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Location of mechanical features in lens mounts

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ABSTRACT

Design of mechanical features such as spacers, retainers and/or cell shoulders used to locate and constrain lens components within a mount entails application of geometric relationships that depend upon the types of glass-to-metal interfaces to be provided. This paper describes the pertinent geometry of the most common surface-contact interface types ("sharp corner", spherical, tangential and toroidal) and gives equations for locating key features of the mechanical parts relative to the associated lens vertices. Examples illustrate the use of these equations to dimension mechanical features in typical lens/mount configurations.

Keywords: optomechanical design, lens-mount interface, lens cell

1. INTRODUCTION

The lens designer typically defines a given optical system, in part, in terms of the relative locations of the sequence of vertices of optical surfaces, the surface radii and apertures. The mechanical engineer or designer is then asked to define the mechanical structure to interface with those surfaces - usually at or near the component rims - and to position the components properly along an axis. While this task is elementary when the ubiquetous "sharp corner" interfaces are employed or if the contacts are spherical, it is more involved when the interfaces are tangential or, toroidal. The design process is especially tedious when computer aided design (CAD) techniques are not available and the required relationships are not immediately obvious.

Here, we develop the pertinent geometry and equations for locating key features of the mechanical mounts relative to the applicable surface vertices for each of the aforementioned interface types. Examples illustrate the use of the more complex of these analytical tools. This discussion is limited to centered spherical surfaces. For convenience, we use the absolute value of surface radius R and apply derived dimensions appropriately as dictated by the specific configuration.

2. DISCUSSION

1. The 90° "Sharp Corner" Interface

Figure 1 illustrates (to exaggerated scale) the geometry of this type interface for a convex surface of radius R and clear aperture A. The design problem is to locate the point P_1 where the sphere contacts the mount corner relative to the surface vertex V. The desired relationship in this case is simply the sagittal depth equation for a sphere, namely:

$$\Delta x = R - (R^2 - y_C)^{1/2} \qquad 1$$

In the figure, y_S is the inside radius of the mount at the interface (typically A/2 plus 1/2 percent of A or 0.505A) and D_G is the lens diameter. In the equation, y_C is the contact height (which here equals y_S) and Δx is the axial distance from the vertex to P_1.

Figure 2 shows a 90° "sharp corner" interface on a concave surface. Point P_1 typically is located midway between the mechanical edge of the polished surface and the edge of the aperture. This quantifies y_C. Equation 1 again applies.

2. The Obtuse Angle "Sharp Corner" Interface

In order to facilitate fabrication of smooth mechanical edges on shoulders, spacers or retainers, the corner is sometimes designed with an obtuse angle such as 135°.[1] Figures 3 and 4 show such corners contacting convex and concave lens surfaces respectively. The geometric parameters are as defined earlier and Eq. 1 defines Δx in each case. Note that this approach requires slightly greater cell outside diameter for a given aperture and cell wall thickness since y_C is larger than y_S. This also is true for the case shown in Fig. 2.

3. The Spherical Interface

Figures 5 and 6 show, respectively, spherical mounting surfaces contacting convex and concave lenses. Here, y_C is at the midpoint of the land contacting the lens. If we use y_S instead of y_C, Eq. 1 can be used to find Δx in either case.

It may be noted from the figures that the radial projection of the spherical land against which the lens is pressed is $2(y_C - y_S)$. This dimension is useful when defining tolerances on the mechanical parts to prevent degeneration of the interface into line contact at the inner or outer edges of this land. Similar lands exist in the cases discussed below.

4. The Tangent Interface

Figure 7 shows a conical mechanical surface contacting a convex lens surface at height y_C. This type interface cannot be used with a concave surface. The half-cone angle is ψ and all other parameters are as previously defined. Equations 2 through 6 can be used to establish Δx.

$$\psi = 90° - \arcsin (y_C / R) \quad (2)$$
$$x_S = y_S / \tan \psi \quad (3)$$
$$x_2 = R / \sin \psi \quad (4)$$
$$x_1 = x_2 - x_S \quad (5)$$
$$\Delta x = R - x_1 \quad (6)$$

Example #1 - A lens has a convex surface of radius 91.500 mm and aperture 64.000 mm. Tangential contact on this surface is desired at y_C = 30.000 mm. Assume y_S = 0.505A = 32.320 mm. Then:

$$\psi = 90 - \arcsin (30.000 / 91.500) = 70.8605°$$
$$x_S = 32.320 / \tan 70.8605° = 11.217 \text{ mm}$$
$$x_2 = 91.500 / \sin 70.8605° = 96.854 \text{ mm}$$
$$x_1 = 96.854 - 11.217 = 85.637 \text{ mm}$$
$$\Delta x = 91.500 - 85.637 = 5.863 \text{ mm}$$
$$2(y_C - y_S) = (2)(30.000 - 32.320) = 4.640 \text{ mm.}$$

4. The Toroidal Interface

Figure 8 shows a toroidal surface of absolute radius R_T in the plane of the figure and with its center at C_T. This mechanical surface interfaces with a convex lens surface of radius R at a height y_C. Figure 9 shows the design in more detail. The X-coordinate of P_1 is found by solving the analytic equation for the circle representing the toroidal section with center displaced from the origin at C by h and k in the X and Y directions respectively when $y_1 = y_S$. Considering all radii as positive, then:

$$\theta = \arcsin (y_C / R) \quad (7)$$
$$h = (R + R_T) \cos \theta \quad (8)$$
$$k = (R + R_T) \sin \theta \quad (9)$$
$$x_1 = h - [R_T^2 - (y_S - k)^2]^{1/2} \quad (10)$$
$$\Delta x = R - x_1 \quad (11)$$

Figure 10 shows the toroidal interface at a concave lens surface. Equations 7, 12, 13, 14 and 11 can be used to find Δx.

$$h = (R - R_T) \cos \theta \quad (12)$$
$$k = (R - R_T) \sin \theta \quad (13)$$
$$x_1 = h + [R_T^2 - (y_S - k)^2]^{1/2} \quad (14)$$

It has previously been shown that advantage is gained with regard to contact stress in an axially clamped lens if $R_T \geq -10R$ for a convex surface or $\geq 0.5R$ for a concave surface.[2]

Example #2 - Consider the same lens as in Example #1 with a convex surface of radius 91.500 mm and aperture 64.000 mm. In this case, we want toroidal contact at $y_C = 30.000$ mm. We assume $R_T = -10R = -915.000$ mm. Once again using absolute values for radii, $y_S = 0.505A = 32.320$ mm, while:

$$\theta = \arc\sin(30.000 / 91.500) = 19.1375^\circ$$
$$h = (91.500 + 915.000) \cos 19.1375^\circ = 950.875 \text{ mm}$$
$$k = (91.500 + 915.000) \sin 19.1375^\circ = 329.967 \text{ mm}$$
$$x_1 = 950.875 - [915.000^2 - (32.320 - 329.967)^2]^{1/2} = 85.640 \text{ mm}$$
$$\Delta x = 91.500 - 85.640 = 5.860 \text{ mm.}$$
$$2(y_C - y_S) = (2)(30.000 - 32.320) = 4.640 \text{ mm.}$$

The sagittal depth of this spherical surface at a height of 32.320 mm is 5.898 mm so the clearance in the X-direction to the point P_1 on the toroid is 0.039 mm.

Example #3 - If the same lens surface as above were concave and toroidal contact with $R_T = 0.5R = 45.750$ mm at $y_C = 30.000$ mm were desired, we would find once again that $y_S = (0.505)(64.000) = 32.320$ mm and:

$$\theta = \arc\sin(30.000 / 91.500) = 19.1375^\circ$$
$$h = (91.500 - 45.750) \cos 19.1375^\circ = 43.222 \text{ mm}$$
$$k = (91.500 - 45.750) \sin 19.1375^\circ = 14.998 \text{ mm}$$
$$x_1 = 43.222 + [45.750^2 - (32.320 - 14.998)^2]^{1/2} = 85.566 \text{ mm}$$
$$\Delta x = 91.500 - 85.566 = 5.934 \text{ mm}$$
$$2(y_C - y_S) = (2)(30.000 - 32.320) = 4.640 \text{ mm.}$$

The clearance in the X-direction from the sphere to the point P_1 on the toroid is, in this case, 0.036 mm.

3. ACKNOWLEDGEMENT

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4. REFERENCES

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2. Yoder, P. R., Jr., Axial stresses in toroidal lens-to-mount interfaces, *Proc. SPIE 1533*, 2, 1991.

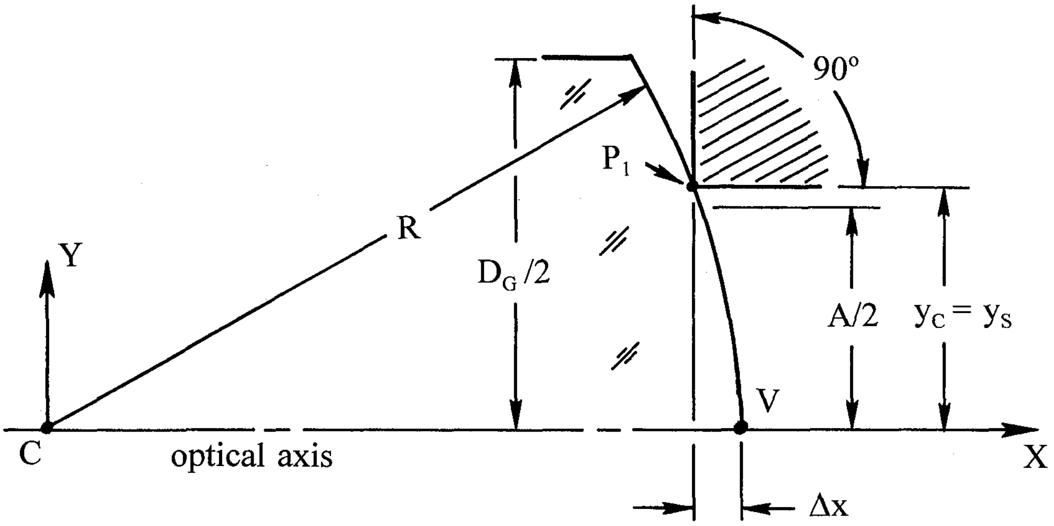

Fig. 1 - Schematic of a 90° "sharp corner" interface on a convex spherical surface.

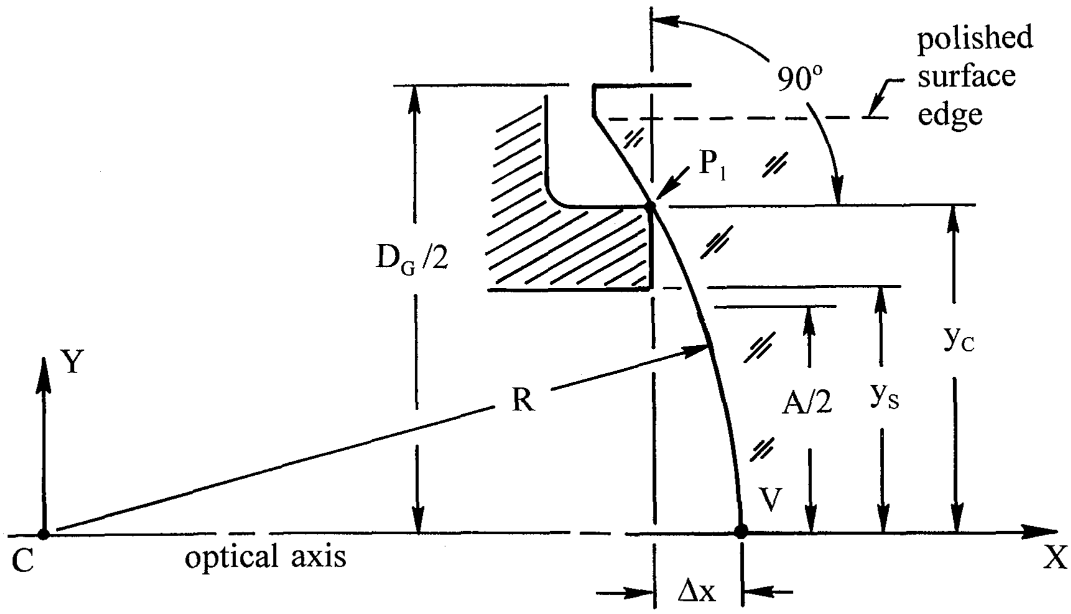

Fig. 2 - Schematic of a 90° "sharp corner" interface on a concave spherical surface.

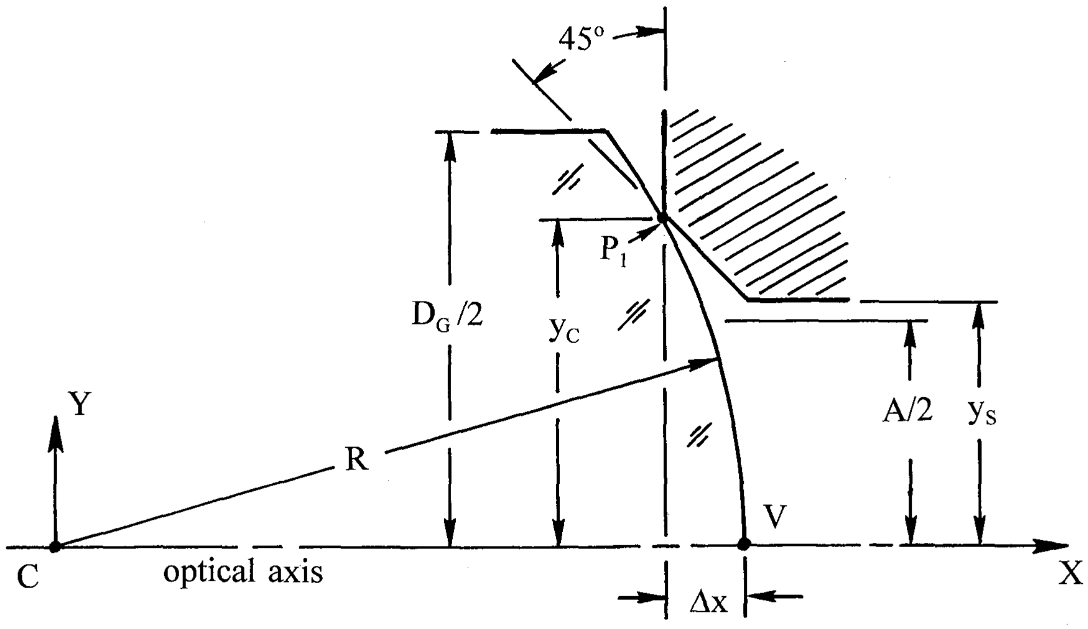

Fig. 3 - Schematic of an obtuse angle "sharp corner" interface on a convex spherical surface.

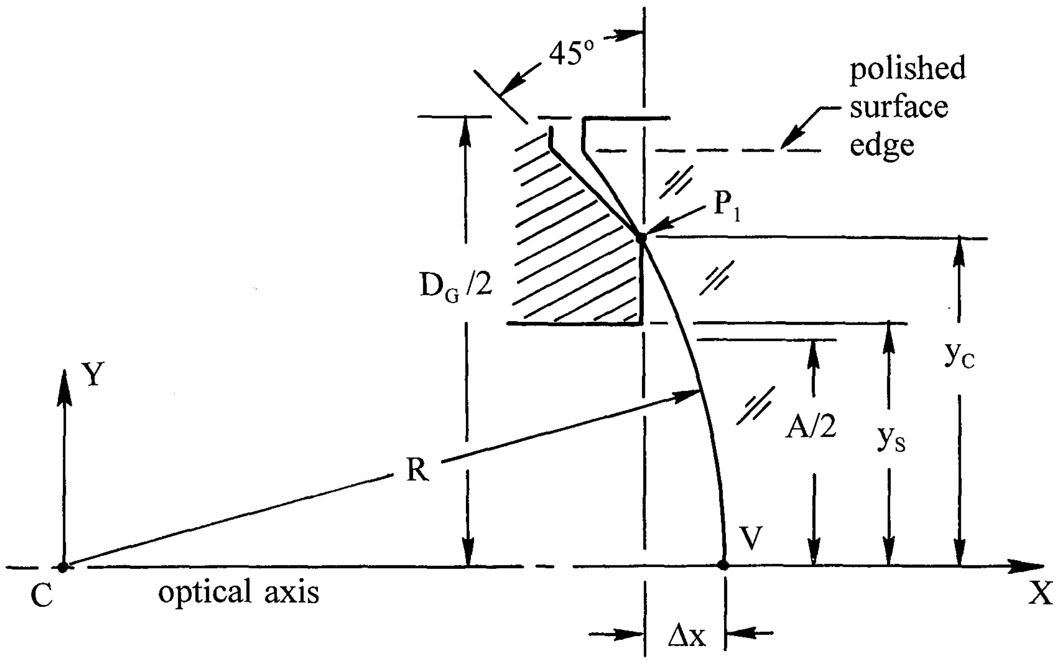

Fig. 4 - Schematic of an obtuse angle "sharp corner" interface on a concave spherical surface.

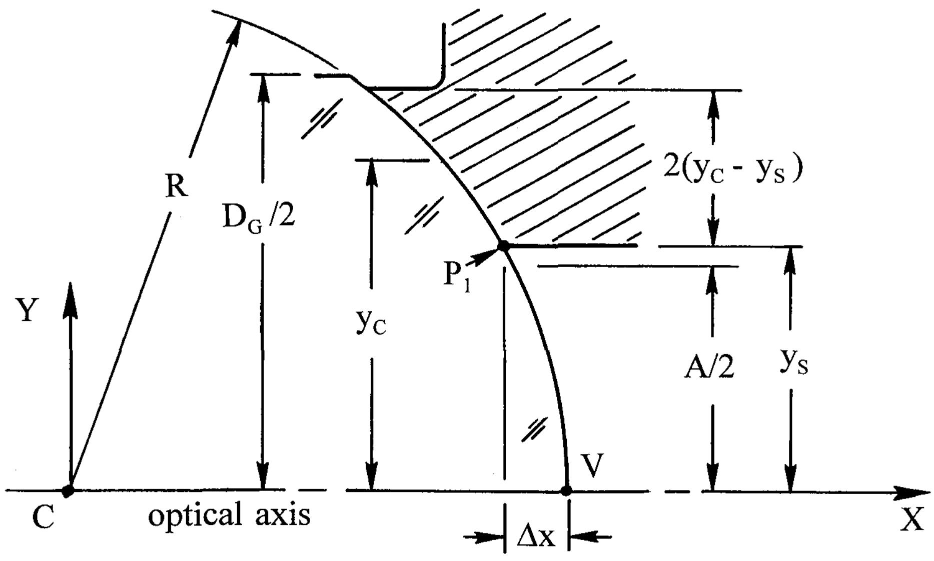

Fig. 5 - Schematic of a spherical interface on a convex spherical surface.

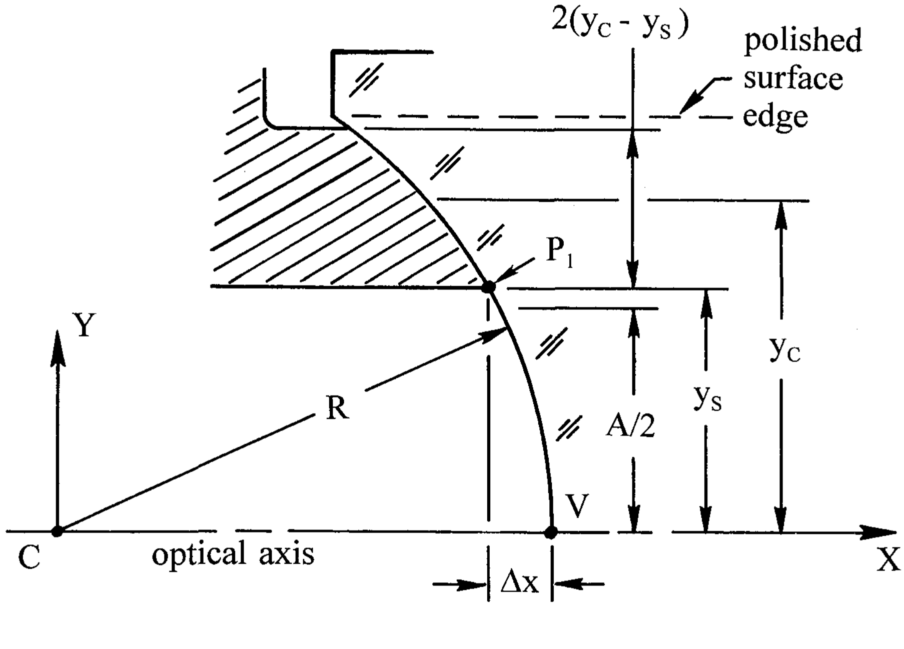

Fig. 6 - Schematic of a spherical interface on a concave spherical surface.

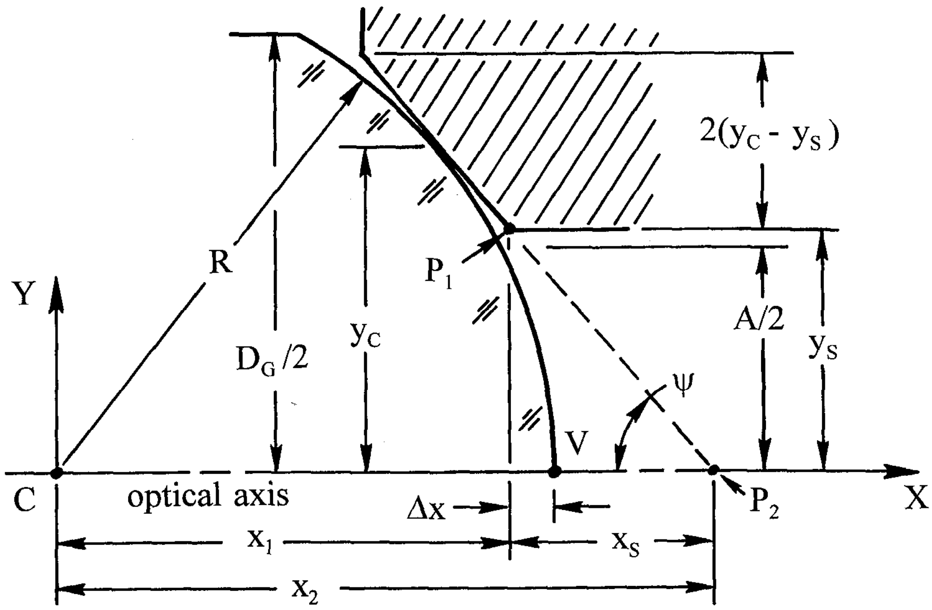

Fig. 7 - Schematic of a tangential interface on a convex spherical surface.

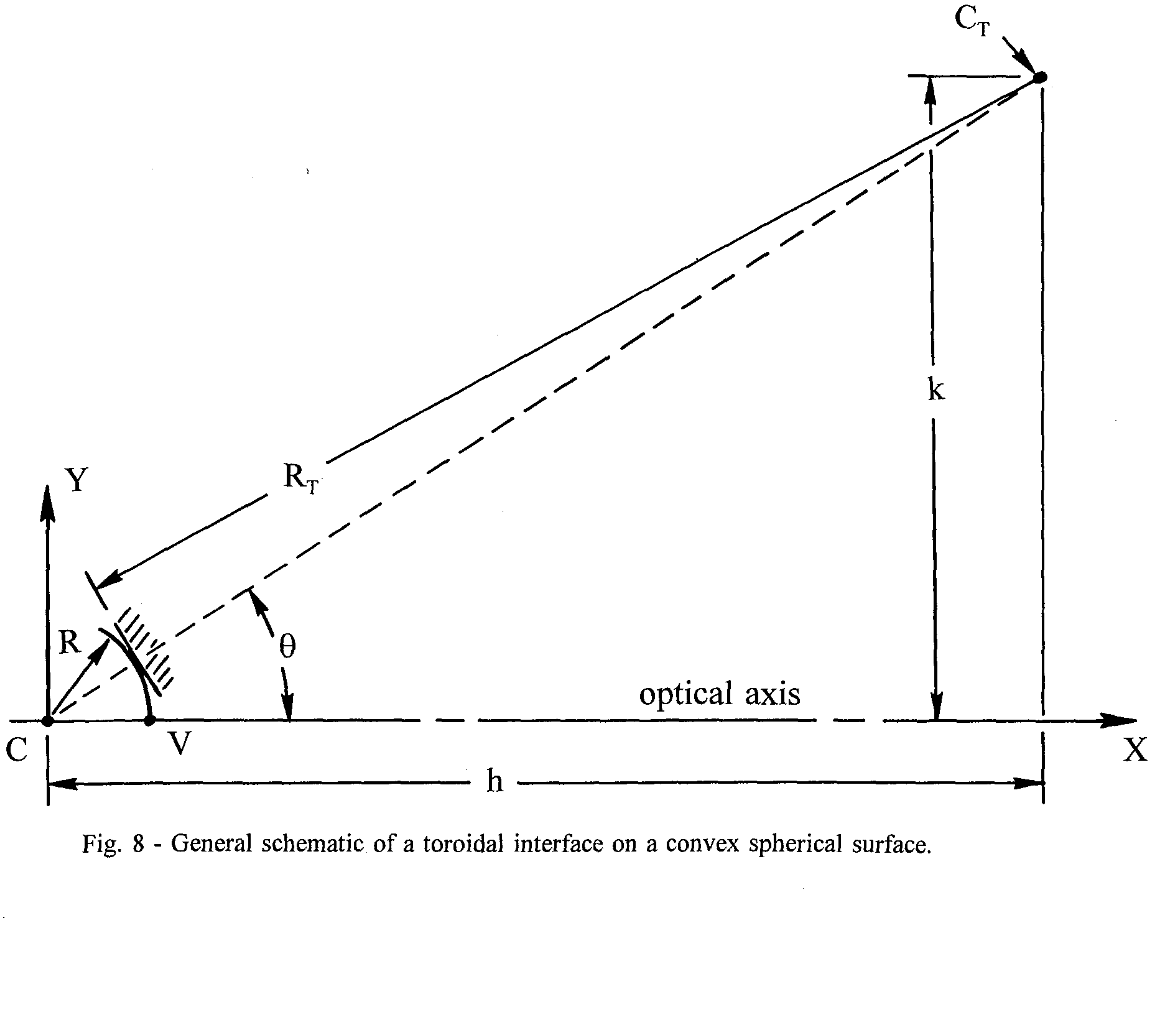

Fig. 8 - General schematic of a toroidal interface on a convex spherical surface.

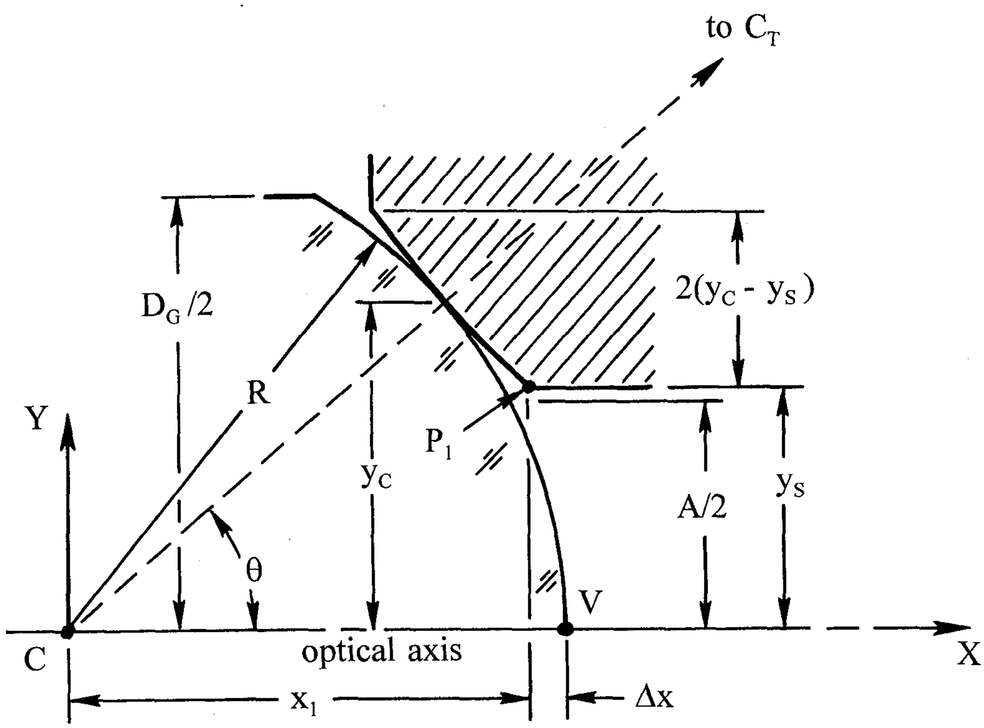

Fig. 9 - Detailed schematic of a toroidal interface on a convex spherical surface.

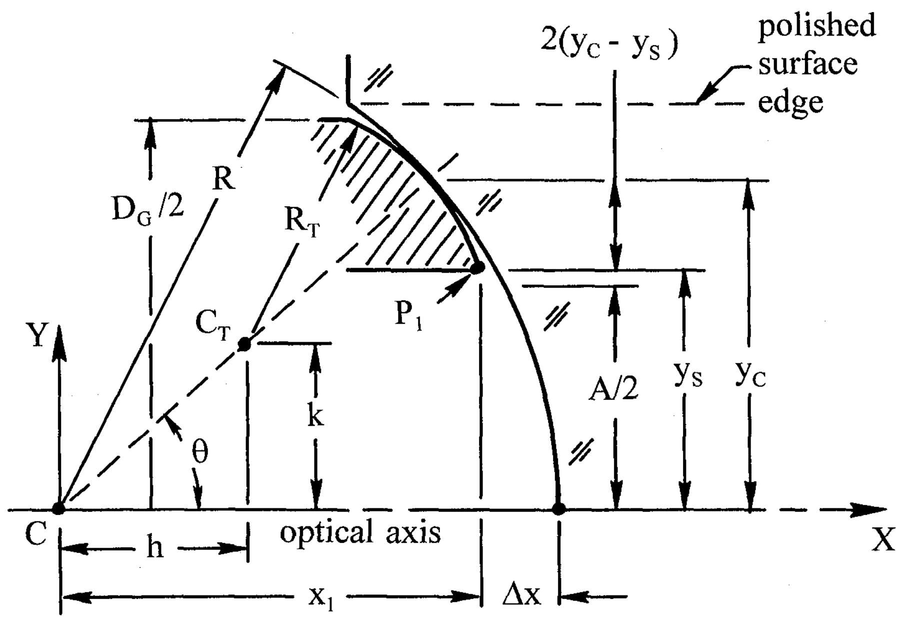

Fig. 10 - Schematic of a toroidal interface on a concave spherical surface.