

Validating EMAT Performance with an Operator

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ABSTRACT

The primary focus of a pressurized piping systems integrity management program (IMP) is to provide safe, reliable operation. One of the preferred tools leveraged by operators is the use of in-line inspection (ILI) technologies to assess the integrity of their assets. A comprehensive inspection program using ILI systems to detect, quantify and accurately classify anomalies is a mitigation strategy for pipeline threats thus reducing risk to the environment.

Magnetic flux leakage (MFL) is the most commonly used ILI technology for pipeline metal loss assessment. However, despite segments having been inspected multiple times with MFL systems, in-service incidents still continue to occur. Some in-service failures have been associated with stress corrosion cracking (SCC) or other cracking related threats. Due to the size and geometry of tight cracks and the limitations of MFL based technologies, they can go undetected.

Electromagnetic acoustic transducer (EMAT) technology generates an acoustic wave in the pipe material. The wave propagates around the pipe and is reflected back to receiver sensors when the acoustic wave encounters a crack. While EMAT development for ILI systems began in the 1980s, significant advancements in performance over the last decade have resulted in greater adoption and has recently been included in some regulation.

This paper will outline TDW's experience validating EMAT performance with Williams, a gas pipeline operator. A review of the added benefit EMAT technology provides to augment more traditional ILI technologies, such as MFL and geometry, will be explained. An outline of the combined effect of multiple technologies to produce the most comprehensive ILI system solution for accurately detecting and characterizing crack anomalies that may otherwise go undetected will be presented.

Key words: Electromagnetic Acoustic Transducer, EMAT, ILI, In-line Inspection, Integrity Management Program, IMP, Magnetic Flux Leakage, MFL

INTRODUCTION

Hazardous liquid and gas transmission pipeline operators make pipeline safety a primary objective. A key to achieving this objective is developing and maintaining a comprehensive integrity management program (IMP). The programs outline specific plans for analyzing, operating and maintaining pipeline assets. A common key element of an IMP is a strategy for assessing risk. While different risks may be identified throughout the system, a common integrity risk that must be mitigated is associated with pipeline anomalies.

Despite mitigative measures, anomalies can be created throughout the life of a pipeline system. Seam anomalies and pipe material laminations may be a result of pipe manufacturing processes. Denting and eccentric loading can occur as a result of the pipe installation process. Additional pipeline anomalies may result from environmental conditions after the system is installed, or as the result of third-party damage. While environmentally induced anomalies may include corrosion and cracking, third-party damage features may result in very complex dent shapes with associated complex stress states.

Adequate processes and procedures built into the companies IMP can be critical to prevent the development or growth of pipeline anomalies. Many IMP procedures provide a plan for leveraging ILI to detect, classify and size pipeline anomalies. The two most common ILI technologies for detecting, classifying and sizing pipeline anomalies are magnetic flux leakage (MFL) for corrosion and metal loss, and geometry (GEO) for dents, ovality, expansions, and other complex geometric anomalies. However, neither is ideally suited for the proper assessment of tight crack detection and sizing, which is part of a crack management plan within an operator's IMP [1].

Two primary ILI technologies are currently recognized for crack detection of pipeline anomalies: ultrasonic testing crack detection (UTCD) and electromagnetic acoustic transducer (EMAT) [2]. While both technologies have a proven track record for inspection in hazardous liquid pipelines, EMAT has a distinct advantage over UT technologies in that it does not require a liquid couplant. This makes EMAT compatible for inspecting both hazardous liquid and gas transmission pipelines.

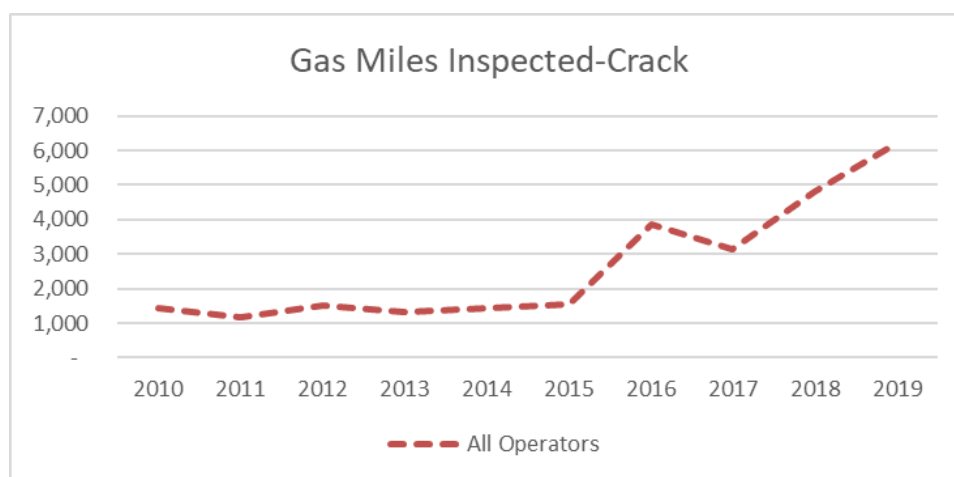


Figure 1: Reported Gas Transmission Pipeline Inspection Mileage [3].

While EMAT for the internal inspection of pressurized pipelines dates back to the early 1980s, systems utilized today were introduced in the early 2000s. [1][2]. As such, operators continue to evaluate and qualify EMAT technology for use. However, EMAT technology may be helping to facilitate an increase in the number of crack inspections of gas transmission pipelines, as indicated by the annual data reported to the Pipeline Hazardous Material Safety Administration (PHMSA) (Figure 1).

Common Crack Features

Crack features located within a pressurized pipeline are usually the result of manufacturing processes, environmental interaction with the pipe material, localized stresses and/or third-party damage.

Cracks that result from manufacturing processes include lack of fusion and hook cracks that are often found within a weld, and surface breaking laminations in the body of the pipe. Cracking as a result of third-party damage is usually found associated with a dent, often as a result of pipe contact with a foreign object such as a rock or excavation equipment. The dent can result in additional strains in the pipe wall or can undergo cycling; this can result in localized work hardened material that is more susceptible to crack initiation.

The term environmentally assisted cracking (EAC) is used to classify crack formation in a material as a result of the interaction of a susceptible material with localized environmental conditions [4]. One of the most common forms of EAC in pipeline material is stress corrosion cracking (SCC). SCC is formed when a susceptible material, like low carbon steel, is subjected to disbonded coating or coating that is shielding the pipeline and a tensile stress above the threshold for SCC formation. When SCC anomalies occur in a pipeline system, the cracking is typically parallel to the pipe axis, since the predominant stress in the system is the hoop stress associated with pipeline pressure. Figure 2 shows an image of a typical SCC anomaly in a pipe wall.

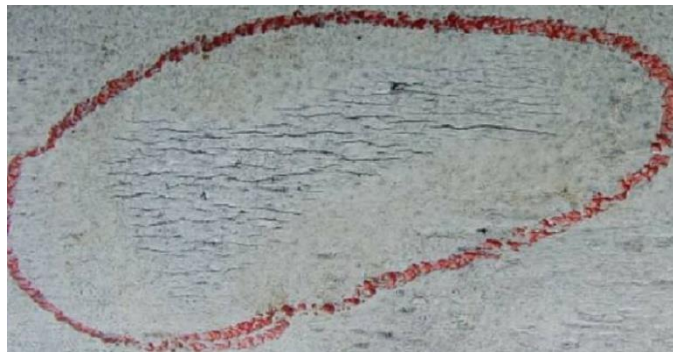


Figure 2: Typical Axial SCC Anomaly.

Brief Overview of MFL and EMAT Technologies

The typical MFL design uses a magnetic assembly to set up a strong field in the pipe wall. Then sensors, typically Hall effect, are placed in close proximity to the pipe wall, recording the magnetic flux leakage field due to magnetic over-saturation in the pipe wall. As the MFL technology incorporates a region of metal loss, the flux leakage field increases, and this increase is recorded by the ILI tool.

Although many EMAT tools also incorporate magnetic assemblies into their design, the physics of the EMAT inspection is significantly different compared to that of typical MFL design. EMAT leverages the field from the magnetic assemblies to produce a bias field in the pipe wall to align magnetic domains. A coil is pulsed in close proximity to the pipe wall, creating a secondary, local pulsing magnetic field. The interaction of the background bias field and the pulsing field produced by the coil, generates ultrasonic acoustic waves in the pipe wall.

The acoustic waves then propagate through the pipe material, reflecting off surfaces they encounter. Ultimately, the EMAT system will collect the signal characteristics of the original wave at some distance from the originating source, along with reflections of the signal going back toward the originating coil. In cases of a crack, the reflections will be associated with the wave's interaction with a crack face. Analysis of the resulting signals can be used to produce crack length and depth measurements.

Not surprisingly, the stark differences between MFL and EMAT physics, result in each technology being sensitive to different pipeline anomalies. While MFL technology is primarily recognized for detecting, characterizing and sizing volumetric metal loss anomalies, some advanced applications can be helpful for the detection of crack-like anomalies that have a minimum opening of 0.1 mm (0.004") [5]. However, cracks with smaller crack openings, which are sometimes classified as tight cracks, are usually considered undetectable by MFL technologies. By contrast, EMAT technology can be utilized specifically to detect, characterize and size crack anomalies.

T.D. Williamson Comprehensive EMAT Inspection System



Figure 3: Image of the 10-inch EMAT tool configuration used for validation.

T.D. Williamson (TDW) validated its EMAT technology using a 10-inch EMAT tool (Figure 3). This design incorporates multiple rare earth magnetic assemblies to set up the bias field, with pairs of receiver assemblies and transmitter assemblies on each individual magnetizer for inspection. The arrangement of transmitters and receivers allows for redundant inspection of the entire pipe circumference, which can increase confidence about pipeline anomalies, since each anomaly is typically seen multiple times. Further, the redundant sensor design increases the probability of detection of seam features, since the EMAT sensors can be upset by an uneven seam trim in some pipelines. While a single sensor assemblies' signal may be disrupted by the seam, the redundant nature of the design allows for another sensor assembly to collect the inspection data.

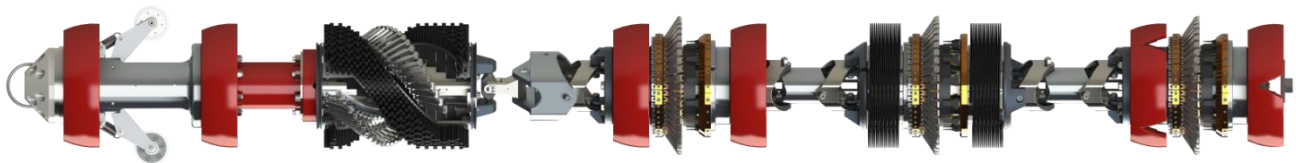


Figure 4: Image of the 10-inch TDW MDS tool configuration used for validation.

As standard practice, TDW runs its Multiple Dataset (MDS) tool in concert with the EMAT tool. The TDW MDS platform comprises several complementary technologies, including high resolution deformation (DEF), high field axial MFL, residual (RES) or low field MFL (LFM), spiral or helical MFL (SMFL), internal/external anomaly discriminating sensors (IDOD), and high-resolution inertial mapping (XYZ) [6].

Although many of those inspection technologies aren't sensitive to tight crack anomalies individually, they contribute to enhanced classification of cracks identified by the EMAT system [7][8]. For example, a marginal linear indication located in the long seam can be better classified with a good understanding of the 'health' of the long seam trim, which can be evaluated by the DEF and SMFL data sets. Another example is the presence of SCC anomalies. Even when the actual cracking is below the threshold for crack-like detection with MFL based technologies, the presence of axially or circumferentially oriented corrosion coincident with the EMAT linear indication in the body of the pipe can be a strong indicator of the presence of SCC anomalies.