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How the use of Probably of Detection (POD) analysis to support Non Destructive Testing gives Mannesmann Stainless Tubes additional validation in the quality of its seamless stainless & nickel alloy tubes and pipes.

With applications for CRA (Corrosion Resistant Alloys) being exposed to ever challenging operational environments requiring unfailing performance additional expectations are placed on materials along the complete supply chain.

Having extensive experience over nearly six decades Mannesmann Stainless Tubes (MST) is committed to continuous improvement in its products through the use of the latest NDT (Non Destructive Testing) techniques. Validation of statistical evaluation of NDT data becomes increasingly crucial with Probability of Detection (POD) analysis providing an essential role.

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Mannesmann Stainless Tubes is a leading manufacturer of seamless stainless steel & nickel alloy tubes and pipes with one of the largest product portfolios in the sector. Consistent high quality products and efficient service have contributed to its long-term success. Maintaining successful long-term relationships with its customers and partners has come through adding value and innovation in its technical service to provide additional confidence and assurance in its products. Mannesmann Stainless Tubes' experts are constantly striving to adopt the latest modern production technologies to meet the ever more stringent product specification and performance requirements. NDT (Non Destructive Testing) is one of the key processes to provide product quality assurance.

Customer preferences: a strategic choice.
Nearly all sectors of industry are facinwg increasingly challenging product performance requirements which in turn have led them to develop individual specifications per product type, material grades, applications, fabrication and installation.

In the case of Corrosion Resistant Alloys (CRA) seamless tubes and pipes, especially in the case of austenitic-ferritic materials such as Duplex and Super Duplex, product specifics will include additional mechanical and metallurgical laboratory tests, but also non-destructive testing (NDT) which in some standards and specifications are either not required or optional.

As a long established industry partner and in response to many end-users recommendations, Mannesmann Stainless Tubes have long since integrated NDT as a systematic control of their products for key market segments - whether specified or not. Through its collaboration with end-users and industry partners Mannesmann Stainless Tubes' acquired knowledge and experience is applied to the most suitable NDT method relative to the product application.

Manufacturing Process Reliability

The reliability of the manufacturing process using both fundamental knowledge through R&D activities such as numerical simulation, advanced laboratory testing, in situ trials, training and operational knowledge through manufacturing procedure qualification, risk analysis, action plans, is mandatory to monitor and define the correct and essential parameters for the quality assurance of both processes and products.

Continuous improvement in MST's manufacturing process through evolved Failure Mode and Effect Analysis (FEMA) techniques provides additional levels of assurance in the quality of the finished tubes & pipes. However, despite the reliability of such manufacturing processes to reach a point of complete product validation with the detection of non-acceptable indications further NDT procedures are used, thus providing MST's customers with full confidence in the final product.

In this context, understanding and characterizing the operational efficiency and sensitivity of the production mills NDT equipment is a pre-cursor for further continuous improvement. This also supports increasing requirements from both customers and specifications to provide statistical analysis data on the inspection process capabilities. POD in combination with PFA (false alarm rate) offers an important resource to give answers to these needs.

Selection of the generic NDT technique from the many available is critical.

The range of NDT methods available is abundant with the techniques often being complementary.

They are divided into two families: volumetric control and surface control. The most commonly used volumetric methods are Ultrasonic testing (UT) and Radiography testing (RT). The most commonly used surface methods beside Visual testing (VT) are the Electric test (ET) in our case Eddy Current test, Magnetic Particle (MT) and Dye Penetrant (DPT).

For CRA seamless tubes and pipes besides VT, ET and DPT, that would typically be considered as near surface product examination, UT is specified as one of the most efficient industrial methods to validate the soundness through the complete wall thickness of the product.

Ultrasounds are mechanical vibrations which propagate in solid or liquid media. The principle is to transmit an ultrasonic wave that propagates through the tested component and is reflected in the manner of an echo on the obstacles it encounters (anomalies, tested component boundaries). These waves are emitted by one or more sensors, each managed by an operator or via an automatic system. Today, advances with the miniaturization of connecting plugs, the segmentation of sensors and the improved speed of signal processing all combine to enhance the science of the production of the ultrasonic beams – leading to the technology that is "phased array".

A phased array ultrasonic transducer contains a number of separate piezo-electric elements in a single housing, and phasing refers to how those elements are sequentially pulsed. A phased array system is normally based around a specialized ultrasonic transducer that contains many individual elements which can be pulsed separately in a programmed pattern. These transducers may be used with various types of wedges in either a contact mode or in an immersion method. The shape of the sensors may be square, rectangular, or round and the test frequencies are most commonly in the range from 1 to 10 MHz. The phase array technique through optimization, allows the detection of very small indications even when of an oblique configuration. The reason being that, by applying different delay laws generating the electronic deflection, it is possible to obtain a variation of incidence angles without mechanical adjustment of the sensor orientation. Each delay law provides a specific beam deviation which enable to detect easily indications having different angle orientations with regard to the tube axis. Another valuable advantage is linked with the translators balancing through electronic compensation ensuring a better consistency / reproducibility in the control.

Mannesmann Stainless Tubes has chosen different UT-benches in their several manufacturing locations to implement the POD analysis, like Figure 1.

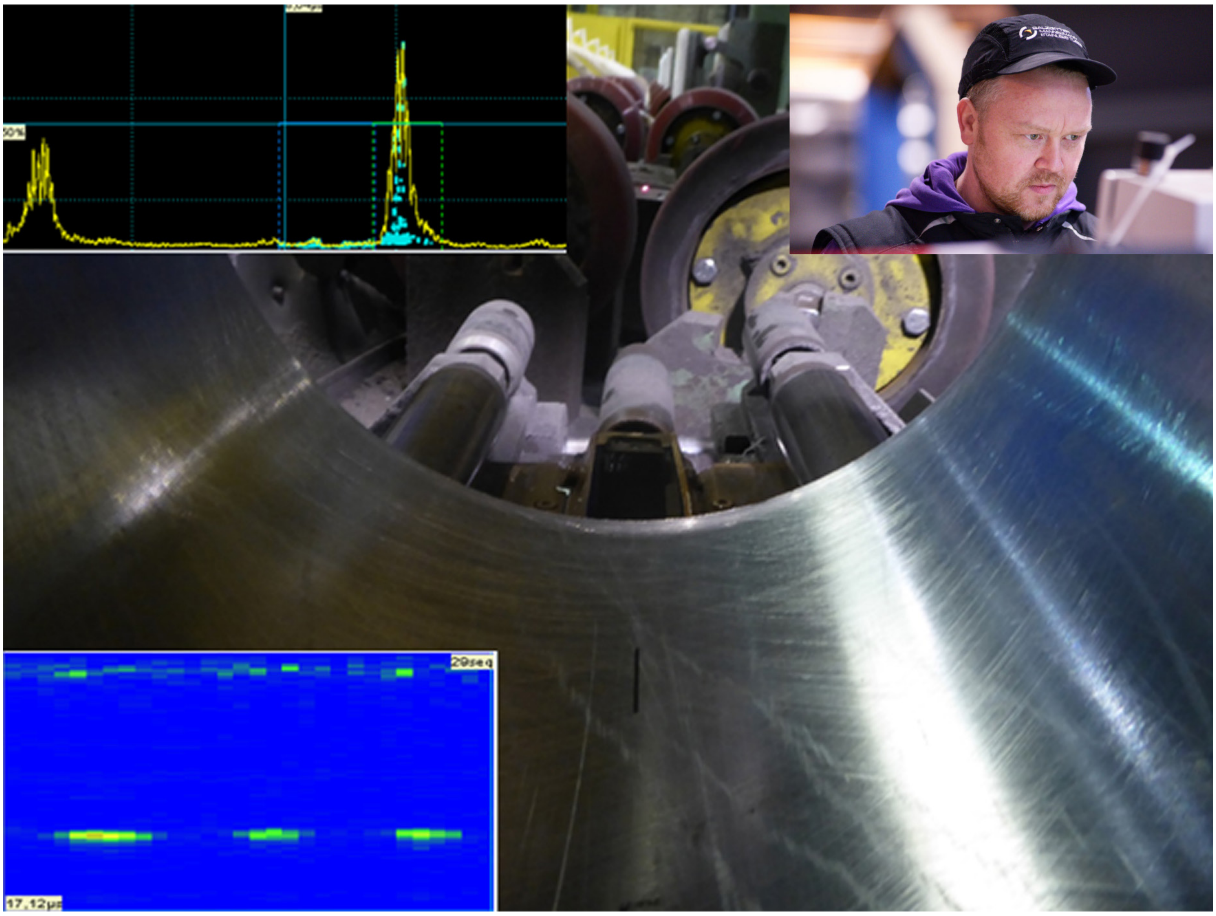

Fig. 1: Ultrasonic testing: semi immersion method while applying POD method

After several test runs on exactly defined test tubes a statistical analysis describes the potential parameters for the optimization of the system.

Figure 2 shows an example of results of a POD performed in one of MST's mills. Five tubes with notch depths ranging from 0.05 mm to 0.15 mm were investigated. At the beginning for reference, the standard tube with a notch depth of 0.10 mm was used for calibration. Following this setup, each tube was tested many times with given UT bench parameters. The figure shows the amplitude distribution for the investigated notch depths. The solid line represents a regression of the data points. The dashed line represents the 95% confidence bound on the regression line. The dotted line represents the 95% prediction bound, i.e. the assumed amplitude distribution in 95 out of 100 cases. Following this step of acquisition the data is processed and a Probability of Detection is then calculated as a specific performance characterization of the applied method for the given equipment and procedure.

ACRONYMS

CRA	Corrosion Resistant Alloy
DPT	Dye Penetrant Test
ET	Electric Test
FMEA	Failure Mode and Effect Analysis
MT	Magnetic Particle Test
NDT	Non-Destructive Test
POD	Probability of Detection
RT	Radiography Test
UT	Ultrasonic Test
VT	Visual Test

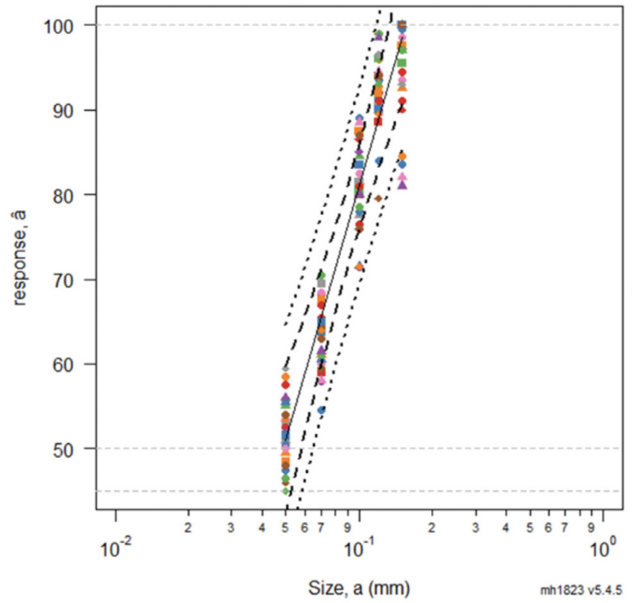

Fig.2: Amplitude distribution for notch depths 0.05-0.15 mm. (log. x-axis)

In adopting this approach the mills have identified the technical reasons of single variations and implemented corrective actions to continuously optimize them.
Furthermore, a methodology for the quick evaluation of the POD results developed by SZMF (Salzgitter Mannesmann Forschung) has made the plants completely autonomous in the yearly evaluations that are performed. Following this successful implementation the next focus for POD technique implementation are the Eddy Current and other continuously working NDT- systems.

By continuous management of this method, MST obtain the full evaluation of its bench efficiency with regard to the applied specifications and limits. In addition, this approach is highly efficient in comparison to the other techniques which consist to lower the reference notches sizes regardless of their probability of detections in view of increasing the detectability of detrimental indications.

Adopting this quality strategy has enabled MST to characterize the different types of indications associated with each product and process whilst also taking into consideration the needs and requirements of the ultimate end use applications. From this MST is able to define the best methods and techniques to be applied to each generic NDT requirement. When combining this with the long existing philosophy of ensuring its NDT operators are always trained and qualified to the highest industry certification standards MST is able to ensure its commitment to continuous improvement is reflected in the confidence of its Customers.

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