NDT Application Note
Measuring Boiler Tube Wall Thickness with EMAT Transducers

Application:
Measurement of wall thickness of steam boiler tubes with the E110-SB magnetostrictive EMAT transducer

Recommended instruments:
Model 37DL PLUS thickness gage
Epoch 4, Epoch 4 PLUS, or Epoch 4B flaw detector

Background:
The very high temperatures found inside steam boilers (in excess of 1500 degrees Fahrenheit or 800 degrees Celsius) can cause the formation of a specific type of hard, brittle iron oxide called magnetite on the inside and outside surfaces of steel boiler tubing. The presence of this oxide layer on the outside of tubes can interfere with ultrasonic wall thickness measurement using common dual element transducers, both because it can have a very rough surface that prevents proper sound coupling, and because oxide thickness will be added to the steel thickness. However, as its name implies, magnetite is magnetic, and that property permits the use of magnetostrictive EMAT (Electomagnetic Acoustic Transducer) transducers such as the Panametrics-NDT E110-SB. EMATs offer several advantages over conventional dual element piezoelectric transducers: it is not necessary to remove oxide scale in order to make measurements, the scale thickness is not added into the wall thickness measurement, and measurements can be made very quickly and without need for liquid couplant. The primary limitation of magnetostructive EMATs is that they work only when scale is present and bonded to the outside of the boiler tube. Additionally, the minimum measurable wall thickness and measurement accuracy will not be nearly as good as what can be achieved with a conventional dual, and EMATs are relatively insensitive to small internal pits. For that reason, EMATs are often used for quick initial wall thickness surveys, while duals can then be used to take a closer look at areas of concern.

Theory of operation:
There are two types of EMATs used within the NDT industry. One is known as a Lorentz EMAT, which does not require the presence of oxide scale, but does require very high driving power. A magnetostrictive EMAT such as the E110-SB requires scale but works at the much lower power levels typical of field portable ultrasonic gages and flaw detectors. It consists of a strong permanent magnet and a coil which acts as an electromagnet when driven by the excitation pulse from the test instrument, as seen in Figure 1. The permanent magnet creates a magnetic field perpendicular to the surface of the scale (B_s in the figure below), while the dynamic field created by the electromagnet

(B_d) causes the scale to be pulled radially outward and inward as the coil is pulsed, as seen in Figure 2. This motion generates a normal incidence shear wave in the scale, which then propagates into the steel. Essentially, the scale acts as the active transducer element to generate the sound pulse. The frequency of the sound pulse will vary as oxide thickness changes, increasing as oxide becomes thinner and decreasing as oxide becomes thinner. With typically thin scale buildups, the frequency will be approximately 5 MHz. The process also works in reverse to generate a voltage in the coil when the returning shear wave echo vibrates the scale.

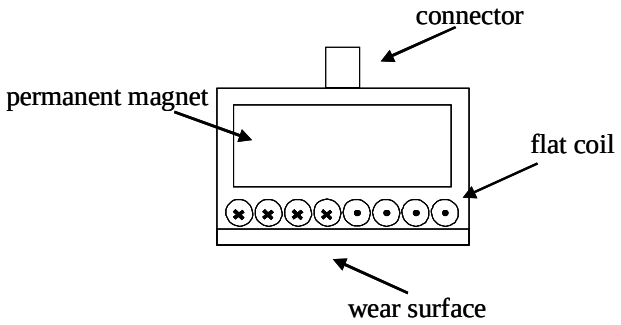

Figure 1 -- cross section of typical EMAT

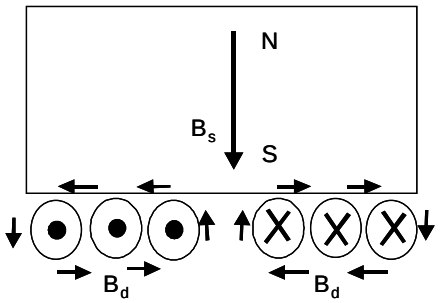

Figure 2 -- Method of sound wave generation

Because the scale itself is the transducer element, scale roughness is not a coupling issue, and the scale is not added into the thickness measurement. The EMAT generates a shear wave, so the instrument must be calibrated to a shear wave velocity of approximately 0.1280 in/uS or 3,240 m/S in typical carbon steel. Typical measurement accuracy with the E110-SB EMAT transducer will be +/- 0.010 inch or 0.25 mm, with a minimum measurable thickness of at least 0.080 inch or 2.0 mm depending on material properties.

Setup and measurement procedures:

As a general note, the quality of ultrasonic echoes in EMAT applications in part depends on the consistency of the oxide scale layer, which can vary from point to point on a given boiler tube. If usable echoes cannot be obtained at one point, try another point nearby. Also, the E110-SB transducer incorporates an adjustable standoff that varies the distance between the transducer face and the surface of the boiler tube. Adjusting this standoff distance will help optimize echo response in many cases.

(a) Model 37DL gage

The E110-SB transducer is used with the Model 37DL thickness gage in conjunction with a 1/2XA/E110 adapter, which provides both probe recognition and added high pass filtering that is necessary for proper signal conditioning. When the adapter is plugged in, the gage will automatically select the EMAT default setup DEFM1-EMAT/E110. As with any gage setup, for optimum accuracy a two-point velocity/zero calibration should be performed on thick and thin reference standards of known thickness, but if such standards are not available the default settings will usually be sufficient as a starting point. Instrument gain and echo blanking may be adjusted as necessary to optimize echo detection. Under the EMAT default setup, the 37DL will display a full wave rectified waveform. A typical waveform display is seen below in Figure 3.

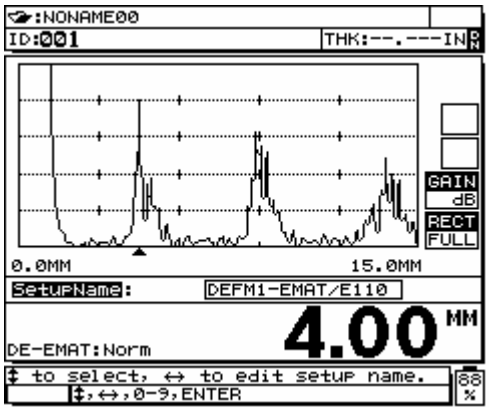

Figure 3 -- typical rectified EMAT waveform

For a more detailed look at the shape of the waveform, which can be useful under challenging measurement conditions, select the RF display more from the gage setup menu. A typical RF waveform from an EMAT measurement is seen in Figure 4.

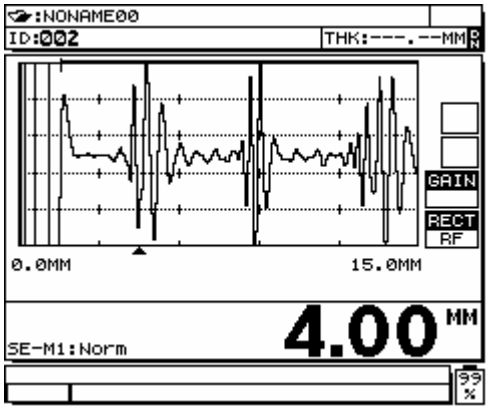

Figure 4 -- typical RF EMAT waveform

(b) Epoch 4 flaw detector

A typical EMAT starting setup and waveform for an Epoch 4 flaw detector is seen in Figure 5. Note that bandpass filtering must always be used to filter out low frequency noise associated with EMATs. Also, because shear wave frequency varies with oxide scale thickness, the Epoch's square wave frequency should be adjusted as necessary for optimum echo response.

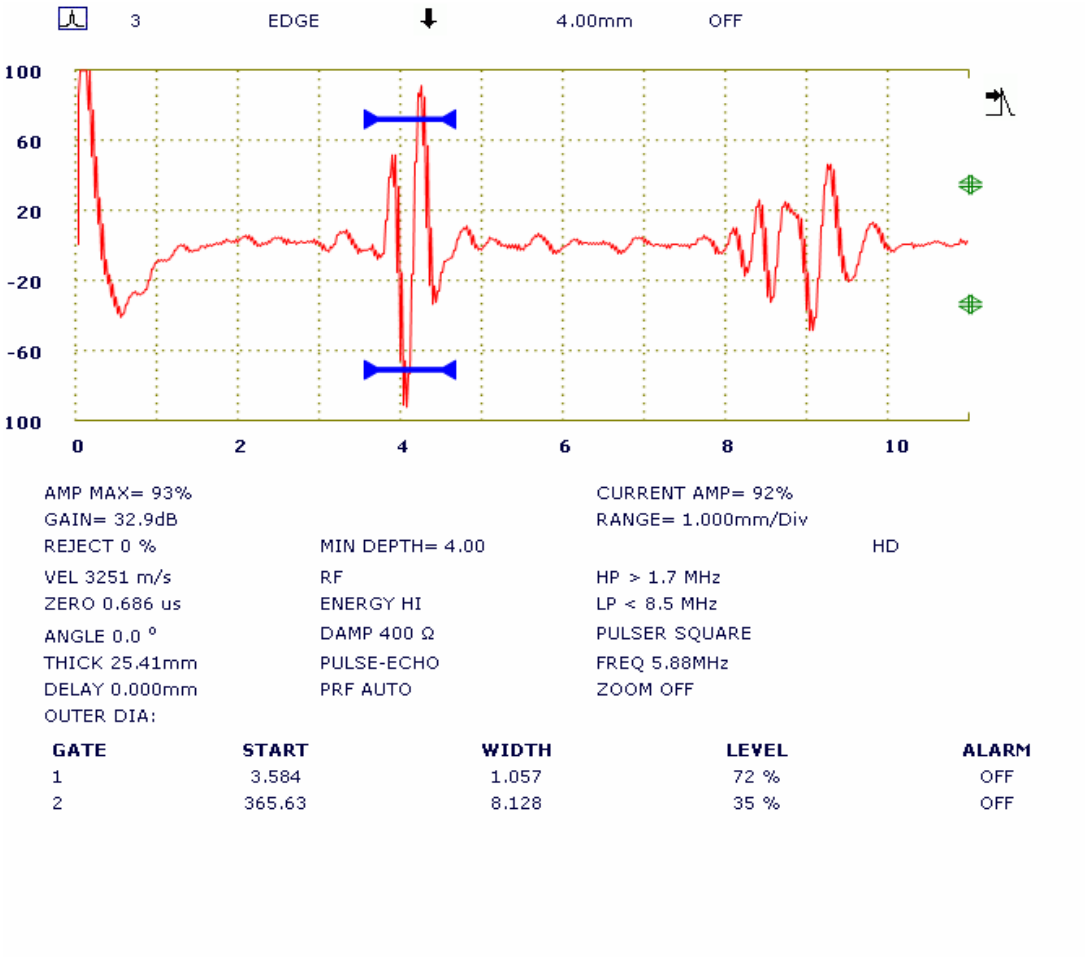

Figure 4 -- typical Epoch 4 waveform and setup

For further information or setup assistance, contact *VISCO at https://visco.com.vn*