getting practical
on lens-edging tolerance

To control component costs and manufacturability, avoid overspecifying tolerances.

By Mike Mandina, Optimax Systems Inc.

In today's market, engineers from a variety of disciplines are now designing lens systems. Manufacturers often are asked to produce optics to tolerances that are not always optimal. The centering attribute is one of the simpler yet most misunderstood tolerances that can significantly impact cost and performance if not specified effectively.

Mechanical wedge, total indicator run-out, total included angle (TIA), and edge thickness difference (ETD) are common callouts that relate to the amount of acceptable beam-deviation error for lenses. The goal is to identify the tolerance range for the optical axis (axis connecting the radii center points) relative to the mechanical axis (determined by the mechanical mounting surfaces). For simplicity, I will restrict my thoughts to ETD, since this is a very common centering test callout.

So let's talk practical manufacturing limits. What I mean by practical is the level of quality a designer can routinely expect with standard manufacturing processing equipment. Most lens-centering machines in use today are bell-clamp machines. Their aligning principle assumes two coaxial spindles that have perfectly trued cups on the ends. At least one of the spindles can slide along the common axis and squeeze the optic. Lenses with significant power will self-align.

The sign and slope of the lens/cup contact ring have a lot to do with the self-centering process. For example, if you take two coffee cups and capture a baseball between them, you will note how easily the ball slides into a secure position. Try the same experiment with a soccer ball and with a basketball, though, and you'll find that the self-alignment properties are less favorable the larger the ball diameter. It's the same with lenses; in addition, the self-centering problem is even more pronounced for meniscus shapes and other optics with long focal lengths.

"So what?" you might ask. Well, you can imagine that a baseball-shaped lens, clamped between coaxially aligned coffee-cup-sized centering bells, will slide right into perfect position. A new edging machine with an experienced operator can probably edge these lenses to better than 5-µm ETD with ease. As the machine ages, bearing surfaces wear, castings bend and twist, and spindle alignment is compromised. Now the 5-µm upper limit increases to 7 or 8 µm. If your supplier is using even older edging machines, the upper limit may be as large as 14 µm.

It is important to note, and it is not necessarily obvious, that the ETD achieved is almost totally independent of part diameter. That is, when scaling a lens, a constant ETD tolerance such as 14 µm is as difficult to achieve for a 25-mm-diameter lens as for a 100-mm lens. This ETD figure translates to approximate wedge TIA of 1.80 min and 0.45 min, respectively. To put it another way, achieving 0.5 min TIA on a 100-mm-diameter lens is much easier than achieving 0.5 min on a 25-mm lens. Keep this in mind when tolerancing your design.

For lenses less than 75 mm in diameter, diameters can be held to within 25 µm routinely. For larger diameters, the machines are still very accurate; gauging, however, is more difficult. Gauging large diameters with handheld micrometers can be tricky, so an extra 5 or 10 µm in tolerance can improve yields. In most cases you can be assured that the lens will be much rounder than its mating metal barrel—but that's another article.

My hope for what you take away from this article is pretty modest. First, when specifying components, see if your tolerance analysis can accept most lenses with 14-µm ETD, independent of diameter. Be aware that tolerances tighter than 14-µm ETD for self-aligning lenses will probably increase cost; specifying below 5 µm is very expensive. On the other hand, loosening tolerances beyond 14 µm will not lower cost very much unless the lens shape is unfavorable (low power). If the lens shape is concentric, or has weak cupping angles, it will be more costly to center since the self-aligning advantage of bell-clamping is reduced. In this case, increasing ETD to 20 µm may help get costs back in check.

Remember, these are not the state-of-the-art limits; they are merely practical guidelines for precision lenses. **oe**

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