THE CHALLENGES OF MFL/DEFORMATION/IMU ILI FOR SMALL-DIAMETER, DIFFICULT-TO-INSPECT PIPELINES

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Abstract

Despite advancements in inline inspection (ILI) technology over the last half century, inspecting small diameter pipelines utilizing ILI tools continues to be a challenge as most small diameter pipelines were designed and built without consideration for ILI tool passage. Nonetheless, those that were, may have configurations or operational conditions that do not allow for an ILI tool to navigate the pipeline.

Arguably, one could modify a pipeline to be made ‘piggable’, this however would require an interruption of service to modify and/or remove any ‘un-piggable’ features; a task which would invariably prove to be expensive, time consuming, and in some cases impossible due to technical feasibility, risk factors and a host of other considerations.

This paper will describe the design parameters used to develop a new system to overcome these challenges and present several case studies showing real-world applications.

Introduction

Intelligent pigs have come a long way since their introduction more than half a century ago[1]. The first commercial ‘smart pig’ – utilising MFL technology – had few sensors, no odometer wheel, only collected data on the bottom quadrant of the pipe and recorded data on reel-to-reel tape.

Recent advancements in microprocessor computational power, memory density, sensor technology, engineering design and modelling software, as well as rare earth magnetics, have allowed the evolution of an MFL inline inspection (ILI) system capable of navigating small-diameter pipelines.

However, applying these advancements remains a challenge in small-diameter ILI tools due to space constraints and pipeline geometry and as such many small diameter pipelines have been labeled as ‘un-piggable’.

Some of the pipeline features that have caused these small diameter pipelines to be classified as ‘un-piggable’ include short radius elbows, mitred bends, heavy wall tees, bore restrictions, back-to-back bends, unbarred tees, Y connections, off-takes, laterals, dead-legs, vertical pipe, thick or thin pipe wall, lack of launcher/receiver facilities and accessibility to name a few.

ILI System Development

Several design parameters were selected and applied to the development of these inspection tools.

1. The inspection tools would utilize the MFL (magnetic flux leakage) technology to detect metal loss.
2. The tools would have deformation sensors to measure the bore of the pipe and detect geometric anomalies in the pipe wall.
3. The tools could be configured to be bi-directional, allowing access from a single point of entry.
4. The tools would need to traverse 1.5d bends.
5. The tools would need tight circumferential sensor spacing, twice the density of other ILI tools.
6. The tools would need a tight axial sample distance, twice the sample rate of other ILI tools.

These parameters created two major challenges for the design.

1. Induce a magnetic field into the pipe wall with adequate strength to detect metal loss and still navigate a 1.5d bend.
2. Create a data acquisition system that was small enough to fit into the pipeline bore yet have enough capability and capacity to process and record data collected by the tool.

The design process began in 2010. The magnetic section was refined using finite element (FEA) software to model the magnetic fields. Advanced finite element software simplified the design of the magnetic circuit used to induce a magnetic field into the pipe wall[2].

The electronics required the use of state-of-the-art microprocessors, memory chips and magnetic sensors.

The design process began with a 3” inspection tool. This specific tool size was chosen due to the limited quantity of pipelines smaller than 3” and the physical limitations in generating a magnetic field in pipelines smaller than 3”.

The first commercial 3” inspection was conducted in the fall of 2015. It was a success and afforded the opportunity to compare the results of the inspection to an ultrasonic inspection in the same pipeline. The MFL/Deformation tool and the ultrasonic tool saw the same dents and almost all the dent depths detected by both tools were within 1% of each other. The metal loss detection was vastly different. The ultrasonic tool reported 1 metal loss anomaly, while the MFL/Deformation tool reported 27 metal loss anomalies, with two of them being >70% deep. Defect verification was done by the pipeline operator and the metal loss calls from the MFL/Deformation tool were located and verified.

Case Study #1 - 3" Line with 1.5d Bend

Pipeline Background:

- The pipeline in question was a 3-inch, 2-mile natural gas pipeline.
- It had never been inspected by an inspection tool.
- The nominal wall thickness was 0.156 inches (ERW pipe).
- The pipeline was constructed in 1962.
- There were no launcher or receiver facilities installed on the pipeline.
- The pipeline typically operated at a low pressure of around 100 psi.
- A confirmed 1.5d (45-degree) bend was present in the pipeline.

Figure 1 A confirmed 1.5d, 45 deg. bend in the pipeline.

Inspection Approach:

- Due to low pressure, it was decided to take the pipeline out of service for the inspection.
- The inspection tool (ILI tool) would be propelled through the line using water.
- Temporary launchers and receivers were installed.
- Prior to running the KMAX inspection tool, a cleaning/gauge pig was used to clean the pipeline.
- The cleaning/gauge pig encountered challenges, including getting stuck in the nominal pipe of the receiver due to a heavy weld in heavy wall pipe.
- The pump truck used for water propulsion had a centrifugal pump, a pressure gauge, but no flow meter.

Challenges and Solutions:

- The cleaning/gauge pig's initial pass left ferrous debris, necessitating a second pass.
- The pump truck's inability to produce enough pressure to move the pig past the weld led to two options: Obtain a pump with higher pressure or reconfigure the pipe at the receiver (chosen due to time constraints).
- The absence of a flow meter caused confusion during the ILI tool run.
- The operator assumed water was flowing, but the water level in the tank remained unchanged.
- A system check revealed that the valve at the receiver had not been opened.
- Once the valve was opened, water flowed through the pipeline.
- The ILI tool successfully passed through the 1.5d bend without pressure spikes or stopping.

Figure 2 Debris on Magnets of Cleaning Pig

Lessons Learned:

- Proper preplanning is crucial for successful inspections.
- Choosing the right pump truck matters; a positive displacement pump would have been better than a centrifugal pump.
- Inline flow meters can provide real-time information about water flow during inspections.

In summary, meticulous planning, equipment selection, and attention to detail contributed to the overall success of this inspection. The pipeline was out of service for 3 days to complete the process. Lessons from experiences like this help improve future inspections and enhance pipeline integrity management.

Case Study #2 - 4” Line with Heavy Welds

Pipeline Background:

A valued client ran an ILI tool in one of their pipelines and discovered numerous heavy welds, resulting in sensor damage and a subsequent failed run. Three welds were cut out for analysis to better understand the issues they were facing in their 4’’ pipelines and ensure a positive success rate in future inspections.

Heavy Welds and Analysis:

- Heavy welds were encountered during an ILI run, the worst having a 7% restriction.
- These heavy welds can pose challenges for ILI tools, especially in smaller-diameter pipelines.

Inspection Approach:

- KMAX developed a simulation using machined rings inserted between flanges. The smallest ring (3.55 inches) allowed their standard magnetic flux leakage (MFL) tool to pass through without any issues.
- To address sensor damage risks near sharp edges Kevlar was embedded into the sensor straps.
- The ILI tool was then tested using pipe samples with heavy welds to simulate an actual pipeline environment.
- During this test, the standard 4-inch tool (with a 3.55-inch minimum bore specification) was pulled through the spool five times.
- All sensors survived, except for one deformation sensor that sustained damage on the fifth pull.
- The inspection tool was reconfigured with uni-directional deformation sensors, reducing spring force. This design allowed the core of the tool to move away from the pipe center when encountering dents or obstructions, making it suitable for lines with vintage welds and excess penetration.

Figure 3 Machined Rings Inserted Between Flanges

Lessons Learned:

- Overall, KMAX’s focus on small-diameter ILI equipment fills an important niche within the pipeline industry, addressing challenges that may not exist in large diameter pipelines.
- Our commitment to innovation and specialization ensures the integrity and safety of oil and gas infrastructure.

Case Study #3 - 6” Line with Pinhole Corrosion

Pipeline Background:

6” pipeline with suspected pinhole corrosion. Detecting and sizing pinhole defects using Magnetic Flux Leakage (MFL) technology - especially in small-diameter pipelines - has historically posed several challenges.

Pinhole Corrosion:

- Pinholes are tiny defects (≤10mm in length) caused by corrosion mechanisms such as micro-biologically induced corrosion (MIC) or third-party activity (e.g., illegal tapping). They can be a significant threat to pipeline integrity, leading to leaks.
- Limited Volume of Metal Loss: The small surface dimensions of pinholes result in limited metal loss volume. Traditional MFL technology struggles to generate a magnetic flux leakage signal strong enough to detect these small defects.
- Challenges with Pinhole Detection: While MFL tools have been successful in managing corrosion threats, small pinhole-sized metal-loss anomalies remain a concern. These pinholes can grow undetected, leading to leaks and significant environmental consequences.

Factors affecting MFL detection and sizing of pinholes include:

- Anomaly dimensions.
- Proximity to other anomalies.
- Tool speed.
- Pipe cleanliness, etc…

Solutions:

- Utilizing 3D finite element modelling software, KMAX engineers were able to simulate MFL signals from pitting corrosion of different depths and dimensions to better understand MFL responses to metal-loss anomalies.
- Armed with this knowledge, KMAX designed a magnetizer that would produce a strong enough magnetic field to detect these small anomalies and still navigate 1.5D back-to-back bends.
- KMAX then increased the MFL sensor count by doubling the number of MFL sensors around the circumference of the pipeline making detection of these small defects possible.

Lessons Learned:

In summary, KMAX’s innovative approach and commitment to pipeline health and safety allowed for the detection and characterization of pinhole defects less than 3mm in length at 10% metal loss.

MFL technology continues to play a crucial role in maintaining pipeline integrity by identifying hidden defects

Conclusion:

Understanding the challenges of inspecting small-diameter pipelines requires focus and determination.

Addressing these challenges requires innovative solutions specifically tailored for small-diameter pipelines.

Pigging small-diameter pipelines presents unique challenges due to their limited space and intricate geometry. Advancements in Inline Inspection (ILI) tools have not been readily applicable to smaller pipelines. As a result, many of these pipelines have been deemed “unpiggable” and have never undergone ILI assessments.

To help overcome the “unpiggable” label and ensure thorough inspection even in constrained environments, we’ve meticulously crafted a range of ILI tool configurations.

Standard Tool:

- Dependable and versatile, this tool serves as the foundation for pipeline inspection. It’s designed to handle a variety of scenarios.

Restricted Bore Tool:

- Flexibility is key here. Our restricted bore tool adapts to varying pipeline dimensions, ensuring accurate inspections even in tight spaces.

Heavy-Wall Tool:

- Sturdy and robust, this tool tackles pipelines with thicker walls. It’s engineered to withstand challenging conditions.

Additionally, our in-house flow loop is meticulously calibrated to align with your technological requirements. This ensures seamless integration, precise results and tailored methods for each small-diameter pipeline.

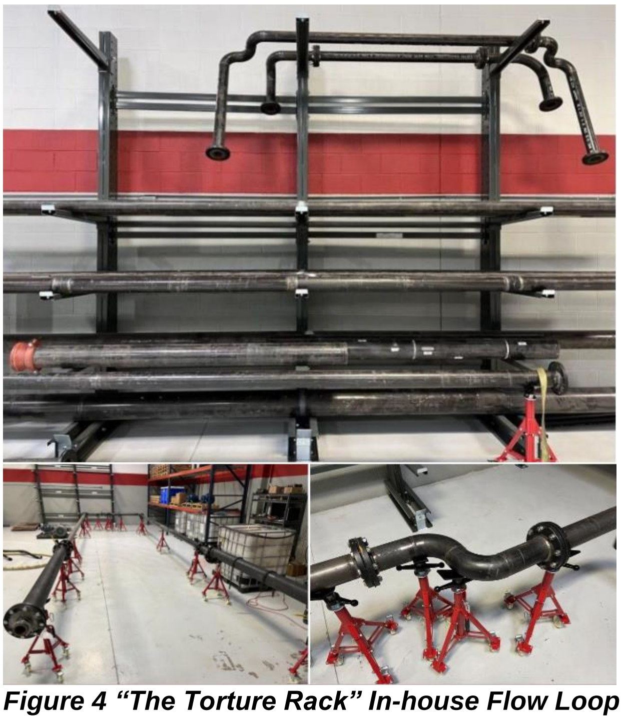

Figure 4 “The Torture Rack” In-house Flow Loop

Reference

[1] Water and Wastewater Pipe Nondestructive Evaluation and Health Monitoring: A Review, Piervincenzo Rizzo, Advances in Civil Engineering, Volume 2010, Article ID 818597

[2] Advances in 3D Electromagnetic Finite Element Modeling, E.M. Nelson, Los Alamos National Laboratory, Los Alamos, NM 87545