Assembly Method Considerations for Cemented Assemblies

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This paper will examine options in assembly methods of cemented lens assemblies, and techniques for communicating critical items will be presented.

ASSEMBLY METHODS

When cementing lenses together at Optimax, there are two main options for assembly methods, V-Block and Air Bearing. They are detailed below, and each has its own benefits and challenges.

V-Block Assembly

In V-block assembly, the component elements are edged to equal diameters. Adhesive is applied to the interface, and air bubbles and tilt in the cement layer are worked out. Tilt is seen as cement fringes, interferometric indication of thickness variation or tilt in the cement layer[1]. The assembly is placed against a V-block, referencing the assembly's diameters, and the cement cures.

V-block assembly requires equal diameters for the elements, and the elements must be of a size big enough (> 20mm) to permit easy handling and contact with the V-block. The assembly must have a sizeable external surface-to-external surface wedge allowance[2], ideally equal to twice what the elements have. It is possible to orientate element wedge in opposing locations, producing a doublet with external surface-to-external surface wedge equal to the difference in the element wedges. However, there is still misalignment between optical axes and the wedge is not really eliminated. With occasional exception, elements must be completely finished (full value-added) before assembling. For economy of scale reasons, V-block assembly is the most economical option.

There is a risk of overhang if the diameters are not equal, with the amount of overhang growing in proportion with the diameter difference. The overhang makes effective lens diameter larger than the diameter of the elements, and it may obstruct later drop-in[3], edge reference lens mounting. Figure 1 shows the effect of unequal diameter in V-Block assembly, grossly exaggerating the condition for illustrative purposes. On the positive side, there is reduced risk of assembly process-related distortion since no constraining force is applied to the element while curing as in other methods.

There can be a quality penalty. Each element can have considerable centration errors made undetectable to the eye depending on orientation of

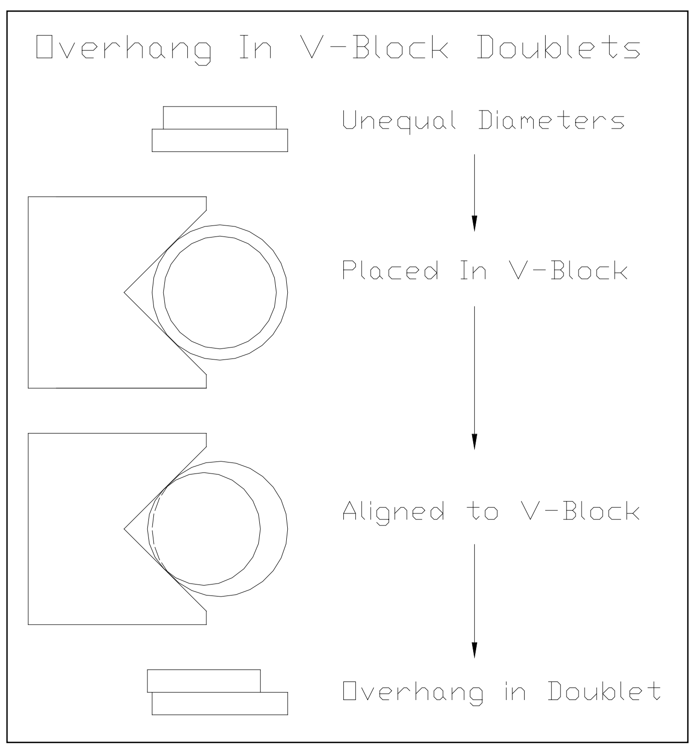

Figure 1 – Assembly-Related V-block Overhang

opposing element mechanical tilts when assembling. Centration errors can be canceled out relative to the external surfaces. Figure 2 shows the same assembly, one with perfectly centered elements and the other with tilted interface surfaces. The mechanical tilt is grossly exaggerated (~5°) for illustration, and in reality, a typical edge thickness difference would not be perceived by eye.

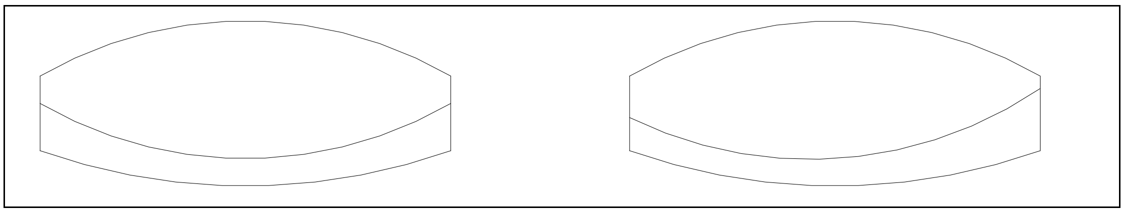

Figure 2 – Equal total edge thickness from unequal elements

Air Bearing Assembly

Air bearing assembly involves placing lenses on a trued chuck on an air bearing and indicating the lenses into position. If the chuck runs true, the spherical surface resting on it will automatically run true. Vacuum is used to temporarily lock one element in place relative to the air bearing's axis. By rolling the elements around centers of curvature while on the air bearing and verifying positions with mechanical indicators or lasers, the lenses are moved into position and the cement cured. Figure 3 shows the basic layout and features of an air bearing assembly station.

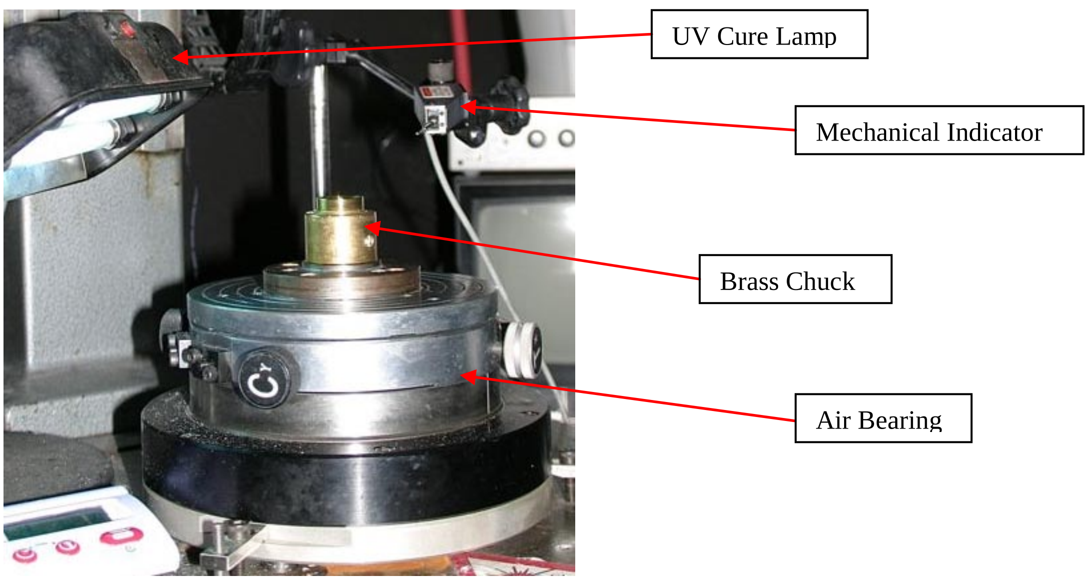

Figure 3 - Air Bearing assembly station layout

There are two distinct routes for air-bearing based assembly of cemented lens assemblies used at Optimax, differing only by which datums are used. Each has advantages and disadvantages as detailed below.

Coaxial Air Bearing Assembly

Coaxial air bearing assembly involves aligning the centers of curvatures of all surfaces on a common axis. During assembly, elements are layered, alternating between element and cement, built directly on the air bearing. Each added element is positioned while measured mechanically or optically, aligning the centers of curvature to the air bearing's mechanical axis. The assembly optical axis becomes coincident with the air bearing mechanical axis, emphasized in Appendix A. The cemented assembly can be edged to a common diameter or potted in a cell for mounting purposes, making the assembly's mechanical and optical axes coincident.

Coaxial assembly on the air bearing represents the method of highest cost and quality. Alignment between elements is the most complete, limited to the resolution of the metrology used, yielding the smallest assembly-induced image quality penalty. Cementing and ringing-out takes place on the air bearing, a confined and restricted space relative to a laminar flow bench. It requires specialized skill from the assembler and ties up the air bearing. Wedge in the cement layer is the dominant source of error. Any subsequent operations, edging or potting for example, involve full value-added assemblies, so risk is high.

Floater Air Bearing Assembly

Floater air bearing assembly involves using one element as the main mechanical reference, aligning any other elements to this reference element. During assembly, additional elements are "floated" in to position by rolling the element around the center of curvature of the interface. It requires unequal diameters for the elements to allow room to roll one element without creating interfering overhang or allowance for the resulting overhang. Figure 4 illustrates movement of the floater element along the interface.

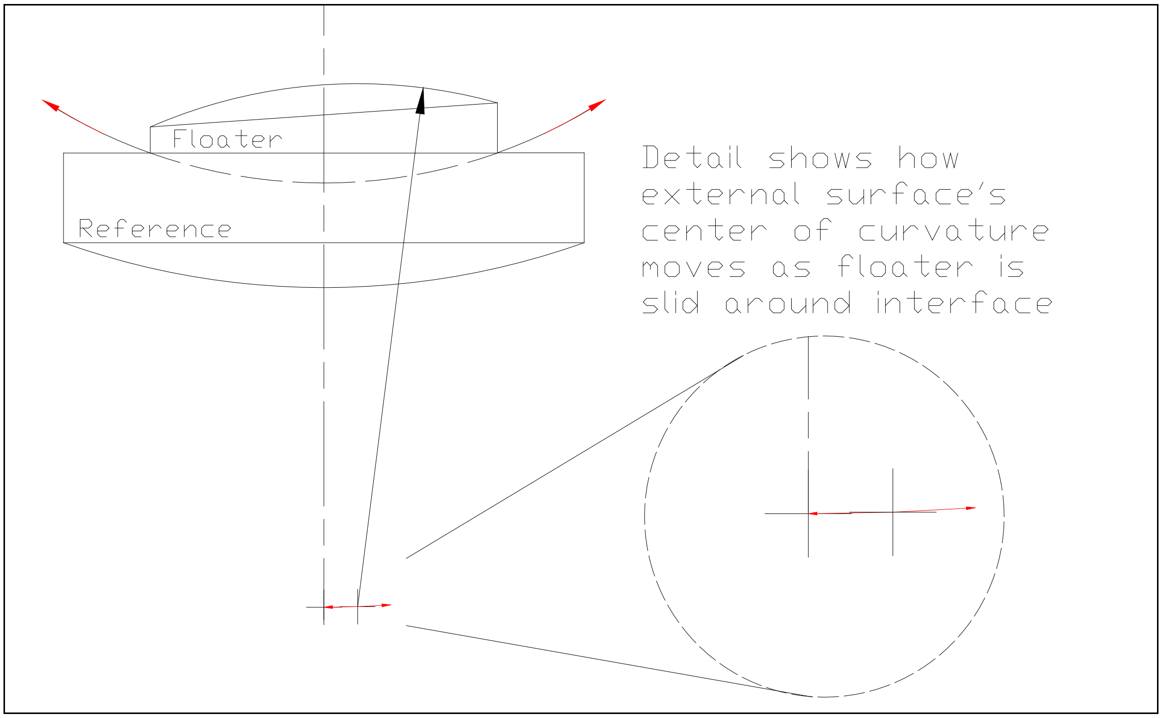

Figure 4 - Rolling of Floater element around center of curvature

As the floater is rolled, the edge thickness difference (ETD) present in the floater element is converted to edge runout (ERO), increasing the effective diameter of the floater. Allowance needs to be made in the mechanical mounting scheme for the resulting ERO. Figure 5 shows the before and after position, effective diameter and effective diameter distribution relative to the centerline of the floater element. ETD present in the reference element will remain, and there will be tilt in the interface proportional to the ETD in the reference element. This is emphasized in Appendix B.

Floated assembly on the air bearing represents a compromise between cost and quality. With no further operations after assembly, fabrication risk is confined to the elements rather than the full assembly. Cementing and ringing-out takes place away from the air bearing, reducing risk, facilitating an easier smoothing of the cement layer, and permitting some economy of scale. Alignment error is equal to that of the reference element plus cement layer wedge. Any wedge in the reference element remains, raising the assembly-induced image quality penalty relative to coaxial assembly.

Reference Considerations in Floater Air Bearing Assembly

For both coaxial and floater assembly, reference surfaces are used or created as part of the process. Disclosing the intended cemented assembly mounting scheme will emphasize what surfaces are critical. The fabricator may have the opportunity to use future reference surfaces as assembly process datums. For example, if one element half will be edge referenced in a barrel, the fabricator could choose to use that half as the reference element in floater assembly, bringing reference continuity to assembly and mounting.

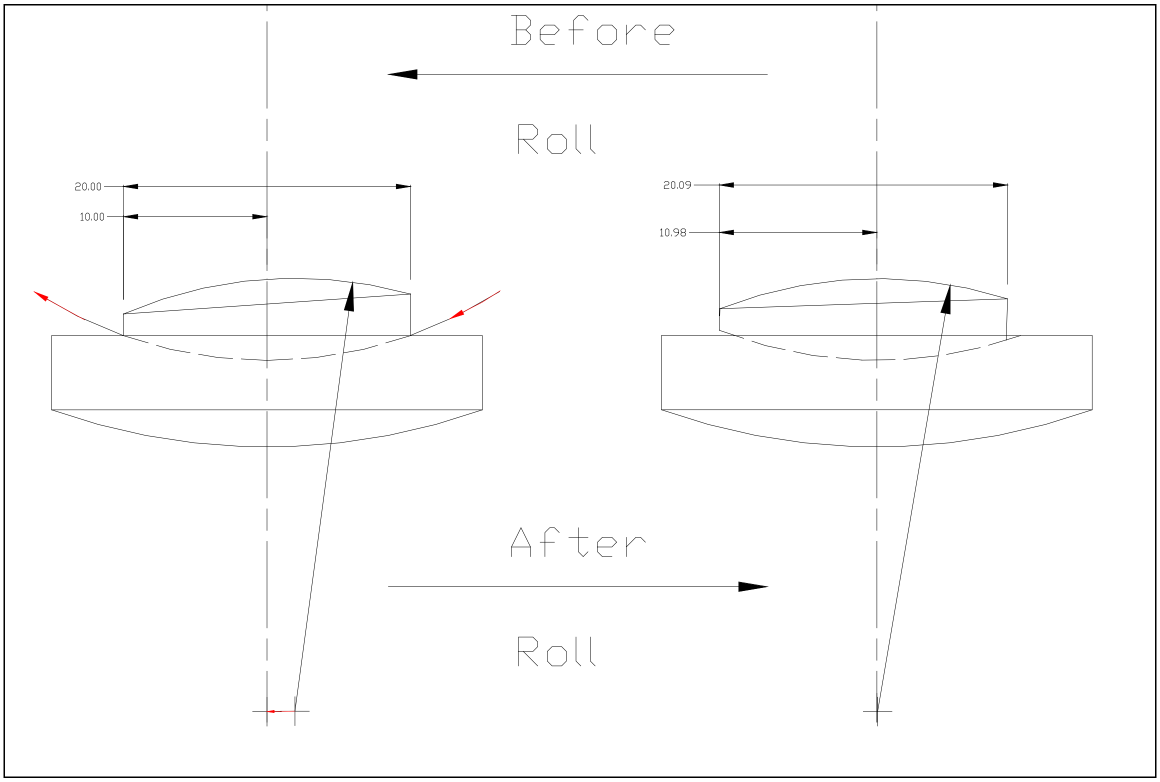

Figure 5 - Floated assembly before and after roll with effective diameter shown

Ideally, the surface referencing the air bearing chuck would be convex and the interface an upward looking concave. This reduces risk of accidental damage when rolling the floater element and keeps gravity from pulling cement out of the interface. During assembly, the reference element is temporarily positioned using vacuum, and a mechanically robust reference element reduces risk of vacuum distortion. In order for vacuum to be effective lenses need to be > 15mm in diameter. Options for smaller lenses are available.

A Specialized Technique for Assembly

Though seldom used at Optimax, there is another option for assembly where elements are positioned using the bell clamping feature of a centering machine. Element placement has roughly the same accuracy as air bearing assembly, with either all or the external centers of curvature on the mechanical axis depending on steps used. Bell clamping allows the assembly to be rigidly held in position while the cement cures. Assembly centration can be checked the same way a single element would be checked after centering.

MECHANICAL DRAWINGS

The mechanical drawing is the tool for designer to communicate intent to the fabricator. At Optimax, it's most important the drawing serves this purpose, independent of draftsmanship, appearance, or format.

Communicate items critical to function; the manner of communication is comparatively unimportant.

As mentioned earlier, datums to be used in mounting can also be used as datums in the assembly process. Communicating which are the key surfaces on the assembly drawing passes this information to the manufacturer. ASME-style Geometric Dimensioning & Tolerancing indications work, but a note on the drawing listing surfaces works too. References must be physical surfaces – not theoretical axes like the optical axis. At Optimax axes may NOT be declared as datums.

Figure 6 shows a sample of how to declare datums and show sample allowable runouts. While the examples may not correctly apply drafting rules, at Optimax they are sufficient to communicate intent.

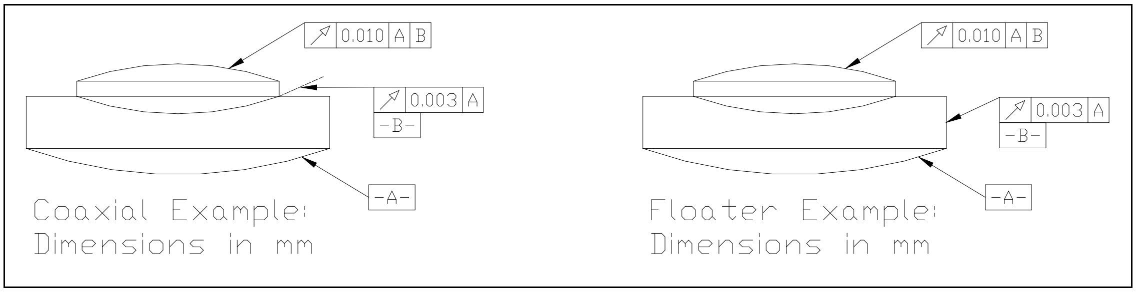

Figure 6 – Samples of how to declare datums for air bearing assembly

CEMENTED ASSEMBLY DATA PACKAGE OPTIONS

The data package generally includes:

- Serial numbers of the elements composing a given cemented assembly.
- Measured attributes, including Center Thickness and ETD, for each element listed by serial number
- ETD of the cemented assembly
- Cement Wedge (where detectable)
- Certificate of Compliance

Upon request, the data package can be expanded to include:

- Measured Assembly Thickness
- Cement Thickness (Calculated)
- Environmental Test Results

CONCLUSIONS

- Declare the mounting scheme. It will help in assembly process selection.

- The mechanical drawing is the tool for the designer to communicate intention to the fabricator.

[1] G Sharma and G Dimri, "Interferometric Countercheck In Precision Cementing", *Applied Optics*, Vol 22, Pg 1132-1133, OSA, Washington DC, 1983
[2] R.E. Fischer, B. Tadic-Galeb, P. Yoder, *Optical System Design*, Pg 501, McGraw Hill, New York City, 2008
[3] P. Yoder, *Mounting Lenses In Optical Instrumentation*, Pg 56 - 57, SPIE, Bellingham, WA, 1995

APPENDIX A – COAXIAL CASE

Figure 7 shows the location of surface centers of curvature relative to the air bearing axis. The biconvex element has no centration error while the meniscus element contains some ETD. As a result, the meniscus element must be mechanically tilted relative to the air bearing axis to locate the centers of curvature.

The centers of curvature of all surfaces are located on the air bearing axis, and the diameters will exhibit runout when the assembly is rotated about the air bearing axis. This is the runout that needs to be modeled in addition to any permitted tolerance on the Runout of the external surface of the floater element.

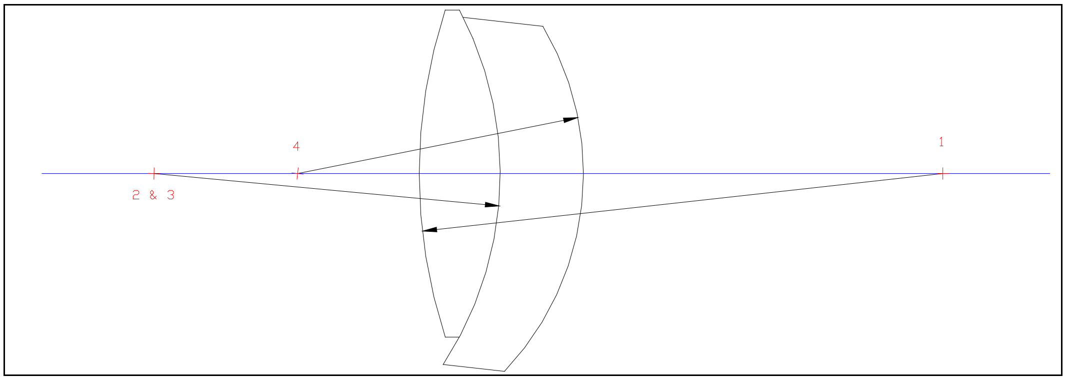

Figure 7 – Coaxial Case showing explicitly the location of centers of curvature

APPENDIX B – FLOATER CASE

Figure 8 details the arrangement of element axes relative to the air bearing axis. The meniscus element in this case is the reference, and it contains some ETD. The floater, while free of its own centration error, is tilted relative to the air bearing axis to locate the external surface centers of curvature.

The centers of curvature of the interface surfaces are not located on the air bearing axis, with the error determined by the ETD in the interface surface of the reference element. The centers of curvature will exhibit runout when the assembly is rotated about the air bearing axis. This is the runout that needs to be modeled in addition to any permitted tolerance on the runout of the external surface of the floater element.

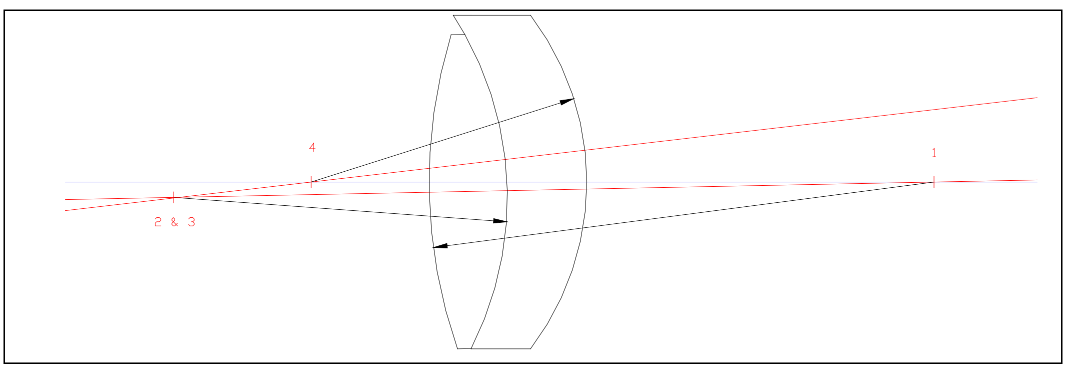

Figure 8 – Floater Case showing explicitly the location of optical axes and centers of curvature

Key for Figure 7		Key for Figure 8	
Air Bearing Axis	Blue Line	Air Axis	Blue Line
Optical Axes (Coincident)	Blue Line	Optical Axes	Red Lines
Centers Of Curvature (1 – 4)	Red Crosshairs	Centers Of Curvature (1 – 4)	Red Crosshairs

Note: Drawings are cross sections, hatching and hidden lines omitted for clarity