Cylinder Manufacturing Considerations

Brandon Light, James VanKouwenberg, Alan Gould
Optimax Systems, 6367 Dean Parkway, Ontario, NY USA

This paper will look at how cylinder manufacturing methods can influence specification, offering recommendations on what to consider when designing.

CYLINDER MANUFACTURING METHODS

A cylindrical lens contains an optical surface that has a radius in one direction and is flat in the orthogonal direction. The manufacturing methods used in making cylinders account for this axis, conserving its position as part of the process. There are two main options in cylinder manufacture, with R-number (radius of curvature divided by diameter/width) and order quantity determining which of the two is chosen.

There is an important geometry convention to remember with cylinders. Length is always the dimension along the plano axis and width is the dimension across the power axis, even if length is smaller than width.

Arbor

This process involves rotation of a rod of optical material on a lathe or similar device and grinding and polishing the diameter to an optical tolerance. The rod could be one single piece of material or called an arbor, a precision tool with multiple parts blocked to it. The rod is then made into smaller segments and a second surface, typically a plano surface, is added to complete the lens.

This process makes convex cylinders only, with radius restricted to less than 150mm, and the number of parts run will vary with size. The process works best with larger quantities, where tooling cost can be amortized. The shape of the part determines what is considered larger quantities. For example, a 50mm convex radius, 200mm long and 15mm wide cylinder could be processed in a block of around 15 pieces.

X-Y

While the arbor process involves making a cylinder and then segmenting it, the X-Y process is the opposite. A cylindrical surface is added to a slightly oversized segment via a figure-eight motion, and the motion is where the process gets its name. These parts are shaped and pre-polished using multi-axis CNC equipment. The final polishing is done on proprietary polishing equipment creating Optimax's highest quality cylindrical surfaces and alignment.

Concave surfaces and longer radius (>150mm) convex surfaces can be made using this process. This process does not lend itself well to volume production unless parts are relatively small and can be fixtured as multiples, polishing several parts simultaneously.

CYLINDER MANUFACTURING CHALLENGES

Part mechanical geometry (diameter or length/width, thickness, radius) not only drives process selection, it influences process capability as well. Aspect ratio (diameter divided by thickness) comes into play in X-Y cylinder manufacture, where the part may flex or twist while being polished. Careful consideration of fixturing can manage effects, but can only go so far. Concave cylinders with radii below 5mm also present challenges due to space limitations. For arbor polishing, the length of the rod relative to its diameter is an issue. Exceeding 4 to 1 opens the door to flexing of the rod under polish. Convex radii shorter than 4mm become extremely difficult to process due to poor mechanical strength and difficulty with fixturing.

For cylinders, the main metrology tool for optical specification is a computer-generated hologram (CGH). Coverage is limited to what the CGH can see, and full aperture interferometry of cylinder surfaces may not be available due to limited range of available CGH cylindrical nulls. Interferometric metrology options for cylinders become limited at radii over 350mm. Accordingly, long radius cylinders are the most difficult to fabricate and test.

Managing orientation of the cylindrical axis relative to the mechanical features is the next critical manufacturing challenge. Errors can involve wedge (axis not orthogonal to thickness) or twist (axis not parallel to length/width). Recurring measurement can detect errors, and creating datums early in the process and conserving them throughout is the key tactic for preventing centration errors. Figure 1 below shows the effect centration errors have on corner thickness.

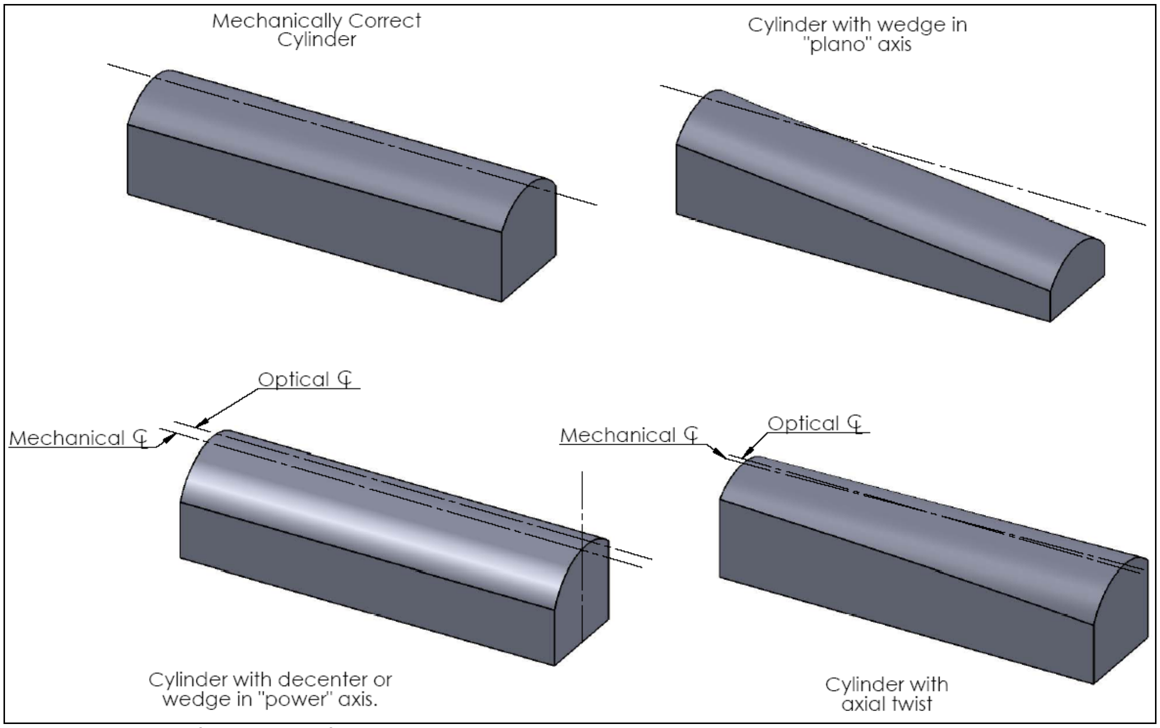

Figure 1 - Representations of centration errors for cylindrical lenses

RECOMMENDATIONS

To minimize cost, incorporate one plano surface on each cylindrical lens. Plano surfaces are comparatively much less expensive to fabricate and allow for greater flexibility in the manufacturing and testing methods of the cylindrical surface. Bicylinders, in contrast, take longer to fabricate, have more risk of centration errors and require more expensive tooling than lenses with only one cylindrical surface.

Plano-convex cylinders designed with radii between 25 and 100mm may be the least expensive and have the best figure and finish quality. Plano-concave cylinders in that same range will have similar benefits, but are more expensive.

For a requirement of 100s or 1000s of lenses per year, choose a convex cylinder with both length along the cylindrical axis and radius in the 50-100mm range. This lens would polish well using the arbor method, the most cost-effective method for making dozens of parts with extremely closely matched radii.

For a given mechanical geometry, long radius cylinders typically cost more than short radius cylinders.

Measurement must not be overlooked. Factor in what CGHs the manufacturer has available, and include that as a consideration in selecting radius. If full aperture interferometry is required, give careful consideration to the limits this places on length, width and radius of the surface.