# Antivibration mount for mirror-lens telephotography

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**Abstract.** When compact mirror telephoto lenses are used with light tripods, a major source of image blur is shutter-induced camera vibration. The impulsive torque about the center of mass of the camera-lens system, produced by the sudden shutter motion, generates an angular velocity that sweeps the optical axis across the object during the exposure. The antivibration mount, by means of an adjustable counterweight, relocates the system's center of mass to coincide with the shutter plane, thus reducing the impulsive torque to zero. Because the optical axis now maintains a fixed direction during the exposure, a sharp image is registered on the film. Tests with an 800 mm lens demonstrate that this simple mount permits very light tripods to be used with very long focal lengths.

*Subject terms: telephotography; camera stabilization; motion blur reduction.*

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## 1. INTRODUCTION

Photographs blurred due to camera motion are common when catadioptric (mirror) telephoto lenses are used in conjunction with lightweight tripods. The motion can arise from several sources, such as wind or vibration of the surface upon which the tripod rests. The most significant source, however, is camera vibration generated by the motion of the focal plane shutter and/or viewfinder mirror during the exposure. The very compactness that is considered an advantage of mirror lenses is a disadvantage here, for the relatively small moment of inertia of these lenses makes vibration blur especially hard to control. In this paper, the camera-induced vibration is examined, and a method for its elimination is described.

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## 2. ANALYSIS

Following the precepts of classical mechanics, the camera/lens combination is considered to be a rigid body. The lightweight supporting tripod is modeled as a massless elastic member. When the shutter is released, the sudden motion of the focal-plane shutter curtain acts as an impulsive force applied to the rigid body.

The general motion of rigid bodies is well described in standard texts. It can be decomposed into a translational motion of the center of mass (c.m.) and a rotational motion about the c.m. It is the rotational motion of the lens axis about an axis perpendicular thereto that concerns us: a small rotation produces a large image shift, whereas a small translation can generally be ignored. In concrete terms, consider an 800 mm lens that, during the exposure, suffers a lens-axis rotation of 1 arcmin and a translation of the c.m. of 1 mm. The rotation shifts the image by 0.23 mm, which destroys sharpness completely, while the translation shifts the image by 0.004 mm if the object distance is 200 m (and proportionally less if the object is more distant).

The law governing angular motion relative to the c.m. states that the angular impulse equals the change in angular momentum. The magnitude of the angular impulse is the product of the impulsive force with its moment arm about the c.m. Because the shutter motion is perpendicular to the

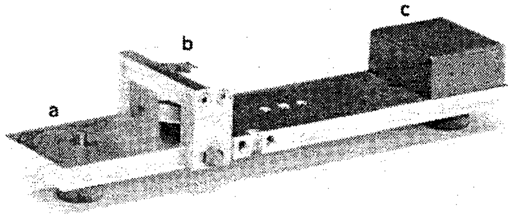



**Fig. 1. The antivibration mount. (a) Attachment of lens; (b) bridge for attachment of camera body; (c) movable counterweight.**

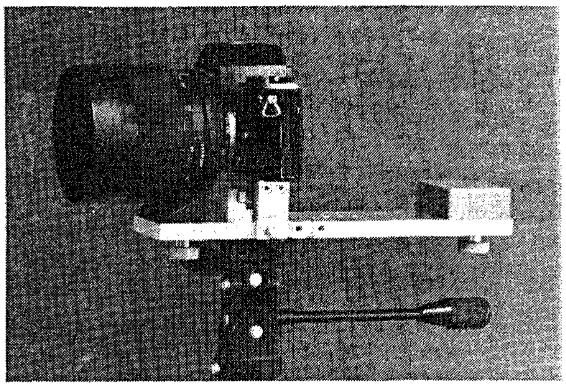


**Fig. 2. Assembly of camera, lens, mount, and tripod.**

optical axis, the equivalent impulsive force is likewise normal to this axis (lateral or vertical, depending on the direction of shutter travel). For a long focal length lens, the moment arm is not zero; the c.m. is usually somewhere within the lens, approximately above its own tripod mount, and any additional mass provided by the tripod head does not move the c.m. Therefore, the angular momentum (which was initially zero) will not be zero after the shutter release.

In other words, the exposure generates an angular velocity whose magnitude is inversely proportional to the moment of inertia of the camera/lens system with respect to rotation of the optical axis. The elastic tripod converts the initial angular velocity into a damped angular vibration. As previously stated, it is angular motion that is most harmful to image sharpness. The moment of inertia of mirror lenses is an order of magnitude less than that of long refractors, making the former particularly susceptible to such vibration.

## 3. DESIGN OF THE ANTIVIBRATION MOUNT

Once this principle of angular impulse and momentum is appreciated, a system can be designed to eliminate the lens axis rotation. The camera and lens must be firmly attached to a mount equipped with an adjustable counterweight. This whole system must behave like a single rigid body. If the counterweight is so positioned that the shutter plane coincides with the c.m. of the system, then the shutter impulse will have no moment about the c.m.; i.e., the angular impulse will be zero, and no rotational motion will be initiated. The light elastic tripod upon which the system rests thus has no rotational vibration to contend with, and the image remains firmly stabilized on the film.

The viewfinder mirror should be locked up before the exposure because the mirror and shutter impulses act at slightly separated points. If lock-up is not possible, however, a good compromise balance can still be achieved.

Figure 1 shows a simple realization of this design. The mount consists of an aluminum bar, to which the lens is fastened, and a bridge, onto which the camera body is tightened. Figure 2 shows the assembled system on a tripod. The height of the bridge is adjustable to accommodate the dimensions of cameras from different manufacturers. The movable counterweight is positioned so that the system balances, with the bar horizontal, when placed upon a knife edge directly under the shutter plane. The shutter impulse

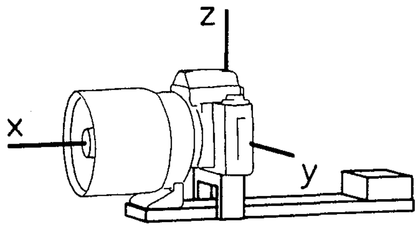



**Fig. 3. Coordinate system: optical axis = x axis; center of mass is in yz plane.**

now falls in the same vertical plane as the c.m., and it has no moment about the y and z axes (Fig. 3). Hence, no rotation of the lens axis is initiated.

A small residual impulsive moment may remain, in spite of the mount, for cameras in which the shutter curtain travel is horizontal. This moment exists because the c.m. is somewhat below, rather than coincident with, the shutter curtain. It acts about the x axis and tends to translate the lens axis, without changing its direction. The effect on the image is thus of the translational kind, an order of magnitude smaller than that of rotating the lens axis. In practice it is negligible.

When the mount is placed upon the tripod, the attachment point should be near the c.m. of the system, in order not to upset the carefully adjusted balance. A beneficial side effect arises because the system remains in balance on the tripod and causes minimum stress on the tripod's pan-head controls.

In use, a few simple precautions will ensure that the benefits provided by the mount are not lost. Nothing should touch the camera or tripod just before and during the exposure. A cable release or self-timer should be used, and the photographer should stand still, for many types of soil are elastic enough to transmit vibration. If the wind is gusty, protection is required.

## 4. EXPERIMENTAL RESULTS

The mount was constructed from a 30 cm length of aluminum bar stock. Its mass, including the iron counterweight, was 1.3 kg. It was tested with a catadioptric telephoto lens of 800 mm focal length on a good tripod weighing about 2 kg. Masses of lens and camera body were respectively 1.4 kg and 0.7 kg. Figures 4 and 5 compare the

(a)

(b)

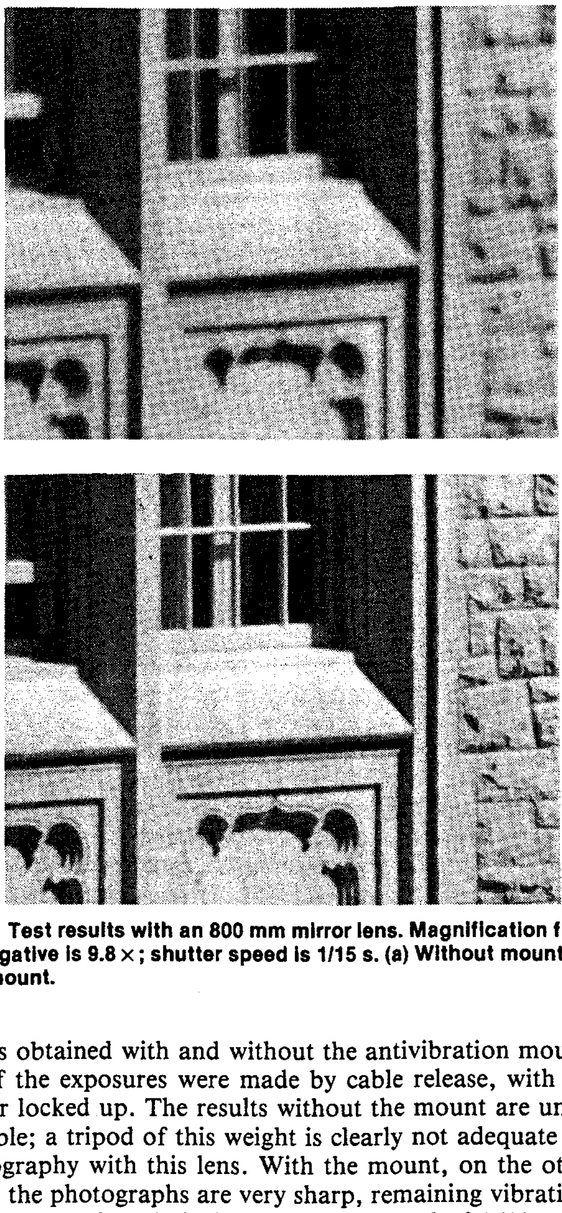


**Fig. 4. Test results with an 800 mm mirror lens. Magnification from the negative is 9.8 ×; shutter speed is 1/15 s. (a) Without mount; (b) with mount.**

(a)

(b)

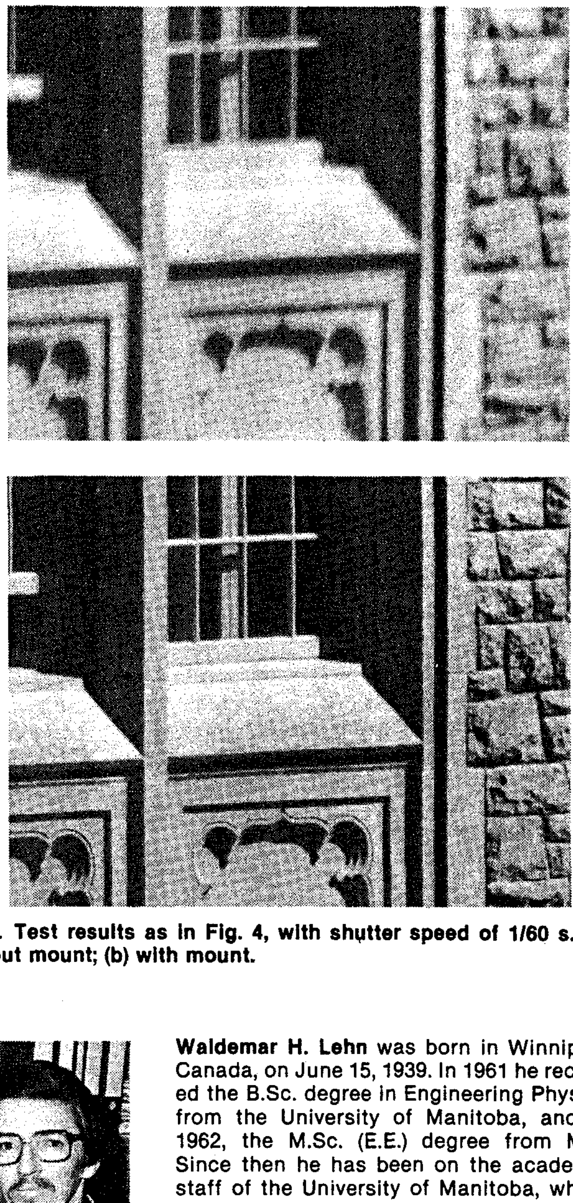
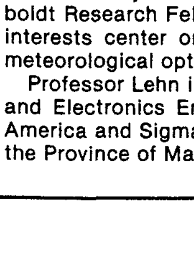


**Fig. 5. Test results as in Fig. 4, with shutter speed of 1/60 s. (a) Without mount; (b) with mount.**

results obtained with and without the antivibration mount. All of the exposures were made by cable release, with the mirror locked up. The results without the mount are unacceptable; a tripod of this weight is clearly not adequate for photography with this lens. With the mount, on the other hand, the photographs are very sharp, remaining vibration-free down to the relatively low shutter speed of 1/15 s.

This antivibration mount is an effective method for eliminating blurred telephotographs. Because its design is based on physical laws, it is lighter, more compact, and far more convenient than the frequently suggested procedure of placing sandbags under and over the lens, and it permits the use of lightweight portable tripods that need be only strong enough to support the dead weight of camera, lens, and mount. ⊙



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