A NEW METHOD OF LENS CENTERING IN THE OPTICAL SYSTEM BY USING SPECIAL MOUNT

Bui Dinh Bao[1*], Doan Van Bac[2]

Abstract: *Decentration in lens systems (for example objectives) significantly degrades the quality of image, such as the coma. In order to reduce lens decentration, the lenses are centered while manufacturing, while gluing, while attachment in the mounts. Significant decrease in the lenses decentering in the mounts is achieved by using a special manufacturing equipment, which allow combining the optical axis of the lens with the base axis of the mount in assembly process. Solutions for coma's alignment by shifting, tilting and rotation their components are also provided in the construction of high-quality objectives (microscopes [1-7], photolithographic, aerophotographic). For optimization of methods for such adjustment the influence coefficients of decentering of each optical surface of the lens system on the value and sign of coma must be calculated and taken into account. In this paper, we propose a special mounting which combined with the Opticentric of Trioptics device to center the lenses. The results show that the decentering is significantly reduced (0.9µm) compared to (44.2µm) with using a reference mount.*

Keywords: Len’s decentering; Aberration; Coma; Manufacturing.

1. INTRODUCTION

As we all know, in order to have a quality optical system, in addition to ensuring the quality of each optical element when manufacturing, they need to be centered precisely when assembled into the optical system.

For precise centering, each lens is usually assembled individually into the mount. Two methods of such aligning are known:

The first method of centering (autocollimation) consists in that lens in the beginning that or by another method fasten in a mount that is executed with allowances on outward sizes, after a mount is fastened in the centering ("floating") cartridge of machine-tool, combine the centers of curvature of lens by means of cartridge and autocollimator with the axis of rotation of spindle of machine-tool and process a chisel the outward (base) surfaces of mount to the nominal size.

The lacks of similar method of centering are: necessity of the use of the special difficult equipment, errors of centralizes from influence of cutting forces, and also "contamination" of workplace at treatment of mount.

The second method of lens centering is based on that a lens is set in a mount, the base outward surfaces of that are made in a nominal size, with a megascopic gap in landing for possibility to move or incline a lens in the process of fixing for combination of her center of curvature, with the base axis of frame, revolving the last about base axis. This method is used at fixing of lens in a mount curling or gluing. Presently there are the stations for automation of process of similar centering, for example such as "OptiCentric" produced by a firm TRIOPTICS. There is one such device at hte National Center for Technological Progress in Viet Nam.

The main disadvantage of this method of lens centering in the mount is the fact that a centering is performed by only one (second) of the working surface of the lens. If a collar of a cylindrical hole rim under the lens not being perpendicular to the reference axis of the hole in the rim or rim is positioned eccentrically to the core axis, the center of curvature of the first (base) surface of the lens will not coincide with the rotation axis, i.e., decentralize.

In this paper, the centering means, which allow to center the lens axis relative to the base mount, not only at one working surface but also on the second are presented. This capability is achieved by the fact that the lens mount is performed by component which has major and minor parts. The lens is mounted with clearance in aligning the intermediate part of the mount which, in turn set with a clearance adjustment in the main mount. Lens is centered by lens and intermediate lens mount tilting, and then fixed with adhesive UV curing.

2. PROBLEMS WITH LENS CENTERING

As it is known lens decentering in lens systems, especially in objectives, substantially degrades the quality of the image that they created. They most strongly affect the aberration of "coma". Detection of this and other aberrations in objective's assembly is usually done by using a diffraction image of a pinhole.

Figure 1 shows diagrams of the monitoring of the image quality of a microscope lens (b) and a camera lens (a) using the diffraction image of a pinhole and the forms of the diffraction images (c-f) in the absence and the presence of various aberrations.

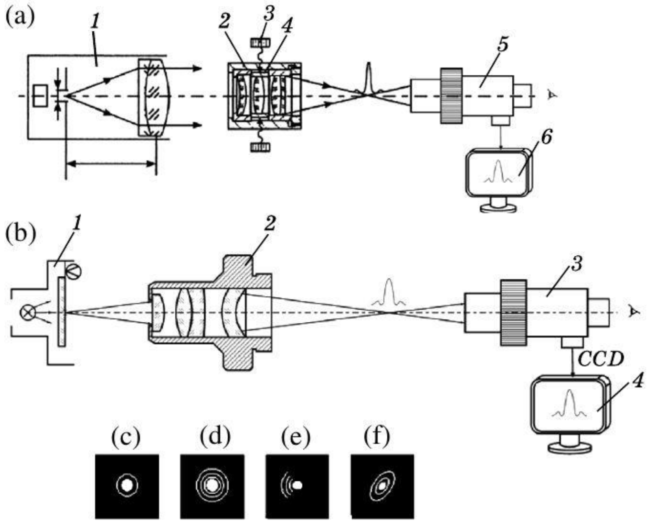


Figure 1. *Layouts for monitoring the image quality of microscope (b) and camera lenses (a):*

(a) 1 - Collimator with a pinhole, 2 - Test camera lens, 3 - Adjustment screw,

(b) 4 - Displaceable mount, 5 - Video camera, 6 - Monitor;

(c) 1 - Object module with pinhole, 2 - Test microscope lens,

(d) 3 - Video camera, 4 - Monitor; (c)–(f) Diffraction images.

Figure 1(e) shows the presence of coma in the objective, which results from technological errors of fabrication and assembly of its elements, leading to decentering of the components.

Let us consider these errors, using as an example the connection of a lens with a mount by cementing. Figure 2(a) shows a simplified design for attaching a planoconvex lens, while figure 2(b) shows one for a biconvex lens in a mount.

In the first case, it is required that the center of curvature of the spherical surface of the lens (C_F) must lie on the base axis of the mount (formed by its base surfaces *A* and *E*), while the flat surface of the lens is perpendicular to it. However, the indicated requirements are not satisfied because of the decentering of the lens itself, the tilt (play) of support flange *G* of the mount and its roughness, the displacement of the lens in the mounting gap along diameter D_1, and the eccentricity of this diameter relative to the base axis.

In the second case, it is required that both centers of curvature of the working surfaces of the lens must lie on the base axis of the mount. Here the centers of curvature become displaced because of the decentering of the lens itself, the tilt of reference flange *G*, the error of shape (flash) of the end border formed by the surface of flange *G* and by aperture D_2 relative to the base axis of the mount, and the relation (tilt) of the lens within the mounting gap along diameter D_1.

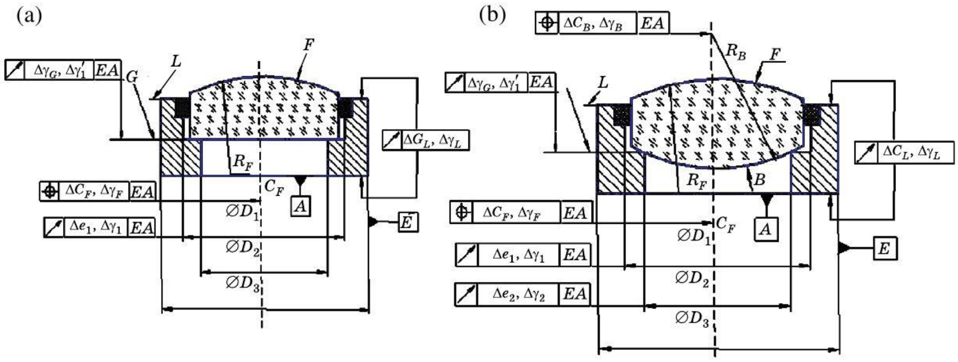


Figure 2. *Connection of the lens with the mount. (a) Planoconvex lens, (b) Biconvex lens.*

Note that the non-parallelness of the surface L of the mount relative to base surface A does not cause decentering of the given lens but can subsequently cause tilt of another lens module that abuts this surface. All the enumerated errors have a vectorial character and are therefore characterized not only by the magnitude but also by their direction (the azimuth of rotation around the base axis).

The influence of these errors can be reduced and compensated when the lens and the mount are being assembled either by adjusting the lens in the mount (by shifting or tilting it in the increased mounting gap relative to the base axis of the mount during attachment), or by the final processing of the outer surfaces of the mount to the nominal size from the optical axis of the attached lens [1].

It is a fact that currently, in the process of designing and manufacturing lenses in Vietnam, the calculation of decentering tolerance as well as its control during processing and assembly have not been given due attention. That leads to when the quality of the objective is not high, we have to spend a lot of time analyzing the cause. If detected because of the eccentricity of the lens, it is imperative that we go and remake the lens.

For these reasons, to improve centering accuracy we need to centering both surfaces of the lens. In this article, we propose an alternative to centering the both faces of the lens using a special mount on device Opticentric.

3. SPECIAL DEVICES FOR LENS CENTERING AND EXAMPLES OF LENS CENTERING

Automatic equipment is currently available that makes it possible to carry out these operations. For example, Trioptics produces the automatic OptiCentric station [2], which centers lens *3* when it is being cemented in mount *2* with fast-hardening cement under the activation of UV radiation (figure 3a). Here *1* is a chuck (collet) for attaching the mount, *4* is an automatic manipulator for displacing the lens, and *5* is an automatic collimator.

A drawback of this and similar stations is that the centering of only one lens surface (F) is carried out here. Therefore, if the reference end (G) is not perpendicular to the base axis of the mount the decentering of the second (reference) surface of the lens remains.

For example, if the reference end G has a tilt (play) with an angle $\Delta\varphi$, then the center C_B of curvature is displaced from the base axis of the mount with value:

$$\Delta C_B \approx (R_B - h)\Delta\varphi \tag{1}$$

where R_B is radius of the lens surface *B*; *h* is deflection of the lens surface, while bearing on the end *G*.

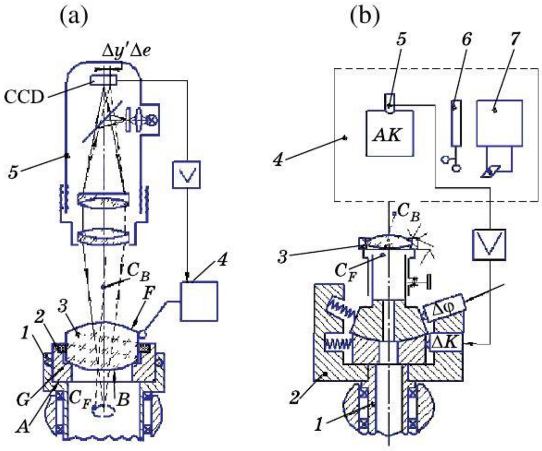


Figure 3. *Functional layouts of stations*
(a – [2], b – [3]) for centering lenses in mounts.

Figure 3. (b) shows the functional layout of such a station, used by Carl Zeiss [3]. Here 1 is the spindle of the machine, 2 is a chuck for automatic centering of the mount with lens 3, and 4 is the "support" of the station, containing autocollimator 5, probe head 6, and cutter 7.

Thanks to aerostatic bearing of machine and high precision of work of centering chuck, the lens centering on this station achieves micron accuracy.

Even though such machines can be used to obtain high centering accuracy of the individual lenses (and cementing of the lenses) in the mounts, it is impossible to obtain the required image quality in a number of multicomponent, high-quality lenses (photolithographic, microscope, photogrammetric, and projection lenses) because of residual decenterings of the lens components, their radial displacement in the gaps with the housing, and tilts.

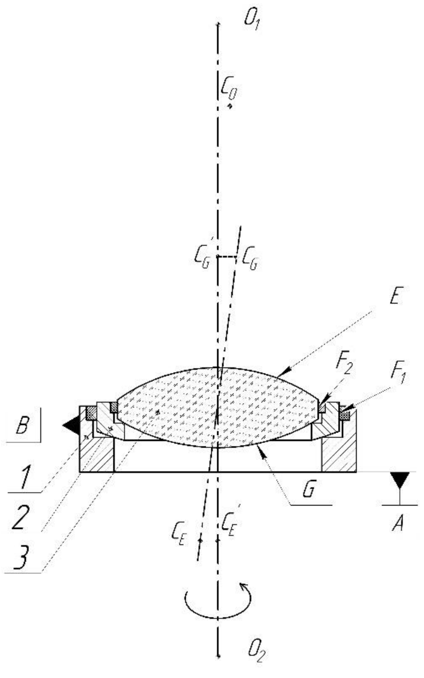


Figure 4. *Special design of the lens mount.*

Special constructions of the lens mounts can provide centering lenses on similar station by both of their working surfaces. Figure 4 shows a similar lens mount, which consists of basic *1* and intermediate *2* parts that allow to carry out lens centering *3* by working surfaces *G* and *E*. Here, at the beginning with the rotation axis O_1-O_2 of the basic mount is combined (by tilting of intermediate mount around the center C_0 of curvature its reference spherical surface) center C_G of curvature of the lens surface *G* and this position of the intermediate mount in the basic is fixed (by using UV glue). Then, by tilting the lens in the intermediate mount, center of curvature C_E of the second working surface *E* is combined with the rotation axis O_1-O_2 and the position of the lens in the intermediate mount is fixed.

Final processing of the external surfaces of the mount makes it possible to obtain the highest accuracy of the lens centering. It is carried out on specialized machines (stations), some of which are also equipped with a three-coordinate measuring head that make it possible to measure the dimensional errors of the mount after it is processed.

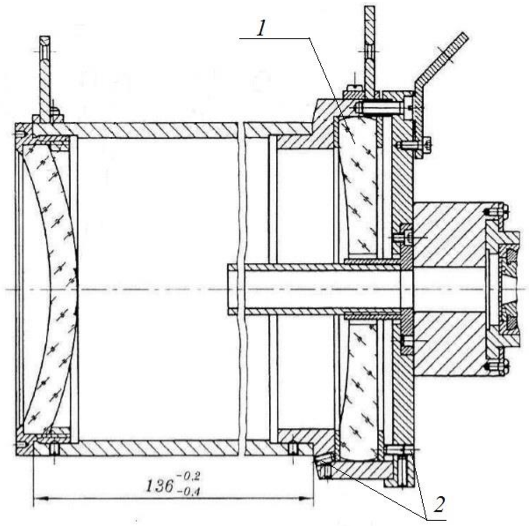


Figure 5. *Design of the mirror-lens telescope.*

Examples of centering lens components and compensation of aberrations influence by tilting and turning components of objectives [1, 8] are shown in figure 5, 6. Figure 5 shows the construction of a mirror-lens telescope (set up by Maksutov), in which centering is provided by tilting of the mirror 1 using screws 2.

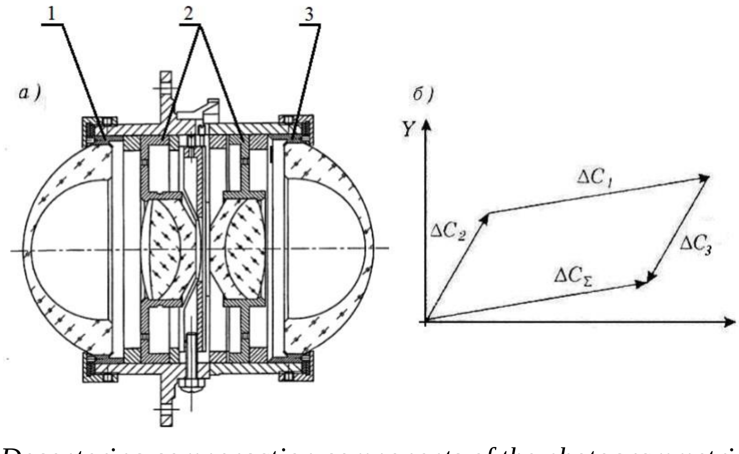


Figure 6. *Decentering compensation components of the photogrammetric objective.*

Photogrammetric M.M Rusinov's objective (figure 6). Centering is provided by turning the first (*1*) and the last (*3*) menisci, relative to the fixed medium components (cemented lenses *2*) in which the vector sum of the tangential distortion is equal to zero (figure 6b). This is possible if one of the unit vectors is no greater than the sum of the other two modules.

4. EXPERIMENTS AND RESULTS

In the experimental part, we center (while gluing to the frame) a biconvex lens in two different cases.

Case 1: Center the lens in an individual mount (this is often used for simple lens assemblies).

Case 2: Center a biconvex lens in a special mount (Figure 7) consisting of two parts (basic and intermediate mount).

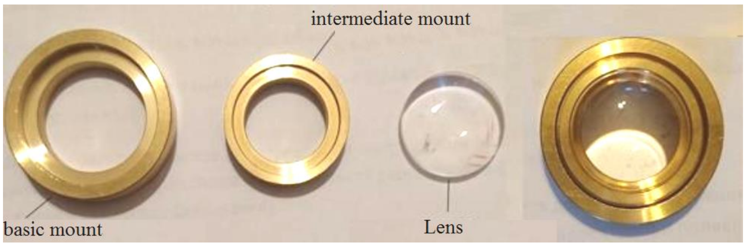
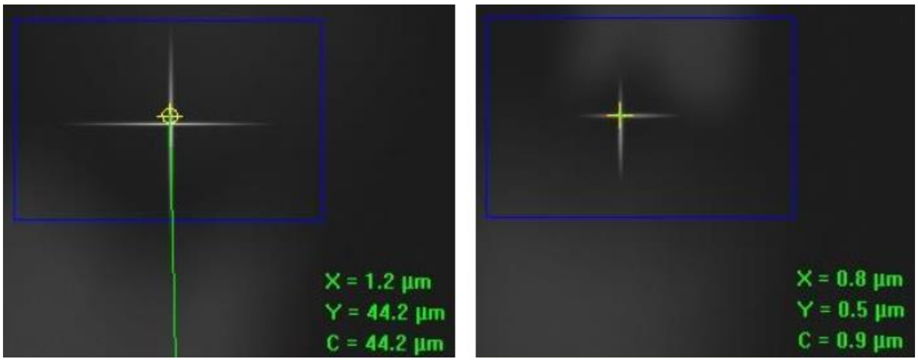


Figure 7. *Special mounting complex for lens centering.*

For the first case, the essence of the centering process is to coincide the optical axis (the line connecting the center of curvature of the two surfaces of the lens) with the mechanical axis of the mount (in this case we use the intermediate mount).

Because of the error when manufacturing the mount, the surface *G* (figure 3) on which the lens rests is not perpendicular to the mechanical axis of the mount, resulting in the decentration of surface B (according to formula 1). The results on the software show that the decentration of the lens is 44.2µm (figure 8a).



a) *b)*

Figure 8. *Results of lens centering by using special mount on Opticentric.*

a) Decentration of the lens when using a conventional mount;

b) Decentration of the lens when using a special mount.

To overcome this shortcoming, we design a special mount so that the contact surface of the intermediate mount with the basic mount has a sphere shape. The center of curvature of that sphere coincides with the center of curvature of the surface G of the lens (figure 4).

Centering (during gluing) is carried out as follows:

Step 1: Place the lens in the intermediate mount. Then place them in the basic mount and place on the Opticentric device (figure 9).

Figure 9. *Opticentric device [2].*

Step 2: Proceed to center the underside of the lens along the mechanical axis of the basic mount.

Step 3: Use UV glue to fix the lens to the intermediate mount.

Step 4: Adjusting the complex intermediate mount + lens assembly to center the top surface of the lens along the mechanical axis of the basic mount.

Step 5: Use UV glue to fix the intermediate mount with the basic mount.

Thus, the lens has been centered on both sides. The results show that the decentration of the lens is significantly improved (0.9 µm) (figure 8b).

5. CONCLUSIONS

The research and development of equipment and lens centering mechanisms have always been of interest to scientists and optical companies to improve the quality of optical systems. In Vietnam, the issue of lens centering has not been given adequate attention. The accuracy of centering is highly dependent on the skill of the worker. The existing Opticentric equipment in Vietnam has not been used much in the production of optical devices. Therefore, the research, exploitation and use of this device along with the manufacture of special mounts for lenses will significantly improve the centering accuracy of the lenses, increase the quality of the systems. optical system. With this dedicated mounting system, we can center both sides of the lens in turn during assembly. However, this mounting design will increase the size and complexity of the objective. Therefore, this mounting structure will be more suitable for objectives working in a laboratory environment or for objectives where high centering accuracy is required. In future studies, we will continue to explore and propose new textures to further improve the centering accuracy of the lenses.

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TÓM TẮT

PHƯƠNG PHÁP ĐỊNH TÂM THẤU KÍNH MỚI SỬ DỤNG KHUNG GIÁ ĐẶC BIỆT

Sự lệch tâm của các thấu kính trong các hệ thống quang học làm giảm đáng kể chất lượng của hình ảnh mà hệ thống quang học đó tạo ra, trong đó, đáng kể nhất là ảnh hưởng đến quang sai coma. Để khắc phục sự lệch tâm đó, các thấu kính thường được định tâm trong các giai đoạn như: trong gia công, trong khi dán (đối với các thấu kính dán) và trong khi lắp ráp. Trong bài báo này, chúng tôi nghiên cứu khả năng định tâm thấu kính trên thiết bị chuyên dụng – opticcentric của hãng Trioptics với việc sử dụng khung gá đặc biệt để tăng độ chính xác định tâm.

Từ khóa: Độ lệch tâm; Định tâm thấu kính; Quang sai; Coma; Sản xuất thấu kính; Lắp ráp quang học.

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