Using NDT to Ensure Product Quality

Stainless steel is becoming the default material for many uses, consequentially making product reliability even more important. The market is demanding the highest quality, defect-free components that meet customer specifications.

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

Industrial heat exchanger users, aerospace, medical, and some military applications require the highest quality materials and require also that high inspection levels be applied to the long intermediate product (wire, tube, and bars). Automotive materials can also, surprisingly, require the highest quality because some components can lead to huge expenses if a small number of defective parts that are safety critical or integral to engine lifetime or fuel systems fail.

Detecting Defects

A common concern for stainless bar suppliers is that the customer needs to receive seam-free material. Bars are generally rolled from billet stock and the resulting hot-rolled product can have elongated defects from the original billet material. These can be stretched and seen as seams.

Additionally, the hot rolling process can introduce some rolling mill under-fill or over-fill stages, and these can result in laps or seams. The final sizing process can remove surface seams if some surface removal is done as part of the process. This processing is always proprietary to the individual processor, but the finished product may benefit from some final inspection of the raw material surface. The use of non-destructive testing (NDT) in the process becomes a cost-benefit consideration.

Stainless tubes made by an extrusion process or by welding process require at least encircling coil eddy current (EC) testing, but may require that full body ultrasonic testing be done on 100% of the tubes that are supplied. These are done according to an ASTM testing requirement tailored to the tubing application.

Some final products such as finished gears, nozzles, and others, can benefit greatly from internal bar inspection and that method could be full volumetric ultrasonic inspection. This method can detect surface defects but also internal defects such as voids, porosity, segregation, non-metallic inclusions, cracks, and more. Many of these conditions come from the billet that has been hot rolled and drawn so that the original defect possibly is processed into needle-shaped inclusions or voids.

Figure 1: Eddy Current Wiretester Coil with inset guide bushing for testing small diameter wire.

One reason for the greatly improved product reliability presently enjoyed by consumers is that automated ultrasonic inspection is being applied to 100% of the bar volume of critical quality bar stock before shipping to the final complex product producer.

It can be said that using an NDT method is not enough if extremely high quality is desired. NDT can be used to determine the quality level of some product or process but in order to obtain a consistent quality level the process must be designed to produce the needed quality. This includes close examination of the entire bar or tubing manufacturing method and use of materials that have inherent high-quality origins.

For stainless steel, long continuous material lends itself to automated, high throughput inspection. There are opportunities to inspect material as part of the continuous coil process and other opportunities to test or inspect the material in finished or semi-finished lengths.

Spools of small diameter wire can be tested to a high-quality level, but this must be done in such a manner as to rate the quality of the entire coil because no one can afford to test a coil and reject it because of one indication. One can economically test finished bars and reject bars with an indication that exceeds a predefined quality level.

Eddy Current Testing

EC Inspection can be accomplished with a simple encircling coil, and the process will not suffer any speed limitations. This test coil can sometimes be located strategically in the production process. When testing and shipping long coils of wire, the test done in-process can be used to grade the spool quality. For larger diameter materials, if seam defects are detrimental to the final product quality, then a spinning EC probe type inspection can be utilized.

Since a spinning probe produces a helix coverage pattern, the probe test plan must be shown to cover 100% of the product surface or at least the process must be designed to detect natural defects of some minimum length. Sometimes, a test standard is manufactured with an artificial notch that has a desired minimum rejectable notch length and minimum seam depth. These standards can also consist of a length of product that contains rejectable natural mechanical surface conditions.

If internal inclusions or centerline segregation can produce a condition that is detrimental to the final product, then the ultrasonic method should be used. Some surface seam conditions in stainless steel are better detected with the ultrasonic method where extreme high quality is desired.

The simplest inspection can be done by using an encircling coil. Generally, the material needs to be centered in the coil to assure that all the material surface is tested in a uniform fashion. Centering needs to be controlled to approximately 1% to

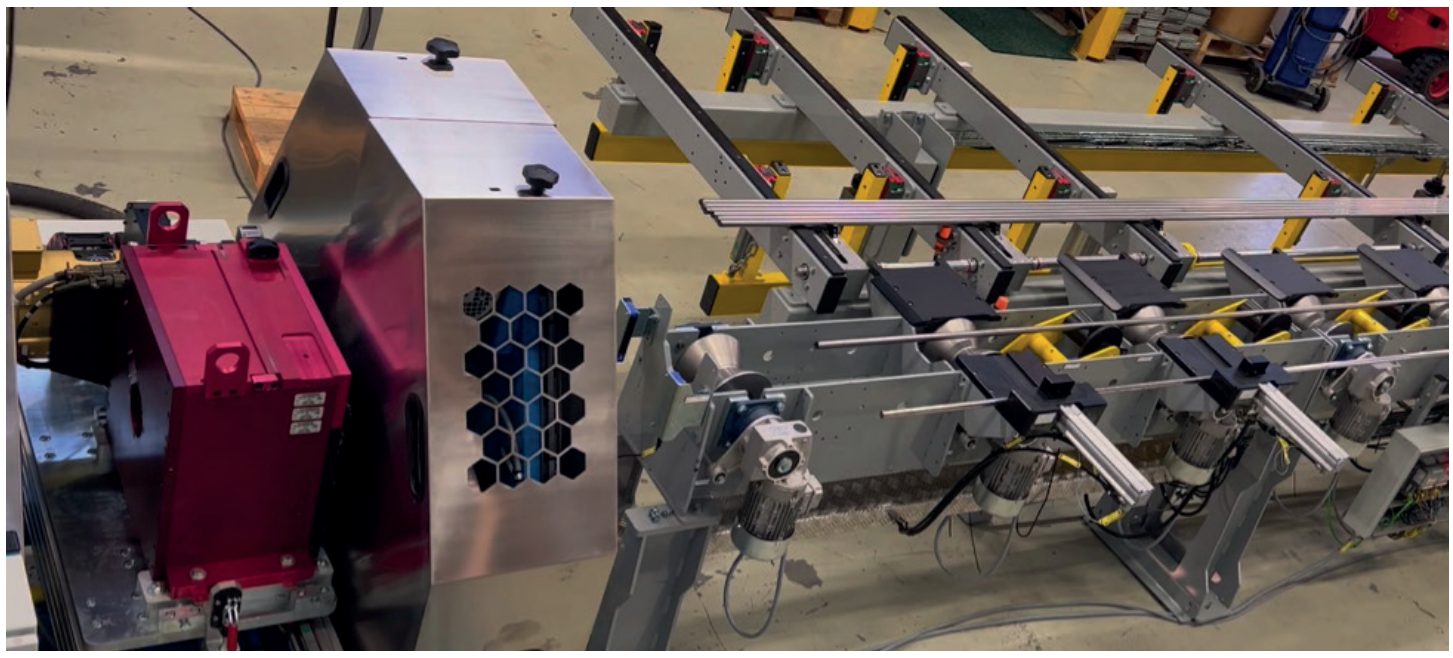

Figure 2: Eddy Current Rotomac® rotary tester, at left, with automated feed system at right, part of a 32M long system for inspecting cold finished, close tolerance round bar. The system also includes an Echomac® ultrasonic rotary tester.

3% of the product diameter to achieve repeatable results. This centering can be achieved by using slightly oversized draw dies when the material is a small diameter. With small diameter material, this centering method is economical because the customer can get these from the market or from a die shop.

As the material diameter gets larger, there is a need to use centering rolls with some oversized protection guide bushings. The centering rolls can be simply 'V rolls' with a top securing roller, but a more economical solution may be a triple roll arrangement with a constant centerline configuration.

Finished stainless bars up to 4" in diameter benefit from some EC NDT. This is normally in the form of a rotary device designed to spin EC probes around the bar to detect any surface defects that are detrimental to the customer's finished product. The producer knows if the delivery must be defect-free material (zero seam depth) or whether the customer will remove the material further.

If defect-free material must be supplied, the producer will EC test the material before final processing to some defect level – for example, about 0.15mm, then finish grinding that amount of material from the bar surface. Many producers will remove some surface from the finished part and the round supplier can then supply material free of surface defects with a depth that does not exceed the customer-removed material.

Ultrasonic Testing

For the highest quality materials, the producer will need to use the ultrasonic method or a combination of ultrasonic and EC methods. The ultrasonic method allows inspection of internal, surface, and subsurface quality. Generally, the bar customer will specify a bar quality level reflecting the final product quality level. A popular specification is AMS- STD-2154. ASTM has a similar document ASTM-E2375. The levels of testing is reflected in the needed quality level. AAA, AA, A, B, C, with AAA being the highest quality level.

Some ultrasonic testing bar quality users will specify the use of a side drilled hole of some drilled hole diameter 'x' length. Others will require the use of a flat bottom drilled hole, commonly referred to as FBH or FBDH. This type of reflector is used for the highest quality level specified material. There are also many ASTM-mandated inspection practices and inspection levels for stainless tube inspection, for various uses. For bars and tubes in Europe, there are ISO/EN standards for use in those countries.

Recent demand for high-quality bars and tubes in the small diameter range has created a need for a small diameter ultrasonic tester. The top of the range for this ultrasonic machine is 25.4 mm. Common sizes in demand can be ¼" to ¾". Because the size is small, there is a need to test these bars or tubes at a high rate of inspection to achieve tonnage or needed footage.

Stainless bar producers are also using phased array ultrasonics to achieve fewer complications when setting up the NDT inspection station, although they will give up some flexibility.

Conclusion

In conclusion, the demand for high quality, defect-free stainless steel components and tubes in industries such as chemical, power, aerospace, medical, military, and automotive requires thorough and reliable NDT methods. These methods include EC and ultrasonic inspection that can be used to detect surface and internal defects in stainless steel tubes, bars, and wires. These inspection methods should be used to produce the desired quality level, and additional processing such as grinding or other methods may be necessary to meet customer specifications.

The use of test standards with artificial notches mandated by ASTM or AMS-STD can be used to meet the required quality level. Sometimes products with marginally rejectable natural defects can supplement the mandated notches and help verify the effectiveness of the inspection process.

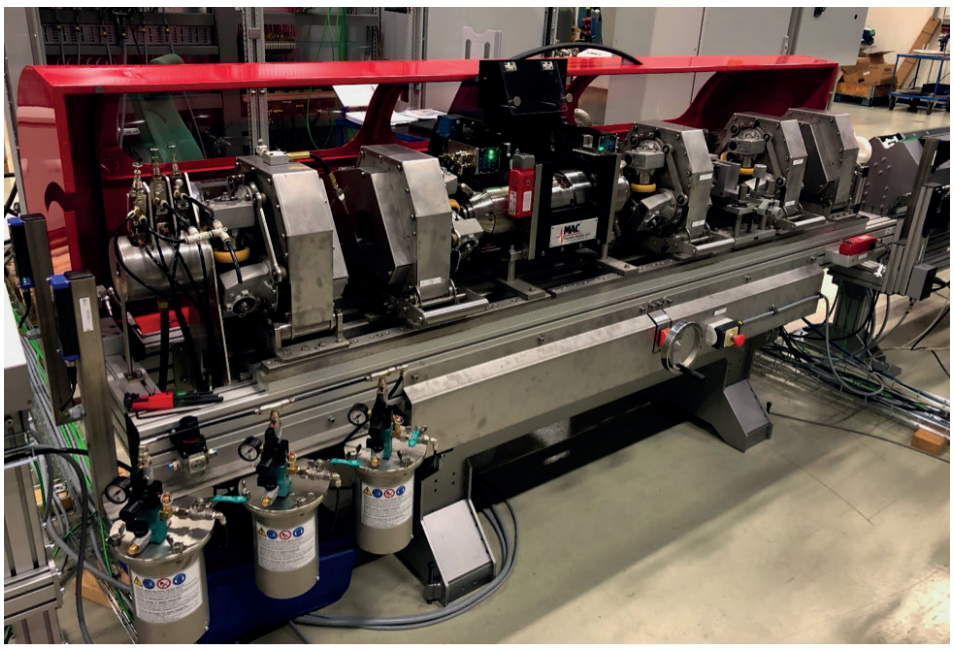

Figure 3: Picture of an Echomac® UT-25mm rotary system that includes an Eddy Current mounted encircling test coil. The Rotary UT inspection line is capable of inspecting the material passing through it in up to 8 directions of interrogation. It can test for internal (Normal incidence), CW Shear, CCW Shear, Transverse FWD, Transverse REV, and more. This NDT system can test bars or tubes.

About the Author

Joseph Baldauff, Vice President – Technology for Magnetic Analysis Corp, has over 40 years of experience in the field of nondestructive testing specifying, installing and implementing eddy current and ultrasonic inspection systems for production mills throughout the world. 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.