Cylinders in Vs

An optomechanical methodology

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Tutorial for Opti521

November, 2006

Introduction

For rotationally symmetric optical components, a convenient optomechanical approach which is usually underutilized is to mount them in cylinders and then locate the cylinders in a V-shaped trough. The benefits of this methodology include:

- The mechanical constraints correspond to the optical requirements of high precision in lateral position.
- The arrangement is kinematic or semi-kinematic and is of simplest which provides enough constraints and no overconstraints.
- The most important benefit is that it provides repeatable quick, accurate swapping between setups, with critical adjustment made once. This is especially useful for laboratory equipments and products require modular replacement and interchange.
- Centering of optical elements can be done in the V itself.

The methodology

The critical adjustments for rotationally symmetric optical components are displacements orthogonal to the axis and tilts orthogonal to the axis, figure 1.

In the cylinder in V system, optical components are mounted in cylinders with identical diameters and the optical axis is collinear with the cylinder axis. The cylinders are then located in the V-shaped trough, the critical degrees of freedom are constrained, figure 2.

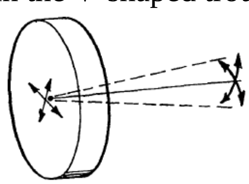

Fig.1 Critical DOF of rotationally symmetric optical elements.

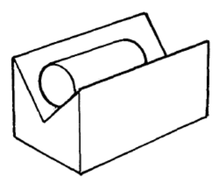

Fig.2 Basic cylinders in V, 4 DOFs are constrained

Simple cylinder and general cylinder

A simple cylinder is the surface formed by all circles of a given radius, in planes perpendicular to a given line (the axis), whose centers are on that line. The term general cylinder refers to any shape that behaves like a simple cylinder with respect to a V, figure 3.

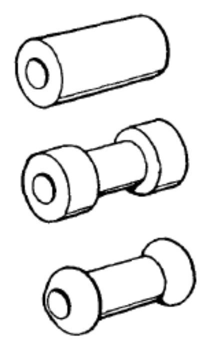

Fig.3 Simple and general cylinders

Planar V and general V

The planar V is a trough defined by two non-parallel planes. The general V, refers to any shape that behaves with respect to a simple cylinder as a planer does, it may be defined as "a shape that contacts a simple cylinder tangentially on two parallel lines", figure 4.

The cylinder and V form a pair. What is a V to a cylinder of one diameter may not be a V to a cylinder of other diameters.

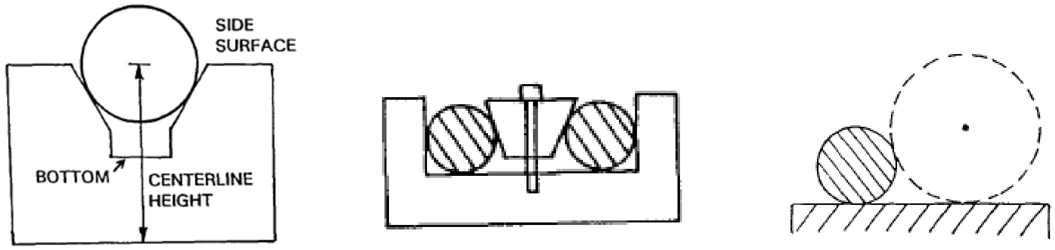

Fig.4 Planar V (left) and general Vs. The middle one comprises of a pair of parallel cylinders, while the right one is formed by a cylinder and a flat.

The V

Some terminologies

Figure 5 shows the fundamental geometry of an ideal general V. The V contacts a cylinder tangentially on two parallel contact lines, around which are two regions, the contact strips. The defining planes are the planes tangent to the cylinder containing the contact lines. The vertex is the intersection of the two defining planes. The V angle is the angle to both defining planes. The bisector is the plane that makes equal angles with the two defining planes. The center line is the axis of an ideal cylinder of a specific diameter in the V.

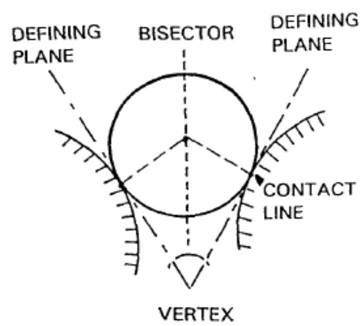

Fig.5 Geometry definition of V

The V angle

90 degree is the easiest to make and most convenient in the laboratory. They can hold both cylinders and square objects like square filters. The 60 degree planar V produces symmetric forces on a cylinder clamped on the bisector, this is advantageous for hardware used outside of laboratory. The smaller the angle, the greater the variation of vertex-to-centerline distances due to diameter variations.

Structure of Vs

Monolithic --- Constructed from a single, continuous piece of material. They are stiffer and more stable.

Fabricated --- Made of two or more parts that provide the contact surfaces, and possibly additional structural components. Since the two planes are made separately, the fabrication is simplified and higher precision for straightness and flatness can be achieved. Figure 6 shows some examples of fabricated planar Vs.

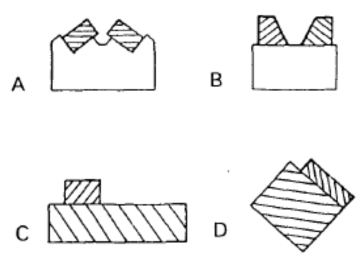

Fig. 6 Examples of fabricated Vs

Measuring the straightness of Vs

The most important geometry requirement for a V is its straightness. There are a lot of measuring ways available. One easy way illustrated in figure 7 is to measure the straightness with reference to a surface plate by an indicator. Other methods include by using autocollimator, or a level.

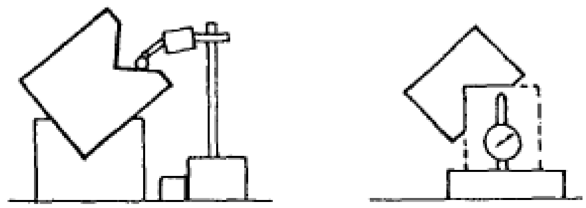

Fig. 7 Measuring the V straightness

The cylinder

The most useful cylinder forms for mounting optical components were shown in figure 3. The simple cylinder contacts the v over its full length. The bar bell shaped cylinder can be less expensive since the critical size needs to be held only at the two ends. The bone shaped cylinder with rounded ends engages a V kinematically with four point contacts for best repeatability. With the aid of CNC machining, the bone shape can be routinely machined.

The length of the cylinder or separation between the contact points should be great enough for stability. A rule of thumb is that the diameter of the cylinder should be no greater than the length. For the most repeatable interchangeability between cylinders, their length should be the same.

Defects of a cylinder

The defects of a cylinder include varying diameter with good roundness, good roundness and diameter with a non-straight centerline, non-roundness and deform. These are illustrated in figure 8.

Fig. 8 Examples of non-cylindricity

Roundness measurement can be done by rotating the cylinder placed in a V and measuring the runout with an indicator.

Diameter of a cylinder

The cylinders used in a V should have identical diameters. For a group of cylinders used only with each other, their absolute diameter doesn't matter, but they must be identical.

It's worthy to mention that when designing cylinders, it's useful to set one or more standard diameters that match available stock materials, gages and tooling.

The cylinder and V together

Repeatability and interchangeability

Since there is line or point contact, the cylinder in V system provides repeatable and interchangeable location. This is so even with imperfect components. Identical ideal cylinders can be removed from and repeatably replaced into the same or other ideal Vs of any angle. In addition, an ideal cylinder can be reversed end to end in an ideal V.

Centering optical components

This can be done by rotating the cylinder in a V and check the runout, which can be measured optically or mechanically. Figure 9 shows a basic method of centering a positive lens optically. The image of the pinhole formed by the lens being centered stays static when the cylinder holding the lens is rotated as the lens is centered.

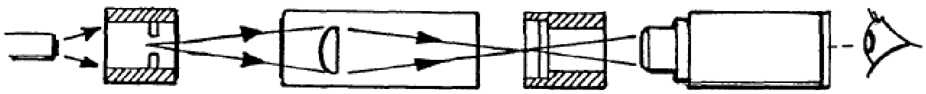

Fig. 9 Centering a positive lens in a cylinder

The pinhole and reticle are masters centered previously. Although centering by rotation with optical runout detection can be done if the pinhole and reticle are not on axis, it is advantageous if they are. An axial pinhole provides rotationally symmetric image, which makes the observation more sensitive. A centered reticle simplifies the observation of runout.

Video cameras can be used to reduce the fatigue of visual observation when centering. This also provides the advantage that the view can be shared by several people.

Axially spacing lenses in cylinders

After the lens is mounted in its cylinder, the distance from its vertices to the end of the cylinder can be measured by a depth micrometer. The separation between cylinders can then be determined by the information of cylinder lengths.

Mounting optical element assemblies

Standard mounting techniques are used, like thread connecting a lens cell to the cylinder, using sets of three or four screws. When separate cylinders are desirable for nearby lenses, a “snout” can be used. Figure 10 shows typical configurations.

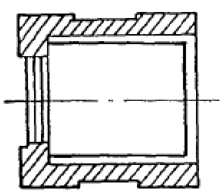

Fig. 10a. Mounting threaded Lens assemblies

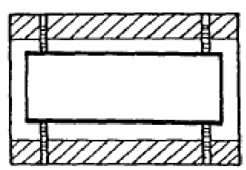

Fig. 10b Mounting by using sets of 3 or 4 screws

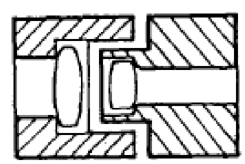

Fig. 10c Nearby lenses on separate cylinders

Clamping cylinders onto Vs

Forces are applied on the cylinder to keep its location in the V. The positions of cylinders are determined by the V, not the clamp, so the clamp should not be stiff. Spring and flexure are good choices. The clamping force should be symmetrically applied along the bisector of the V to avoid moving the cylinder. The cylinder wall must be thick enough to avoid significant deformation under clamping loads. Figure 11 is a clamping example.

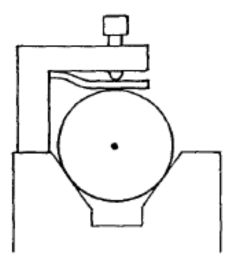

Fig. 11 Flexure clamping

Conclusion

The cylinder in V system is a convenient optomechanical approach which provides a number of beneficial attributes. The location of the cylinder is kinematic or semi-kinematic and position is repeatable even with imperfect objects. The system provides repeatable quick, accurate swapping between setups and cylinders can be reversed end to end without disturbing the alignment. Cylinder roundness and optical element centering can be done in the V itself. Fabrication of the cylinder and V is relatively easy, only a small portion of parts is critical. Standard machining gives enough accuracy for most of the optical applications.

References

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