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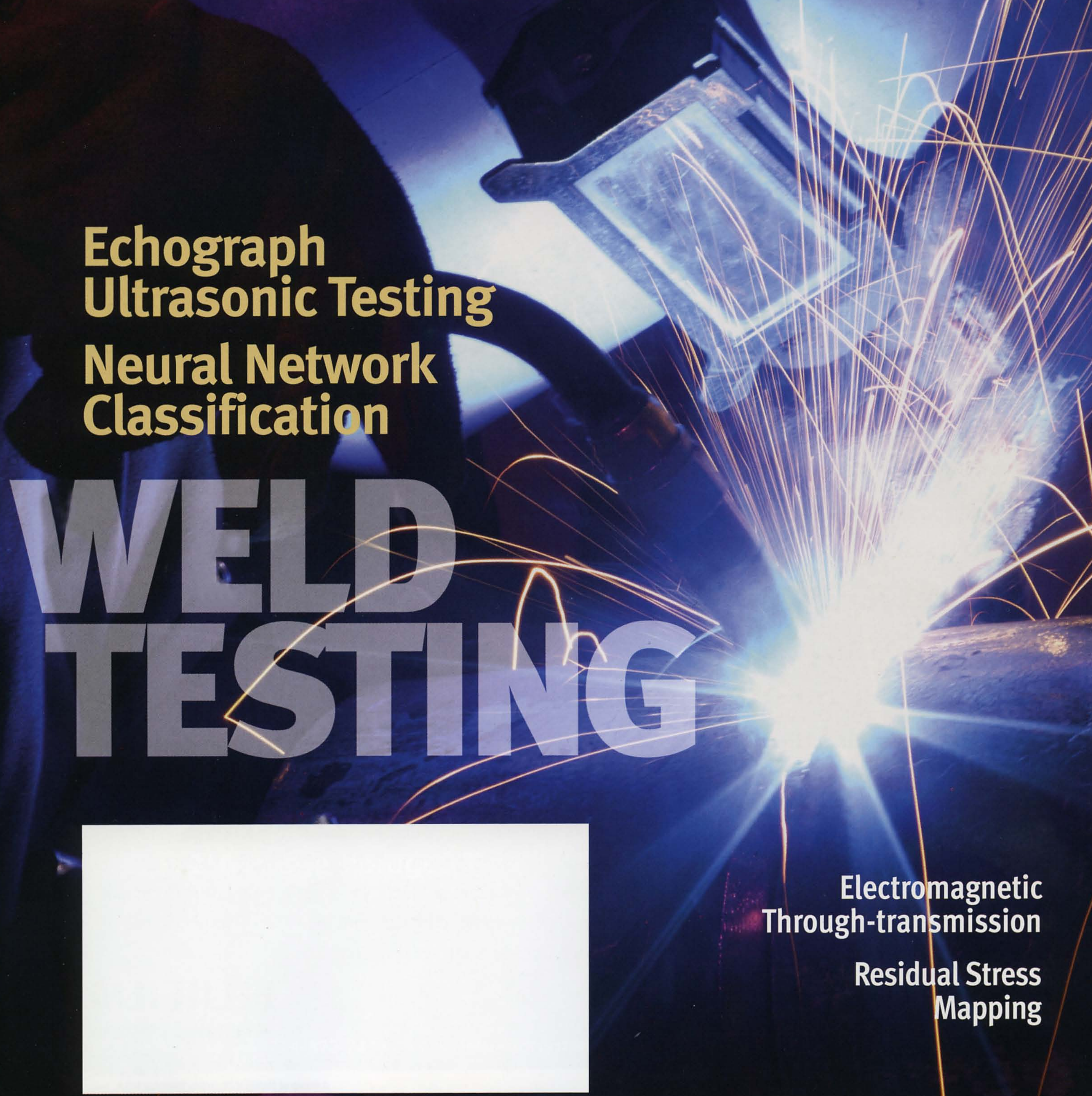
MATERIALS EVALUATION

NOVEMBER 2012
VOL. 70 • NO. 11

PROMOTING THE PROFESSION AND TECHNOLOGIES OF NDT



Echograph Ultrasonic Testing

Neural Network Classification

WELD TESTING

Electromagnetic Through-transmission

Residual Stress Mapping

THE AMERICAN SOCIETY FOR NONDESTRUCTIVE TESTING

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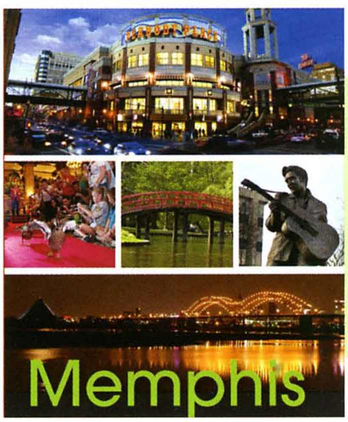
FEATURES



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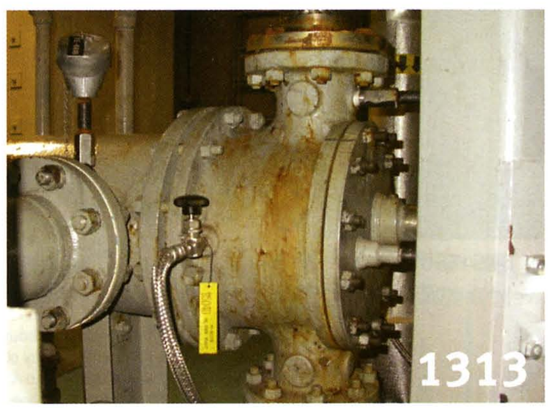
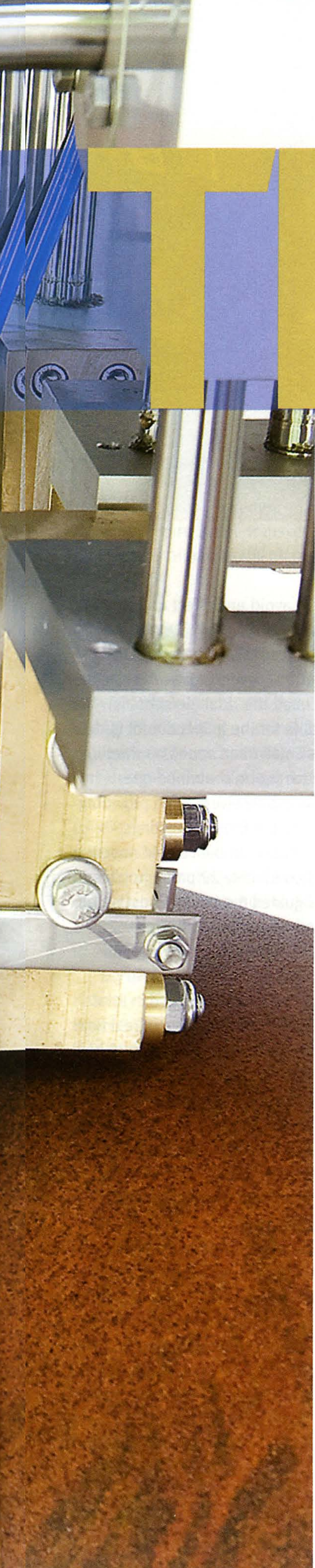


WELD



TEST

Echograph Ultrasonic Testing of Helical Submerged Arc-welded Pipes

by Wolfram A. Karl Deutsch, Michael Joswig, Rainer Kattwinkel and Martin Gessinger

Founded in 1958, the largest pipe producer in Turkey currently has an annual production capacity of one million tons of welded pipe. More than 1200 people are employed in the company's plants in Turkey and Italy. A new spiral pipe plant was recently built in Gemlik, Turkey, and full production started in 2012. The Gemlik plant is located directly on the Sea of Marmara, which eases transportation of raw materials and finished pipes by ship. Three ultrasonic testing (UT) systems were ordered to fulfill the highest quality control requirements of the oil and gas industries.

Strip Testing

A test of the pipe body is performed in the strip stage before welding. The strip widths range from 1100 to 2050 mm (3.6 to 6.7 ft). The testing speed corresponds with the uncoiling process, at a rate of up to 10 m/min (0.55 ft/s). The test specifications in recent years require a high percentage

The specified sensitivity can be adjusted electronically and automatically.

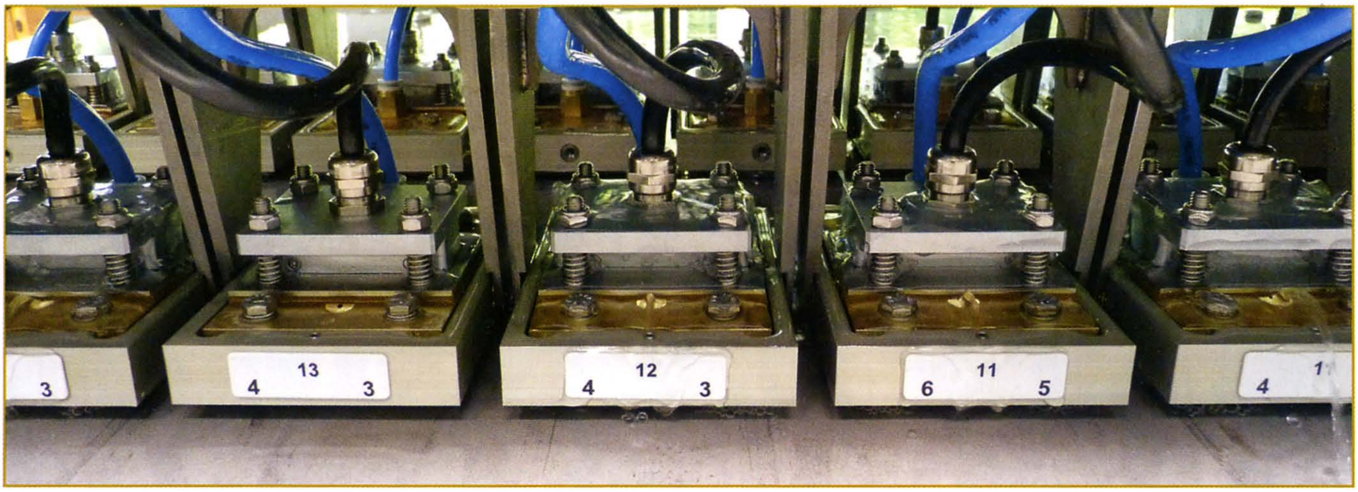


Figure 1. Strip testing with overlapping probe arrangement for 100% coverage without oscillation.

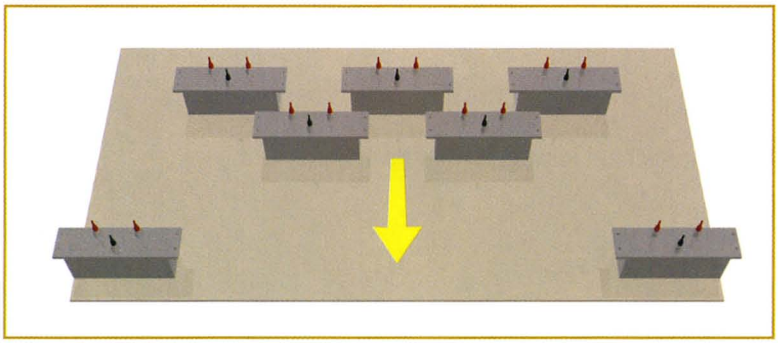


Figure 2. Testing principle for strip testing with 100% coverage. Two rows of overlapping probes are used for the strip middle. The probes with separate guidance are provided for the strip edges.

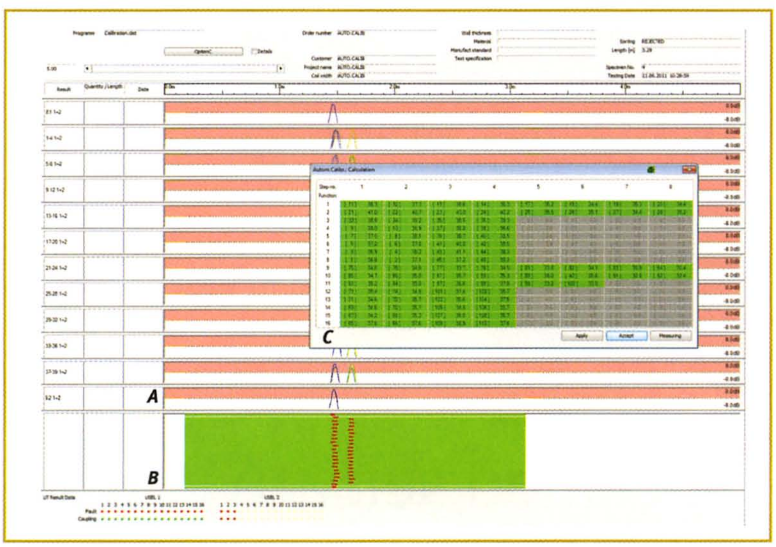


Figure 3. Screenshot of the strip testing system. *A* marks the ultrasonic amplitudes of the 83 lamination channels in 12 groups versus strip length. *B* marks the C-scan report corresponding to the top view of strip with red marks from the test notch detected by two rows of probes. *C* marks the matrix for automated probe calibration indicating that all signals are within the preset tolerance band.

of ultrasonic coverage. To avoid any effect due to mechanical oscillations (mechanical wear or vibrations that can degrade the test results), a test setup using 41 probe holders with 100% coverage was chosen, as in Figure 1. The probes used the dual-element principle, which is suitable for the inspection of fairly thin strips and provides small dead zones on the top and bottom surfaces. Each probe contained one common transmitter and two receivers, thus providing a test track of 50 mm (2 in.) per probe. A testing frequency of 4 MHz was chosen. In the case of narrow strips (width 1100 mm [3.6 ft]) only 22 probe holders were active. Steel rollers guided the two outmost probe holders along the strip edges, as shown in Figure 2. Three additional channels were provided to measure the wall thickness at both strip edges and the strip middle. Thus, 85 test channels were provided in total.

The test results could be viewed online in real time during the test. Each probe could be monitored either in a strip chart representation (amplitude versus strip length) or in a C-scan representation (top view of strip with color-coded amplitudes). Since a so-called virtually endless strip is tested, the results are scrolled on the screen continuously. A spatial resolution that is convenient for the supervision of the test can be chosen by the operator (Figure 3).

Special attention was given to the convenient and reliable calibration of the system. All probes were calibrated automatically and quickly within one step using a specially prepared test plate mounted on a movable support, as shown in Figure 4. This calibration unit allows a linear movement of the test plate with respect to the probes with a maximum welding speed up to 10 m/min (0.55 ft/s) – a difficult task because of the limited space on the carriage of the uncoiler. For that purpose, the testing system was twice as wide as the maximum strip width so that all probes could be moved from the test position (online) to the service and calibration position (offline).

The specified test sensitivity for the lamination detection is a 5 mm (0.2 in.) flat-bottom hole or 6.4 mm (0.25 in.) flat-bottom hole (API, 2004; DNV, 2000; ISO, 1994; ISO, 2007; Shell, 2000). The calibration reflector is a notch over the entire plate width: 5 mm (0.2 in.) long in plate transportation direction, with a depth 50% of the wall thickness. This allows a uniform sensitivity calibration for all probes. The specified sensitivity can be adjusted electronically and automatically. The C-scan representation is a convenient tool to supervise the calibration procedure. The overlapping probe positions can be clearly seen in the C-scan in Figure 3. The transverse notch in the calibration plate is picked up by all probes and is marked in red.

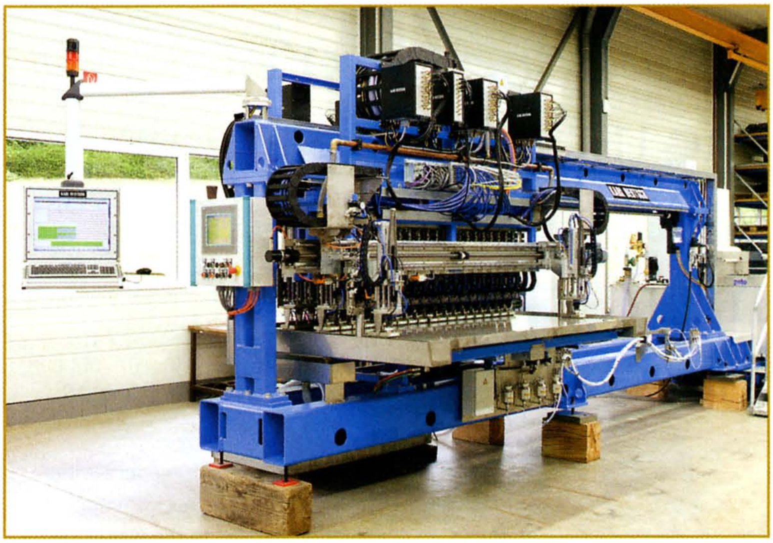


Figure 4. Strip testing machine with calibration unit. In this image, all probes are moved above a test plate. The plate support is motorized to perform a dynamic check of the calibration.

First Ultrasonic Weld Test

After the strip test, the pipe forming and welding process takes place. In many helical submerged arc-welded pipe mills, the first UT is carried out immediately after welding on the endless pipe (so-called online test) (Deutsch, 2000). The new plant in Gemlik was designed for a high production rate and operates one high-speed tack welding station and three parallel welding stands. Therefore, the pipes are already cut to customer-specific lengths and the UT is carried out pipe by pipe in the so-called offline test. Typical pipe diameters range from 508 to 1625.6 mm (20 to 64 in.), and the wall thicknesses range from 6.35 to 25.4 mm (0.25 to 1 in.).

Longitudinal and transverse discontinuity detection are the respective test tasks, as shown in Figure 5 (API, 2004; DNV, 2000; ISO, 1990; ISO, 1994; ISO, 2007; Shell, 2000). Many existing test machines use off-bead probes to detect transverse discontinuities. The K-setup uses a total of four probes; two probes detect longitudinal discontinuities, and two off-bead probes are used for the detection of transverse discontinuities in pitch-catch mode with 90° sound reflection from the discontinuity. An alternative is the X-setup, with four off-bead probes that are oriented 45° with respect to the weld seam. With the X-setup, two probes always work together for the detection of longitudinal and transverse discontinuities, again with a 90° sound reflection from the respective discontinuity. In addition, the X-setup allows constant coupling monitoring by evaluating the V-path reflection from two probes facing each other (pitch-catch mode). Both setups are difficult and time-consuming to adjust for the operator. The X-setup especially requires a lot of space within the test mechanics (Deutsch, 2008).

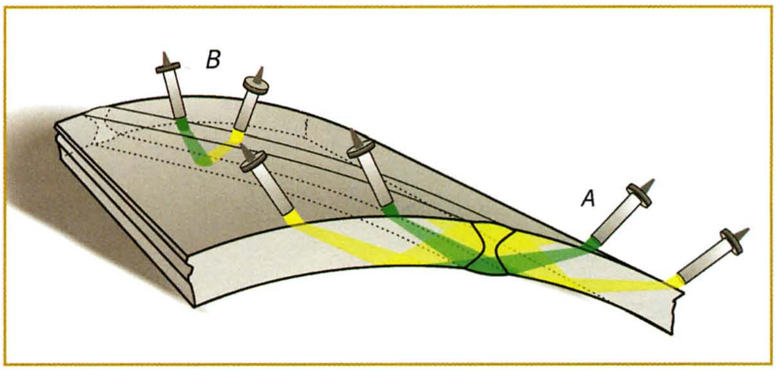


Figure 5. Probe configuration for helical weld testing with four longitudinal probes at *A* and two on-bead transverse probes at *B*.

Therefore, a new approach with two on-bead probes was designed, which is also suitable for a large wall thickness. A compact, double-probe holder using water jet coupling was guided above the pipe weld by means of steel rollers. The test angles were fixed to 45°, and the testing frequency was 4 MHz. The V-reflection (pitch-catch mode) is used for a constant coupling check. Only minor mechanical adjustments are required when changing the pipe dimension, thus enabling short changeover times. The nozzle outlet is pre-positioned just above the weld crown.

Because of unavoidable tolerances regarding the pipe diameter and ovality from the production process, the seam tracking unit is much more important for the inspection of helical welds compared to longitudinal welds. The weld crown is automatically tracked by a laser-based seam tracking system that

The evaluation of the ultrasonic signals is carried out with multi-channel testing electronics.

keeps the probe pairs centered with respect to the weld, as shown in Figure 6. A line laser pointer produces an illumination parallel to the weld crown, which is always monitored by a camera. The camera image is transferred to the operator panel and is checked by the operator for proper functioning.

The test mechanics are mounted to a machine stand with a horizontal boom. The boom must be adjusted in height in accordance with the pipe diameter to be tested. The pipe is transported by a carriage, where linear and rotational speed must be chosen such that the test position of the weld is always in the 12 o'clock position, as shown in Figure 7.

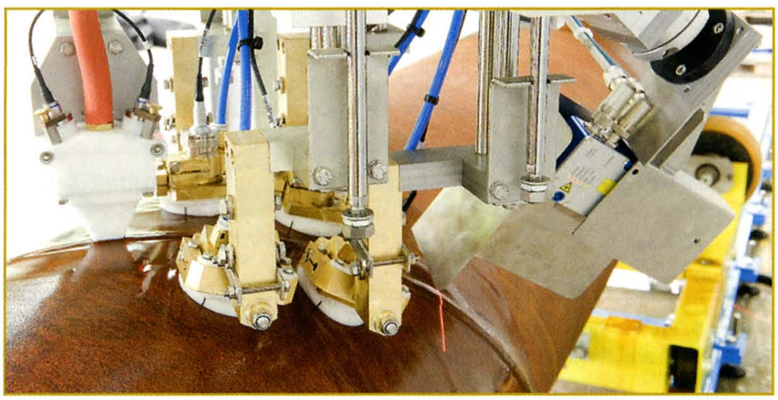


Figure 6. First weld test with six ultrasonic angle beam probes and laser-based seam tracking unit.

Figure 7. Weld testing system with machine stand and pipe before testing.

Final Ultrasonic Testing of Weld, Heat-affected Zones Next to Weld and Pipe Ends

After further production steps (pipe end beveling, hydrostatic test and so on), final UT is performed. The final test consists of three steps: test of front pipe end with rotation of pipe; helical weld test; and test of rear pipe end with rotation of pipe, as shown in Figure 8. Concerning longitudinal and transverse discontinuities, the same probe arrangement was chosen. Additional lamination probes are provided for the heat-affected zone. A test track of 25 mm (1 in.) on both sides of the weld must be covered, and because of the pipe curvature, this test task is split into two probe pairs. Four dual-element probes, each with a test track of 18 mm (1 in.) are employed such that sufficient overlap is ensured. Because of the compact design of the probe holders and the seam tracking unit, a total of ten ultrasonic probes could be mounted to the same testing mechanics. Therefore, a second machine stand (often found in combination with the X-setup for transverse discontinuities) to accommodate additional probes is avoided. The helical weld test is carried out with speeds of 10 to 20 m/min (0.55 to 1.1 ft/s).

The pipe ends deserve special attention because they will later become the joints within a pipeline. A test track of 50 mm (2 in.) is required, and laminar discontinuities shall be detected (DNV, 2000). Since the long side of the dual-element probe is oriented parallel to the pipe axis, a test track of 25 mm (1 in.) per testing channel is now possible. A dual-channel probe using one transmitter and two receivers in the same probe housing is mounted to the respective probe holder. Two steel roller guiding units are used for the respective pipe end. The rotational speeds for the pipe end test are typically 6 to 10 m/min (0.33 to 0.55 ft/s).

Echograph Testing Electronics

The evaluation of the ultrasonic signals is carried out with multi-channel testing electronics. The electronics can be programmed according to all previously mentioned testing tasks. In general, a multitude of channels is necessary, and each channel can be individually configured. The harsh environment in a pipe mill suggests the use of external pre-amplifiers close to the ultrasonic probes. The probe cables have to be

Figure 8. Final ultrasonic test of weld with 10 probes and both pipe ends with two-channel probe.

well shielded and the electronics need a large amplification range with a high signal-to-noise ratio.

The testing electronics are constantly reworked and adapted to meet situation-specific requirements. All three testing machines are equipped with separate electronics. Both weld testing machines operate one standard module that can drive up to 16 channels. The strip testing machine requires 85 test channels and is built from several modules.

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