Low-cost adjustable mirror mount

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Abstract. Complex optical systems commonly employ adjustable optical mounts for alignment purposes. The design of a low-cost adjustable mirror mount that provides simple tilt and height adjustments is described. This mirror mount employs conventional machining and standard off-the-shelf hardware and is, therefore, very suitable for low-cost rapid prototyping applications. A diamond-machined metal mirror is directly assembled to the mount with three screws and two precision dowel pins. The adjustments are provided by three spring-loaded screws between the mount and a fixed base plate. Two set screws are used for locking purposes after the adjustments have been made.

Subject terms: mirror mounts; low-cost prototypes; adjustment mechanisms; athermalization; metal mirrors; diamond machining.

Optical Engineering 33(6), 2062–2064 (June 1994).

1 Introduction

Low-cost rapid prototyping plays a key role in concept validation and in determining the performance of a complex optical system cost effectively. Optical engineers, to a great extent, rely on building quick and inexpensive breadboards of optical systems by using commercially available optical mounts, stages, and optical tables. In some cases, the commercial adjustable mirror mounts may not be suitable because of their size or cost. This paper describes the design of an adjustable mirror mount that can be machined in a conventional machine shop. Therefore, this adjustable mirror mount may be a viable alternative to commercial mirror mounts in some applications because of its compact size.

Typically, a custom mirror mount consists of a number of parts such as a mounting plate, clamps, springs and screws.[1] Other designs involve bonding a mirror directly in a bezel with a room temperature vulcanizing elastomer, or using flexures to hold a mirror in a frame.[2] Most of these mounting schemes have their own advantages and disadvantages, but these tend to be quite expensive and bulky for some applications. Moreover, these designs do not provide any adjustments for alignment purposes. Therefore, in most cases, these types of mirror mounts may not be very suitable for low-cost prototyping.

2 Material and Fabrication Considerations

Single-point diamond machining is an economical and commonly used method for manufacturing flat, spherical and aspheric metal mirrors, and the materials of choice for such mirrors are some type of aluminum alloys. These alloys include 6061-T4 or T6 aluminum and aluminum/silicon metal matrix composites or alloys, the 6061-T6 aluminum alloy being the most economical. To minimize the effects of differential thermal expansion between a mirror and its mount, it is a good idea to make some provision for athermalization in the design. Athermalization may not be necessary in some applications, but it is always preferable to fabricate the mirror and its mount from the same material to minimize the thermal problems. Aluminum alloys have a fairly high coefficient of thermal expansion (CTE), but have excellent machining properties and are very suitable for diamond machining. Therefore, for low-cost rapid prototyping, it may be most economical to make the mirrors and their mounts from aluminum alloys in certain applications.

3 Mirror Design and Fabrication

The design of a low-cost adjustable mirror mount is presented in Figs. 1 through 5. The mirror and its mount are both fabricated from the same aluminum alloy. The mirror is secured to its mount through three screws and two pins. The mirror back has a precision hole and a slot for the dowel pins pressed into the mount, and three threaded holes for the screws, as shown in Fig. 1. The diameter of the dowel pin hole and the width of the slot must be controlled very precisely. Normally, these features must be oversized by 0.0001 to 0.0002 in. larger than the diameter of the pins to provide a snug fit. These same features are also used for holding the mirror during diamond machining. The back surface of the mirror must be lapped flat for strain-free mounting to the diamond machining chuck. If the mirror is large, distinct pads on the back surface of the mirror, similar to those shown on the mount, may be required to minimize the surface area over which good flatness must be maintained.

4 Design of Adjustable Mirror Mount

The mirror mount is fabricated by conventional machining methods and does not require diamond machining. The mirror mounting surface has two dowel pins pressed into it and three clearance holes for the screws, as shown in Fig. 2. The five pads on the mount must be machined flat and coplanar to prevent distortion of the mirror when the screws are tightened. The required machining accuracy of the pads is determined by the size and thickness of the mirror, and the allowable mirror surface distortion. In general, the pads on the mount must be flat and coplanar to better than 0.0002 in. These pads

Paper 24113 received Sep. 21, 1993; revised manuscript received Oct. 13, 1993; accepted for publication Oct. 14, 1993.

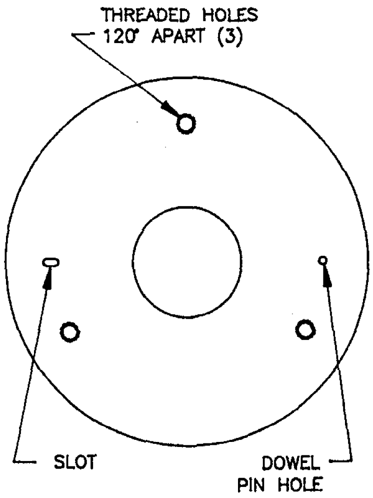

Fig. 1 Rear view of mirror showing mounting features.

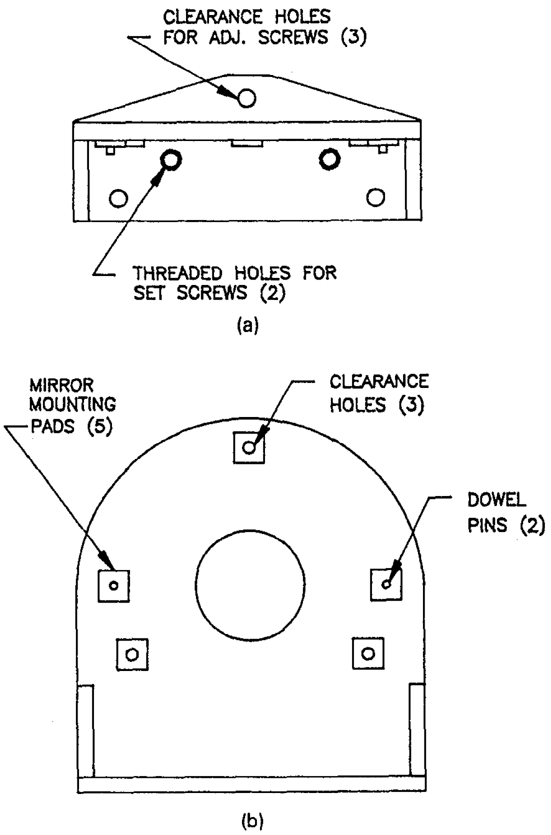

Fig. 2 Mirror mount showing pads, dowel pins, and screw clearance holes for attaching the mirror: (a) top view and (b) front view.

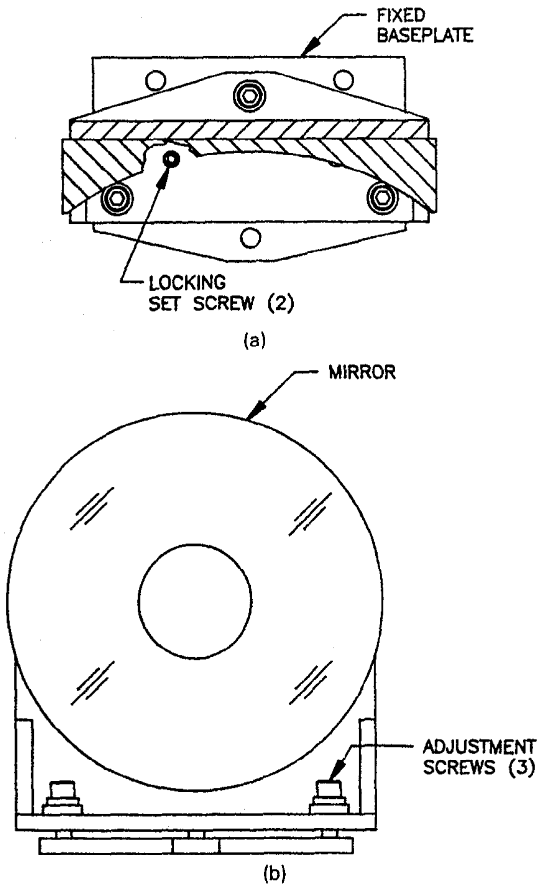

Fig. 3 Mirror mount assembly showing the adjustment scheme: (a) top view, mirror and mount are shown in section to depict the adjustment and set screws, and (b) front view.

can be milled, lapped, or diamond machined depending on the design of the mount and their accessibility for machining.

The top, front, and side view of the mirror assembly are depicted in Figs. 3 and 4. The mirror and its mount are shown sectioned in Fig. 3(a) to clearly depict the three adjustment screws and one of the two set screws. Figure 4 shows one of the two triangular webs or gussets, provided on each side of the mirror mount, to improve the structural stiffness of the mount. For small size mirrors (< 3 in. in diameter), these webs may not be required. For larger mirrors, these webs can be machined as part of the mount. Alternatively, these webs can also be machined separately, and then pinned and bolted to the vertical and horizontal plates. Spring washers are used under the screws holding the mirror, so these screws need to be tightened very lightly to prevent distortion of the mirror.

The tilt and height adjustments are provided by three spring-loaded ordinary socket head cap screws between the mirror mount and a fixed baseplate as shown in the assembly (Fig. 3). The details of adjustment at each of the three screws is depicted in Fig. 5. Each adjustment screw goes through a clearance hole in the mirror mount and threads into the baseplate. A compression spring always keeps the mirror mount preloaded against the head of the screw. The adjustment is performed by threading each screw in or out. The height adjustment is achieved by moving all three screws equally, whereas tilt adjustments are made by moving one screw in or out at a time. A set of spherical or swivel washers is provided under each screw head to compensate for the relative tilt between the mirror mount and the fixed baseplate. A suitable lubricant can be used to reduce stiction between the mating spherical surfaces of the washers. Once alignment has

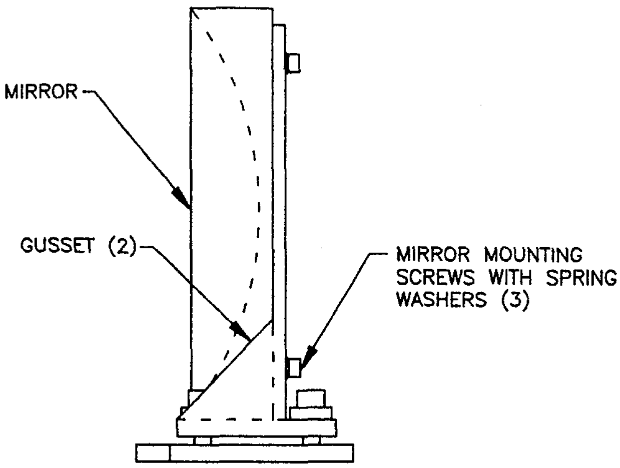

Fig. 4 Side view of the assembly showing a reinforcing gusset and the screws holding the mirror to the mount.

been achieved, the two set screws are locked down against the fixed baseplate to maintain the adjusted mirror position. Fairly precise adjustments can be achieved in this design even with relatively coarse threaded screws such as 0.25-28 or 10-32 screws. Depending on the length of thread engagement, a range of ±0.125 in., with a resolution of 2 to 3 μm can be provided for the height adjustment. For a center-to-center distance of 2.00 in. between the screws, this translates to a range of ±3 to 4 deg and a resolution of 10 to 15 arcsec for the tilt adjustments. All hardware used in this design are standard off-the-shelf items, which are very inexpensive and easily available. If a better resolution for the adjustments is required, then commercially available finer pitch screws (80 threads/in.) can be incorporated in this design.

5 Conclusions

The adjustable mirror mount described here is simple in design but its versatility, stability, and low fabrication cost make it quite attractive for prototype applications. The design concept for tilt and height adjustments described in this paper is suitable for mirrors ranging in size from 1 to 10 in. (25 to 250 mm) aperture diameter. For larger and heavier mirrors, the friction in the screws and stiction in the spherical washers may not produce smooth and fine adjustments. Moreover, the shape of the mirror mount should be optimized according to the size of the mirror and the structural requirements.

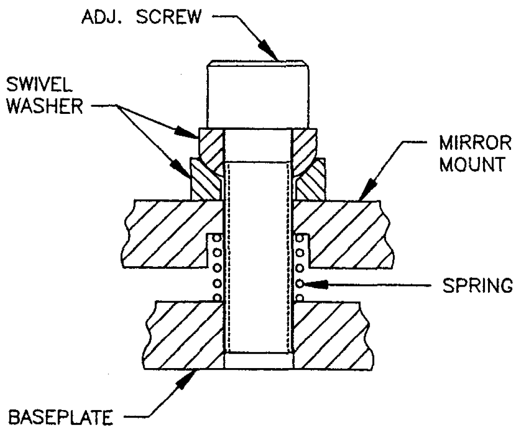

Fig. 5 Sectional view showing the details of adjustment mechanism.

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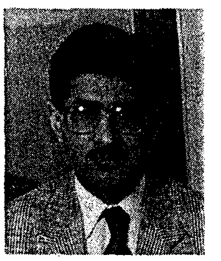

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