Implementation of Engineering Critical Assessment and Fitness for Purpose Approach on TANAP Pipeline Welding

Arash Shadmani¹, Pieter Erasmus²
¹Welding Specialist, TANAP, Ankara, Turkey
²Lead QC Engineer, TANAP, Ankara, Turkey

Abstract

Following the decision of TANAP management to implement the latest technology on the Construction of the Trans Anatolia Natural Gas Pipeline (TANAP), and to validate such technology by means of improvements (in schedule, cost and quality), a decision was taken to implement Engineering Critical Assessment (ECA), as a fitness for purpose approach to produce alternative acceptance criteria, as opposed to conventional Quality Control (QC) approach workmanship acceptance criteria.

By applying this approach to TANAP pipeline girth welds, the average Repair Rate (average repair rate data provided as number of repaired welds versus the total number of welds) significantly decreased for both Onshore and Offshore section pipelines.

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 neighbouring countries, to Turkey and Europe via 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.

TANAP project is an API 5L X70 onshore pipeline system of 1850 km in length comprising 36” diameter with three different wall thicknesses of 19.45, 23.34 and 28.01mm as well as 48” diameter with 16.67, 20.01 and 24.01mm. It also includes a 21 km of API 5L X65 offshore section beneath the Marmara Sea comprising two parallel 36” of 22.9mm wall thickness pipelines. The pipeline system will transport natural gas to required specifications and quantity and implemented in four phases. The project also comprises 7 Compression Stations (CS), 4 Measuring Stations (MS), 11 Pigging Stations (PS), 49 Block valve Stations (BVS) and 2 Off-Take Stations.

Engineering Critical Assessment (ECA) is a fitness for purpose approach based on fracture mechanics properties of the linepipe base material and weldments which is used to produce alternative acceptance criteria for TANAP Onshore/Offshore pipeline girth welds flaws. This approach however is only practical when used in conjunction with Automatic Ultrasound Techniques (AUT) as the Non Destructive Testing (NDT) method for the assessment of the pipeline girth weld flaws which is discussed in a separate article [1] (Figure 2 &3).

The fitness for purpose (FFP) approach using Engineering Critical Assessment is to confirm girth welds mechanical integrity under static and cyclic (fatigue loading) stresses during installation and operation in the presence of weld flaws. This approach provides alternative acceptance criteria for planar flaws in the weld metal other than the Quality Control approach workmanship criteria as specified in the various international codes and standards [3] & [6].
2. Experimental Procedure

Engineering Critical Assessment is used to provide alternative acceptance criteria for TANAP pipeline girth weld flaws, which is generally a more realistic approach compared to Quality Control workmanship acceptance criteria. This is based on a fitness for purpose approach, using much more realistic conditions such as the actual flaw size and the specific service conditions.

2.1. Welding procedure qualification tests

API 1104 Annex A guidelines with additional project specification requirements is followed for TANAP onshore stress based designed pipeline sections. In addition to conventional welding procedure qualification tests, fracture toughness properties of the weld metal and Heat Affected Zone (HAZ) identified by Crack Tip Opening Displacement (CTOD) testing in accordance with ISO 15653. Overmatching of actual weld metal strength relative to actual pipe martial strength is confirmed by both conventional cross weld tensile testing in accordance with API 1104 Annex A as well as all weld tensile testing using round specimens in accordance with ASTM E8.

In order to be able to apply ECA to TANAP pipeline these properties are to be identified for each pipe mill and steel source combination. Considering the pipeline supply chain complexity, applying ECA approach to TANAP pipeline required an extensive welding procedure qualification tests.

To reduce the number of welding procedure qualifications, repair and tie-in welds excluded from fitness for purpose approach and ECA only applied to mainline welding. TANAP mainline welding produced using mechanised welding systems (m-GMAW). Providing a same filler batch by supplier, the fracture toughness of the weld metal considered independent of the linepipe supply condition. Hence by qualifying combinations of the sources, the number of required qualifications is significantly reduced.

Table 1. Simplified rationalization philosophy for reducing number of welding procedure qualification tests.

<table>
<thead>
<tr>
<th>Mill/Steel</th>
<th>Source 1</th>
<th>Source 2</th>
<th>Source 3</th>
<th>Source 4</th>
<th>Source 5</th>
<th>Source 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source 1</td>
<td>1-1</td>
<td>1-2*</td>
<td>1-3</td>
<td>1-4</td>
<td>1-5</td>
<td>1-6</td>
</tr>
<tr>
<td>Source 2</td>
<td>2-2</td>
<td>2-3</td>
<td>2-4</td>
<td>2-5</td>
<td>2-6</td>
<td></td>
</tr>
<tr>
<td>Source 3</td>
<td>3-3</td>
<td>3-4*</td>
<td>3-5</td>
<td>3-6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Source 4</td>
<td>4-4</td>
<td>4-5</td>
<td>4-6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Source 5</td>
<td>5-5</td>
<td>5-6*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Source 6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>6-6</td>
</tr>
</tbody>
</table>

*Total 3 qualification tests between sources shown in red can cover all pipe mill/steel source combinations and reduce the required number of WPQT from 21 to 3.
Seismic fault crossings with axial design strain level more than 0.5%

API 1104 Annex A is not applicable when maximum axial design strain is greater than 0.5%. TANAP pipelines consists of number of seismic fault zones where the axial design strain is higher than 0.5%. For these sections depending on the strain level, different ECA approach based on BS 7910 and by producing JR curve using SENT specimens is considered in line with BS 8571 and DNV-RP-F108 (Figure 5 & 6).

For minimizing the effect of notch tip constraint and applying less conservative approach Single Edge Notched Tensile (SENT) specimens are used instead of Single Edge Notch Bend (SENB) specimens. Furthermore, for higher strain levels, stable tearing assessment considering the stability of the flaws are carried out using more advanced fracture toughness behaviour of the girth weld e.g. J-R curve which is a measure of the evolution of the fracture toughness with tearing of the flaw (Figure 7).

2.2. ECA validation

TANAP pipeline welds fracture toughness properties used as ECA inputs and cross-checked by random and frequent full production tests. This includes cutting out random produced welds during actual construction and perform full destructive tests to check against the results obtained during welding procedure qualification tests. Furthermore, the produced acceptance criteria also validated on a case-by-case basis using full segment tensile tests having the worst detected weld flaw during construction (Figure 8).
In addition, three-dimensional Finite Element Analysis (FEA) modelling is also developed to validate the ECA produced alternative acceptance criteria. In which case, the crack driving force (J-integral) corresponding to maximum nominal strain with presence of surface breaking flaw in weld toe at Internal Diameter and Outer Diameter in conjunction with maximum misalignment (worst case scenario) is modelled.

3. Results Discussion

Table 2 tabulated the comparison for reject rate percentage between ECA and QC approach on TANAP onshore and offshore sections as well as The Welding Institute industrial survey figures [11]. For Onshore section applying Annex A of API 1104 reduced the repair rate (average repair rate data provided as number of repaired welds versus the total number of welds) from 9.76% to 3.54%. This essentially decreased the required weld repair activities and boosted construction productivity. As for offshore section by applying Appendix A of DNV-OS-F101 and BS 7910 fitness for purpose approach for girth weld acceptance criteria repair rate reduced from 2.6% to less than 0.5%.

By applying fitness for purpose approach acceptance criteria to TANAP onshore pipeline the Repair Rate became closer to the TWI industrial survey figure of 3%. For offshore section however the TWI figure of 2% obtained through Quality Control workmanship acceptance criteria in accordance with [8] and by following fitness for purpose path repair rate reduced to less than 0.5%.

<table>
<thead>
<tr>
<th>Mainline Location</th>
<th>Number of Welded Joints</th>
<th>Rejection Rate FFP Approach</th>
<th>Rejection Rate QC Approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>Onshore - Lot 4</td>
<td>30124</td>
<td>3.54%</td>
<td>9.76%</td>
</tr>
<tr>
<td>Offshore</td>
<td>1232</td>
<td>0.48%</td>
<td>2.6%</td>
</tr>
</tbody>
</table>

TWI industrial survey [11] indicates 3% average repair rate for onshore pipelines and 2% for offshore but doesn’t clarify with ECA or QC workmanship acceptance criteria.

4. Conclusion

This paper in conjunction with reference [1] discusses the implementation of fitness for purpose approach using advanced technologies in the pipeline industry and its effect on the delivery of the TANAP project’s construction, quality, schedule and cost. Engineering Critical Assessment (ECA) in conjunction with Automated Ultrasonic Testing (AUT) effectively implemented on the TANAP project.

The fitness for purpose approach ECA is implemented to produce alternative girth weld flaws acceptance criteria for TANAP Onshore and Offshore pipeline. Applying ECA to the TANAP pipeline girth weld led to produce a fit for purpose acceptance criteria comparing to conventional workmanship criteria represented in API 1104 Section 9 for onshore and DNV-OS-F101 Appendix E for offshore. Following the fitness for purpose approach essentially boosted the construction productivity and reduced the average repair rate substantially (Table 2).

Engineering Critical Assessment is also used to produce practical acceptance criteria for where the API 1104 Annex A is not applicable, such as seismic fault zones with axial design strain greater than 0.5%.

The number of required Welding Procedures Qualification Tests (WPQT) rationalized by applying a specific qualification strategy (Table 1). Fracture toughness properties used as inputs for ECA are cross checked by random and frequent production tests against the qualification test results. In addition, the alternative acceptance criteria is validated by full segment tensile test and finite element modelling on a case by case basis.

All of the ECA approved welds on the TANAP project passed progressive system hydrostatic design proof tests at 1.25 X design pressure (in accordance with ASME B31.8 TANAP pipeline design code) successfully.

References