VERIFICATION OF ILI INSPECTION RESULTS WITH THE USE OF AUTO UT DATA:

A CASE STUDY OF AN OFFSHORE PIPELINE

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ABSTRACT

Verification of inspection results is a challenge to the industry. This is notable in situations of offshore pipelines which are a challenge to access and repair. It is essential that operators have accurate and reliable information on their pipeline condition to enable informed decisions with regards to maintaining and ensuring the ongoing integrity of their assets.

The case study presented in this paper is based on data collected on the condition of a large diameter crude oil pipeline which has undergone several in-line inspections, corrosion investigations and integrity assessments.

In order to verify the results of these in-line inspections and subsequent assessments, automated ultrasonic in-field inspection results were utilised. A combined technology review and assessment was then completed to determine the accuracy of the measured metal loss features and corrosion rates identified by in-line inspection surveys. In order to enable this investigation, A PII developed software package named DigCom was utilised.

This paper aims to highlight the results of this investigation and the subsequent benefits of utilising in-line inspection tools as part of an ongoing integrity management strategy.

INTRODUCTION

PII has inspected the offshore crude oil pipeline on several occasions using various technologies including Magnetic Flux Leakage (MFL), UltraScan™ Wall Thickness Measurement (USWM) and Caliper inspection vehicles. The most recent inspection was conducted using an MFL inspection vehicle.

This is a critical line in terms of operations and supply. In addition the consequences of a leak would be severe. Therefore several Fitness-For-Purpose (FFP) and Corrosion Growth studies have been conducted on this pipeline.

The pipeline has over 600,000 corrosion features distributed throughout its length, predominantly internal at the bottom of the line (i.e., the 6 o'clock position). Previous corrosion growth studies found that the corrosion was active and growing. The internal corrosion features are typical pitting and areas of general corrosion as can be seen in Figure 1. The most recent Fitness-for-Purpose assessment had identified internal corrosion features which are predicted to require repair within 5 years of the latest inspection survey.

The operator made the decision to shut in and mothball (de-oiled and preserved with treated water) the pipeline but it is the intention to put the line back into service. Whilst out of operation, the operator has conducted corrosion mapping (Automated Ultrasonic scanning or AUT) at several locations along the pipeline. The aim of these investigations is to verify the In-Line Inspection (ILI) results and confirm repair options. In addition AUT has been conducted at several of these locations previously.

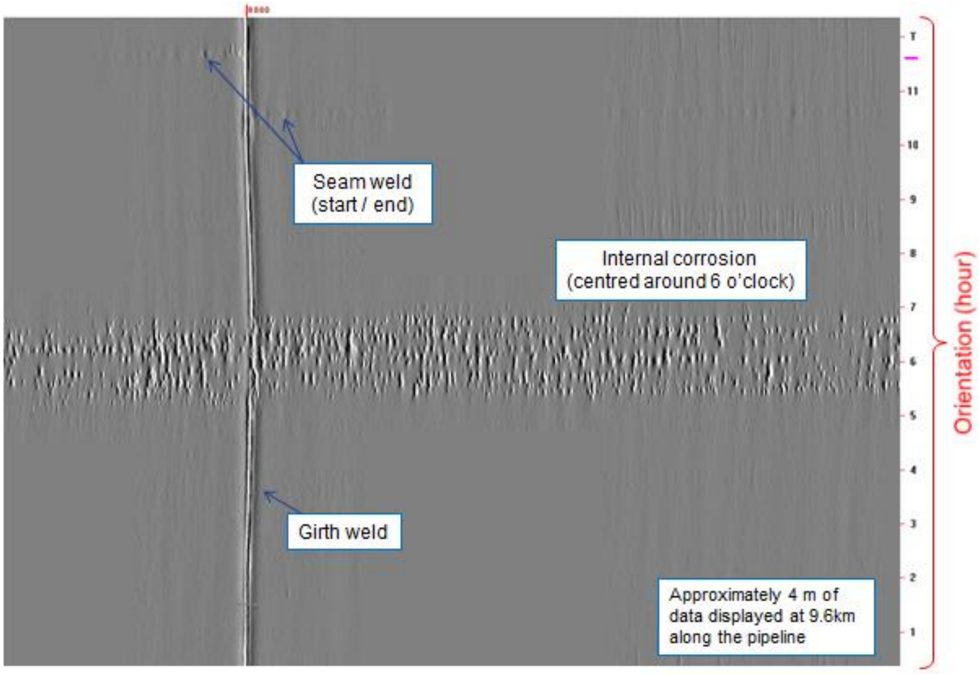

Figure 1 – Example of Metal Loss/Corrosion pattern present in the Pipeline

The AUT measurements have been taken at locations where the MFL ILI survey reported significant corrosion (predicted to require repair in the near future). To conduct AUT the concrete coating was removed from the pipeline and the survey was conducted by scanning the outer surface of the pipeline centred on the 6 o'clock position of the pipeline.

However the challenge with AUT scanning is that it is very difficult to match the results exactly with MFL ILI data. It is difficult to be certain AUT is scanning exactly the same area of corrosion that was reported by the MFL ILI given the various tolerances (length/depth/distance/orientation) of the AUT and MFL inspection technologies and the difficulties of carrying out AUT in-field. .

In order to verify the ILI inspection tolerances and the estimated corrosion growth rates from previous studies the AUT investigations were used. In addition these results were then used in a further updated Fitness-For-Purpose and Remaining Life Assessment.

The AUT is a direct measurement system and as such provides highly accurate measurements of the corrosion dimensions. Therefore the AUT data is treated as the master data set and can be used to verify the MFL data.

METHODOLOGY

Software

In order to compare pipeline operator in-field measurements (typically provided from laser / UT NDT survey of the pipeline) with the raw MFL inspection data signals a software package called DigCom was used.

DigCom has been developed by PII to perform detailed comparison of ILI data with ultrasonic (UT) or laser scan data. Previously this comparison of excavated areas was performed on the peak depth of a small number of defects per site; DigCom allows not only the comparison of the depths of all individual pits, but also investigation of the full profile and interactions within complex corrosion features.

The software first maps ILI data directly onto the in-field scan (UT or laser scan data). Given the upstream weld ID and relative distance of the scanned area, DigCom can automatically locate and import the ILI data. Then a simple and highly visual process allows the ILI data to be aligned and scaled to give a point to point match for the whole data set, and a high degree of confidence that points are accurately matched.

DigCom then creates metal loss 'boxes' within the UT data using an algorithm equivalent to PII's analysis software. These boxes highlight single pits of corrosion which are matched on an individual basis to the corrosion pits detected in the ILI data. This results in a list of matched points with depths, lengths, widths, and the ILI measurement accuracies that can be exported and analysed. This process ensures a high degree of confidence in validation of the ILI results.

DigCom works with in-field measurements in a grid format of measured wall thickness values; it will accept a range of text and Excel based input formats. The more refined the resolution the better in terms of accuracy of measuring defect depths and lengths. The AUT data provided by the operator was 1mm x 1mm and was provided as overlapping scans (each being approximately 300mm in length) with a total scan area length of 3m. In addition to this Time of Flight Diffraction (TOFD) was conducted at the girth weld beads where access to area was possible.

Figure 1 below shows one of the AUT locations from the operator's pipeline. The AUT data can be seen in the top half of the screen where the warmer coloured points (yellow and reds) are sites of metal loss and the white and blue shows sound pipe wall. The PII MFL data is shown in the lower half of the screen (the normal trace signals are displayed in colour mode to allow for easier matching with the AUT data); again, the warmer colours denote metal loss sites.

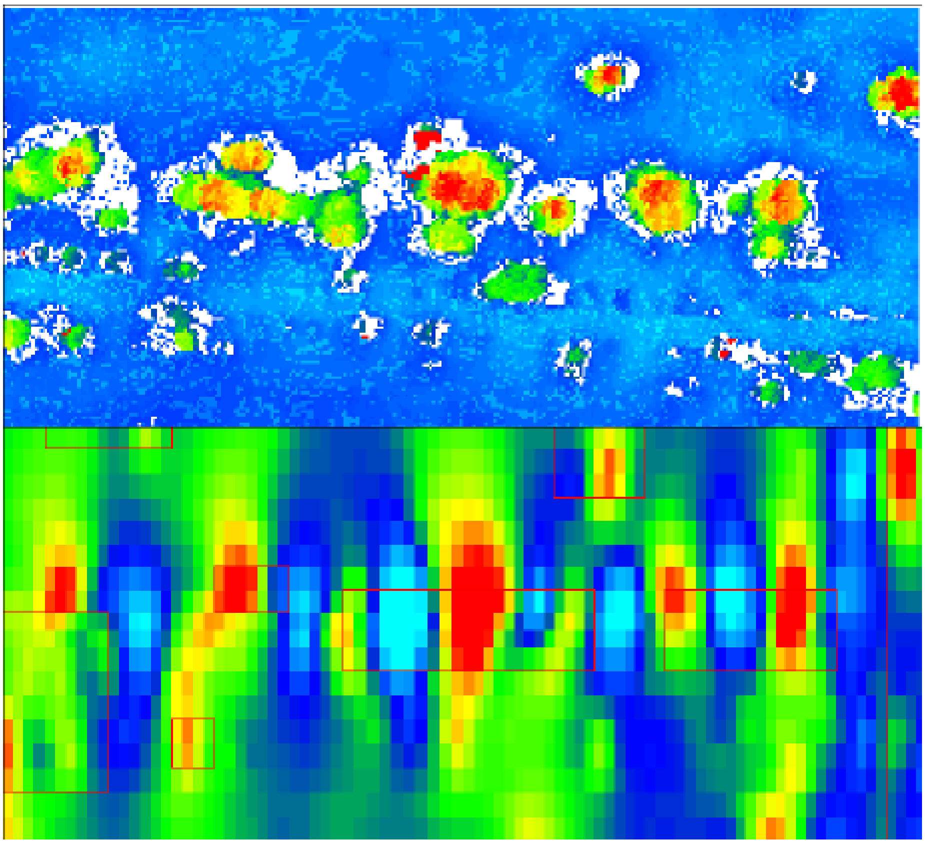

Figure 2 – Example DigCom Defect Matching:
(AUT Data (Top) vs MFL (Bottom))

Pattern matching is vital in ensuring the 2 data sets are correctly aligned and the comparison between the surveys is accurate. Only accurately matched sites were used in the ILI inspection verification.

RESULTS

Inspection Tool Performance

The accuracy of the depth measurement by the AUT investigations allowed calculation of the sizing errors present in the ILI data.

The comparison between AUT and MFL data allowed sizing errors (in terms of feature depth) present in the ILI data to be determined (i.e., any trends of over or under sizing).

A total of 532 metal loss indications have been matched between the MFL inspection data and the AUT scans. This sample was taken from 9 spools throughout the line. The number of sites accurately matched as part of this study is a significant sample size, especially considering the pipeline is offshore and the corrosion is internal.

The following figure shows the unity plot for the 532 matches. The sample included a range of feature depths distributed along the full pipeline length and is considered representative of the internal corrosion present in the pipeline.

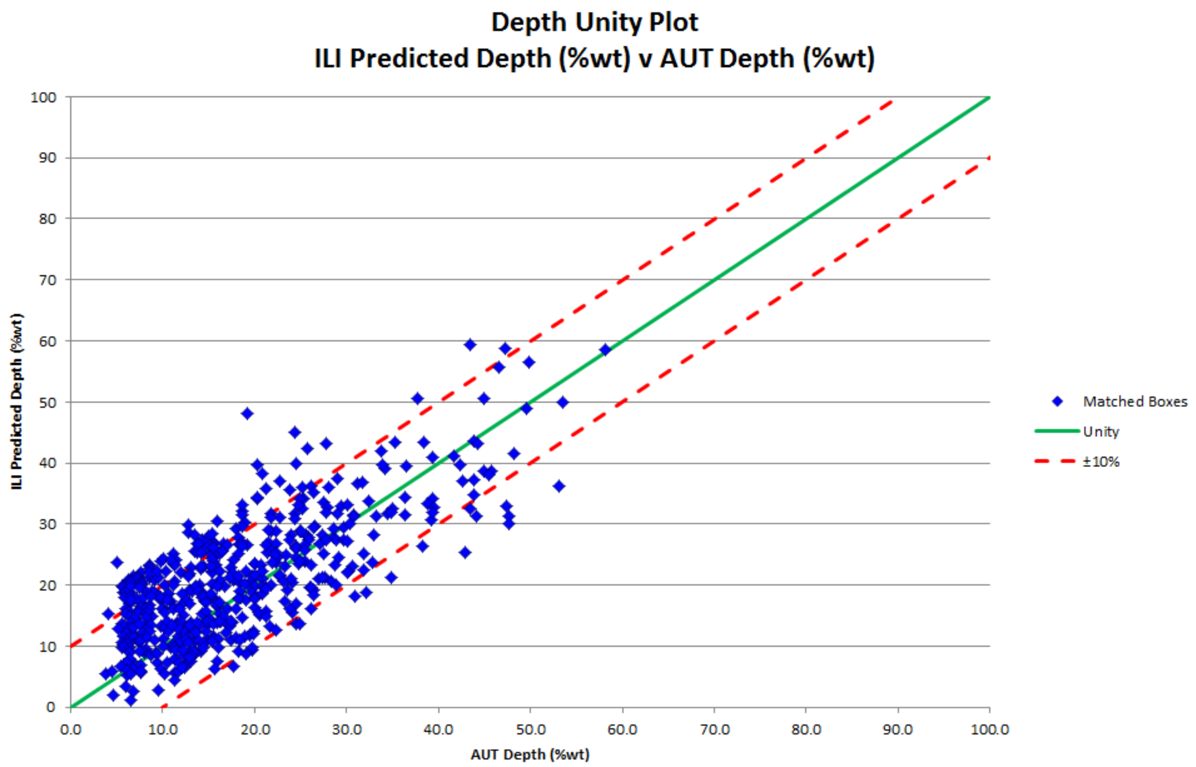

Figure 3 - AUT Depths Plotted Against the MFL ILI Depths

The contractual sizing tolerances of +/-10% for pits and general corrosion are shown on the figure.

Based on these 532 matches the MFL 2012 tolerance has been calculated using the following method.

An actual MFL tool depth sizing accuracy for metal loss, expressed as a percentage of the wall thickness (wt) (the tolerance), achieved 80% of the time (the confidence) is calculated using the following procedure detailed in the Journal of the Statistical Association[i]:

$$80\%CI = \pm 1.28 . \sqrt{Var(ILI) - Cov(ILI, AUT)} \ [\%WT],$$

where Var (ILI) is the variance in the in line inspection results [%wt^2], and

Cov (ILI, AUT) is then covariance between the in line inspection results and the AUT measurements [%wt^2].

The above formula has been developed by Grubbs[i] and validated by an ILI operator[ii]. It is applicable, where more than one instrument is used to measure the metal loss feature depths, while true values of feature depths are unknown. This approach provides the best estimate of the MFL tool scatter, when each of the instruments (MFL ILI and AUT respectively) measures the same defect only once.

It is highlighted that all 532 metal loss matches are located within the pipe body.

As a result of the calculation the true MFL tool sizing tolerances have been obtained. The 80% confidence interval is equal to ± 5.96% wt tolerance, i.e., for the matched metal loss indications the ILI contractual sizing specification was exceeded (where contractual sizing specification for general corrosion and pitting within the pipe body is ± 10% wt at the 80% confidence interval). At 95% confidence the MFL tool sizing tolerance would be ±9.12% wt.

The MFL inspection tool has been shown to be exceeding the contractual reporting specification, i.e., tool performance is better than stated. This new information about the tool's sizing abilities can be used to improve the accuracy of the Fitness for Purpose results.

APPLICATION OF RESULTS IN INTEGRTY ASSESSMENTS

Internal and external corrosion are leading causes of pipeline failures. ILI tools often detect thousands of areas of corrosion, many requiring repair. Therefore engineering consultancy reports (such as Corrosion Growth and Fitness-for-Purpose studies) are needed to evaluate the current and future pipeline condition.

Due to the presence of active corrosion and the importance of this pipeline asset, the operator wanted the AUT results to be utilised in further engineering assessments of the pipeline condition. In previous studies a sizing tolerance was applied in-line with typical ILI specifications (+/- 10% wt, 80% of the time), however with the benefit of the AUT investigations it was possible to verify and improve these applicable tool depth tolerances as discussed previously.

In order to complete the integrity assessment on these defects a combination of the measured defect morphology was used. A combination of the AUT findings and information taken from MFL inspection ensured that the most accurate measured dimensions were used in the Fitness-For-Purpose study. The final metal loss area (combination of AUT depths and MFL feature depths, lengths and widths) were assessed in terms of immediate integrity.

Several sites had been scanned using AUT previously. Corrosion growth rates were determined by matching and comparing the depths from these in-field investigations. This was carried out using the DigCom software using the MFL ILI data as a reference to enable defect matching.

The significance of the reported metal loss features was then assessed in terms of their updated through wall thickness depth and axial length using accepted industry assessment methods. The remaining life of the pipeline was then estimated using the updated feature dimensions and the measured corrosion growth rates from both the AUT matching and the most recent corrosion growth investigations comparing MFL ILI data.

CONCLUSIONS

The results of this verification demonstrated a methodology to compare Magnetic Flux Leakage in-line inspection data with in-field Automated Ultrasonic scan data to enable metal loss feature sizing accuracy.

- Automated Ultrasonic scan data was successfully matched and aligned with Magnetic Flux Leakage in-line inspection data
- The Magnetic Flux Leakage in-line inspection tool exceeded stated specification at the 80% confidence interval (± 5.96% wt compared to ± 10% wt for general corrosion and pitting within the pipe body)
- Corrosion growth rates were successfully determined from comparison between Automated Ultrasonic Scans.
- Defect morphology was successfully combined between technologies to determine improved feature sizing in investigated areas.

Using the actual tolerances versus the contractual tolerances and the determined growth rates in Fitness-For-Purpose studies has meant the operator can defer repairs to this pipeline. In addition the operator intends to continue to inspect with the MFL vehicle to ensure the ongoing integrity of this pipeline asset.

PII would like to thank the pipeline operator for their co-operation and commitment to development of in-field verification and development of integrity assessment methodologies.

REFERENCES

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ii A Bhatia, NS Mangat, TB Morrison — Estimation of measurement errors, proceedings of the International Pipeline Conference 1998, Volume 1, pp 315-325, Calgary, Alberta, May 1998