Automated systems for ultrasonic testing of steel plates

Institut Dr. Foerster GmbH & Co. KG (FOERSTER), headquartered in Germany, has been one of the world market leaders and internationally known for over 60 years, for its technological expertise in the development and production of instruments for non-destructive testing (NDT) of metallic materials. The company develops and realises solutions ranging from one instrument up to entire test sections for demanding operating conditions in close cooperation with its customers from the metal producing, metalworking, automotive supply and aerospace industries. This article deals with FOERSTER's enhancements to the proven NDT solutions as, in times of rising demand and severe cost pressure, automated ultrasonic testing systems for semi-finished products, such as heavy plates, can contribute significantly to cost efficiency and quality.

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In 2014, NDT Systems GmbH, a pioneer and world market leader in ultrasonic non-destructive testing of heavy plates, was taken over by FOERSTER. The two companies had co-operated efficiently for many years, combining their major competencies – NDT Systems' ultrasonics and FOERSTER's eddy current – for quality testing in rail production.

FOERSTER's new sector, NDT Systems, technologically complements the existing range of products and, therefore, provides additional value to customers in different testing applications. The FOERSTER Group, comprising 10 international sales and service subsidiaries, representatives as well as 60 well-trained field engineers and highly experienced technical support teams in over 60 countries, acts as a 'Hidden Champion' on all continents and offers its customers access to a well-established worldwide service network.

ULTRASONIC TESTING OF PLATES

Globally valid inspection standards are fundamental to the vast majority of purchase orders for semi-finished products, such as heavy plates. With DEFECTOPLATE™, a highly developed automated ultrasonic testing system, FOERSTER now offers a well-established NDT solution, especially for the inspection of heavy and thick plates in the steel and pipe industries. One of the main advantages of this testing system is its modular design, which combines proven components to achieve the highest functionality and process suitability for the best price. The know-how behind the 70+ available systems ensures flexible adaptation of the testing system to meet individual customer requirements, as the commitment is not to provide just any solution, but the most suitable one.

Depending on the production layout, the testing systems are designed to be either installed above or integrated beneath the roller table. Both variants provide an inspection speed of up to 1,000 mm/s, making them fast enough to stay concurrent with the production line and, therefore, suitable for even the highest production volumes. Each design has characteristic advantages. For example, systems that test from above can be easily equipped with a transverse front-and-tail inspection device to minimise untested transverse edges, avoiding falling debris and coupling water, hence reducing their exposure to contamination. This configuration is especially good for both off-line testing of ready-cut plates or on-line, after the cut-to-length cropping shear.

Systems that test from below provide a better view on to, and accessibility of, the roller table, as well as protection from damage due to plate transport by crane. A particularly practical placement for these testing systems is in-line between the cooling bed and the shearing line, as this position both minimises untested edges and covers the crop margins during a complete body and edge inspection, virtually eliminating uninspected edges in cut plates. As the scrap on transverse plate fronts and tails is usually greater than on the longitudinal edges, the system does not require an additional transverse inspection device or the plate to be stopped in order to perform this inspection. Furthermore, a separate service area is installed to one side of the roller table, depending on the production layout and the plate feed direction. This allows maintenance to be performed in a protected environment without interrupting production lines, as inspection carriages can be moved to the service area while the roller table continues to operate. Its flexibility and utility make DEFECTOPLATE™ an ideal solution, not only for

Attribute	Value
Length	3,000 ≤52,000mm
Width	600 ≤5,400mm
Thickness	4 ≤200mm
Temperature	0 ≤110°C
Surface	As-rolled – free of dirt, oil, grease, paint, loose impurities and loose scale

Table 1 Plate characteristics (deviating values upon technical clarification)

newly designed production lines, but also as an additional installation into existing lines with limited space.

COMPONENTS OF THE TESTING SYSTEM

All modules are robust and suitable for use in rolling mills, providing for long life and operational safety with a low maintenance requirement. The functionality of existing modules has been proven in long-term field testing, allowing DEFECTOPLATE™ to cover a wide range of products (*see Table 1*).

The plate width is scalable, requiring modifications to the body inspection carriages. Body and edge inspection carriages are defined as main components and by engaging all the inspection carriages, the testing system provides complete, single-run inspection coverage, except for defined untested longitudinal and transverse edges.

The body inspection carriages A and B are the individual bases for probe holders and media supply, as well as for the control and signal cables and their corresponding sensors (*see Figure 1*). Providing 50mm of inspection width per probe holder, the maximum plate width is the reference basis for the total number of probe holders required on both body inspection carriages. In the 'inspection' position, the two carriages (A and B) are locked in an off-set position to ensure their inspection tracks result in full coverage of the plate body.

The edge inspection carriages D1 and D2 are each equipped with one probe holder of 100mm inspection width (*see Figure 2*). Their basic function is to reduce untested longitudinal edges down to ≤5mm by following the contours of the edges, complementary to the body inspection coverage. For transverse edge inspection, one longitudinal edge inspection carriage is designed with a rotating mechanism that inspects the plate front and tail. This feature is indispensable when testing final-cut plates.

The testing system can be set to accommodate any plate dimensions. All body inspection probe holders necessary for scanning a specific plate width are selected automatically by the system's PLC during an initial inspection sequence, without requiring any operator involvement. The evaluation software combines the results from the individual body and edge inspection tracks.

Fig 1 Ultrasonic testing system in operation, showing body inspection carriages A and B for full coverage of plate body in one run

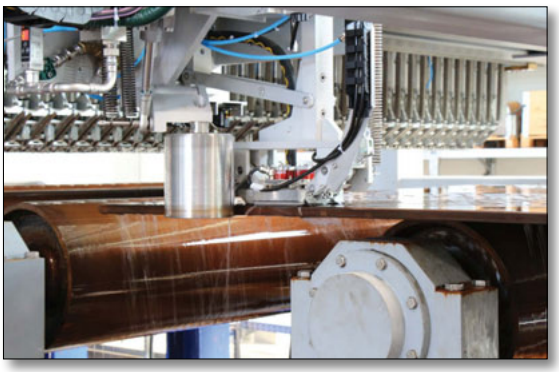

Fig 2 Ultrasonic testing system in operation, showing carriage D for simultaneous longitudinal edge inspection

Auxiliary components further enhance the functionality of the system, tailoring it to suit a broad range of processes. The automated inspection sequence is started when it detects a plate (via a light barrier) entering the system, reducing the speed; plate data is then routinely requested by the Data Evaluation Unit (DEU) from Level 2. To ensure uninterrupted inspection, the PLC provides travel and speed commands to the rolling stand's control system. Next, the plate temperature can be measured (via infrared sensor) and its height detected to prevent thermal and mechanical damage. When defined limits are exceeded, inspection is stopped so the plate can be removed.

The automated testing system is equipped with at least two odometers, exposing potential flaws in plate feed as well as providing longitudinal resolution via distance-triggered shots. Information about plate width and position within the boundaries of the roller table is also provided by the light barriers, assigned to the selection of probes via the PLC to be used for body inspection.

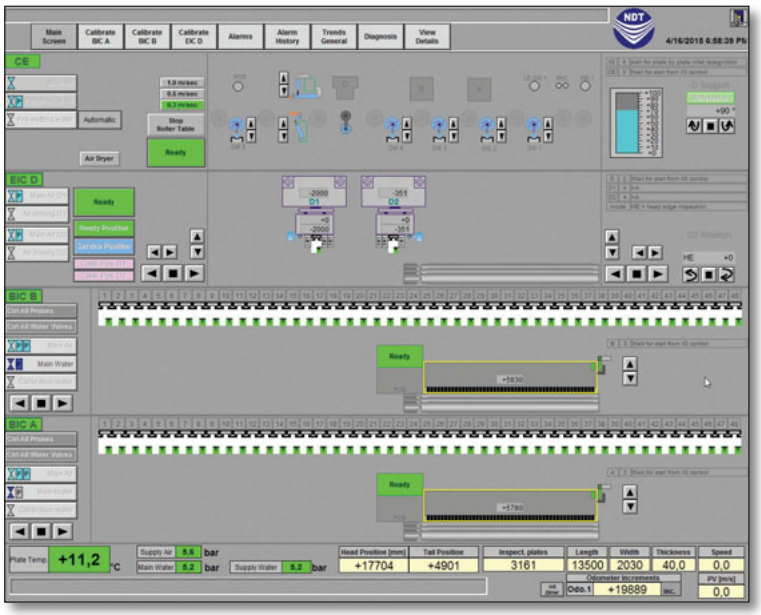

Fig 3 **Sample view of WinCC user interface for a testing system designed for inspection from above**

Inspection parameters	
Inspection speed	≤1m/s
Distance between two inspection shots	≤1mm
Sensitivity	
Over entire thickness range	3mm FBH (Flat Bottom Hole)
Over limited thickness range	2mm FBH
Untested zones of the plate	
Probe side	1.5mm
Probe opposite side	1.5mm
Minimum untested edges	≤5mm

Table 2 **Inspection standards**

Because ultrasonic inspection requires unbroken contact between the probes and the tested object, the probe holders provide an adjustable water gap as transferring media. When inspection is complete, a wiper is applied to remove residual coupling water from the plate, preventing contamination of downstream machinery. Upon detection of a plate leaving after inspection, the system is cleared for the next plate to enter. Utilities like compressed air and coupling water are connected to the media distribution module in the service area and distributed from there to the testing system. The main electrical cabinet is the takeover point for all cabling works and is usually installed in the control room. To minimise on-site installation and commissioning times, all testing systems are completely set up and tested in FOERSTER's assembly shop prior to delivery.

CONTROL SYSTEM

Control and inspection tasks are handled by separate software and visualisation functions, meaning that once engaged in an automatic inspection process, the operator is free to focus entirely on the evaluation. The system control is implemented using Siemens S 7, designed as a closed system that does not actively interfere with other operational equipment. For compatibility reasons, Siemens WinCC is used as the human machine interface (HMI) for system control and visualisation, making it easy for the operator to access status indication, alarm list and operation functions (*see Figure 3*).

ULTRASONIC ELECTRONICS

Used in conjunction with either simple or complex multi-channel testing systems, the ultrasonic electronics make it straightforward to configure distributed systems. The unit has a robust, compact design – achieved through a high degree of miniaturisation – that is proven for use in industrial environments. Being quick and easy to implement, it also integrates well with a variety of evaluation technologies. High-performance, standard interfaces, an extensive application of standards and low power consumption are just a few of its special qualifications.

Online testing systems collect huge amounts of inspection data: the vast number of probe shots, generated at production velocity, requires an automated data reduction method that is both fast and cost-effective without losing important A-Scan information details. These requirements are met by a technique called ALOK (Amplitude Time-of-flight Locus Curve), which is implemented into the hardware. Using this method, each identifiable reflection can be detected regardless of dimension or shading.

The distance-gain-size method (DGS) serves as the basis for assessment of defect size. The testing system automatically employs this along with additional settings

based on the transmitted plate data, ensuring the reproducibility of inspection results. Of additional benefit is the ability to execute automated reporting according to international or customised inspection standards, while the storage of inspection data preserves the option to review or re-evaluate later using different standards. At the full inspection speed of 1 m/s, the sensitivity for online testing systems is 2mm FBH (Flat Bottom Hole), not counting the untested zones, as described in *Table 2*.

EVALUATION SOFTWARE

The DEU software serves as the operation interface for the graphical display (C-scan) of the ultrasonic heavy plate inspection system. It generates an overview of all flaws detected in a probe track and displays it as a C-scan on the separate DEU screen; this can also be printed as C-scan inspection report (*see Figure 4*).

Integrated maintenance and service functions activate self-tests such as the determination of the probes' dynamic range or a check of their sensitivity; the A-scan is displayed for each probe channel selected and the raw data can be read out after an inspection run. The data from the ultrasonic inspection electronics is received, processed and stored for future offline activities. Simultaneously, the information is converted online to an appropriate data format and transmitted to the Automatic Evaluation System (AES), allowing for real-time evaluation of the inspected plate against standards (*see Figure 5*).

During automatic inspection of heavy plates, the AES software performs visualisation and evaluation tasks on the generated data, applying international or customised inspection standards. Another major advantage of using the DEFECTOPLATE™ testing system in conjunction with the AES is its extensive library of implemented standards (*see Table 3 Inspection standards*) and the ability to create customised inspection standards without additional costs. For that, the AES incorporates a module for defining – by freely combining predefined inspection criteria – up to 99 individual standards for body inspection and additional 99 for edge inspection.

The application features a single document interface (SDI) showing several simultaneously active views of the document.

In offline mode, the system allows for comfortable re-evaluation or simple viewing of the measured inspection data. For such purposes, FOERSTER provides a second AES licence with Hardlock and a floating licence so that the AES software can be installed on several offline computers. All operating modes are supported by the same executable file, whereas the current operating mode is defined by a command line parameter.

For testing uncut plates, AES provides the possibility to define, within the area of a mother plate, different ▷

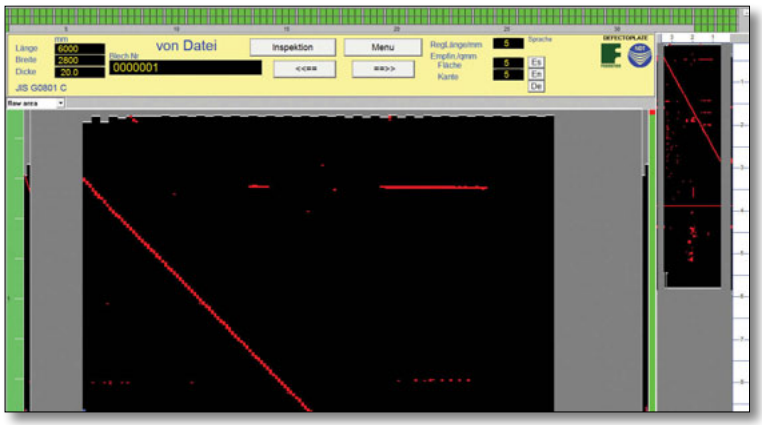

Fig 4 Sample view of DEU user interface showing results from a test plate with oblique and transverse notches

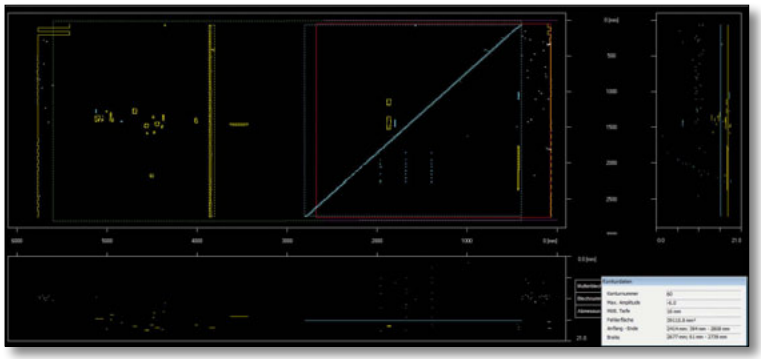

Fig 5 Sample view of AES user interface showing results from a test plate with oblique and transverse notches

Table 3 Definition of inspection parameters – (deviating values upon technical clarification)

EN 10160
EN 10246-15
ISO 12094
ISO 17577
ISO 10893-9
EU-160:1994
SEL-72
NF A04-305
BS 5996:1993
ASTM A 435
ASTM A 578
ASME SA 435
ASME SA 578
JIS G 0801
JIS G 0901
DNV OS-F 101
KS D 0040
KS D 0233
GJB 1496A-2000
GB 2970-1991
JB 4730-1994
AS 1710-2007
GOST 22727-1988

inspection standards for evaluating the ultrasonic data from individual daughter plates. All inspection data and evaluation reports are locally stored as text on the evaluation computer and sent to the production control system.

CREATING ADDED VALUE

Due to its high level of automation and robust design, the DEFECTOPLATE™ testing system has an enhanced inspection capacity of about 720 plates per 3-shift day and is therefore perfectly suited for inspection of large production volumes.

This is further enhanced by the AES software's ability to provide automated and reproducible inspection reports according to international or customised standards. Because inspection data can be stored without loss of information for later review or to perform offline re-evaluations against different standards, repeated inspection runs are no longer necessary, greatly simplifying plate handling.

Tested material is the entry ticket not only to premium segments – such as the oil and gas or shipbuilding industry – but also to higher commercial values for the 'same' product (compare the price of tested material versus the same steel grade without certificate!).

Moreover, the data generated by such systems can be used to assess the process itself: using the testing system as a process-monitoring and optimisation tool not only prevents poor product quality, but also waste of material and production time.

FOERSTER offers a global network of technical support and professional service by more than 60 experienced field engineers. Throughout the entire procedure – from the first planning phases to installed systems – FOERSTER draws on its long experience and industry-proven expertise to create the most appropriate solution for their customers, combining ultrasonic and eddy current inspection methods. **MS**

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