STATE-OF THE ART QUALITY CONTROL DURING PRODUCTION OF SAW LINEPIPES

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ABSTRACT
An essential prerequisite for a longitudinally welded large-diameter pipe to meet the most stringent quality requirements are efficient production units and the latest technologies for online quality control. To capture all data obtained during the various steps of production and testing and to control these data within close tolerances, an integrated IT-system covering all production stages - from the steel mill to the pipe coating - is indispensable to ensure a precise traceability of data and products. By an extensive automation of data acquisition and control, the factor of human errors can be excluded.

In the following we would like to give you an overview of measures and investments which have already been realized by Europipe over the last years or which are going to be introduced with the aim to meet customer's ever increasing demands on quality.

Keywords: Quality Control, PRODIS, AUT-inspection, Filmless radiography, Surface inspection

INTRODUCTION
"Bursting oil pipeline in Nigeria - Explosion of a gas line in Siberia" - these and other similar news in the media attract the attention of the public, since these accidents usually entail both considerable damage to the environment and severe injuries to persons. Although in almost all cases a defective pipe is not the primary reason for the accident, a steel pipe supplier automatically tries to find an answer to the question of how the quality of a pipe and thus the safe operation of the pipeline can still be enhanced. The term "quality" comprises more than the mere fulfillment of customer's requirements - it is also the observance of individual pipe properties within narrow limits.
to the inspection of the coated pipe. The system makes sure that a certain plate is only used for the pipe production, if all plate data (chemical analysis, mechanical properties, plate sizes) are within the specified limit values and the plate has been clearly identified and released by the system. Traceability is guaranteed, and the use of a non-conforming plate is excluded.

Figure 2: Control of all test and production steps by PRODIS

This principle of a systematic control of release is applied during all phases of inspection and testing up to the final inspection of the pipe, in order to be able to exclude any human errors. By this integrated IT system, data are provided for the statistical process control. Production data are evaluated in different quality classes in order to enable a fast assessment of the quality and a detailed defect analysis. Thanks to the mandatory recording of each production and inspection step in the PRODIS system, the customer may benefit from a constantly transparent production, which is graphically depicted in Figure 2.

Figure 3: PRODIS data entry for circumference/ovality measurement

As an example Figure 3 shows the data entry mask (dialogue) to record the measurement of circumference/ovality. The actual measured value is entered to PRODIS and automatically controlled regarding its acceptability. In the same way all dimensional measurements are captured and controlled. Statistical evaluations during and at the end of the production process form an integral part of the quality control and constitute an important element of continuous quality improvement.

NON-DESTRUCTIVE QUALITY CONTROL WITH STATE-OF-THE-ART INSPECTION AND TEST METHODS

Following details about the test methods applied in the Mülheim large-diameter pipe mill as well as an overview of the new technologies currently being developed at Europipe is presented. Figure 4 shows the different NDT methods used before and after the expansion process and their connection to the PRODIS system.

Figure 4: Non-destructive quality control linked to PRODIS

The aim of all these methods and developments is the application of objective measuring procedures, which along with an automated evaluation allow the exclusion of human subjective assessments. The following test procedures are presented in detail:

- Optical surface inspection by optical laser system
- Automatic UT-testing of the weld
- Filmless radiography
- Surface wave inspection

Optical surface inspection by optical laser system

By a new optical inspection procedure preventive quality assurance takes place in the area of the forming line. After machining of the longitudinal edges a laser system based on the light-section principle assures that potential remains of the machining like filings are detected on the plate and removed before getting pressed into the pipe surface by the forming tools.
Following the completion of the submerged-arc longitudinal weld, the pipes are subjected to a complete visual control of the inside and outside surface, in order to detect defects of the pipe body such as bulges, scratches, or grooves as well as other visible defects in the weld area immediately after the forming and welding process. This activity, which is currently performed by experienced inspection personnel, is to be replaced in the area of the weld by the same optical measuring procedure on the basis of the laser light-section principle. The prototype of the unit installed in the mill can be seen in Figure 5.

![Figure 5: Prototype for optical weld seam surface inspection](image)

Judging from the results of the first test operations, undercuts can be found with a local resolution of 1 mm and a depth of approximately 0.3 mm. The test speed can amount to 60 m/min. Further experiments and optimization are, however, required, in order to obtain a precise knowledge about the detectability and localization of different types of defects.

**Automatic ultrasonic testing of the weld**

The first ultrasonic examination of the longitudinal pipe welds by means of an automatic ultrasonic test unit is performed after the visual control and prior to the mechanical expansion. The new equipment built up in 2001 combines most modern inspection and assessment technologies with the know-how of an internal expert system. Compared to the inspection performed according to the customer requirements after the expansion process, it results in a multiple higher test sensitivity at a simultaneously reduced pseudo-echo rate. By this, areas of potential defects are reliably detected and repaired prior to the expansion process. Any post-expansion repair is neither permitted by the majority of specifications nor by the internal Europipe quality standard.

Within the scope of a large-scale investment in 1995, the Mülheim and Dunkirk pipe mills were equipped with a computer-controlled ultrasonic test unit for inspection testing (Figure 6). In order to guarantee a reliable and trouble-free inspection, a completely new solution was found for the sound coupling. The weld is tested in the so-called 12-o’clock-position and the ultrasound is coupled by means of the water jet procedure. Unlike the conventional water gap coupling, this procedure does not cause the probes to wear out and allows also at a inspection rate of 10km/day reliable and constant test conditions. In order to avoid possible irregularities during the test as a result of the pipe movement, the test unit travels along the stationary pipe in a frame construction. The test probes of the different planes are guided along the weld individually. The newly developed test probes with composite transducers (4 MHz test frequency) allow the entire pipe length to be tested for transverse and longitudinal defects. The test speed amounts to 30 m/min. at a pulse repetition frequency of 2 kHz. The resolution is 0.25 mm. The evaluation is performed every 1mm under consideration of the maximum of the corresponding 4 values.

![Figure 6: Automatic weld seam ultrasonic inspection](image)

Figure 7 shows the test probe arrangement of the basic setting (test mode A) using 5 x 2 probes for the detection of longitudinal and 2 x 2 probes for transverse defects. The latter are guided on the weld in a line pattern. They are oriented in opposite directions in pairs. The test probes are operated in the pulse-echo-mode or as pairs in the tandem procedure. In addition to a possible distinction between inside and outside defects, this test arrangement offers the advantage that the entire wall thickness in the weld area is tested with a uniformly high sensitivity. By altering the test probe arrangement and adjusting the testing technique, this unit also allows the heat-affected zone adjacent to the weld to be tested for transverse defects or laminations. The overall positive experience gained with this test equipment has of course been transferred and developed to the ultrasonic test equipment upstream of the expander.
Use of the filmless radiography

All indications found during ultrasonic testing, all repairs of the weld as well as the pipe ends are subjected to radiographic testing, which means that the Mülheim large-diameter pipe mill produces a daily quantity of up to 1000 radiographs, each of which is to be evaluated and listed. A large part of the films is submitted to customer's representatives in connection with the pipe inspection. Warranty provisions require a storage of the films for a period of 12 years following the inspection. This causes a substantial logistic effort for the procurement and timely provision of the films and high storage costs. From the ecological point of view, the vast amount of chemicals required for the processing of films and their expensive disposal pose an additional problem.

In connection with a project promoted by the ECSC (Agreement No. 7215-EB/101) it could be demonstrated by means of a pilot unit that the filmless radiography may replace the film without impairing the test quality. The production unit shown in Figure 8 represents a further development of this pilot equipment with improved test features. It is fully integrated into the production process (see Figure 2).

The equipment is located within the so-called U-cycle, i.e., upstream of the mechanical expander. In this area, a certain amount of repairs is permissible. After the expansion of the pipe, repairs are not allowed. From the economic point of view, the reliability of non-destructive testing in the U-cycle is thus of considerable importance for the production process. The processes used have to anticipate the results of final inspection and testing. To be able to observe the required cycle times, the entire process has to be automated. The operator merely enters the production number of the pipes and monitors the smooth course of inspection. The equipment was set up in January 1998 and has been used for all radiographic test activities in the U-cycle since the summer of 1998. The draft of standard prEN 13068, part 2 and 3, is applied as a reference criterion for the minimum requirements regarding the image quality. According to this standard, the system complies with the most stringent demands. The required sensitivity amounts to approximately 1%. The resolution has to achieve 0.13 mm according to wire pair number DS9 as per EN 462-5. Demands made by customers on the film quality (e.g., Agfa D5, sensitivity of 1.5%) are thus fulfilled. This is also confirmed by third-party expert opinions of the RWTÜV (Technical Inspectorate of Germany) as well as DNV.

It has so far turned out that the introduction of the filmless radiography has not caused any rise in the number of rejected pipes during final inspection, i.e., all defects, which can be detected by inspection testing according to customer's requirements, could already be discovered beforehand by means of the filmless radiography and could be repaired. The system thus meets the high quality requirements of Europipe. In the near future, Europipe intends to completely replace film radiography by the filmless technique.
Parallel examinations have shown that even experienced film evaluators only detect approximately 70 to 80% of all defects. It is intended to increase this percentage by the integration of a fully automatic image evaluation on the basis of a self-learning software with database. This automatic image evaluation under the name of AXION (Automatic X-Ray Image Evaluation) is to be implemented in three stages (Figure 9). In the first step, the images (approximately 200,000) were initially controlled by an evaluator and transferred to the database. The development has meanwhile reached stage 2, the actual phase of learning.

AXION suggests an evaluation and is either corrected or confirmed by the evaluator. The system is thus refined to the point of a reliable defect classification. In the final stage, the evaluation process is to proceed automatically with the evaluator only being involved to decide in ambiguous cases.

The filmless radiography in connection with that objective assessment is meanwhile classified by Shell Global Solutions as a technological progress. Its use is in all aspects in line with the actual Shell specification on linepipe and with the ISO 3183-3 code [4]. Therefore the necessary investments to replace completely the conventional film radiography by the filmless radiography are currently planned.

### Surface wave inspection (EMAT)

All pipes intended for the construction of an offshore-line are subjected to a 100% surface inspection, which is currently performed by means of magnetic particle testing. The evaluation of indications is made by experienced personnel and - in the absence of any measurement - is to be regarded as subjective. Information about the actual depth of an indication is completely missing. This leads to a high rate of cosmetic grindings on pipe as a differentiation between relevant and non-relevant indications is not possible. In future, this test is to be replaced by the so-called surface wave inspection by means of electro-magnetically induced Rayleigh-waves. Since the sound is produced in the work piece, a coupling agent is not required. To precisely locate a defect close to the surface of a large-diameter pipe, the information obtained from 3 transducers at a time is evaluated, which simultaneously transmit and receive sound (Figure 10).

A test with rotating surface waves completes the ultrasonic test of plates, which are subjected to conventional ultrasonic inspections in the plate-rolling. This process does not allow the resolution of defects close to the surface. The surface inspection performed at Europipe in the Mülheim large-diameter mill, however, detects imperfections in particular in the area down to approximately 4 mm below the surface. Through the integration of the test unit into the production flow, in-process measurements have been made possible, which allow a control of sensitivity and the reproducibility of test results.

The surface wave inspection applied at Europipe has been meanwhile qualified by Shell Global Solutions as being fully in
line with the requirements of ISO 3183-3 and is judged as a qualitative advance.

REFERENCES