditional polynomial (e.g. even asphere):

$$sag(\rho) = \frac{\rho^2 Curv}{1+\sqrt{(1-(1+K)\rho^2 Curv^2)}} + \sum_{j=1}^{Amax} A_j \rho^j$$

Diffractive (can be added to any aspheric form):

$$sag(\rho) = \frac{\rho^2 Curv}{1+\sqrt{(1-(1+K)\rho^2 Curv^2)}} + \frac{DiffrOrder}{n_1 - n_2}\left\{\left(\sum_{j=1}^{Cmax} C_j \rho^{(2*j)}\right) + \lambda * floor\left(\frac{1}{\lambda}\left|\sum_{j=1}^{Cmax} C_j \rho^{(2*j)}\right|\right)\right\}$$

References:

1. Youngworth, R. N. and Betensky, E. I., "Lens design with Forbes aspheres", Proc. SPIE 7100, 71000W (2008)
2. Ma, B., Li, L., Thompson, K.P., and Rolland, J.P., "Applying slope constrained Q-type aspheres to develop higher performance lenses," Opt. Express 19, 21174-21179 (2011)
3. Forbes, G. W., "Shape specification for axially symmetric optical surfaces," Opt. Express 15(8), 5218–5226 (2007).
4. Forbes, G. W., "Better Ways to Specify Aspheric Shapes Can Facilitate Design, Fabrication, and Testing Alike", International Optical Design Conference, Optical Society of America, JMA1 (2010).
5. Youngworth, R. N., "Tolerancing Forbes aspheres: advantages of an orthogonal basis", Proc. SPIE 7433,

	Advantages
Optical Design	• Eliminates Forbes conversion • Fewer equations • Increased design efficiency
Diamond Turning	• Eliminates Forbes conversion • Maintains geometric tolerance integrity • Direct DT programming • Increased production efficiency
Test and Measurement	• Eliminates Forbes conversion • Direct fabrication to test • Maintains design integrity

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