Indirect Measurement—Exchanging Certainty for Dividends

by **Ray Harkins**

The indirect route is often the best way to go.

Direct measurement applies a standard directly to a characteristic to measure it. Indirect measurement involves sizing up some other characteristic that happens to be statistically dependent on the characteristic of interest. Measuring the other characteristics provides an estimate on the first characteristic—indirectly.

Indirect methods often provide sufficient measurement certainty for the application and cost much less than direct measurement options.

For example, to calculate the area of a plot of land, you could use a steel tape to directly measure its length and width. Or indirectly, you could obtain a rough approximation by simply counting your paces across the parcel to measure the plot's dimensions in yards. The number of paces is proportional to the plot's dimensions—the larger the plot, the more paces required to cross it.

In this example, you're essentially exchanging measurement certainty for a quicker, less expensive estimate. If your reason for knowing the land's area is to purchase the proper amount of fertilizer to spread over it, the added certainty gained by measuring it directly is unnecessary. This same exchange is possible in many of the measurement problems engineers face.

PEX Example

A team of engineers at Mercury Plastics in Middlefield, OH, recently developed a method for indirectly measuring the percentage of crosslinked polyethylene (PEX) in the plastic tubing it manufactures for the plumbing and appliance industries.

PEX tubing is manufactured by first extruding the polyethylene, then crosslinking it by passing it through an electron beam accelerator. The accelerator crosslinks the material by breaking up the long molecular chains in the polyethylene, causing them to form a more stable, crystalline structure. The resulting material has numerous benefits over the uncrosslinked polyethylene.

Regardless of the amount of exposure to the accelerator, a portion of the polyethylene remains uncrosslinked. Various industry standards require some minimum percentage of crosslinked material in the PEX tubing, typically determined using a solvent extraction method.[1]

Following this method, a sample of the crosslinked plastic is weighed and then immersed in a bath of boiling solvent for up to 12 hours. This process dissolves the uncrosslinked polyethylene from the sample, leaving only the crosslinked material. The specimen's crosslinked percentage is calculated by dividing its weight after the process with its weight before the process.

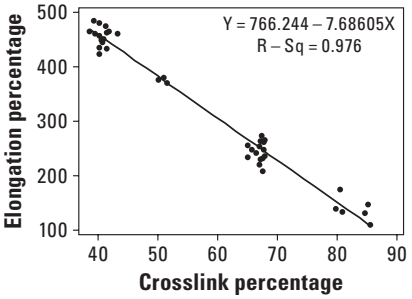
> Sometimes, rough measurement approximations can be enough.

While this method is considered the gold standard for estimating the crosslinked percentage of PEX, it is time consuming and expensive. By examining a range of physical properties at varying degrees of exposure to the accelerator, the Mercury Plastics team found the strongest correlation between the material's crosslinked percentage and its elongation at elevated temperatures.

When plotted against crosslinked percentage, this hot elongation trends downward with a reasonably narrow variation (Figure 1). The regression formula generated from the test data serves as an estimator of a sample's crosslinked percentage given its hot elongation.

Using their results as a baseline, the engineers designed a test apparatus that applies a standard load and temperature to a PEX tubing sample and then measures its elongation. Samples that elongate beyond the distance associated with a minimum crosslinked percentage trip a limit switch notifying the inspector of the failure. Likewise, the apparatus passes samples that remain within the elongation limit for a predetermined test time. The test is completed in less than five minutes—a fraction of the time required for the solvent extraction method.

FIGURE 1 Crosslink vs. Elongation Percentage



Although the loss of measurement certainty is an obvious drawback, it is within acceptable limits for this application. Using indirect measurement can be justified considering the significant safety, cost and throughput benefits. A similar trade-off might be possible for your difficult or time consuming measurement problem.

REFERENCE

1. ASTM, *D2765-01 Standard Test Methods for Determination of Gel Content and Swell Ratio of Crosslinked Ethylene Plastics*, 2001.

BIBLIOGRAPHY

Griffith, Gary K., *The Quality Technician's Handbook*, fourth edition, Prentice Hall, 2000.

RAY HARKINS *is the quality manager of Mercury Plastics Inc. in Middlefield, OH. He earned a bachelor's degree in engineering technology from the University of Akron. Harkins is a senior member of ASQ and a certified calibration technician and quality technician.*