PRODUCTION OF SOFT LENSES HAVING REDUCED SPHERICAL ABERRATIONS

Aspheric surfaces have many desirable uses in all types of optical lenses. Their extensive uses have been limited by the difficulty in producing them in quantity and economically. The object of the present invention is to provide a reliable and economical method of producing large numbers of quality aspheric surfaces. A sphere is a poor refracting surface due to spherical aberration. Spherical aberration is the inability of all parts of a spherical surface to bring parallel light rays to a point focus. The periphery of a spherical refracting surface has a shorter focal length than the central area. This condition worsens rapidly with the increase of the aperture. Spherical aberration increases by the square of the aperture. This rapid increase limits the effective use of many larger aperture lenses. Coma and astigmatism of oblique incidents are two off axis manifestations of spherical aberration. If the paths of parallel light are traced through many zones of a large aperture spherical surface, each zone will be found to have a different focal length. If these rays are plotted, a geometric figure, the caustic, will result having no point focus. A zone may be found within the caustic where the rays come closest together. This zone is called the circle of least confusion, and will be located nearer the lens than the focus of the central rays.

If the periphery of the convex lens surface is gradually flattened in precisely the correct degree and place, the caustic may be eliminated and a point focus will result. It has been found that a spherical surface may be changed into such a surface if the area near the edge is flattened slightly. The point of greatest departure from a sphere will be located seventy-one percent of the distance from the center to the edge.

The following is from a report entitled; "A Clinical Evaluation of the Merits of the Front Surface Aspheric Contact Lens for Patients Manifesting Residual Astigmatism," Ronald L. Kerns, College of Optometry, University of Houston, Aug. 5, 1971, page 5.

"Based upon the results of our study, it is apparent that the front surface aspheric contact lenses will increase visual acuity in patients manifesting residual astigmatism between 0.50 D and 1.75 D. The amount of increase will depend on the amount of residual astigmatism and the resolving power of the eye but should not depend on pupil size."

Tscherning described the spherical aberration of the eye in detail in his book, "Physiologic Optics," in 1900. Carl Zeiss explored the possibilities of correcting microscope eye pieces for the spherical aberration of the human eye. Zeiss abandoned the project when he discovered the irregularities of curvature present on the corneal surface. In camera and instrument lenses, spherical aberration is corrected by bending the lens form. The least longitudinal spherical aberration occurs in a single element plus lens if the front surface has six times the refractive power of rear surface.

Aspheric front surfaces are used on the higher quality cataract spectacle lenses to correct the aberration present in the spectacle lens only.

The optical system of the eye is unique in that the light enters the refractive media and comes to a focus within the refractive media.

Spherical aberration is the inability of a spherical lens to focus light from the center and periphery to the same point. This condition is corrected by an aspheric convex curve having a longer radius toward the edge.

The present invention describes a unique method of providing an aspheric soft lens to reduce the spherical aberration. Spin cast lenses have a parabolic aspheric concave curve which is produced by the spin cast process.

The shape of the spinning concave liquid surface can be expressed in a coordinate system as:

$$z(r) = \frac{w^2r^2}{2g} + \frac{o}{pg}\left[\frac{1}{R_s} + \frac{1}{R_t}\right]$$

where,

w is rotational speed,

g is gravitational acceleration,

o is surface tension,

p is liquid density,

R_s is surface sagittal radius of curvature and

R_t is surface tangential radius of curvature.

As can be seen, the peripheral concave area will have a longer radius than the center which translates to a shorter peripheral radius when the lens is in place on the eye. This is contrary to the laws of optics and produces aberrations which increase toward the lens edge. This is an unwanted convex aspheric surface having a shorter radius toward the edge.

The present invention, a method of providing a convex curvature having a longer peripheral convex radius will improve the optical performance of all soft lenses.

The desired convex curve having a progressively longer radius toward the edge is achieved by providing a concave lens surface having a progressively selected shorter concave radius toward the edge. Such a lens when in place on the eye will have a progressively selected longer convex radius toward the edge. This is not correction for an eye defect such as astigmatism, myopia, or hyperopia. Spherical aberration cannot be corrected with eye glasses, only with contact lenses at the corneal surface. The eye is unique in that light enters the dense refractive media at the corneal surface and is brought to a focus within the dense refractive media without again entering air. Aspheric eye glass lenses correct only the spherical aberration of the eye glass lens itself not that of the optical system of the eye. The present invention is a method of improving the optical performance of all soft contact lenses regardless of the refractive state of the eye.

PRIOR ART

U.S. Pat. Nos. 3,641,717 and 3,778,937 disclose the use of convex aspheric surfaces on contact lenses for the enhancement of visual acuity.

STATE OF THE ART

Soft lenses being flexible conform to the shape of the cornea upon which they are placed. The concave surface of the soft lens assumes the curvature of the convex corneal surface. Spin cast lenses have a progressively longer concave radius toward the edge which results in a progressively shorter convex radius toward the edge when in place on the eye. This condition degrades the image quality provided by the lens.

IN THE DRAWINGS

FIG. 1 shows the negative aspheric blank in section.