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METROLOGY

# Using Ultrasonic Gauges to Measure Thickness

## This fast, reliable, nondestructive tool can measure thickness from just one side

PUBLISHED: THURSDAY, FEBRUARY 5, 2015 - 00:00

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Ultrasonic thickness gauging is a widely used nondestructive test technique for measuring the thickness of a material from one side. It's fast, reliable, and versatile, and unlike a micrometer or a caliper it requires access to only one side of the test piece. The first commercial ultrasonic gauges, using principles derived from sonar, were introduced in the late 1940s. Small, portable instruments optimized for a wide variety of test applications became common in the 1970s. Advances in microprocessor technology led to new levels of performance in today's sophisticated, easy-to-use handheld instruments.

## What can be measured?

Virtually any common engineering material can be measured ultrasonically. Ultrasonic thickness gauges can be set up for metals, plastics, composites, fiberglass, ceramics, and glass. On-line or in-process measurement of extruded plastics and rolled metal is often possible, as is measurement of individual layers or coatings in multilayer fabrications. Liquid levels and biological samples can also be measured. Ultrasonic gauging is always completely nondestructive, with no cutting or sectioning required.

Materials that are generally not suited for conventional ultrasonic gauging because of their poor transmission of high-frequency sound waves include wood, paper, concrete, and foam products.

## How do ultrasonic thickness gauges work?

Sound energy can be generated over a broad frequency spectrum. Audible sound occurs in a relatively low-frequency range with an upper limit around twenty thousand cycles per second, or 20 kilohertz (KHz). The higher the frequency, the higher the pitch we perceive. Ultrasound is sound energy at higher frequencies, beyond the limit of human hearing. Most ultrasonic testing is performed in the frequency range between 500 KHz and 20 megahertz (MHz, which represents one million cycles per second), although some specialized instruments go down to 50 KHz or lower and as high as 100 MHz. Whatever the frequency, sound energy consists of a pattern of organized

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mechanical vibrations traveling through a medium such as air or steel according to the basic laws of wave physics.

Ultrasonic thickness gauges work by very precisely measuring how long it takes for a sound pulse that has been generated by a small probe called an ultrasonic transducer to travel through a test piece and reflect back from the inside surface or far wall. Because sound waves reflect from boundaries between dissimilar materials, this measurement is normally made from one side in a “pulse/echo” mode, as seen in figure 1.

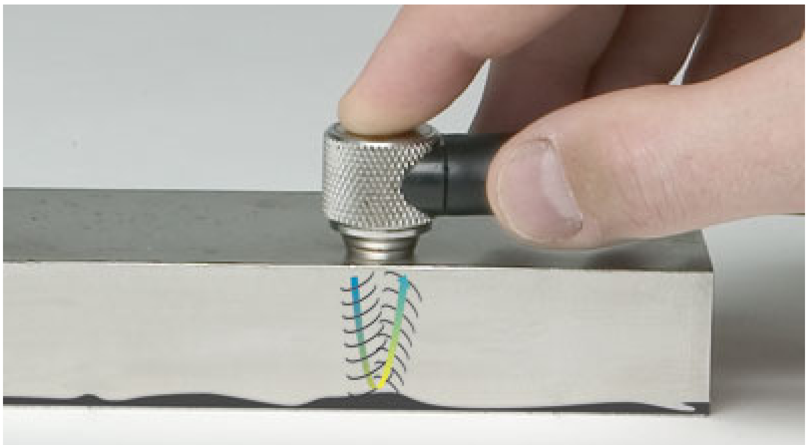

**Figure 1:** A sound wave pulse is emitted from the transducer, reflects from an acoustic boundary, and is received back at the transducer.

The transducer contains a piezoelectric element which is excited by a short electrical impulse to generate a burst of ultrasonic waves. The sound waves are coupled into the test material and travels through it until they encounter a back wall or other boundary. The reflections then travel back to the transducer, which converts the sound energy back into electrical energy. In essence, the gauge listens for the echo from the opposite side. Typically this time interval is only a few millionths of a second. The gauge is programmed with the speed of sound in the test material, from which it can then calculate thickness using the simple mathematical relationship:

T = (V) x (t/2),

where

T = the thickness of the part

V = the velocity of sound in the test material

t = the measured round-trip transit time

It's important to note that the velocity of sound in the test material is an essential part of this calculation. Different materials transmit sound waves at different velocities, generally faster in hard materials and slower in soft materials, and sound velocity can change significantly with temperature. Thus, it's always necessary to calibrate an

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ultrasonic thickness gauge to the speed of sound in the material being measured, and accuracy can be only as good as this calibration.

Sound waves in the megahertz range do not travel efficiently through air, so a drop of coupling liquid is used between the transducer and the test piece to achieve good sound transmission. Common couplants are glycerin, propylene glycol, water, oil, and gel. Only a small amount is needed, just enough to fill the extremely thin air gap that would otherwise exist between the transducer and the target.

Figure 2 offers an example of how an ultrasonic thickness gauge can be used to measure two different thicknesses. Moving from left to right on the display, the first pulse is the initial pulse from the transducer, the second pulse is from the boundary between the first material and the second material, and the third pulse is from the boundary between the second material and air. In this way, the thickness of both materials can be known.

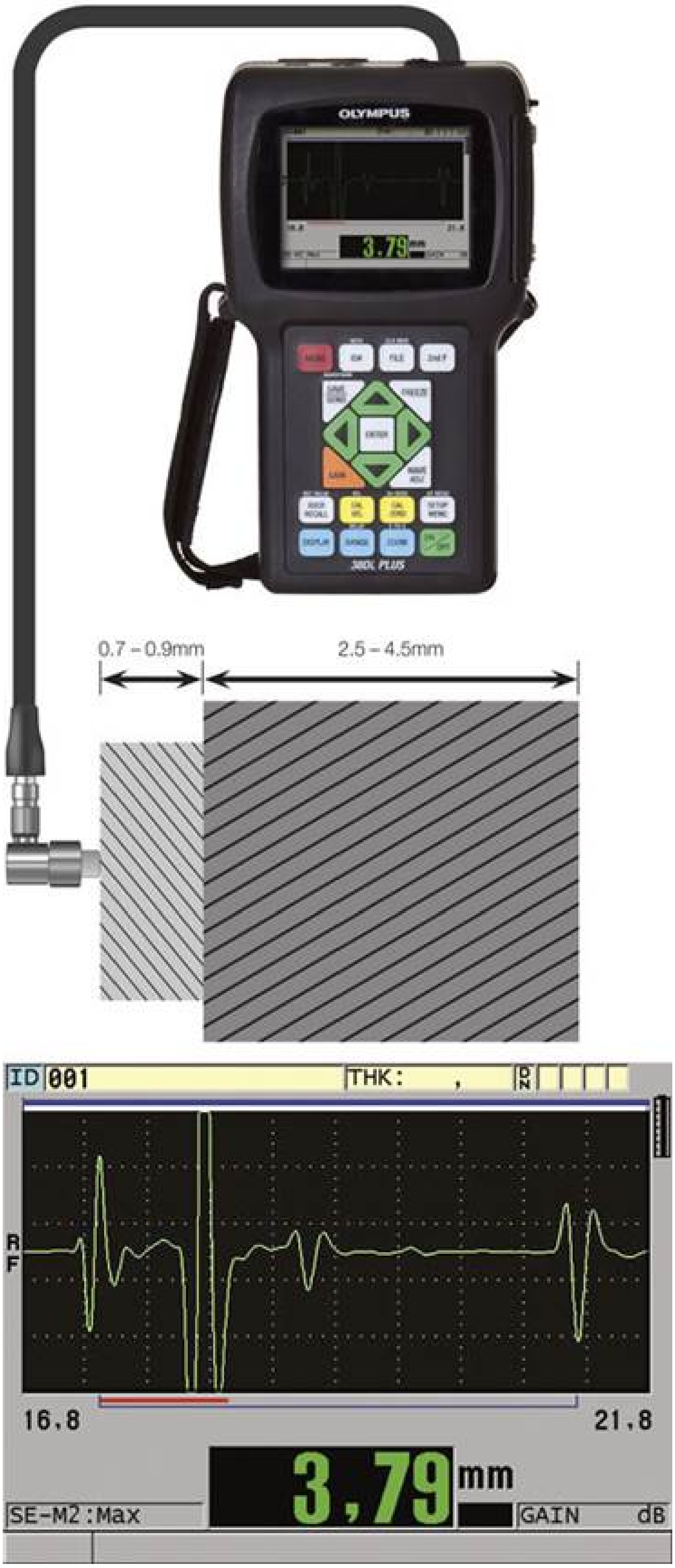


**Figure 2:** An ultrasonic thickness gauge can be used to measure two different thicknesses.

## Measurement modes

There are three common ways of measuring the time interval that represents the sound wave's travel through the test piece. Mode 1 is the most common approach, simply measuring the time interval between the excitation pulse that generates the sound wave and the first returning echo, and subtracting a small zero offset value that compensates for fixed instrument, cable, and transducer delays. Mode 2 involves measuring the time interval between an echo returned from the surface of the test piece and the first back wall echo. Mode 3 involves measuring the time interval between two successive back wall echoes.

The type of transducer and specific application requirements will usually dictate the choice of mode. Mode 1, used with contact transducers, is a general-purpose test mode and is recommended for most applications. Mode 2, used with delay line or immersion transducers, is most often used for measurements on sharp concave or convex radiuses or in confined spaces with delay line or immersion transducers, for on-line measurement of moving material with immersion transducers, and for high-temperature measurements with high-temperature delay line transducers. Mode 3, also used with delay line or immersion transducers, typically offers the highest measurement accuracy and the best minimum thickness resolution in a given application, at the expense of penetration. It is commonly used when accuracy and/or resolution requirements cannot be met in modes 1 or 2. However, mode 3 can be used only on materials that produce clean multiple back wall echoes, typically low-attenuation materials such as fine grain metals, glass, and most ceramics.

This tutorial provides a basic introduction to the theory and practice of ultrasonic thickness gauging for both newcomers and more experienced users who would like a review. It covers basic ultrasonic theory, how ultrasonic gages work and how they are used, and discusses a number of specific gauge applications. A very complete description of how ultrasonic gauges work and how to select them can be found here.

Please visit online for more information. The educational Resource Section of our website has many videos, application notes, tutorials, and white papers on ultrasonic thickness gauges.

*Tom Nelligan and Daniel Kass are engineers for Olympus Scientific Solutions Americas, a Quality Digest content partner.*

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