Ten years ago, the first hand-held instrument appeared that was specifically designed to measure coating thickness ultrasonically. Many industries now use this technology in their quality programs. This article describes the working principle and benefits that ultrasonic testing has brought to the coatings industry.

Coating thickness gauges, which use an ultrasonic principle, are becoming increasingly popular. They support or replace destructive measurement techniques for concrete, wood, and plastics applications.

In the past, thickness measurement of coatings over nonmetals has been a challenge. Earlier techniques included:

- Optical cross-sectioning (cutting the coated part and viewing the cut microscopically—ASTM D4138)
- Height measurement (measuring before and after with a micrometer)
- Gravimetric (measuring the mass and area of the coating to calculate thickness)
- Dipping wet film thickness gauges into the wet paint and calculating dry-film thickness using the percent of solids by volume
- Substitution (placing a steel coupon alongside the nonmetal and coating it at the same time).

The above time-consuming tests can be difficult to perform. They are often subject to operator interpretation and other measurement errors. Inspectors find destructive methods impractical because they require patching and may compromise the coating system. With the arrival of ultrasonic methods, however, many applicators and inspectors have switched to nondestructive inspection.

Ultrasonic Testing

Ultrasonic testing is not new to the corrosion industry. Nondestructive testing (NDT) with "corrosion" gauges permits quick thickness measurement of objects without requiring access to both sides. NDT is commonly performed on steel tanks and pressure vessels.

For coating measurement, however, corrosion gauges are not ideal. The instruments can approximate the depth of some thick coatings and linings, but they do not have sufficient sensitivity to measure paint, lacquer, and other corrosion-inhibiting materials.
The first hand-held instrument designed specifically for coating thickness appeared on the market 10 years ago. Although the instrument is now into its third generation, the basic operating principles remain the same. It uses a single-element transducer and advanced numerical techniques to filter and enhance digitized echoes. Today’s hand-held ultrasonic coating thickness gauges are simple to operate, affordable, and reliable (Figure 1).

How Ultrasonic Test Instruments Work

The probe (transducer) sends an ultrasonic vibration into the coating with the assistance of couplant applied to the surface. The vibration travels through the coating until it encounters a material with different mechanical properties—typically the substrate but perhaps a different coating layer. The vibration, partially reflected at this interface, propagates back to the transducer. Meanwhile, a portion of the transmitted vibration continues to travel beyond that interface and experiences further reflections at any material interfaces it encounters (Figure 2).

Because a potentially large number of echoes could occur, the gauge is designed to select the maximum or “loudest” echo from which to calculate a thickness measurement. Instruments that measure individual layers in a multi-layer application also favor the loudest echoes. The user simply enters the number of layers to measure, say three, and the gauge measures the three loudest echoes. The gauge ignores softer echoes from coating imperfections and substrate layers.

Coating and Substrate Interfaces

Coatings over nonmetal substrates serve a variety of functions. Some coatings are designed to restore, protect, waterproof, and beautify structures constructed of wood, masonry, or concrete. Others are specifically formulated to fill pores and surface defects in masonry or concrete and to provide an aesthetically pleasing surface texture. Thick elastomeric coatings provide flexibility and long-lasting resistance to salt spray, chemical attack, and normal weathering. They bridge hairline cracks and continue to expand and contract during their service life. On wood, appearance often plays a major factor. Some wood coatings minimize the rate and range of changes in the wood’s moisture content. Others, like solventless polyurethane (PU), provide a tough, flexible impact-resistant “plastic-like” protection. Penetrating finishes are absorbed into the wood and harden to create a strong protective barrier that will not flake off.

A factor influencing the accuracy and repeatability of ultrasonic measurement is how the coating and substrate interface with one another. Figure 3 shows two examples of coated concrete. These photos, taken at higher resolution than most field destructive tests are capable of, clearly show the boundary between coat-
ing and substrate. The coating may look smooth on top, but thickness may be inconsistent. Masonry substrates often are porous, with varying degrees of surface roughness. Such porosity and roughness may promote adhesion, but they increase the difficulty of attaining repeatable thickness measurements.

Ultrasonic gauges are designed to average small irregularities to produce a meaningful result. On particularly rough surfaces or substrates where individual readings may not seem repeatable, comparing a series of averaged results often provides acceptable repeatability. Documents such as ASTM D6132 and SSPC-PA 2 outline standard methods for this measurement method and provide useful strategies for these situations.

If more detailed information about this coating/substrate interface region is desired, ultrasonic instruments with a graphical liquid crystal display (LCD) (Figure 4) illustrate substrate roughness by displaying wide “peaks” when the substrate is rough and a narrow “peak” when it is smooth. An LCD is useful when measuring a coating system with an unknown number of layers. In the hands of a skilled operator, the display presents interface information about bond strength and material densities.

Uses on Wood

Ultrasonic testing has brought distinct benefits to the wood industry. Furniture, flooring, and musical instrument manufacturers often apply several layers of lacquer or similar finishing materials to properly fill the wood. Some processes require the ability to identify the thickness of individual layers (or series of layers). When applied at the wrong thickness, the coating layer that beautifies and protects a high-quality guitar, for example, can easily detract from its sound. Too much coating can dampen the guitar’s acoustic resonance; too little can have the reverse effect. Quick, nondestructive measurements can be taken over the surface of a guitar to ensure a smooth, even coating without disrupting the production process. Potential cost reductions include minimizing waste, minimizing rework and repair, and eliminating the need to scrap guitars to perform destructive coating thickness measurements.

Measurement Accuracy

The accuracy of any ultrasonic measurement directly corresponds to the sound velocity of the material being measured. Sound travels slower through paint than it does through metal. Because ultrasonic instruments measure the transit time of an ultrasonic pulse, they must be calibrated for the “speed of sound” of that particular material.

From a practical standpoint, sound velocity values do not vary greatly among the coating and lining materials used in the corrosion industry. Therefore, ultrasonic coating thickness gauges usually require no adjustment to their factory calibration settings.

To ensure optimum accuracy, however—especially when measuring a coating for the first time—a known thickness of that coating is measured ultrasonically. Methods of first obtaining this known thickness value include removing the coating and measuring with a micrometer, cutting the coating and viewing the cut under magnification, or applying the coating to a metal substrate and measuring it with a magnetic or eddy current gauge. The coating is then measured with the ultrasonic gauge. If the result is not within tolerance of the known thickness, the displayed value is adjusted to match the thickness value obtained by other means.

Applications

One can now take quick, nondestructive thickness measurements on materials that previously required destructive testing or lab analysis. Such applications include:

- Urethanes, lacquers, and two-component PUs on wood and wood products
- Paint on gypsum board (dry wall)
- Multilayer coatings on automotive plastic
- Coatings on carbon fiber composites
- Conformal coatings on fiberglass printed circuit boards
• Latex paints, acrylics, lacquers, urethanes, epoxies, and polyester resins on masonry substrates including stone, brick, tile, concrete, asbestos-cement board, renderings, and plasterboard
• Other homogeneous coatings on nonmetal substrates.

Testing can be done without significantly disrupting the production process. Potential cost reductions include:
• Minimizing waste from overcoating by controlling the thickness of the coating or lining being applied
• Minimizing rework and repair through direct feedback to the operator and improved process control
• Eliminating the need to destroy or repair objects by taking destructive coating thickness measurements.

Summary

Ultrasonic coating thickness measurement has become an accepted and reliable testing method in many industries. These instruments are affordable, reliable, and simple to operate.

References

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