

PRACTICAL APPLICATION OF THE PHASED-ARRAY TECHNOLOGY WITH PAINT-BRUSH EVALUATION FOR SEAMLESS-TUBE TESTING

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Abstract.

Testing seamless pipes with phased-arrays nowadays has become a preferred technique, due to its excellent detection capabilities and versatile programming possibilities. It is considered as well for the upgrade of existing lines as well as in the planning of totally novel manufacturing plants. To optimally serve the needs of the application, the same sensor arrangements can be realized within several mechanical solutions fitting to the explicit conditions in the environment. The PORTAL solution of the well-known GRP-PAT Technology is a totally novel implementation for the advanced phased-array methods. It allows to couple from above and has been particularly optimized to the transversal transportation of pipes, as it is considered in many novel plant layouts. The solutions, which allowed to transfer the phased-array methods, including the paint-brush technology, will be reported and presented with together application results recorded from the final installations.

Introduction:

Seamless OCTG pipes diameters start at 60.3mm and go up to more than 500mm depending on the method of manufacturing. Due to the high quality level of these products, extensive ultrasonic testing is carried out to ensure the integrity of the shipped pipes. Originally, tests have been carried out for longitudinal defects and transversal defects and a WT measurement has been recorded. Additionally, Lamination tests and smooth shape defect Tests are done. This is sometimes accomplished by additional tests for isolated oblique defects.

Modern machines implement a Paint Brush algorithm to extend the defect range around the longitudinal defect, which reflects the characteristic of the typical rolling process widely used in manufacturing seamless pipes. It allows finding defects, whose angle characteristics cannot easily be described by an isolated angle.

Test Mechanics

We present herein in new implementation of these techniques, based on a Gantry-Solution. While the pipe is revolving at constant speed, a carriage running on a gantry is moved linearly along the test piece. The test mechanics is mounted to this gantry. It contains in the case described herein 5 so-called probe-holders. Each of these probe-holders comprises a probe, a water chamber and a wear-plate.

During the Test, the probe-holder is set down to the pipe. The wear-plate closes the water chamber, which fills up with water, until UT coupling takes place

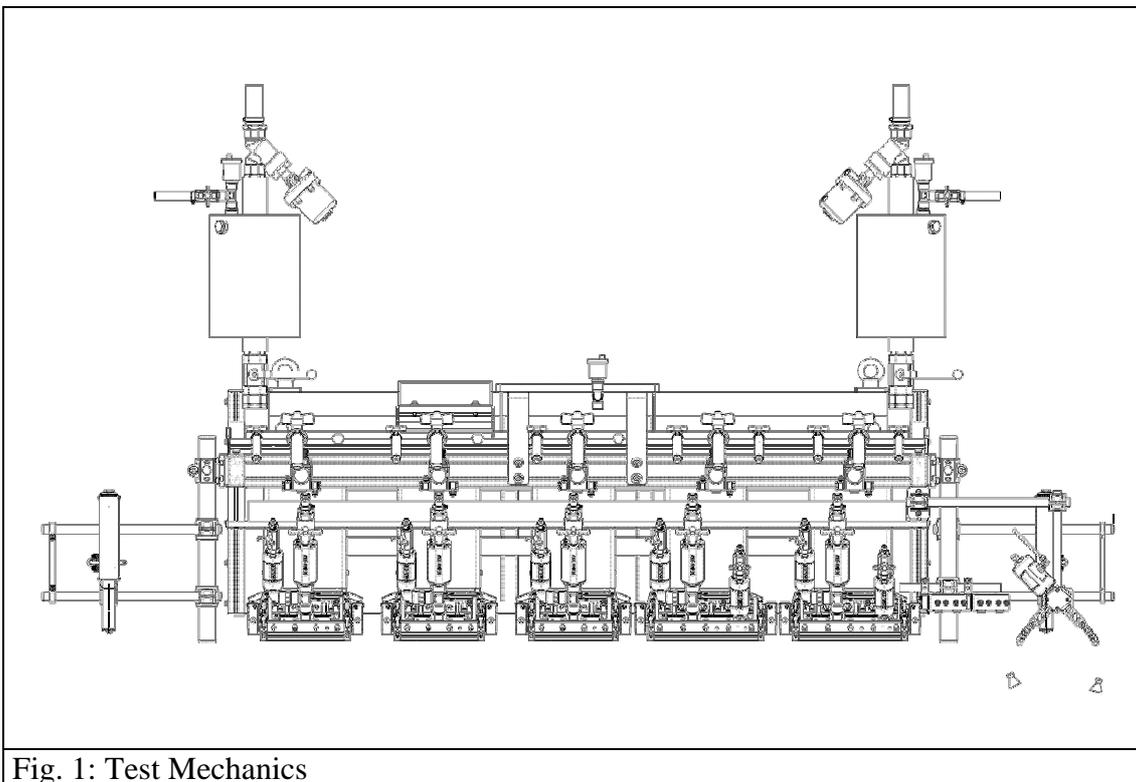


Fig. 1: Test Mechanics

Two probe holders are used for longitudinal defects. The probes are linear phased array probes, whose axis is aligned to the pipe axes. In order to check for defects in clockwise or counterclockwise directions, the probes are rotated around this axis, so the plane of inclination has an overall angle of about 17-19 degree to the pipe. The probe-holders include a separate probe to carry out the coupling check, which is oriented in perpendicular

direction to the probe holder. The coupling check is then carried out by monitoring the amplitude of the first back-wall echo from this probe.

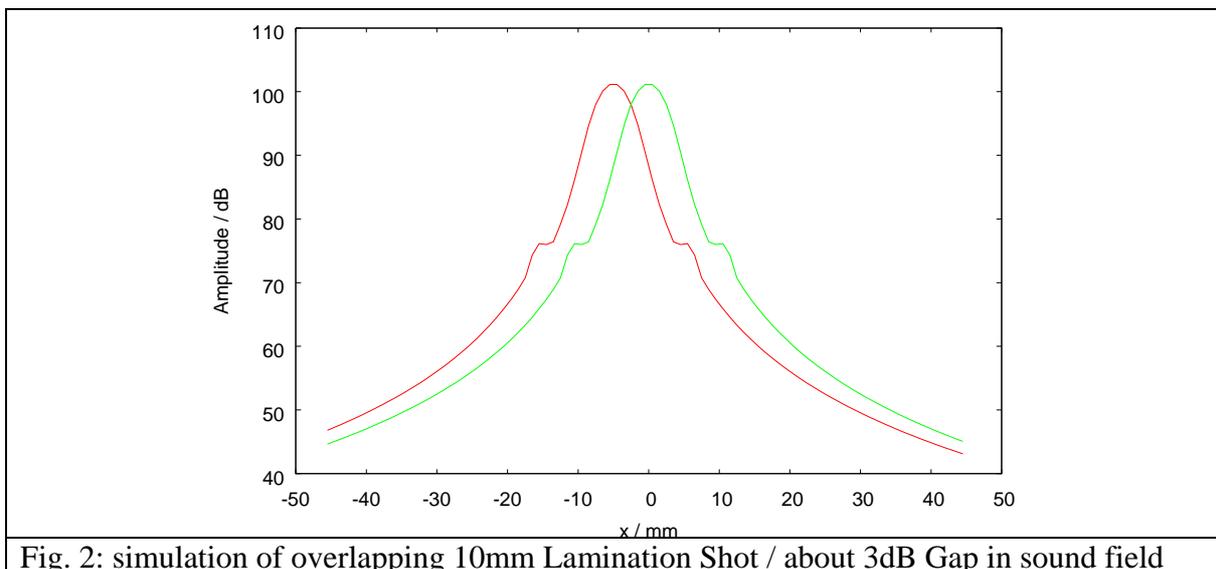
A third probe-holder carries the probe for Wall-Thickness measurement and lamination testing. The remaining two probe-holders are foreseen for transversal defect detection..

Test Principles

The main challenge for this type of machines consists in keeping the shot distances small and allowing a wide range of defects types or a small defect size and at the same time keep the test speed high. Several methods are applied to achieve this, which are described in the latter.

Wall Thickness and Lamination Testing

The probe operates at a higher frequency, so the resolution within the pipe wall is improved. It covers the complete helix of actually 120mm + overlapping. In order to allow the recognition of small laminations at short pulse distances, a 6fold parallel approach has been chosen. A parallel operation of 6 virtual probes at the same time reduces the shot distances to a factor of 6, compared to conventional scanning systems. Ultrasonically, this parallelization is uncritical. The pitch of the array has been chosen larger than the standard values, which is possible, since no steering is applied here. Virtual probes formed vary between 10 and 20mm, overlapping may go up to 75% maximum. This fits to find even small laminations of 1/4" and below. Typical radial step distances are within 2mm.



Transversal Defects

For the transversal defects as well, a 6fold electronic system has been prepared. Due to potential ultrasonic crosstalk, it is not as easy to operate 6 virtual probes at the same time, as it can be done for the WT case. For this reason, a decomposition of the transversal shots onto the two has been chosen. This allows reasonable shot distances at high speed and in particular strong overlapping, which is of major importance for TF Testing. Without causing major crosstalk issues, 2 virtual probes can be operated at the same time, if they are oriented in opposite directions. In most cases, this is the limiting factor for speed issues. Depending on the wall thickness, the size of the virtual probe varies between 10mm and 20mm.

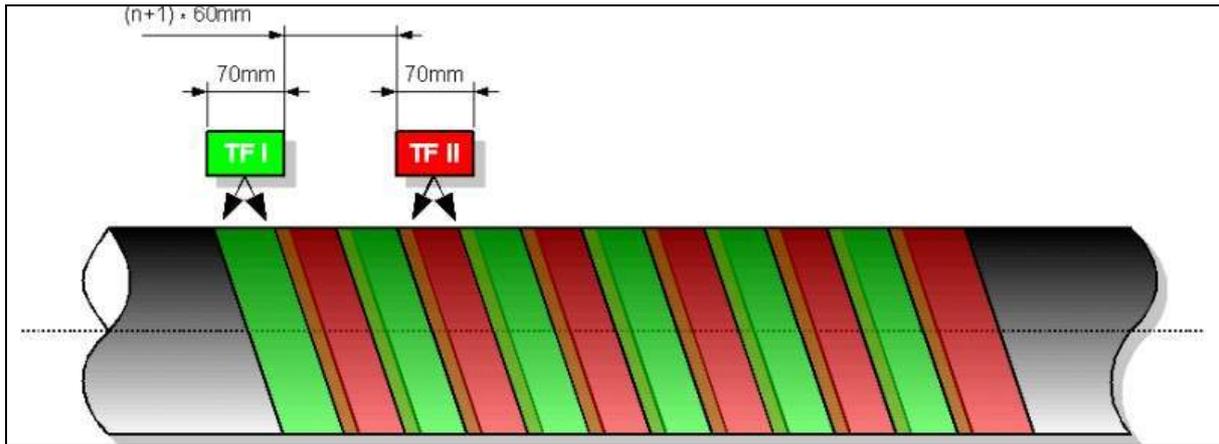


Fig. 3 Helix Overlapping

The traditional approach would mean to fire 2 Shots within one cycle. To improve this, the transversal shots are distributed over two probes. This allows shooting 4 virtual probes simultaneously. In order to Typical steps distances vary between 2mm and 4mm. Overlapping between the traces is done, to keep the total helix pitch of 120mm. The probe parameters have been chosen in order to minimize cross-effects. Inappropriately chosen frequencies or pitches lead to considerable grating lobe effects. Grating lobes irradiate into the opposite direction of the desired test direction and therefore cause a number of problems. The major issues with grating lobes therefore consist in undesired echoes from edges or pipe ends.

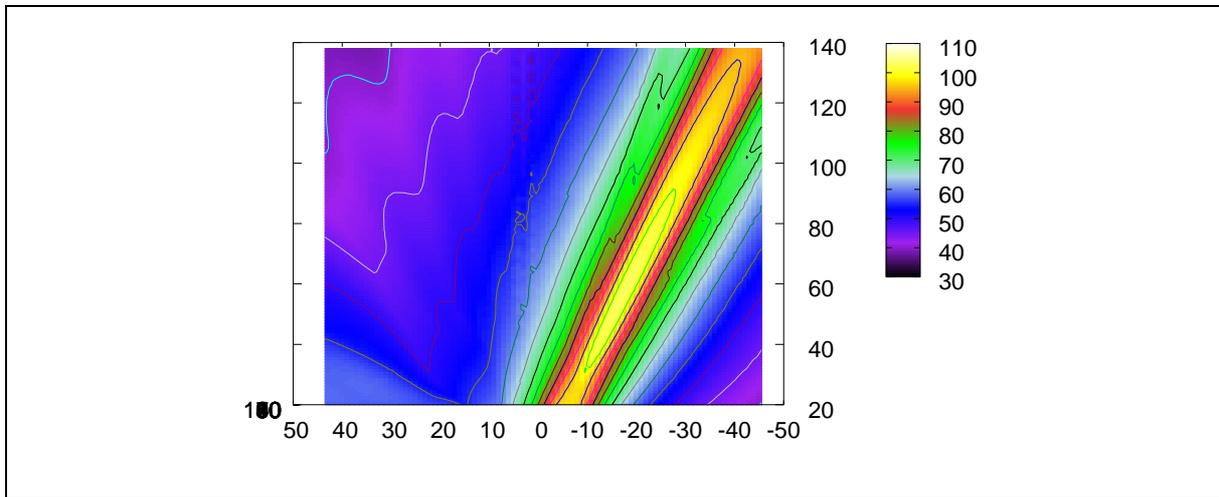


Fig. 4: Simulation of Sound Field for transversal testing (17°)

Longitudinal and Oblique defects

Defect lengths, longitudinally and oblique, are typically 1" here, so the virtual probe length is 20mm and the overlapping is 50%. In order to achieve high test speeds at small shot-distances and large angle bandwidths, the Paint-Brush Method is applied¹. It allows transforming a more detailed evaluation to the hardware processing units, which utilizes the lost time between two real shots in water-gap coupled systems.

Reference angle / ° \ Evaluation Angle / °	0	1	2	3	4	5	6	7	8	9	10
0	90	77	56	45	20						
2,5	90	95	85	67	58	45	35				
5	45	62	81	90	85	74	48				
7,5	52	80	94	96	86	75	31				
10				40	54	65	70	56	40		
12,5			25	35	43	60	85	50	38		
15					27	34	42	46	45		
20							20	21	25	25	21

Tab. 1: Signal Amplitudes for reference notches with different evaluation angles for a test pipe of 70mm

Deducing from the amplitudes on non-orthogonal fields of this matrix, we can see, that to obtain a complete coverage, two measures are necessary:

1. Use calculations for different angles.
2. Increase the gain for the larger angles.

To keep the number of additional sub-cycles within a reasonable range, the number was chosen to be 4. Due to this, a certain oversensitivity of about 20% does occur in this example. This value may vary within several dimensions and thicknesses of the pipe wall.

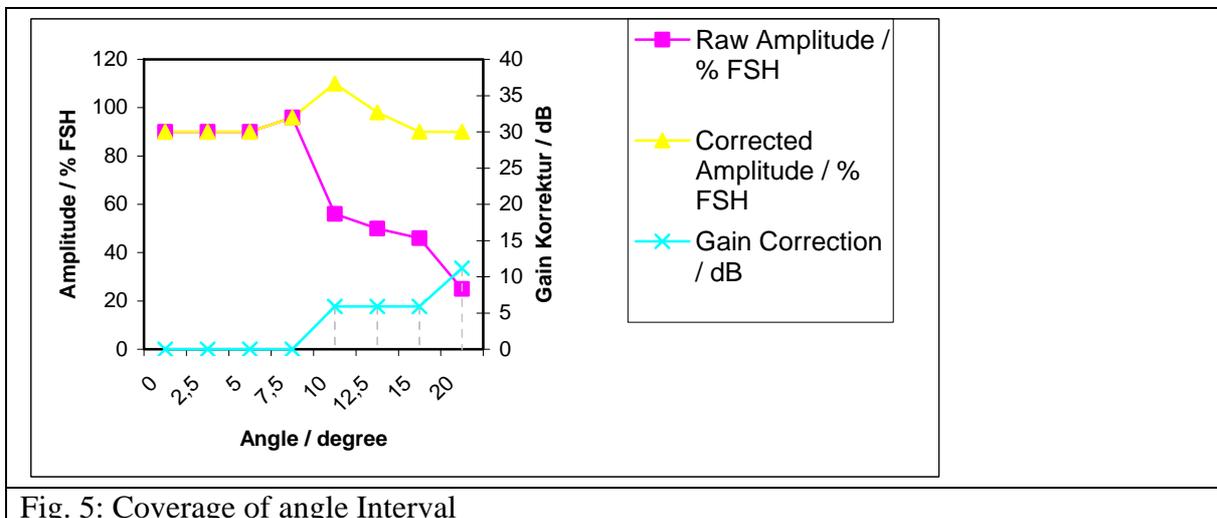


Fig. 5: Coverage of angle Interval

Special Applications

Raw Data Interface

The raw data interface is a special high-speed link from the ultrasonic electronics to the evaluation PC and the customer. While conventional evaluations are done on gated data on a shot-to-shot base, as is the standard in ultrasonic testing, the raw data is acquired from each shot itself.

For Flaw evaluations, the raw data is originating from the gate data itself in terms of its amplitude and the TOF of the triggered event. In opposite to the conventional channels, where these data are undergoing eventual averaging or de-noising algorithms, the raw data values are not treated any more. Instead, they are exported directly to the so-called ODA PC, which carries out an additional buffering and checking and position correlating of the data. From here, they are exported through an Ethernet line to the final evaluation system. For each test type, the plurality of shots on the pipe surface forms a grid. These grids look different for the various testing methods, attributed to the fact, that virtual probe sizes and overlapping are different. All of these grids share a common origin. With this information, an offline evaluation system can synchronize the grids on the pipe and correct the shot data to defect position data. This enables an enormous potential for offline evaluation, which is in particular useful for natural defects.

Not all defects have a clear orientation or reflection behavior, as it is assumed within conventional strategies. Especially for lamination type defects, not only one test method can give indications. In many cases, a plurality of signals is present within the various test channels. As an example, smooth shape defects, which are originated in the rolling process on the internal wall, may give contribution to longitudinal, transversal or oblique defect channels. On the other hand, the Wall-Thickness measurement is influenced as well. There may be cases, where each signal alone does not trigger an event, because the defect is very small.

Having now the opportunity to correlate all those indications in a common position, one could sum up, that this defect is more serious, than it is indicated by the standard channel evaluations.

The Raw Data Interface is unique to all testing systems, not depending on the special application and modality. It is therefore possible, to get a standardized and comparable overview of all test benches. Tab. 1 contains examples of results from various lines.

<p>WT Cscan representation of a pipe with smooth shape defect– zoom on the defect / GRP UT16</p>	<p>LFD Cscan representation of a pipe with longitudinal imperfection – zoom on the defect / GRP UT09</p>
<p>Complete WT C-Scan of a pipe / ROWA</p>	
<p>Tab. 2: Examples of Raw-Data generated C-Scan Representations</p>	

Virtual Drift

To ensure that a seamless pipe product can be penetrated by a cylinder with given dimensions, API 5 CT asks for the use of a drift and defines it as a “gauge used to check minimum internal diameter of tubular components”

It is a machined cylinder with known diameter and length. It is put inside the pipe to be tested and must travel through the whole length of the pipe or penetrate it until a certain distance.

This test requires several cylinders to be machined and managed depending on the dimensions of the tested pipes. This operation is time-consuming, especially when the drift is blocked inside a too narrow pipe.

In order to avoid these drawbacks, V&M is studying the possibility to perform the drift test virtually with the use of the pipe inner surface 3D coordinates.

The application of GEIT Special Raw data interface on dimensional test functions enables the acquisition of both inner and outer surface 3D coordinates of the pipe.

It is then possible to compute the possibility for a drift with given dimensions to travel through the volume contoured by the inner surface.

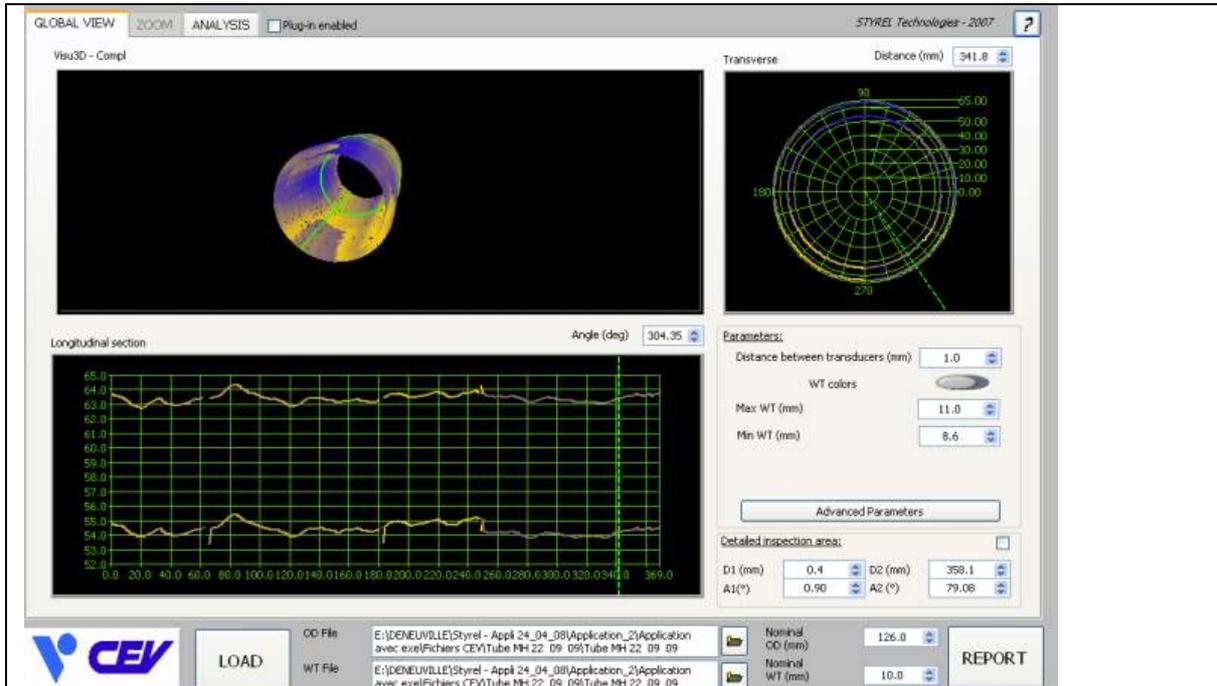


Fig. 6: Coverage of angle Interval Example of 3D representation of pipe resulting from acquisition of 3D coordinates of outer & inner surfaces through GE S&I raw data interface

Setup and Performance

Installation

The system is worked out as a full gantry with two carriages. Below the gantry is a stationary roller block device, which allows rotating pipes up to 2.5m/s surface speed. This may mean a problem for small diameters, because they are flexible and tend to vibrate at high speed. For this reason, down holders are attached to the roller-block units, which prevent the pipe from vibrating. During the test, i.e. while the carriages are moving, the down holders are removed successively as the carriage moves on and reinstalled after the carriage has passed.

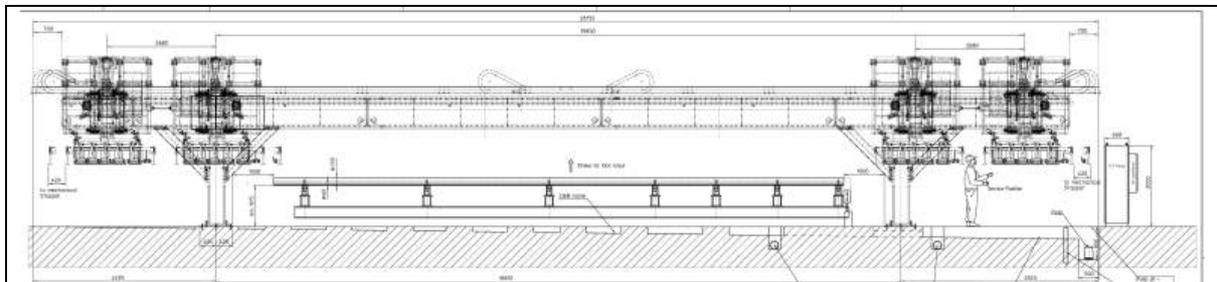


Fig. 7: Gantry Layout

Carriage number 1 tests the left half of the pipe, while carriage number 2 tests the right part of it. In the middle of the gantry, both carriages overlap, so a small part of the tube is tested twice for safety reasons.

The coupling is realized with a water gap. The water chamber is designed to allow a very fast chamber filling to reduce the unproduced time. It contains the necessary degrees of freedom to follow all the pipes movements even in case of irregular geometries.

Behind both carriages is a fully featured electronics and acquisition system. In case of a failure of one of these carriages, it is possible to go with only one of them along the complete tube and carry out the maintenance work for the other one.

The test pipes are fed into the pipe flow and loaded onto the stationary rotation unit. The calibration is carried out in the line. It is automated and driven by the central PLC of the Gantry, with which the UT System interacts.

The UT installation covers the small OCTG range, starting from a diameter of 60.3mm to 177.8mm with walls from 4,5mm to 15mm. The pipes can have lengths of 6m up to 14m. It is typically used to test more than 50.000t a year, which equals more than 630.000 pipes.

Conclusion

A system for testing of OCTG pipes with diameters starting from 60.3 mm has been described in this paper. It has been carried out as a gantry in order to fit into the transversal product flow. Using 2 carriages on the gantry, the testing time can be strongly reduced.

The testing principle is realized fully in Phased Array technology. It allows high throughput and with a large variety of detectable defects. In addition, the flexibility is very high. By using advanced evaluation algorithms like paint brush and parallelizing the electronics capabilities of the equipment, very small shot distances are possible.

Modern extensions, as for example raw data output allow to investigate the results in great depth and to carry out additional evaluations and tests, which result in a higher quality level and in the replacement of traditional working steps, such as callipering the pipe diameter. This significantly enhances the future potential of application.

References

¹ R. Pawelletz, E. Eufrazio, B. Bisiaux, M. Vahé, S. Falter, R. Prause, "PRACTICAL APPLICATION OF THE PHASED-ARRAY TECHNOLOGY WITH PAINT-BRUSH EVALUATION FOR SEAMLESS-TUBE TESTING", Proceedings of the WCNDT 2004