플렉셔를 이용한 비열화 렌즈 마운트 설계
Flexured Lens Mount for Athermalization

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1. Introduction

Precision lens systems under a large temperature variation require athermal mounting structures. The mount should minimize thermo-elastic stresses and maintain the axial/ lateral alignment of a lens element. Athermal lens mounting methods are using flexures, elastomers, or their combinations [1]. The flexure mounting is a semi-kinematic method constraining all motions without using any adhesive. Kvamme et al. used sophisticated flexures as low stress mounts for space-borne optics [2]. On the other hand, the elastomeric mounting method adjusts the thickness of a bondline filling the gap between a lens and a cell. Theoretical derivations to the athermal bondline thickness have been used as design guidelines. Bayar used a simple equation using CTE (coefficient of thermal expansion) differences [3]. Muench derived an equation using CTEs and a Poisson's ratio [1]. Herbert considered nonlinear material properties, especially of adhesive, to derive an athermal equation [4]. These equations, however, only consider radial stresses. Stresses in axial or lateral directions can be evaluated using finite element analyses (FEA) [5, 6]. Doyle et al. used an FEA to show that discrete bondings are preferred for nearly incompressible adhesives of which Poisson's ratio approaches 0.5 [7]. According to Miller, the thermo-elastic stress is relatively insensitive to the adhesive thickness as the bondline becomes thicker [8]. But, thick bondline is not desirable for the adhesive strength. Combining elastomers and flexures can secure optics with the maximum adhesive strength as well as minimizing thermo-elastic stresses. For instance, Saggin et al. presented tangential edge flexures with thermal adapters for a space-borne infrared optic [9]. Froud et al. introduced radial flexures in cryogenic mounts for large fused silica lenses [10]. So far, most lens mounting flexures have been made independent of other lens mounts due to manufacturing difficulties. Machined flexures are assembled into a lens barrel making the whole system bulky and heavy. Also the fabrication cost is high due to the frequent use of an electrical-discharge machining. In this paper, we present a new type of radial flexure for athermal lens mounting. Flexures are made monolithically on a lens cell or a barrel itself. Two circular grooves are concentric at the adhesive injection hole. They are implemented easily with a generic mechanical machining. Each flexure can accommodate six degree-of-freedom (dof) motions by controlling dimensional parameters. Stability and flexibility of the flexure are compromised to meet the performance requirements. We used the FEA for optomechanical simulations and verified optical performances of a batch of pilot samples using a commercial optical interferometer. Optical displacements and birefringence induced by thermo-elastic stresses were measured under temperature variations.

2. Design & Configuration

Figure 1 shows the pilot sample configuration of an elastomeric lens mount. An optical flat is used representing a lens element. The optical flat is made of a fused silica (Corning® HPFS code 7980) and its dimensions are 50.8mm in diameter and 8mm in thickness. The front surface is anti-reflection (AR) coated and the back surface is mirror-coated. They are slightly wedged by 30 arcmin to reduce unwanted interference effects caused by multiple reflections. Thermo-elastic distortions and birefringence inside the optical flat can be observed at once with a single interferometric measurement.

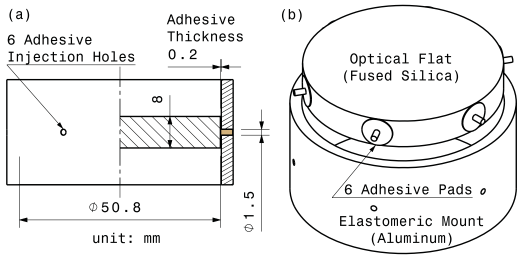

FIG. 1: Elastomeric lens mount. (a) Section view. (b) Disassembled view

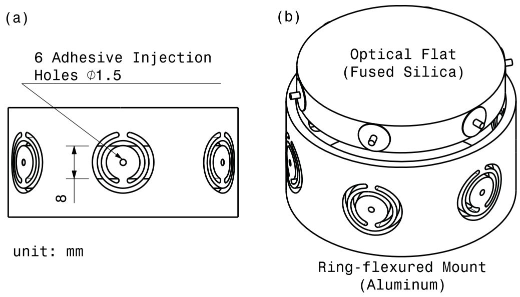

FIG. 2: Ring-flexured lens mount. (a) Front view. (b) Disassembled view

Figure 2 shows the ring-flexured lens mount configuration. Six ring-flexures are made monolithically on a lens cell. Two circular grooves are concentric at the adhesive injection holes. The diameter of the central ring is 8mm which is the thickness of the optical flat. The ring and its annular space is 1.5mm in thickness. Each ring-flexure can accommodate six dof motions by adjusting dimensional parameters. The stiffness of the flexure should be sufficiently high to keep the optical element from sagging, but also low enough to avoid the deformation, birefringence, and even breakage of the optic. The ring flexures are sized to survive handling, transportation, and launch loads. The bondline thickness is 0.2 mm, which is the vendor's recommendation for the maximum shear strength. The next section discusses the athermal performances of the elastomeric mount and the ring-flexured mount from FEA results.

3. Simulation & Experimental Results

We made four different pilot samples. They are (a) an elastomeric mount with EC2216 adhesive, (b) an elastomeric mount with EA9394, (c) a ring-flexured mount with EC2216 adhesive, and (d) a ring-flexured mount with EA9394. Isothermal load with unit temperature is applied as a load. Surface displacements of the front and the back surfaces are recorded and processed with Zernike polynomial fitting for qualitative analysis

4. Conclusions

We presented a new athermal lens mounting scheme made of cascaded ring flexures. We evaluated thermo-elastic deformations by interferometric measurements and verified the results with finite element analyses. Also we compared the athermal performances from a simple elastomeric mount and a ring-flexured mount. This lens mounting scheme would be a promising candidate for environmentally challenged optical systems like space and military applications..

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