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Assessment of low-frequency Electric Resistance and Flash Welded line pipe defects by EMAT and CMFL In-Line Inspectio

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Background

The occurrence of low-frequency Electric Resistance Welded (LF-ERW) or Electric Flash Welded (EFW) line pipe imperfections has been the root cause of many integrity management initiatives to minimize and mitigate the risk of pipeline failure across the oil & gas pipeline industry. Since their first appearance in the 1920s, defects in or near the LF-ERW and EFW seam repeatedly lead to either hydrostatic test or in-service failures. Where in the past In-Line Inspection (ILI) technologies might have experienced limitations in addressing vintage ERW line pipe defects, modern smart ILI technologies show enhanced capabilities. High resolution Electro-Magnetic Transducer (EMAT) and Circumferential Magnetic Flux Leakage (CMFL) ILI technologies have advanced in the recent years enabling more challenging inspections. This paper summarizes the inspection results of 22" ERW line pipe defects detected and reported by EMAT and CMFL. Correlation of ILI and manual NDE data enables evaluation of current ILI capabilities and improvement of current defect assessment methods.

Aim

A variety of anomalies present in pre-1970 ERW and EFW pipe have been identified as the root cause for in-service or hydrostatic pressure test failures in the past. Among those Lack Of Fusion (LOF) or cold welds, J-shaped hook cracks and Selective Seam Corrosion (SSC) are likely to be the most frequent and prominent types of anomalies. In contrast to other line pipe defects, seam-weld anomalies are located in an area where the pipe geometry and material can be significantly different from the properties in e.g. the pipe body. Local properties of the material are mostly unavailable preventing formal integrity assessment of the asset and prediction of critical anomaly dimensions. In the past line-pipe integrity has therefore been mostly secured by hydrostatic pressure testing at certain intervals in time of the order of typically several years apart. By development of technologies for Non-Destructive Examination (NDE) and more recently smart ILI tools, technologies have become available, that can successfully acquire rich information to examine complex seam-weld irregularities. Nowadays and in the absence of either material properties and seam-weld anomaly assessment criteria, hydrostatic testing, direct assessment and ILI data are incorporated into pipeline integrity management programs. The inevitable procedure and industry practice is to repair detected crack-like seam-weld anomaly which has likely resulted in the unnecessary repair of numerous anomalies.

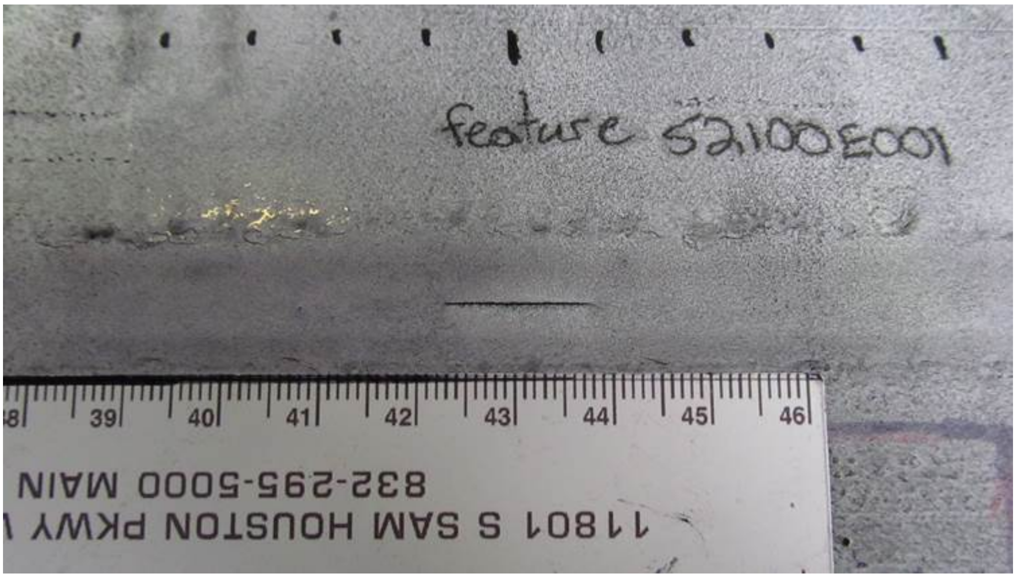

Figure 1: Photograph of verified LOF defect surface breaking on the OD after b/w MPI of the external pipe surface.

Methods

In order to assess the capability of the utilized ILI technologies with regards to natural defects and to accurately measure a targeted defect profile, the ILI raw data need to be considered and evaluated in detail. Thus captured ILI data have been correlated to PAUT profile of the present seam welds as seen after black and white wet Magnetic Particle Inspection (b/w MPI). Fig. 1 and 2 show a verified LOF defect and corresponding detailed correlation of the different data respectively . The reported indication has been indicated by vertical lines. Fig. 2 is organized by showing the recorded EMAT frequency of the reflection signal of an individual sensor capturing the seam weld in a B-Scan representation on top. The color coded B-Scan is used during the analysis of the data. The manual PAUT depth profile is shown at an absolute scale. The EMAT frequency response shows the normalized reflected EMAT frequency signal. The CMFL magnetization shows the pipe magnetization of a single sensor with respect to an offset correction to visualize the data. The sensor data displayed were manually selected by the highest S/N ratio. All ILI datasets have been used during data analysis of the tool runs

Results

The defect shown by Fig. 1 has been identified as a LOF at the bonding line of the seam. The length of the defect of 15 mm (0.590 inch) is significantly smaller than the wall thickness of the pipe 7.2 mm (0.281 inch). For such penetrators, the lower frequency reflection clearly indicates the reported defect. The CMFL signal indicates the defect as well. An increase in the recorded magnetization is detected. MPI and PAUT confirmed the presence of the penetrator. The length of 15 mm (0.590 inch) is well below the specified minimum defect length for the EMAT and of the order of the shortest EDM notch tested upfront. The reported ILI depth matches the NDE depth and is within the specified accuracy. Although no destructive testing result is available at this point for this defect, it is assumed, that the defect depth profile is similar to that of a machined EDM notch. The ILI overestimates the length of the defects with respect to the reference MPI length. This can be explained by the extent of the measurement area of the EMAT sensor. Assuming a Gaussian EMAT sensor sensitivity distribution and a significant overlap of individual measurements in axial direction the extension of the defect is enlarged.

Manual PAUT was used as a benchmark with regards to detection and sizing capabilities for a series of similar LOF and hook crack defects. From the different dimensions in terms of lengths and depths of the investigated defects the capabilities are demonstrated and compared to destructive testing results. The applied EMAT and CMFL show high sensitivity to defects in the ERW weld. The EMAT successfully resolves different defects ranging from exemplary penetrators to continuous seam-weld anomalies of varying depths.

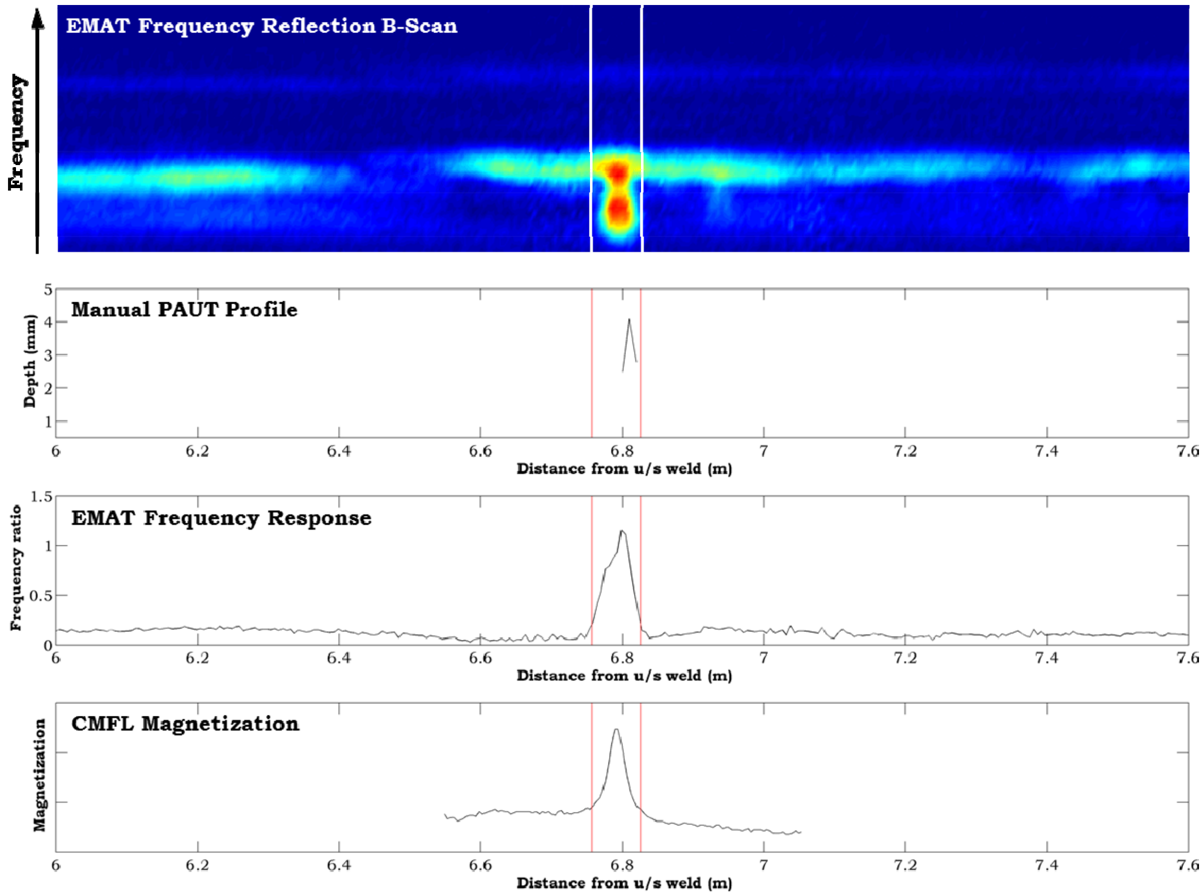

Figure 2: ILI and manual PAUT NDE data for spool No. 1. High correlation of the PAUT depth profile and EMAT frequency response is visible for defects that exceed 1mm depth. Further description is given in the text.

Conclusions

In a joint effort of the pipeline operator and ILI vendor, the EMAT and CMFL ILI technology has been utilized to detect, identify and size anomalies of vintage pre-1970 ERW line pipe. Manual PAUT was used as a benchmark with regards to detection and sizing capabilities. Correlation of PAUT depth profiles of LOF defects in the weld and ILI data has been performed. From the different dimensions in terms of lengths and depths of the investigated defects the capabilities have been demonstrated. The applied EMAT and CMFL show high sensitivity to defects in the ERW weld. The EMAT successfully resolves different defects ranging from exemplary penetrators to continuous seam-weld anomalies of varying depths. The same holds for the CMFL, where the signal of short penetrators is supposed to be effectively influenced by volumetric defects at or in the seam weld area. Consequently the signals are superimposed as demonstrated for one sample.

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