ULTRASONIC TESTING SYSTEM FOR THE AUTOMATIC INSPECTION OF SEAMLESS TUBES OF UP TO MAX. 250 MM OUTER DIAMETER, WITH INTEGRATED TUBE END TESTING

S.Schmitz[1], P. Meyer[2], and R. Prause[1]
[1] GE Inspection Technologies, Huerth, Germany,
[2] Benteler Stahl/Rohr GmbH, Dinslaken, Germany

1.0 Introduction
1.1 General Remarks

The subject of this presentation is an ultrasonic testing line which was installed in the summer of the year 2002 in the works of Messrs. Benteler Stahl/Rohr GmbH.

Test task:
- Test objects: hot-rolled, seamless tubes
- Outer diameter range: 30 - 180 mm
- Wall thickness: 2 - 20 mm
- Untested ends = 0 mm
- Additional demand: Inspection for inner wall deformations
- Additional demand: Inspection of tubes with upset ends

For this purpose GEIT installed in Benteler‘s production line, a rotational testing machine type ROT 250 VIS and two tube end testers type REP-VIS.

1.2 Test Sequence

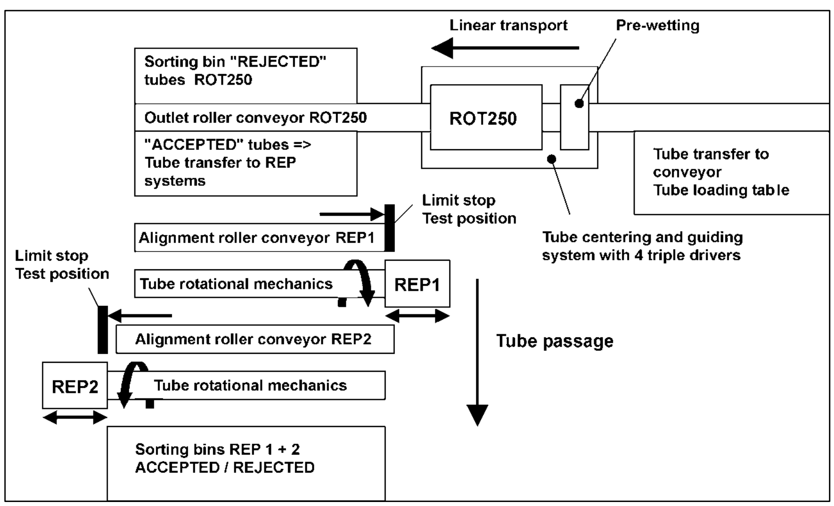

Fig. 1: Schematic Diagram / System Layout

Together with a prewetting system, the rotation tester was installed in a tube guiding unit equipped with 4 triple drivers (constant center drives).
The tubes to be tested are transported on a belt conveyor with a linear advance through the prewetting and rotational test stations. After testing in the ROT 250 VIS, pre-sorting as ACCEPTED / REJECTED tubes is carried out. The accepted tubes are transferred onto a tube loading table from where they will automatically be fed to the tube end testing unit.
A walking beam conveyor takes the tube to be end-tested from the loading table and places it on an alignment conveyor which moves the tube to a limit stop corresponding to the test position for the first tube end test (REP1). From there the tube is transferred onto a conveyor capable of

rotating the tube. The tube is brought into rotation in its stationary position, and the REP1 test mechanism moves beneath the tube end to be inspected. Afterwards the tube is transferred to the second testing station. After completion of the two tube end tests, sorting occurs in accordance with the combined test results from the REP1 and REP2 stations.
In case that no tube end test shall be performed, the tubes can immediately be transported directly to the final "ACCEPTED" sorting bin of the testing line.

2.0 Rotational Testing Machine
2.1 Rotational Test Mechanism

The rotational testing machine ROT 250 VIS (max. testable diameter 250 mm) is fully equipped with 28 probes in 8 probe modules.

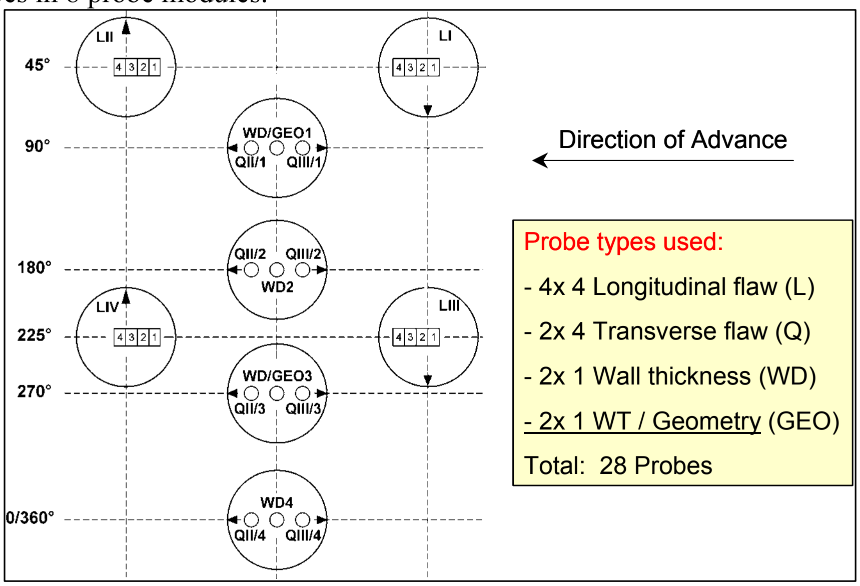

Fig. 2: Probe Configuration ROT 250 VIS

In a developed view of the rotor referred to the longitudinal axis, figure 2 shows the locations of the probe modules in the testing machine.
The system is equipped with four holders with 4-fold longitudinal flaw probes. To increase the machine throughput, always 2 diametrically opposed probes are operated in the same scanning direction.
In addition, the testing machine contains 4 probe holder modules, each of which is equipped with 2 transverse flaw probes and 1 wall thickness respectively wall thickness / geometry measuring probe.
The following test functions are possible:

- Longitudinal flaw test
- Transverse flaw test
- Lamination flaw test
- Wall thickness measurement
- Eccentricity calculation
- Outer diameter measurement
- Inner diameter measurement
- Ovality calculation
- Measurement of inner wall deformations

Of the number of 28 probes available, depending on the test mode, a maximum of 20 probes can be operated simultaneously in different probe combinations.
Depending on the test task and the flaw sizes to be detected, the maximum test speed is 100 m/min.

2.2 Inspection for Inner Wall Deformations

Conventional methods to detect such deformations utilize visual inspection or wall thickness measurement. However, these methods are critical, as the possibilities of visual inspection are limited and in areas with inner wall deformations often the wall thickness measurement is impossible, because no easily evaluated echoes are available. The two limitations were the basis for the alternative test technique used here.
The inspection for inner wall deformations is performed by means of the wall thickness measurement probes. Using vertical beam probes, a multiple reflection is obtained at the flawless tube backwall. If however the sound waves are interfered due to deformations at the backwall, the backwall echo sequence will be reduced in such a characteristic way that this will be detected by the evaluation gate.

2.3 Inspection of Tubes with Upset Ends

In addition to the inspection of plain end tubes, upset end tubes can also be tested while being fed linearly through the rotary, if the rigid guide bushes are replaced by flexible rubber seals. The inner rubber seals, laid out for the tube's nominal diameter, will expand in reaction to the incoming tube's upset end, but will later - during the testing phase - seal the probe area with the rotating water jacket within.
In order to ensure reproducible test runs, the tubes must be accurately guided by the triple drivers of the tube guiding device, because there is no more guidance while the tube passes through the rotational test mechanism. The exact center alignment of the drivers, one to the other, as well as with the rotational test mechanism is a prerequisite here.
The testable diameter range is the same as for the plain end tubes. Depending on the length of the upset end and the straightness of the tubes, the untested ends can range between approx. 250 and 450mm.

3.0 Tube End Tester

Behind the rotational testing machine are installed two tube end testers (type REP) which inspect the untested ends of approx. 50 - 100 mm length which have remained uninspected by the rotational tester.

3.1 Test Mechanism of the Tube End Tester

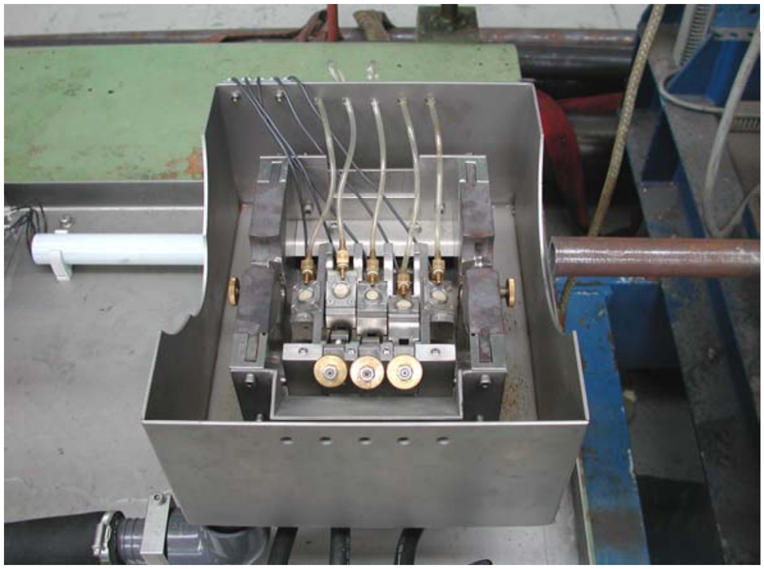

Fig. 3: Test tank of the tube end tester

The tube end test is performed using the partial immersion technique.
Each test tank is equipped with 2 longitudinal and 2 transverse flaw probes as well as 1 wall thickness measurement probe. The wall thickness probe also performs the “lamination” flaw test, the “eccentricity” measurement and the “inner wall deformation” detection.
The test tank is spring loaded, and by application of a low pressure it is brought into contact with the tube from below in such a way that it can adapt to every movement of the tube in any direction. Dimension-dependent guide elements of half shell shape ensure that the test tank tracks the tube.

Fig. 4: Inspection of upset ends with REP-VIS

In its stationary position in the test conveyor, the tube is brought into rotation and will then automatically run against a limit stop as a consequence of a slight contact pressure applied by the driven upper roll. The fixed limit stop corresponds to the tube diameter and seals the test tank, so

that the water level has the correct height when the test is started. During testing, the limit stop serves to seal the tube opening to prevent water entry into the tube.
For the tube end test, the test tank is moved at a defined advance speed beneath the tube end to be inspected.
The tank movement triggers the test data release for each probe individually, thus enabling a test start as close as possible to the tube end.
The test tank advance can be adjusted via the PLC. Depending upon the test task, the advance will range between 8 and 10 mm per revolution. Typical surface speeds range between 1 and 1.5 m/sec, depending on the straightness of the tube ends to be inspected.
Practical experience has shown that the length of the untested ends ranges between 0 and 7 mm. In case of the transverse flaw test, the length also depends on the wall thickness.
Just like in the rotational test mechanism, the inspection of tubes with upset ends is also possible in the REP tester. In case of a cylindrical outer and inner wall, the REP inspects the upset part of the tube over the entire upset length. Because the system can deactivate each probe individually, the test can be performed up to the transition area between upset end and nominal tube diameter.

4.0 Test Electronics

4.1 General Remarks

Both testing machine types are operated with a test electronics of the type VIS.
In the rotational tester ROT 250 VIS, the principal items of the test electronics are two electronic racks with 20 channel boards in total and one standard industrial-type PC with the appropriate operation and evaluation software. All channel boards operate one probe each with a pulse repetition frequency of up to 20 kHz, in parallel mode.
All channel boards are identical, whether required to perform a flaw test or a wall thickness / geometry measurement. This fact simplifies the configuration of the system for different test tasks and test modes.

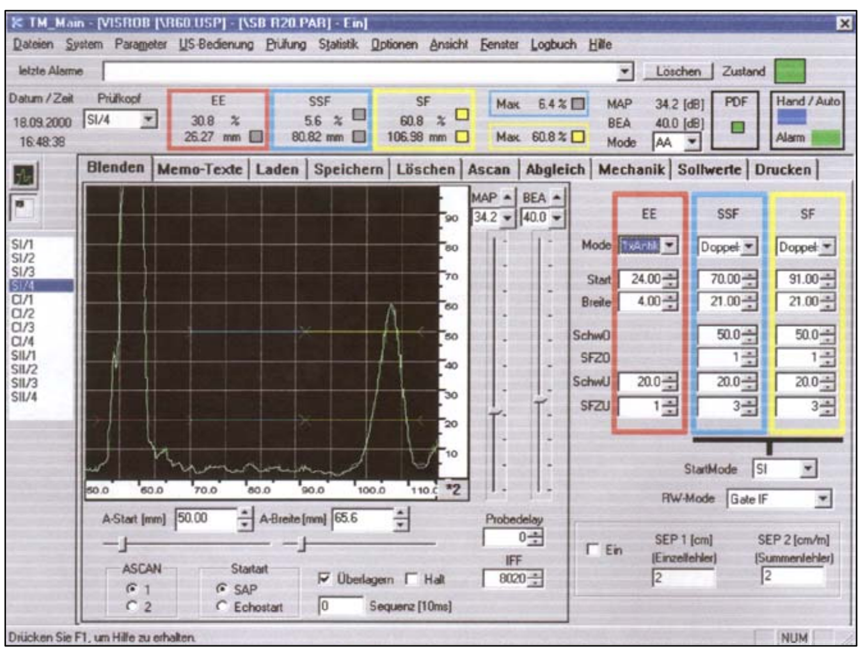

Fig. 5: Windows-based graphical user interface - Menu “Flaw test“

The complete test electronics configuration is done solely via keyboard, mouse and the Windows-based operation software on the machine’s PC.

The digital A-Scan is provided with an additional capture function for maximum values, which also records the maximum amplitudes that occur between the refresh phases of the monitor screen. This is done, so that maximum values do not get lost from the screen image. This function is of major importance during setup of the rotational test mechanism, since otherwise a maximum flaw amplitude would only be indicated if the reference flaw was detected just at the very moment at which the refreshed image was generated.
Without this function and with the rotational test mechanism in rotation, a reference flaw would only be indicated by a short fleeting signal, whereas it will be represented as a constant amplitude display when the capture function has been activated.

5.0 Flaw Documentation and Evaluation

For online and offline flaw documentation, different kinds of graphical representation are available, each of which indicates the detected flaws true to their location referred to the tube length.

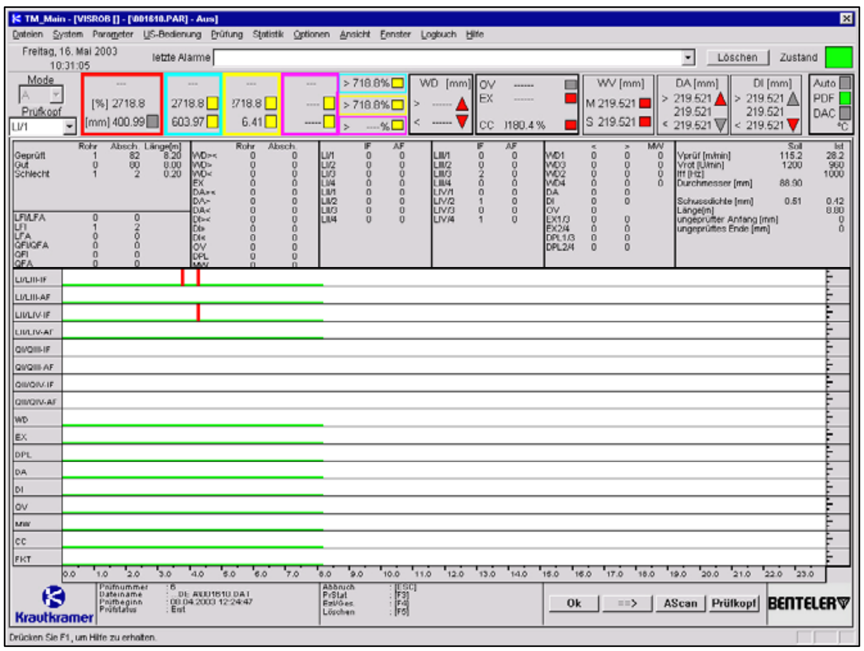

Fig. 6: ”Event Graphics“

Fig. 6 shows the “Event Graphics“ which, as a digital graphics, only indicates the location of a flaw referred to the tube length. In the upper part of the screen, different test statistics are displayed as well as a nominal/actual value comparison of the most important test parameters, such as the conveyor speed, rotational speed, test pulse distance, etc.

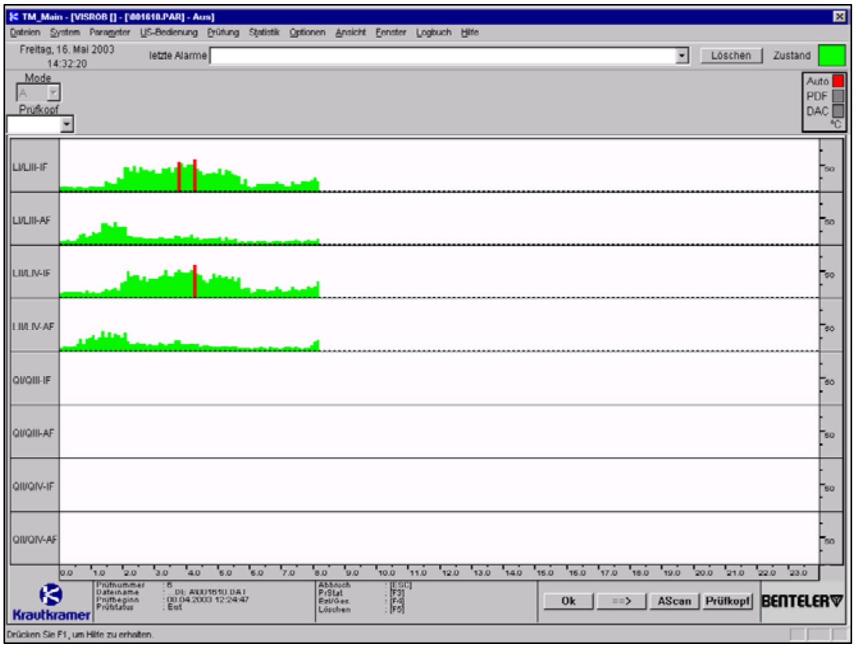

Fig. 7: Analog Graphics "Flaw Test"

In addition, the "analog graphics" also indicate the amplitudes that have occurred in a tube segment true to location, or the measured values acquired from the wall thickness and geometry measurement.
After completion of the test, the test results can automatically be transferred to a Host Computer via a coupling PC, in order to make the results available for further processing and evaluation.

Summary

- Test mechanisms for tube diameters 30 - 250 mm
- High test speeds up to 100 m/min
- Untested ends approx. zero
- Inspection of tubes with upset ends
- Flaw testing, wall thickness and geometry measurement in single testing scan cycle
- Use of advanced, self-adjusting test electronics
- Automated, electronic documentation of test results