Nondestructive testing for stainless steel tube and bar: when, what and how?

Part one of two

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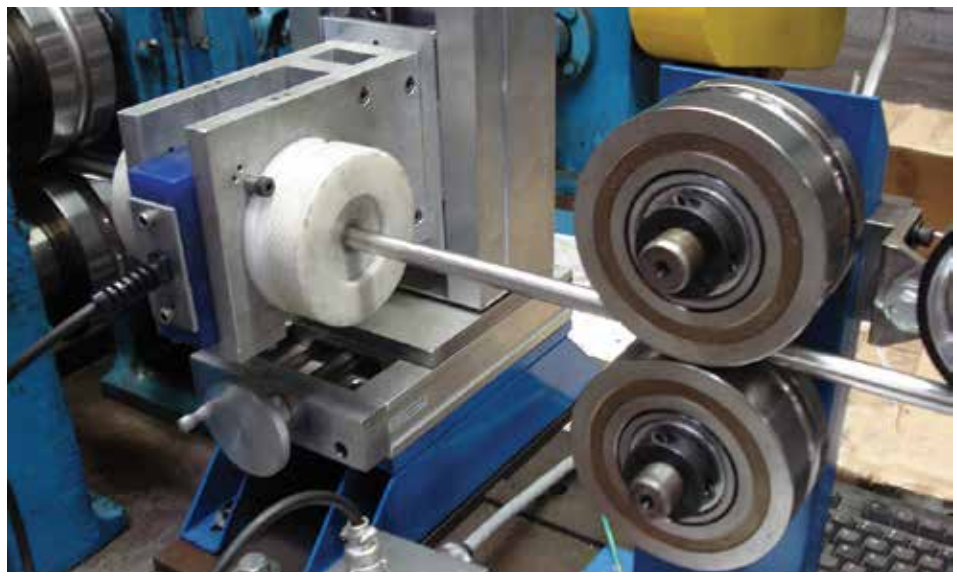
Producers of constant cross-section stainless products such as tube and bar stock must meet the increasingly tighter standards from ASTM, API, ASME, and similar organizations and satisfy the ultimate users, ranging from aerospace, nuclear, and automotive high-end applications, to furniture and consumer goods manufacturers. In many cases, it's not just a matter of rejecting product that fails the inspection, it is also important for the producer to have continuous feedback from NDT testing to be able to make corrective adjustments in their production process.

What follows is a discussion of *what* and *how* tube and bar is being inspected with NDT to meet these requirements.

By Joseph Baldauff, Vice President – Technology, Magnetic Analysis Corp.



Eddy current encircling test coil inspecting welded stainless steel tube.

NDT test systems

Stainless tubes and bars are made from expensive material. The bar and tube users expect that they will receive the highest quality material. Indeed some bar and tube manufacturers enjoy a preferred market position because of their deserved quality reputation and documented ability to meet the tightest quality requirements.

NDT systems come in many different configurations and forms. Some of these systems are more costly than others. Low cost is not always the best choice.

Each NDT supplier has what can be considered as a unique approach. Choice of the NDT supplier/configuration is almost like picking a mate for marriage. There are pros and cons to any partner and any NDT configuration. Some are more expensive than others. The expensive ones can pay returns but not always.

NDT inspection, while moderately priced, adds little to the final cost of the product if the inspection system is reliable and if it can operate at the needed production rates without any bottleneck and without negatively (false rejections) impacting the product scrap rate.

Eddy Current Hot Probe inspecting the weld zone of a stainless steel tube immediately following the weld head.

Characteristics of any NDT system

Demonstrated capability

This means that the NDT system can reliably detect any condition that will cause failure of a final critical device, as, for example, air bag components, brake components, fuel injectors, pressure vessel, transmission components, etc. It is the responsibility of the bar/tube manufacturer to determine that they can and do detect defect types that can lead to failure. This makes good business sense and is at times the only way that certain users will purchase their product.

Demonstrated repeatability

Any NDT supplier understands this term. The system is normally configured to optimize repeatability to ASTM mandated notches and holes. These notches and/or holes are specified by the NDT purchaser. Obtainable repeatability is a good indicator of the NDT system quality and impacts the allowable testing velocity and inspection quality level.

System availability

Most test systems are designed to keep up with the plant production or cell production rate. One issue that can impact the plant production is the NDT system availability. The NDT system can need service, calibration, etc. This can impact the actual plant production. For this reason, a highest quality product drive system is required and a low maintenance testing head is mandated. The entire system must be designed for maximum reliability and zero down time. One of the best things that can be said about a NDT system is that it requires no maintenance.

NDT system support

Some systems can be low cost but the supplier can also be challenged to support the system at a moment's notice. The bar/tube manufacturer at times can need very quick attention to application problems that may develop. A good NDT supplier has a field group that is available quickly. These people must be well trained and very knowledgeable about industry inspection norms.

Changeover time

A good NDT test system must be capable of being changed to handle a new size product very quickly. These size changes can be considered down time if they exceed the change over time of the bar/tube processing cell or the material handling system.

Signal to noise ratio

A good system will allow a signal to noise ratio of at least 4/1. Higher is better. Obtainable signal to noise ratio is a function of the NDT configuration but it is also a function of the material quality, straightness, surface finish, grain size, and melt quality.

Test Technology

Tubes

Stainless tubes in diameter range of <0.1 inches to 40 inches in diameter can be tested at the point of manufacture using NDT technologies of Eddy-Current and Ultrasonic.

Eddy-current (EC)

Weld Mill Application

Tubes can be tested in semi-finished and finished form. Tubes can be tested at the point of manufacture on the weld mill directly beyond the weld head to give quality feedback directly to the weld operator. This feedback can result in higher quality weld operation because the eddy-current device can be looking only at the weld zone and can detect even slag build-up on the weld electrode that doesn't seriously affect the weld but gives an early warning that there can be a welding issue. Serious issues of incomplete welds, cold-welds, penetrators, and off center welds can be detected.

Magnetic Analysis Corp. Echomac® FD-6A Ultrasonic Tester inspects titanium tube in an immersion type TacTic (TAC Technical Instrument Corp.) system.

Off-line EC inspection

Most tubing product is sold to an ASTM or other mandated quality/inspection requirement. This can sometimes be fulfilled using an encircling eddy-current inspection coil device to allow "full body" inspection on the mill. Some applications allow for fulfillment of this requirement on the mill. It needs to be pointed out that product that is situated on the mill is in some respects semi-finished material and the ultimate highest quality is obtained after the material undergoes further processing such as final batch heat treating, straightening, end finishing, etc. The highest level of inspection using the available NDT methods is normally achieved using an "off-line" inspection station. These off-line testing stations can be configured in a manner that allows maximum centering and vibration control through conveyor mechanisms that are optimized to achieve the needed product transport stability.

Stainless tubes are generally considered nonmagnetic therefore they can be directly tested without consideration of magnetic permeability suppression. While this is true for some grades of stainless, other grades will demonstrate some permeability variations. Some slight pickup of magnetic material on the product surface – one steel wool hair for instance can cause a false rejection. For this reason, most eddy current encircling coil testing is done with use of some DC magnetic field to suppress these permeability variations. This saturation should be done with as small a gradient field as possible.

One consumer goods application that can require some NDT inspection is vacuum drink containers. Some high quality drink container manufacturers now require high quality thin wall tubes as incoming raw materials. Some suppliers are now using EC NDT to assure the material quality.

Automotive products suppliers are now required by the automotive companies to supply devices with their quality measured in parts per million. This is achieved in part by fairly high degrees of NDT testing of the tubes and bars that are purchased by the automotive parts manufacturers. These include air bag propellant components, fuel injector components, corrosion resistant brake parts, including brake hydraulic lines, automotive fuel line assemblies, car exhaust tube components, engine valves, and many more. The majority of these parts are made from bar and tube product that has been tested with some NDT full body inspection method.

Don't miss part two!

Part two of this informative article, including ultrasonic technology, will be published in the August issue of *Stainless Steel World Americas.*

An Ultrasonic test (UT) on titanium.

About the author

Joseph Baldauff, Vice President – Technology for Magnetic Analysis Corp., has over 30 years of experience in the field of nondestructive testing specifying, installing, and implementing eddy current and ultrasonic inspection systems for production mills. He holds ASNT Level III certification in eddy current and ultrasonic technology and received a B.S.E.E. degree from the University of Pittsburgh.

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An Ultrasonic inspection system testing stainless steel heat exchanger tube.

Ultrasonic testing method (UT)

Materials for the higher, more critical uses are now required to be tested with the Ultrasonic method. This method of product testing is generally complementary to the Eddy Current method. The Ultrasonic method is very capable of detecting defects in heavy wall tubes. It can be used to measure the tube's full dimensional characteristics including wall thickness, ID (Inside Diameter Defects), OD (Outside Diameter Defects), Ovality, Eccentricity, etc. Ultrasonic methods can detect defects in many different orientations. Ultrasonic inspection may be mandated by the material buyer. It may be specified to conform to ASTM E217 or other norms.

Stainless bars are tested with Ultrasonic methods and can be conducted in up to five directions. The simplest is bar internal quality. This method is limited to the bar internal area but is blind to surface (seams and laps) and sub surface defects (inclusions). This blind area is like an outer onion layer of 2 to 3 mm thickness.

Bars can also be tested with shear method – clockwise and counter clockwise. This allows the bar surface and near surface to be tested and because the sound beam is originated from the inside of the bar, sealed seams can be easily detected. This is a very sensitive test method and it can detect seams and laps that are very shallow. This method allows the inspection to be adjusted to any seam depth. Typical allowable seam depth could be anywhere between 0.002" to 1% of the bar diameter depending on the end-use and the final material finishing method. Two additional directions can be implemented. These are transverse forward and transverse reverse. This direction can detect transverse cracks and internal cupping. Only a small percentage of bars are tested using the transverse method.

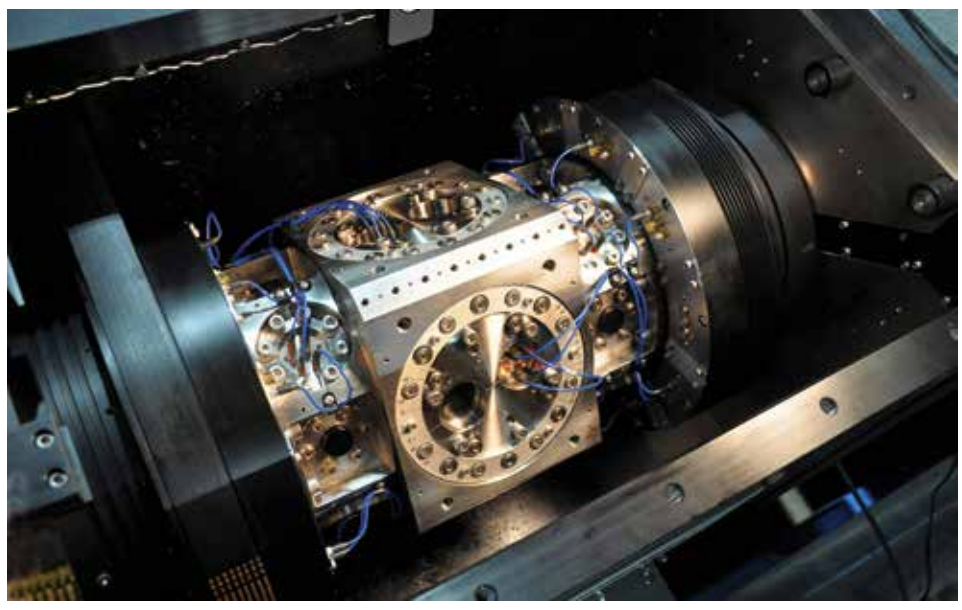
Ultrasonic testing is normally done on a totally finished stainless tube or bar. The test method can be applied to a spinning stationary tube or bar, helical traveling spinning tube/bar or to a conveyed tube/bar that passes through the center of a rotary spinning transducer configuration or Phased Array (PA), spinning sound beam device. The spinning tube is generally limited to 3'(1m)/second circumferential speed.

The rotating transducer rotary or PA can rotate at much higher speeds than the spinning probe test method due to higher coupling water pressure. Rotary devices can achieve the highest inspection throughput. Multiple element arrays can also be used to achieve highest inspection rates in rotary test devices. Phased Array devices can also be used that rotate the sound by use of multiplexed transducer arrays that cover the entire product circumference.

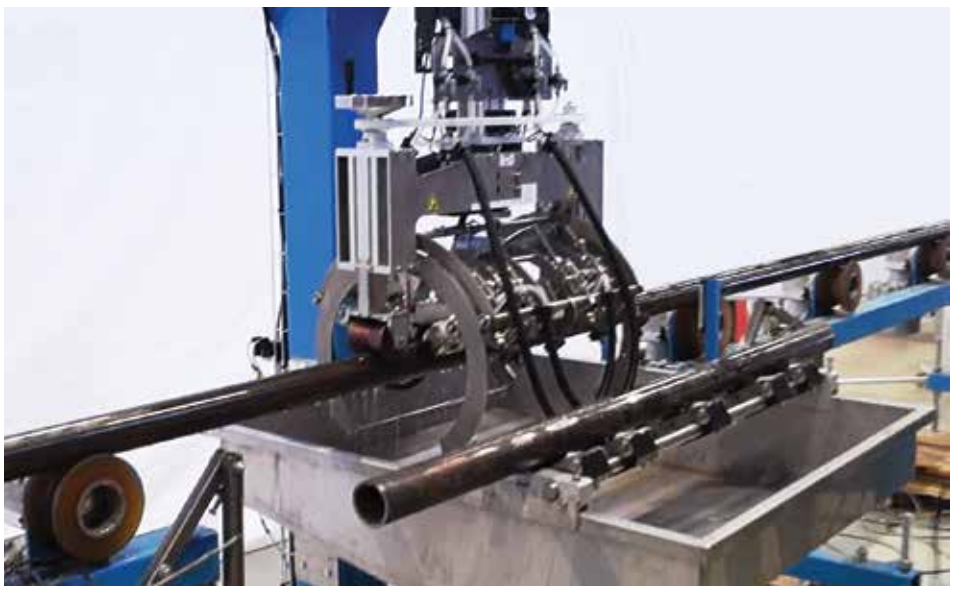
Volumetric testing, repeatability, signal to noise ratio and other considerations

In order to properly test raw stock, it is generally accepted that the entire product volume needs to be tested. This assures that small detrimental defects are detected and eliminated from the raw stock supply. The detection of the smaller defects must be assured but this should not be achieved at the expense of the NDT system noise level. A high noise level system will cause unacceptable false rejections of good product. For this reason, the system signal to noise level is generally a parameter that is critical.

To assist in achieving good signal to noise ratio, short transducer beams are used but this causes the test speed to be reduced. Multiple element arrays can help to increase the testing speed by application of more channels in each direction.



Multi Element Ultrasonic Transducer test head for Echomac® 75mm rotary immersion type coupling.



Ultrasonic Weld Zone Tester uses water irrigated transducer shoes that ride the surface of the tube. The test head can shift forward to test the calibration tube shown in the foreground.

Ultrasonic phased array in bar testing

The newest development in bar testing is using phased array technology. This is a reliable method to obtain three-direction testing. The Phased Array method uses a transducer made from a multitude of small single element devices (64, 128, or 256) to make one of six to eight transducers that encircle the product. This is the needed configuration to allow spinning the sound around a non-rotating conveyed bar. The requirement to test the full bar volume – internal - NI and CW and CCW shear does force the arrays to test in sequential mode. This time-shared transducer device then becomes speed limited if the user or final customer demands repeatability on the mandated flat bottomed drilled holes and notches. If repeatability cannot be obtained at production speed then it is not possible to claim that volumetric testing is being done on the product.

Some rotary devices can operate at up to 400 ft. per minute (2m/s) and still obtain repeatability on all notches and flat bottomed drilled holes and obtain an honest volumetric test.

NDT – An important tool for quality

NDT is a tool that requires care and understanding of the technology and its application during production. For critical applications, it is absolutely essential and for less critical ones, it is still important for optimizing the production quality.

Proper NDT must be ensured to satisfy growing customer expectation and quality demand.

Miss part one?

Part one of this informative article, including eddy current (EC) testing and off-line EC inspection, was published in the June 2018 issue of *Stainless Steel World Americas* under the 'Special Topic' section on pages 6 and 7.

Magnetic Analysis Test system using Ultrasonic and Eddy Current technology to inspect tube 40 - 180mm diameter.

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