Abstract

Following the decision of TANAP management to implement the latest technology on the construction of the Trans Anatolia Natural Gas Pipeline, and to validate such technology by means of improvements (in Schedule, Cost and Quality), a decision was taken to implement Automated Ultrasonic Testing (AUT) to test the integrity of the girth welds. This was further augmented with the implementation of an Engineering Critical Assessment (ECA) as a qualification approach in the acceptance criteria, as opposed to normal workmanship acceptance criteria, in order to assist the fast tracked Schedule, minimize the Costs in rework, and maximize on the Quality of the pipeline.

1. Introduction

As part of the Southern Gas Corridor, the Trans Anatolia Natural Gas Pipeline (TANAP) aims to transport Azeri Gas from the Shah Deniz gas field and other fields of Azerbaijan, and possibly from other neighboring countries, to Turkey and Europe via the Southern Gas Corridor. The Southern Gas Corridor comprising of the South Caucasus Pipeline (SCPX) extending from Caspian Sea to Georgia/Turkey border and the Trans-Adriatic Pipeline (TAP) extending from Greece/Turkey border to Italy (Figure 1).

The TANAP project is API 5L grade X70 – PSL2 steel grade, Helical Submerged Arc Welded (HSAW) and Longitudinal Submerged Arc Welded (LSAW) 56” and 48” diameter onshore pipeline system of 1850 km in length with a 21 km offshore section beneath the Marmara Sea comprising two parallel DNV 450F equivalent to grade X65, LSAW 36” diameter pipelines. The pipeline system will transport natural gas to required specifications and quantity and implemented in four phases. The project also comprises of 7 Compressor Stations, 4 Metering Stations, 11 Pigging Stations, 49 Block Valve Stations and 2 Off-Take Stations.

2. Automated Ultrasonic Testing (AUT)

Since the initial inception of the Rotoscan patent in 1952 and the first commercial implementation in 1989 on large diameter cross-country pipelines in Canada, today [2][3], AUT inspection concept has become the basis of the world standard for onshore and offshore pipelines in conjunction with automated welding processes. Various systems followed onto the market and the pipeline industry embraced carrying out automated ultrasonic inspections in lieu of Radiography.

Two AUT systems have been utilized on the TANAP project by two different Non-Destructive Testing (NDT) Subcontractors at different locations of the pipeline. One of the AUT systems was developed by Technology Design (initial inception of Technology Design was in 1995 and the roll out of the Technology Design AUT option was in 1999) which was further developed and used by JES Pipelines [11]. The other AUT system was the Rotoscan system, which was utilized by Applus.

AUT provides a higher Probability of Detection (PoD) of planar flaws such as lack of fusion and cracks being the most critical flaws affecting pipeline integrity during construction. Environmental impact is negligible and time...
saving advantages are evident, with AUT weld inspection carried out immediately after the weld has been completed following the welding team. Obtaining real time results of possible welding defects within the joint, caused by human or machine errors affecting the joint welding, quality is a major advantage and added benefit of using AUT methods.

The Pipeline girth weld is divided into a number of depth zones (Figure 2) referred to as a zonal approach and is related to the wall thickness and weld bevel configuration. Full weld inspection coverage is achieved by placing the ultrasonic probes on both sides of the weld, such that each generated inspection function or probe examines a dedicated depth zone (Figure 2) within the weld. This is also known as zonal discrimination [4][6][8] and predominantly made up of Pulse Echo (PE) channels.

In addition to the PE channels, Time of Flight Diffraction (ToFD) and Mapping channels are used. This increases the PoD of defects with not favorable flaw orientations with respect to weld method and bevel configuration. It furthermore provide pattern recognition, which aids in interpretation to avoid false calls. Additionally the Mapping channels technique is able to detect and quantify the presence of cluster porosity and other non-planer (volumetric) flaws.

3. Preparations Required

In order to utilize AUT on the TANAP Project, some preparations up front were required:

- Establish the scope of work for Project Specific AUT Procedure Validation in accordance with DNV-OS-F101 Appendix E [4] and DNV-RP-F118 [6]
- Source material from various pipe mills to carry out Acoustic Velocity Measurements in accordance with DNV-OS-F101 Appendix E [4] witnessed by TANAP NDT Level 3.
- Based on the results of the Acoustic Velocity Measurements calibration block requirements were established.
- Prepare weld map drawings of deliberately induced defect (seeded defects) coupons for J and V bevel design as well as welding method.
- Validation program undertaken by all AUT Subcontractors, all AUT inspection results recorded and supplementary NDT (Radiographic Testing /Manual Ultrasonic Testing, etc.) carried out.
- Hard stamping and marking of seeded defects in the validation weld test coupons (Figure 3).
- Cut seeded defect weld coupons (Figure 4) and send to Mechanical Test Laboratory (Exova) in The Netherlands for Salami slicing and final reporting after completion of validation testing.
- Review final Project Specific Validation report to establish compliance with Project Specific demands.

4. Calibration Block Manufacturing Regime

In order for the AUT to be successful, a well-defined and controlled calibration-block manufacturing regime is crucial. Firstly, material selection is critical at this stage. On the TANAP project, X70 HSAW and LSAW pipe were used for constructing the pipeline. Thermo-Mechanical Control Process (TMCP) coil material was used for the manufacturing of HSAW pipes. Anisotropic steels such as TMCP in many cases have adverse effects on higher refracted angles, which needs to be compensated for and factored in during the initial AUT Inspection Setup prior to weld inspection.

Unless a fully documented procedure and testing program is carried out to verify the limits set out within DNVGL-CG-0051[5] with angle variations not exceeding ± 2° and attenuation or echo height variations exceeding ± 2dB (identical requirements as per DNV-OS-F101 App. E[4]).
Materials being inspected needs to be married with calibration blocks manufactured from the same materials and rolling direction. Exceeding these code specified limits requires reference calibration blocks from each coil supplier.

TANAP insisted on AUT Subcontractors submission of Calibration block drawings. Upon approval of the drawings, manufacturing could proceed. Calibration block reference reflectors consisted of Flat Bottom Holes (FBH), notches and a through drilled hole for positioning. Flat bottom holes and notches were then verified by molds extracted from all reference reflectors introduced into the block. These were then verified to be in accordance with the tolerances identified within DNV-OS-F101 Appendix E Section B 500 Calibration (reference) blocks (Table 1)[4].

Table 1. Machining tolerances for calibration reflectors[4]

<table>
<thead>
<tr>
<th>Machining tolerances</th>
<th>Tolerances</th>
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<tbody>
<tr>
<td>Hole diameters</td>
<td>± 0.2 mm</td>
</tr>
<tr>
<td>Flatness of FBH</td>
<td>± 0.1 mm</td>
</tr>
<tr>
<td>All pertinent angles</td>
<td>± 1°</td>
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<tr>
<td>Notch depth</td>
<td>± 0.1 mm</td>
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<tr>
<td>Notch length</td>
<td>± 0.5 mm</td>
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<tr>
<td>Central position of</td>
<td>± 0.1 mm</td>
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<tr>
<td>Hole depth</td>
<td>± 0.2 mm</td>
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Each reflector was verified by ultrasonic testing to ensure that the reference reflector pairs yield reflective signals within ±2dB. DNV-OS-F101 Appendix E requirement[4]. A calibration block register was established which included all calibration blocks, spare blocks, unique serial numbers assigned to each block and included the drawings, dimensional verification records, ultrasound velocity check reports, name of the plate/coil supplier and the heat number. DNV-OS-F101 Appendix E requirement[4].

5. Validation of the AUT System

The objective of the project specific AUT procedure validation is to verify that the qualified AUT system performance can be implemented on project specific applications. The project specific AUT validation shall normally only comprise the reliability aspects provided that all essential variables remain within reason equivalent to what has been qualified. The reliability aspect as per DNV generally do not include any new PoD (Probability of Detection) analysis.

Due to the nature of TMCP material and the effects anisotropic material has on ultrasonic propagation, TANAP’s request was to fulfill the requirements outlined in the Project Specifications[9][10], which was as follow:

“System qualification shall be in accordance with DNV-RP-F118 with documented capability to size all potential defects with an accuracy of ±1.0 mm or better for flaw height depending on ECA criteria. Length sizing shall be accurate to ± 3 mm or better depending on ECA criteria.”

Project Specific AUT Procedure Validation procedures were submitted outlining the program and sequence of events to be followed. These Procedures was written in accordance with DNV-OS-F101 App E Section I [4] and DNV-RP-F118 Pipe Girth Weld AUT System Qualification and Project Specific Procedure Validation, Section 9 [6]. Deliberately induced defect (seeded defects) coupons was welded using project proposed welding procedures being weld bevel geometry and welding method specific.

A calibration block register was established which included all calibration blocks, spare blocks, unique serial numbers assigned to each block and included the drawings, dimensional verification records, ultrasound velocity check reports, name of the plate/coil supplier and the heat number. DNV-OS-F101 Appendix E requirement[4].
Figure 5. Macro for seeded defect

Above image (Figure 5) shows final macro result from Mechanical Test Laboratory (Exova). Seeded defect number M03-P3944 (Figure 3), identified and measured, tabulated (Figure 2) by Contractor and reviewed by TANAP. This result from the Mechanical Test Laboratory (Exova) indicates tolerances required by TANAP Project Specification has been achieved.

A minimum of 29 defects [4], [6] were required for both J and V bevel configurations respectively. This regime was followed for both HSAW and LSAW pipe material.

Due to TMCP material a further 12 seeded defects was required when new material and or calibration blocks arrived on site. The purpose of a Project Specific Procedure Validation as described under DNV-RP-F118 [6] is as follow:

“The purpose of the validation is not to perform a PoD analysis but to verify that the project specific AUT procedure capability is adequate for detection of the smallest project specific critical defect. This is obtained by demonstrating detection of all 29 defects and that these 29 defects has been sized and positioned within the qualified accuracy. If this is achieved, the project specific AUT procedure is validated and shall be accepted.”

7. Implementation of the Process

Upon successful completion of Project Specific AUT Procedure Validation, field inspection preparations started with verification of System Logbooks in accordance with DNV-OS-F101 App. E Section E- Field Inspection [4]. AUT systems were setup in accordance with essential variables as per AUT General Qualification and Project Specific Procedure Validation. From there, the TANAP NDT Level III representative would conduct AUT Operator proficiency testing [9], [10] which consisted of witnessing system calibrations, scanning of welds and data interpretation as well as witness pre-field inspection system calibrations in accordance with DNV-OS-F101 App. E Section E 106 [4] prior to field deployment. TANAP also mobilized NDT Level III AUT interpreters on all sites and these NDT Level III AUT Auditors performs counter review of all AUT scans on a daily basis for the duration of the project.

8. Conclusion

The main reason for TANAP to choose AUT during the construction of the pipeline was due to the high standard of quality required in compliance with Project Specifications. Furthermore, the AUT was in Code compliance to: API 1104[7] / ASTM E-1961[8] / DNV-OS-F101[4], which was suitable for onshore pipelines, onshore facilities as well as offshore pipeline construction on the project. It also provided better process control of welding, providing immediate feedback of the quality of welding produced. By implementing the AUT directly behind the Welding teams, the Project ensured prevention of systematic defects, resulting in lower repair rates. One of the main advantages of AUT compared to Radiographic Testing was the capability to determine the defect height; or as also referred as the defect through wall extent, which allowed the use of alternative acceptance criteria based on Engineering Critical Assessment (ECA). ECA approach allowed larger flaw acceptance criteria, resulting in lower repair rates, consequently in cost and schedule savings, which is discussed in detail in a separate article [1]. The technology provided accurate positioning and sizing of discontinuities, and higher probability of detection (PoD) which means improved risk reduction. It minimized unnecessary repairs whilst optimizing inspection time. Also AUT was safer and environment friendly with no chemical consumables to dispose and no radiation hazard and the records do not require large, controlled spaces to be stored during and after the Project is completed.

8. References

[2] Frits Dijkstra, Jan De Raad, The History of AUT ECNDT 2006 – Tu.2.5.1


