Off-Line non-destructive testing of tubular products

Given the rapidly growing NDT choices available to the tube and pipe industry, a sequential multi-test solution reinforces the importance of taking a broad view of the issues before implementing a system.

Applying non-destructive testing early in the manufacturing process – on-line in a welded tube mill, for example – holds obvious incentives for all. However, the need to move downstream after subsequent operations and test discrete lengths is still common.

Downstream testing can be specified for several reasons: for instance, organisations such as ASTM International and American Petroleum Institute (API) may require them; or, for example, operations such as cold forming or heat treating may introduce defects before final inspection.

Recent developments in eddy current, ultrasonic and flux leakage inspection systems allow improved off-line inspection at high throughput speeds and rapid changeover.

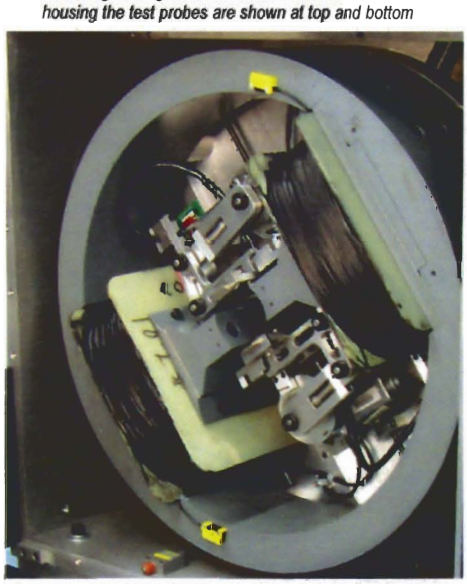
Manufacturers can thus meet demanding specifications, and as a result, producers of non-destructive (NDT) testing systems have developed an increasing selection of techniques that match tube producers specifications.

Emerging technologies such as electric-magnetic acoustic transducers (EMAT) and laser-coupled ultrasonics offer potential. However, conventional ultrasonic technology (requiring a liquid couplant between the transducer and tube) and the two air-coupled electromagnetic methods (eddy current and flux leakage) still dominate off-line testing (1).

Flux leakage works only on ferromagnetic tubing and is usually the method of choice for inspecting OCTG. Convenient and relatively simple, it has fast throughput and changeover speeds, and efficiently accommodates large diameters when compared to large ultrasonic machines.

Figure 3 – screen display for a 20-channel Echomac® UT system to test 30ft-long, 3-6" diameter drill pipe for flaws and wall thickness All data from 20 channels are consolidated into 5 channels for convenient viewing (courtesy Smith Services)

Figure 1 – Rotoflux® flux leakage rotary headplate assembly with magnetizing coils on either side. Probe assemblies housing the test probes are shown at top and bottom



In figure 1, the rotary flux leakage system detects longitudinal defects such as seams, laps, and weld-line defects, and transverse defects can be detected with appropriate mechanics, DC fields and sensors.

NDT is usually applied in general compliance with ASTM standards or, in the case of OCTG, API 5CT or API 5L, which references ASTM E213-04, E-570-04, and ASTM 309-01 (for full ASTM details, refer to footnote 2).

These practices dictate conformance to acceptable testing performance standards. However, once agreed upon, important portions – especially accept/reject criteria – are left to the tube supplier and purchaser to negotiate.

Conversely, although API 5CT does not recommend a specific

Figure 2 – saturation unit with articulating sensors allow accurate testing of the tube body in upset end API pipe

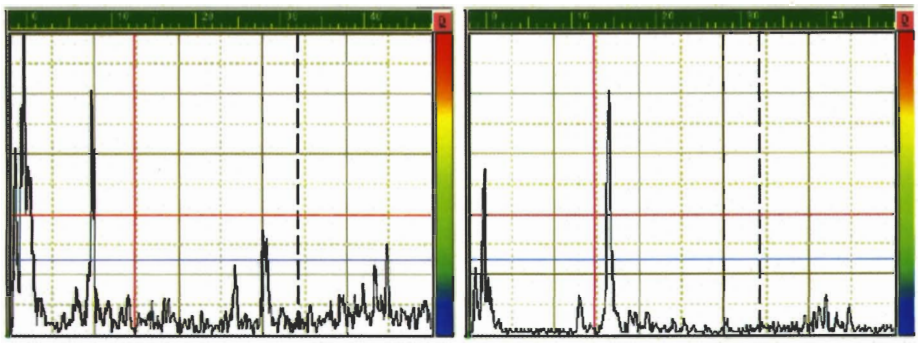
NDT method, the L2 level for high-strength material calls for establishing a reject level for OD and ID defects at a depth of 5 per cent of the wall thickness or greater (3). Such sensitivity to ID defects on tube wall thicknesses typical of OCTG can most reliably be met with ultrasonic testing (UT).

Some API tubing classes may be tested exclusively with eddy current using drilled-through holes as reference standards, especially on thinner walls. Sensitivity on large diameters can be enhanced using multiple sector coils rather than one encircling coil.

Figure 2 shows part of a system that uses four actuated sector coils to provide good sensitivity on the body diameter of upset pipe, still allowing the larger diameter upset ends to pass through.

Where rapid throughput speeds are required, devices that rotate multiple sensors have become the first choice for flux leakage and ultrasonic machines (with optimum throughput and short defect detection). Rotating-head ultrasonic machines for

Figure 4 – control room with 20-channel UT screen display of drill pipe test data. Test electronics and transducers can be observed through the window (courtesy Smith Services)



(Figure 5 – above left) Phase array screen display of a 0.1mm deep x 5mm long longitudinal ID notch (at throughput speed of 120m/min), and (figure 6 – above right). a .1mm high x 5mm long, OD longitudinal notch (at throughput speed of 120m/min)

larger than 9" (228.6mm) capacity are complicated and expensive.

The alternate solution for large-diameter UT inspection is to spin the product past the test sensors. The lower throughput speed of this approach may be improved though the use of multiple sensors.

Figures 3 and 4 show test screens of this system type with 20 parallel channels of ultrasonic electronics inspecting drill pipe. For ultrasonic detection of very small defects, testers are using full-body phased array systems that do not rely on mechanics for a circumferential scan.

Figures 5 and 6 demonstrate the capability of a system that uses six arrays of 128 segments each to inspect tubes in the diameter range of 17.2mm to 56.4mm. They illustrate clockwise and counter-clockwise shear wave for OD and ID defects, and longitudinal waves for lamination-type defects and wall thickness measurement.

Electronically timing the excitation and reception of echoes creates focusing and virtual scanning with shear and longitudinal mode beams. This system operates with throughput speeds up to 2m/sec and changeover times of 10 minutes or less.

Combining eddy current coils to detect short penetrators and ultrasonic transducers for long continuous defects, especially on the ID, has become widely accepted for critical mechanical and high-pressure hydraulic and boiler tubing.

Figure 7 shows a combined rotating ultrasonic and eddy current encircling coil system for inspection of drawn-over mandrel tubing in the diameter range of 20-90 mm.

This system, located at Tube Products of India, utilises Echomac® FD-4 ultrasonic and MAC® 250 eddy current computer electronics with specialised software.

Figure 7 – Echomac® rotary ultrasonic and MAC 250 encircling coil eddy current test of 20-90mm-diameter drawn over mandrel carbon steel tubing at Tube Products of India

A rotating ultrasonic head can prove invaluable when incorporated into a test station for inspecting coiled product, consisting of thousands of feet of stainless steel or duplex alloy instrument tubing (for oil and gas). Obviously, in such a coil-to-coil line there is no practical way to rotate the tube; therefore, a rotary ultrasonic tester is the best choice.

The tube runs first through the ultrasonic rotary to detect relatively long OD/ID defects, then through an encircling eddy current coil to detect small short defects.

If the UT or ET system activates an alarm, the line stops and the eddy current test coil traverses back and forth over the suspect length to find the exact location that caused the alarm.

A superficial yet fixable surface defect is removed and the eddy current coil again traverses the section to verify its removal. In the case of a UT alarm where the defect is not visible, a hand-held UT test is performed. If no remedy is possible, the suspect section is removed and rejoined using an orbital welder. The weld integrity is then verified by X-ray.

Footnotes:
(1) 'Choosing the proper NDT technique exclusively or in any combination', paper presented by Donald N Bugden at 'Better Tube Technology', Tubos Mexico, Monterrey Mexico, October 27-28, 1992, International Tube Association (downloadable from www.mac-ndt com)

(2) Annual book of ASTM standards 2005, section three, 'Metals test methods and analytical procedures', Volume 03.03. Nondestructive Testing. ASTM International, 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959. ASTM stock #S 030305

(3) American Petroleum Institute Publications, 'Exploration and production', series 5 Tubular Goods, Spec 5CT/ISO 11960, 7th edition, Product #GXO5CT7 & Spec 5L, 43rd edition, Product # G05l43 (accessible at www.api-ep.api.org/publications)

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