A SYNOPSIS OF P.R. YODER'S LENS MOUNTING TECHNIQUES

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ABSTRACT

A synopsis of Paul R. Yoder's paper "Lens Mounting Techniques" is provided which reviews a variety of design techniques for securing lenses in their mechanical housings to ensure the proper function of the instrument in its intended environment. Mounting techniques for individual and groups of lenses are briefly described. Component sizes considered here range from less than one inch to more than 10 inches in diameter.

INTRODUCTION

A review of a variety of ways to mount rotationally symmetric lenses in the size range of about 0.5 to 10 inches in diameter is provided. Techniques for mounting individual and groups of lens and mirror elements are considered, progressing from simple, low precision designs to complex designs for high precision applications.

MOUNTING INDIVIDUAL LENSES

Three common individual lens mounting techniques are burnishing a lens into a cell, using an elastomer layer to cure a lens into a cell, and engaging a threaded retainer ring to secure a lens into a cell. Each of these techniques is illustrated along with its respective advantages in Table 1.

Burnishing is accomplished by deforming the cell lip after the lens is inserted. The operation is performed by inserting the lens into the cell, and then mechanically forcing the lip over the lens. A modified method has the burnished edge replaced with a snap ring. This technique is useful when the assembly is to be subjected to severe shock.

With the elastomer layer technique, a radial spacing is allowed between the lens and cell and the annular void is filled with resilient material such as a vulcanizing (RTV) elastomer. The approximate radial thickness of the elastomer layer between the lens and the cell is given by

$$t_E = D_G\,(\alpha_M - \alpha_G)/2(\alpha_E - \alpha_M)$$

where D_G is the lens diameter, α_M is the coefficient of thermal expansion for the metal lens barrel, α_E is the coefficient of thermal expansion for the elastomer, and α_G is the coefficient of thermal expansion for the glass. A typical elastomer thickness value is roughly t_E = 0.1 inches for a 2 inch diameter lens.

The retaining ring method for mounting an individual lens is to secure it against the shoulder in a cell with a threaded retaining ring. The retaining ring loads the element axially against an annular seat and is typically cut square to the axis, but cuts tangent to the radius of curvature of the lens, or cut and lapped to the same radius of curvature of the lens are sometimes used. This technique allows for easy assembly and disassembly of the lens mount, naturally compensates for lens thickness variation, and is compatible with mounting multiple elements in a single housing.

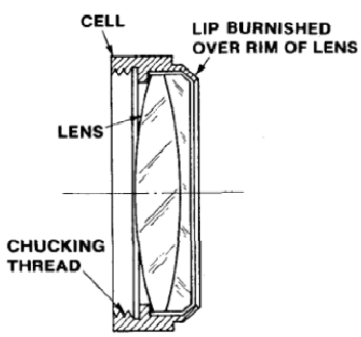
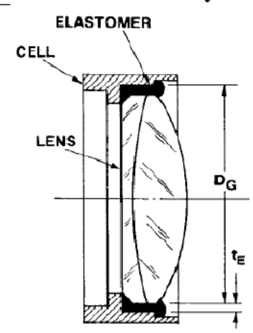
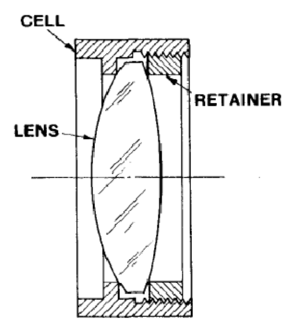
Burnishing	**Elastomer Layer**	**Retaining Ring**
		
Description: Lens barrel is deformed to the beveled edge of the lens.	**Description:** The outer diameter of the lens has a layer of elastomer inserted to secure it to the lens barrel.	**Description:** Threaded retaining ring inserted firmly against the lens in lens barrel.
Advantages: - Inexpensive - Firm mounting technique - Can be modified for a high shock situations	**Advantages:** - Elastomer is elastic leaving the lens unstressed - Inexpensive - Simple	**Advantages:** - Firm mounting technique - Easy to assemble and disassemble - Compensates for axial thickness variations - Adding o-ring creates environmental seal
Disadvantages: - Can induce strain on the lens - Can induce tilt into the lens	**Disadvantages:** - Decentration under shock/vibration	**Disadvantages:** - Can induce axial stress - If lens has a flat edge bevel, then a tight tolerance is required
Notes: - Technique is considered permanent. - Used for low precision (<30 arcmin of wedge).	**Notes:** Typical RTV compounds are - Dow Corning RTV732 - Dow Corning RTV93-500 - GE RTV8112	**Notes:** - Retainer ring can be square, tangent, or spherical.

TABLE 1 SUMMARY OF LENS MOUNTING TECHNIQUES AND THEIR ADVANTAGES

ANALYSIS OF STRESSES

AXIAL

In order to properly select the optimum lens mounting technique, an axial stress imparted on the lens by the mount, including thermal induced contractions, should be considered. An approximation to calculate the stress S_A in the line contact of a square corner spacer is given by

$$S_A = 0.798\sqrt{\frac{P(D_1 + D_2)\big/(D_1 D_2)}{\left(\frac{1 - v_G{}^2}{E_G}\right) + \left(\frac{1 - v_M{}^2}{E_M}\right)}}$$

where P is load per unit length of line contact, D_1 is the lens diameter, D_2 is the corner diameter of the retainer ring, v_G is the Poisson's ratio for the glass, v_M is the Poission's ratio for the metal, E_G is the glass modulus of elasticity, and E_M is the metal modulus of elasticity.

An example using this equation, consider a BK7 lens, a typical axial stress value from an aluminum retaining ring with edge diameter of 0.004 in and load per unit length of 0.3 lb/in. The resulting axial stress S_A on the order of 20,000 psi might be considered safe since the material can generally withstand on the order of 50,000 psi. However, the added stress due to thermal contractions should also be considered. An equation that evaluates the axial compressive stress introduced into a lens by a metal cell that shrinks more than the glass as the temperature drops is given by

$$S_{A'} = \frac{(\alpha_M - \alpha_G)(E_M E_G \Delta T)}{E_M E_G}$$

where α_M is the coefficient of thermal expansion for the metal and α_G the coefficient of thermal expansion for the glass.

In an example scenario characteristic of military equipment survival requirements, if ΔT is equal to 150°F then the axial stress would be on the order of 7500 psi. The axial stresses due to the retaining ring force and thermal changes give a factor of safety of around two. The stress imparted on the glass surface could be dramatically reduced without reducing the required loading force by changing the design to tangent contact between the glass and metal parts, which essentially increases the surface area between the two surfaces.

RADIAL

Some lens assemblies, such as those intended for use in severe shock and vibration environments, are designed with very little radial clearance between the lens and its metal housing. In such cases, the design ideally closely matches the coefficient of expansions of the glass and the metal such that extreme temperature decreases do no cause excessive radial compression of the cell onto the lens. This stress is called 'hoop stress' and can be evaluated analytically analogous to the formulation above; however considering a typical design one arrives at a large safety factor of roughly 50.

The operating temperature range for an optical instrument is certainly less than its survival range. Birefringence and surface deformation due to these lesser temperature changes can adversely affect the optical performance of the instrument. Stress birefringence is mostly of concern in polarization sensitive instruments, and thermally controlled environments are sometimes employed in these demanding applications. Interferometric evaluation of mounting stresses is common in some high-precision applications.

MULTI-ELEMENT MOUNTING CONFIGURATIONS

There are various ways in which two or more lenses can be mounted to form lens sub-assemblies, extending the individual element mounting treatments described previously. Frequently, stack-mounted assemblies consist of lenses inserted sequentially onto a seat in a lens barrel, with spacer rings to maintain proper airspace, followed by a single retainer ring to secure the entire group in place. In addition, a lens can be sealed against the environment by injecting sealing compound into holes though the cell wall. These basic principles are illustrated in Figure 1 below.

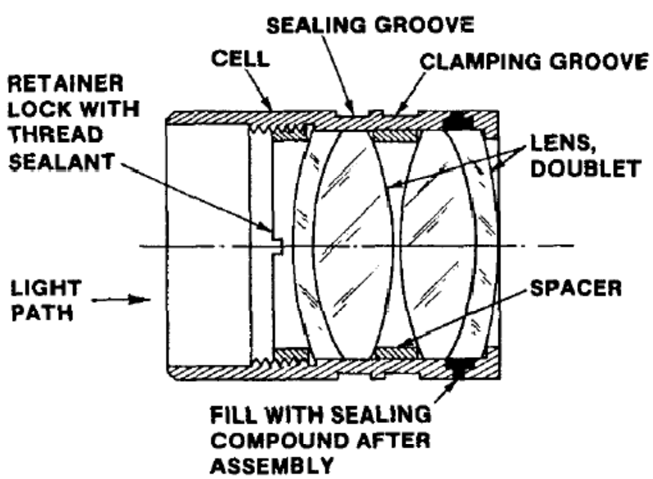


FIGURE 1 EXAMPLE OF MULTI-ELEMENT MOUNTING

LATHE ASSEMBLY TECHNIQUES

With lathe assembly mounting, lens elements are radially positioned to the inner diameter of the mating cell. The outer diameter of each lens is precisely manufactured to a high degree of roundness, and the inner diameter of the mating metal cell is then machined to fit that particular element. In this high-performance lens assembly, the radial loading of the lens due to low temperature contraction is considered by evaluating the 'hoop stress' as described earlier.

CONCLUSION

Techniques for mounting rotationally symmetric individual and groups of lens and mirror elements in the size range of about 0.5 to 10 inches in diameter were considered, progressing from simple, low precision designs to complex designs for high precision applications.

Determination of both axial and radial stress on the glass due to metal contact and thermal contractions are important in understanding failure mechanisms of the glass lenses as well as performance degradations of the device. In most cases, these stresses will fall well below the compressive strength of glass. A basic understanding of these fundamental lens mounting techniques and evaluation thereof is of key importance in the optical and opto-mechanical design process as it helps establish critical lens and housing tolerances which ultimately define the as-built performance of the optical instrument in its intended environment.

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