Evolution of opto-mechanical characteristics of hybrid aspherical lenses

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Abstract:

Aspherical lenses differ from conventional lenses by their complex surface whose radius of curvature varies depending on the distance from the axis of the light beam.
Spherical lenses are capable of producing aberrations. Therefore, they are not able to focus all the light into a single point. Instead, aspherical lenses correct aberrations and provide better resolution even with compact lenses incorporating a small number of lenses.
In this paper, the term hybrid aspherical lens usually refers to the method of manufacture of aspherical lenses, combining glass and resin. Ultra violet flexographic resin is injected between the spherical glass lens and the aspherical metal mold and then irradiated with UV radiation in order to shape a hybrid lens

Keywords: Manufacture of lenses, aspherical surface, precision moulding, radius of curvature, roughness.

1. Introduction

For centuries, the optical designers have simply use plans or spherical profiles, the only one that really knew achieve industrially with sufficient precise details [1]. However the need for instruments more efficient in terms of field, resolution and spectral range, as well as the stress of congestion and weight increasingly reduced (under the impetus of military needs or space and professional instruments phones) has required control implementation process of aspheric surfaces, for example for the realization of space telescopes with compactness and presenting important deformations compared to the sphere [2-4]. There exist various types of manufacturing of the aspheric lenses, such as the moulded lenses [5], lenses out of ground glass, lenses manufactured by the hybrid method [6]. Among these types of manufacturing, the hybrid method is regarded as one of most suitable. The lens carried out by the hybrid method is manufactured by depositing a layer of monomer between the lens out of spherical glass and the aspheric metal mould [7].

2. Experimental Procedure

The optical glass used is a crown refractive index n = 1.48 and the glass transition temperature greater than 570 ° C. The manufacture of spherical lens of diameter 40mm, involves a sequence of operation generally classified into cutting, turning, grinding, lapping and polishing. For the lapping step, it was used by several successive steps of alumina fractions F30, F15 and F9, and the agent polishing is cerium oxide suspension of grain size 300 nm and a polyurethane polishing pad [8]. For coating, we used a resin refractive index n = 1.48 is very sensitive to ultraviolet radiation and polyvinyl butural very reputed to be used

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to make laminated glass. The realization of the aspherical surface by the hybrid method is as follows:
Once the convex lens carried out, a resin is injected between the lens out of spherical glass and the aspheric mould, then irradiated with a radiation UV in order to shape a hybrid lens as shown in the figure 1 [9].

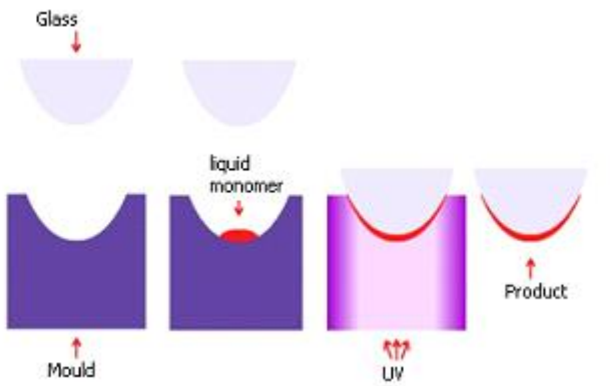
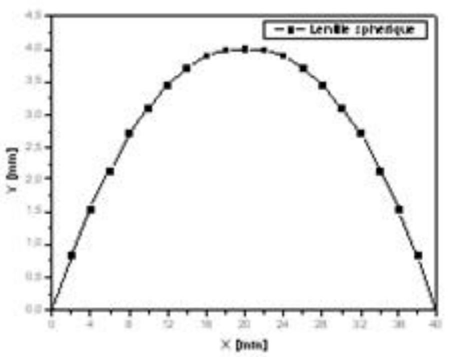


Figure 1. Technique of manufacturing of the aspheric lenses by hybrid method

3. Experimental results

3.1. Control the radius of curvature
3.1.1. Spherical lens
The spherical lens that one carried out in our laboratory is a lens of diameter 40mm and radius of curvature rp=49,23mm. To control the profile of spherical surface, one used an optical measuring equipment which is the profile projector with an enlargement of ×10. Once the profile is projected onto the screen, a line is fixed as a
reference, the ordinate and measuring (x, y) for 20 selected points on the lens, then the profile is obtained according to Figure 2 and the shape of the spherical lens 3D according to Figure 3.



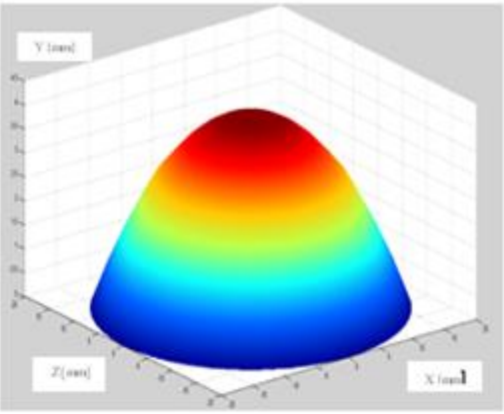


Figure 2. Shape of the spherical lens **Figure 3.** Representation of the 3D spherical lens

The radius of curvature of the lens is obtained by the following formula (1)

g(i)=sqrt((20-x(i))^2+(45.23+y(i))^2)……………………………(1)

The values of radius of curvature Ri according to step of measurement i obtained from the spherical lens are given by table 1.

Table1. Radius of curvature Ri according to step of measurement I of the spherical lens.

Step i [mm]	0	2	4	6	8	10	12
R_i [mm]	49.454	49.446	49.423	49.398	49.374	49.354	49.335
Step i [mm]	14	16	18	20	22	24	26
R_i [mm]	49.311	49,292	49.260	49.238	49.260	49.292	49.311
Step i [mm]	28	30	32	34	36	38	40
R_i [mm]	49.335	49.374	49.434	49.398	49.423	49.446	49.454

The median value of the radius of curvature: R = 49,3631mm measured with a precision of ± 0,0704mm.
According to these results, we find that the spherical lens carried out in our laboratory is canonical in the field of manufacturing because the relative error is very low (<0.5%) in all measured points. These errors are attributed to measurement errors and perhaps manufacturing [10-11].

3.1.2. Aspheric lens with resin

Figures 4 and 5 show the shape of the aspherical lens made of the combination of ultra-violet flexographic resin in two and three dimensions.

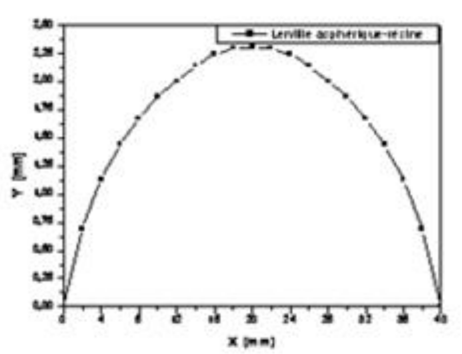


Figure 4. Aspheric shape of the lens made by resin

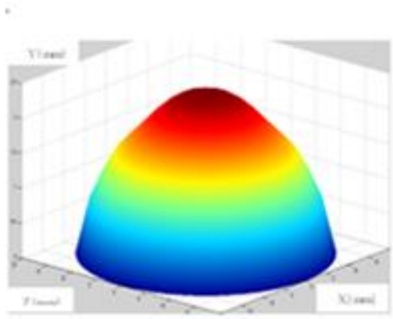


Figure 5. Representation of the aspheric lens carried out by the resin in 3D

It is difficult to measure the radius of curvature by classical techniques. What led us to seek techniques able to estimate the radius of curvature of aspheric surface. One measured the radius of curvature on the optical axis, which corresponds to the distance [OM], then with the software Matlab, one measured the distances [OMi], which represent Ri, such as Ri the radius of curvature for each point of surface, as shown in the figure 6 [12].

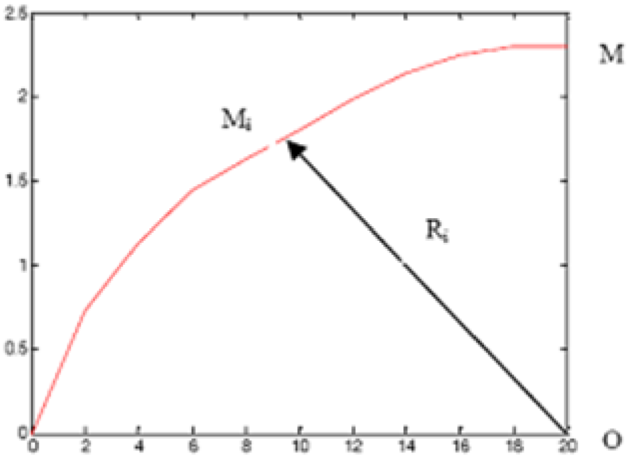


Figure 6. Measurement principle radius of cirvature Ri

The measurement of radius of curvature of the aspheric lens was done by using the following formula these stages:

$$r(i)=sqrt((20-X(i))^2+(47.2+Y(i)^2) \qquad \ldots\ldots\ldots\ldots\ldots\ldots(2)$$

The values of radius of curvature Ri according to step of measurement i obtained from the aspheric lens carried out in combination of the resin are represented by the figure 8.

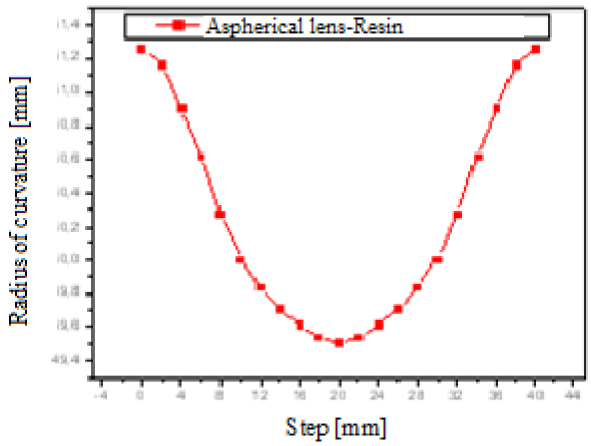


Figure 7. Radius og curvature Ri according to step of measurement i of the aspheric lens carried out by the resin

3.1.3 Aspheric lens with PVB

Figures 8 and 9 show the shape of the aspherical lens made in combination with Polyvinyl butural in two and three dimensions.

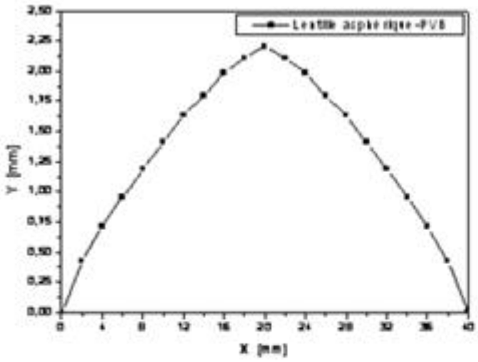


Figure 8. Aspheric shape of the lens made by the PVB

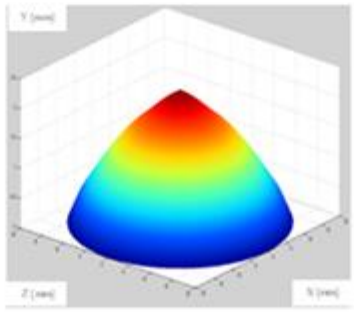


Figure 9. Representation of the aspherical lens made by PVB

The values of radius of curvature Ri according to step of measurement i obtained from the aspheric lens carried out in combination with the PVB are represented by figure 10.

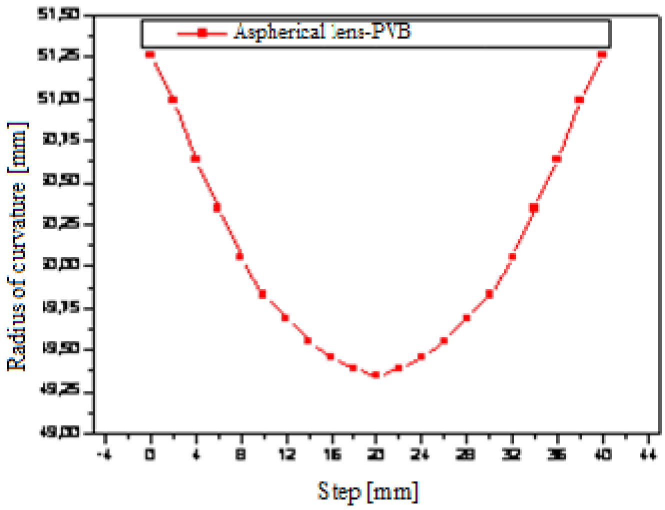


Figure 10. Radius of curvature Ri according to step of measurement i of the aspheric lens carried out by the PVB

Figure 11 compares the radius of curvature of the mould used, the aspheric lens carried out by the PVB and of the aspheric lens carried out by the resin.

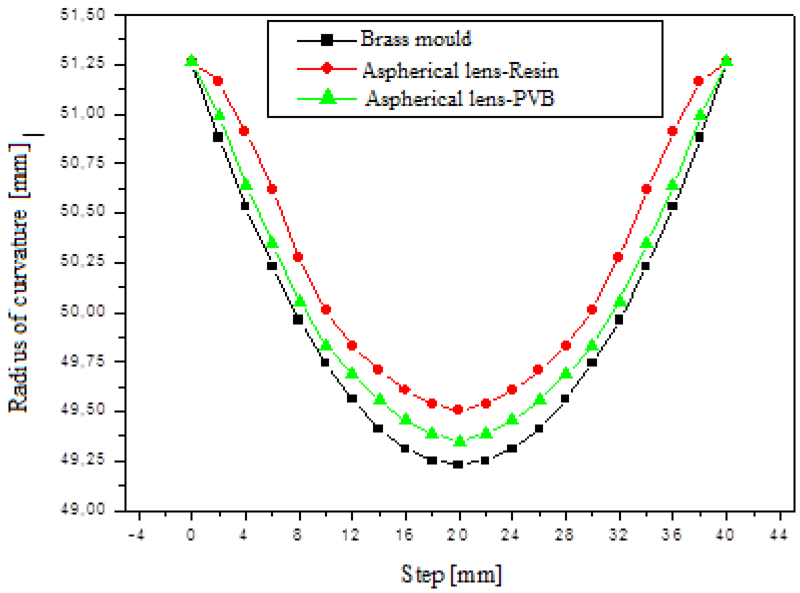


Figure 11. Comparison of the various radii of curvature

The comparison of the results of figure 11 between the rays of the mold used and different radii aspheric lenses with either flexographic resin or polyvinyl of buturale showed that the manufacturing process of the aspherical hybrid method makes it possible to obtain radii very near to the radius of curvature of the mold used. It is observed that the aspheric-PVB lens is better compared to the lens aspheric-resin on the other hand the withdrawal is more important at the flexographic resin with the ultra-violet than the polyvinyl of butural.

3.2. Surface roughness

Roughness was measured at the top of the lens; spherical, aspherical (carried by the resin and the PVB) by an atomic force microscope AFM. Figure 12 shows the surface topography of three lenses.

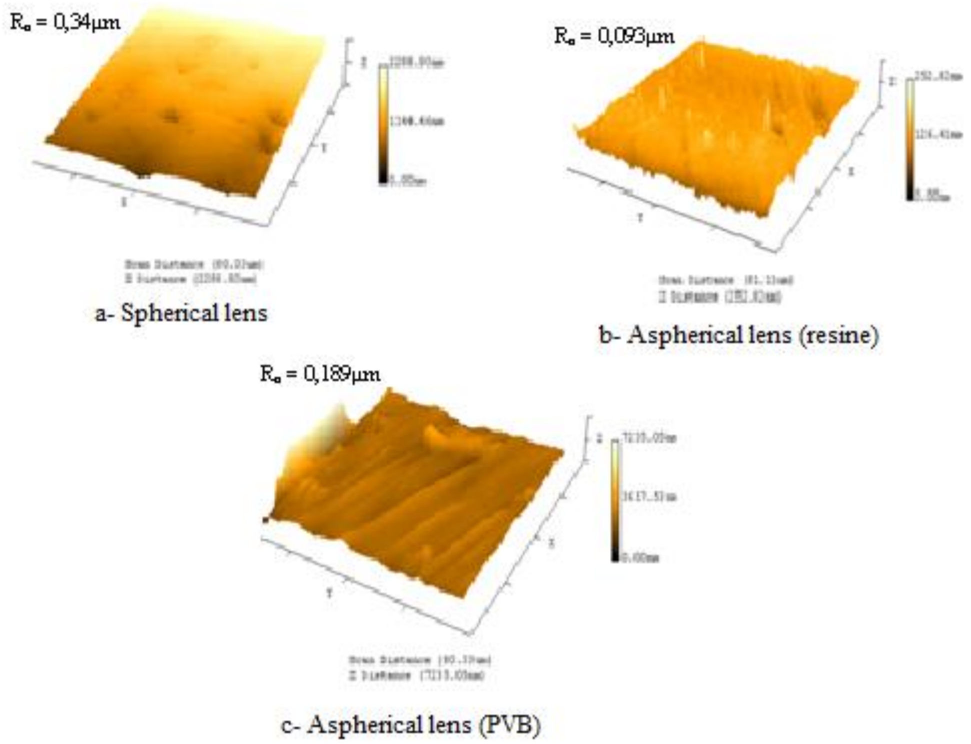


Figure 12. Surface Topography of three types of lenses.

The figure shows that the surface roughness improves in both cases (PVB and resin) compared to the initial state (spherical lens) and we also note that the roughness of aspherical lens made by resin is better compared to the roughness of the aspheric lens surface carried by PVB, this improvement in roughness may be due to a combination of brass (mold material) and resin and physico-chemical properties of coatings on the one hand and the instability of polyvinyl butural which normally requires a SiO_2 layer to secure it. [13]

3.4. Measurement of optical transmission

We have measured the optical transmission for the three lenses: spherical, aspherical- resin, PVB-aspherical with micro-densitometer in three positions A, B and C as shown in figure 13.

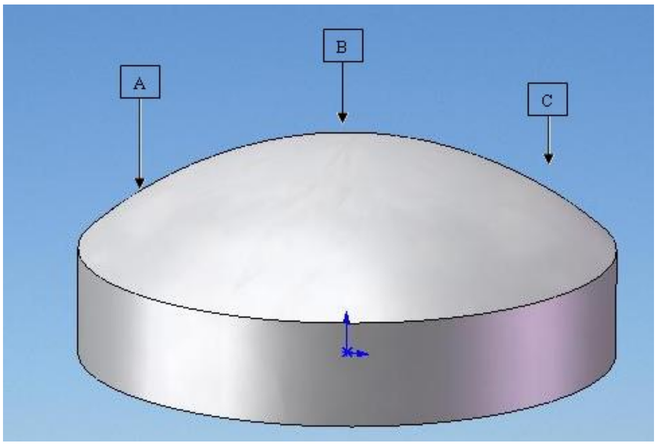


Figure 13. The positions of optical transmission measurement**.**

The results of optical transmission are shown in Table 2.

Table 2. Optical transmission for three lenses

	A	B	C
Spherical lens	70%	83%	75%
Aspherical lens-resin	80%	90%	84%
Aspherical lens -PVB	79%	88%	81%

From the results of Table 2, we notice that the lenses developed in our laboratory transmit more or less light especially in the middle of the lenses; whereas edge, although the improvement is significant but insufficient to cause release problems we encountered during our work, it is recommended that, in future work, using calcium carbonate before casting to prevent lenses from sticking.

4. Conclusions

This work showcased the manufacturing process of the aspherical hybrid method in general and to explore the possibility of applying this method in practice with the study of the influence of various process parameters (mold material, mold aspherical design, material of the aspheric lens material monomer layer (resin, PVB ... etc). From the experimental results, it was concluded that the manufacturing technology with aspherical hybrid method remains to this day and empirically very difficult especially for the demoulding of the lenses by against it can be easily used for organic lenses.

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