Combination MFL/Deformation Inspections of Small-Diameter Unpiggable Pipelines.

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Introduction

The purpose of this paper is to describe a new family of combination Magnetic Flux Leakage (MFL)/Deformation inspection tools used to inspect small-diameter, previously unpiggable, pipelines.

Small diameter pipelines have been historically very difficult to inspect with In-line Inspection (ILI) tools. Small diameter pipelines are challenging because they leave ILI system designers little space to fit the required system components of an ILI tool. In addition, many small diameter pipelines were designed and built without any consideration for ILI tool passage. For example, many of them have tight radius bend fittings and no launchers or receivers installed on the pipeline. Additionally, when a pipeline contains different thicknesses of pipe and/or fittings, these variations add restrictions to the bore of the pipeline. These restrictions to the bore as a percentage of the total bore is much higher than in larger diameter pipelines. For example, in a 3" pipeline, going from schedule 10, with a wall thickness of 0.120" to an extra heavy wall thickness of 0.3" would equate to a bore restriction of 12%. In a 30" pipeline this transition would only be 1.3%.

Recent advancements in microprocessor computational power, memory density, sensor technology, engineering design/modelling software, and rare earth magnetic technology have allowed an inspection system to be developed to inspect these small diameter pipelines.

This paper will describe the design parameters used to develop this new system. A case study of a 4" pipeline will also be discussed showing a real-world application of this new system.

ILI System Development

Several design parameters were selected and applied to the new inspection tools. First and foremost, the inspection tools would use the MFL technique to detect metal loss in the pipelines. The MFL technique is not new to inspection of pipelines or to non-destructive testing. The MFL technique was first used on an ILI tool in the 1960's, over 50 years ago[1]. Second, the tools would have deformation technology to measure the bore of the pipe and detect geometric anomalies in the pipe wall with a tolerance of +/- 1%. Third, the tools could be configured to be bi-directional. This would allow the tools to access pipelines from a single point of entry. Forth, the tools would need to traverse 1.5d bends. Fifth, the tools would need tight circumferential sensor spacing, twice the density of other ILI tools. Sixth, 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. First, induce a magnetic field into the pipe wall with adequate strength to detect metal loss and still pass a 1.5d bend in the pipeline. Second, 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 was started in 2010. The design of the tool's magnetic section was refined using finite element software that models magnetic fields. The advancement of finite element software has simplified the design of the magnetic circuit on the tool used to induce a magnetic field into the pipe wall[2]. The design of the tool's electronics required the use of state of the art microprocessors, memory chips and magnetic sensors.

The design process began with a 3" inspection tool. A 3" tool 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 that was also conducted 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, and 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 4" line

In 2017, KMAX was contacted by a major pipeline operator. The operator has a 4" butane pipeline that is 10 miles long. The pipeline had never been inspected by a metal loss ILI tool. The operator wanted to run an ILI tool through the line to determine the line condition.

The pipeline operator contracted another ILI company to run a caliper tool through the pipeline to determine the minimum bore of the pipe. The ILI company reported several locations that had bore restrictions down to 3.6". The ILI company could not inspect the pipeline with their MFL tool due to the bore restrictions.

The pipeline operator reached out to 6 different ILI vendors to see if they could inspect the pipeline. All 6 vendors declined to inspect the pipeline due to the bore restriction, or the butane product.

The minimum bore of KMAX's 4" tool is 3.6". KMAX and the pipeline operator began a series of discussions to determine if the 4" tool could successfully pass through the pipeline.

The pipeline was built in the 1960's with schedule 40 pipe. Later in 1980's the pipeline was modified by the installation of two above ground valves. The above ground valves were designed and installed with schedule 80 pipe and fittings. Forty-five (45) degree, schedule 80 bends were used to bring the pipe out of the ground and turn the pipe horizontal above ground.

The 3.6" restrictions detected by the geometry tool were associated with the girth welds of the 45-degree, schedule 80 bends and the adjacent pipe or fittings.

Figure 1 Location of 3.6" Restriction--Sch. 80 Bend and Tee (Note the High/Low Weld)

The pipeline was a critical line for the operator. Taking the pipeline out of service with a stuck inspection tool would have a major impact on the operator and the downstream facility. The pipeline operator wanted a very high confidence level that the inspection tool would not stick in the pipeline.

In order to obtain a high level of assurance that the inspection tool would not become stuck in the pipeline the pipeline operator wanted to do full scale testing by duplicating the line configuration of the above ground valve locations.

A testing facility was contracted to create the same pipe configuration as the valve sites in the pipeline. This included a section of straight schedule 80 pipe, a 45-degree 3d bend, a short section of schedule 80 pipe, another 45 degree 3d bend, and another section of straight pipe.

The difficult part of designing the test pipe configuration was figuring out how to simulate the restrictions that were detected in the pipeline. Several ideas were discussed, but the best idea was to place flanges at the ends of the 45-degree, 3d bend. A steel ring could then be inserted in between the flanges to simulate the restrictions. This design would allow the rings to be changed out expeditiously to test different diameters of restriction. It would also allow rings to be fabricated to a very high tolerance level. The rings were designed with full circumferential restrictions. Four different ring sizes were chosen. The inside ring diameters ranged from 3.7" to 3.55". A total of five flanges where installed in the test pipe.

Figure 2 Test Pipe Showing Launcher and Receiver, Bends, and Pump

Figure 3 Test Pipe with Flanges on the End of Bends

Figure 3 Flange with Restriction Ring

Figure 4 Restrictive Rings Installed Between Flanges

A requirement for the simulation test pipe was that the ILI tool testing would be done by propelling the tool with water. The test pipe had to contain a launcher and receiver and fittings to pump water through the pipe. A positive displacement pump was also required to be able to provide the pressure and flow rates needed to test the tool. Pressure sensors were also required to measure the pressure required to move the ILI tool through the test pipe.

Over a four day period, 21 tests were conducted in the test pipe. The first test was conducted with no rings in the system. The largest diameter ring (3.7") was next to be inserted in the system. Smaller rings were then introduced working down to the 3.55" diameter rings. Several tests were run with the 3.55" rings. The tool was stopped at various positions in the test pipe. The tool was stopped prior to the first bend, in the middle of the first bend, between bends and in the middle of the second bend.

The test system was fitted with a pressure monitoring system to measure the pressure it took to push the tool through the test pipe. Each test was monitored to detect pressure spikes when stopping and starting the ILI tool. Figures 5 and 6 show the pressure profile of the ILI tool in the test pipe with 3.55" diameter rings. Figure 5 is without stopping, and Figure 6 is with stopping the ILI tool in each of the two bends. The maximum pressure detected was 163 psi. There is a section of schedule 40 pipe near the end of the test pipe. The pressure to push the tool through the schedule 40 pipe was less than 30 psi.

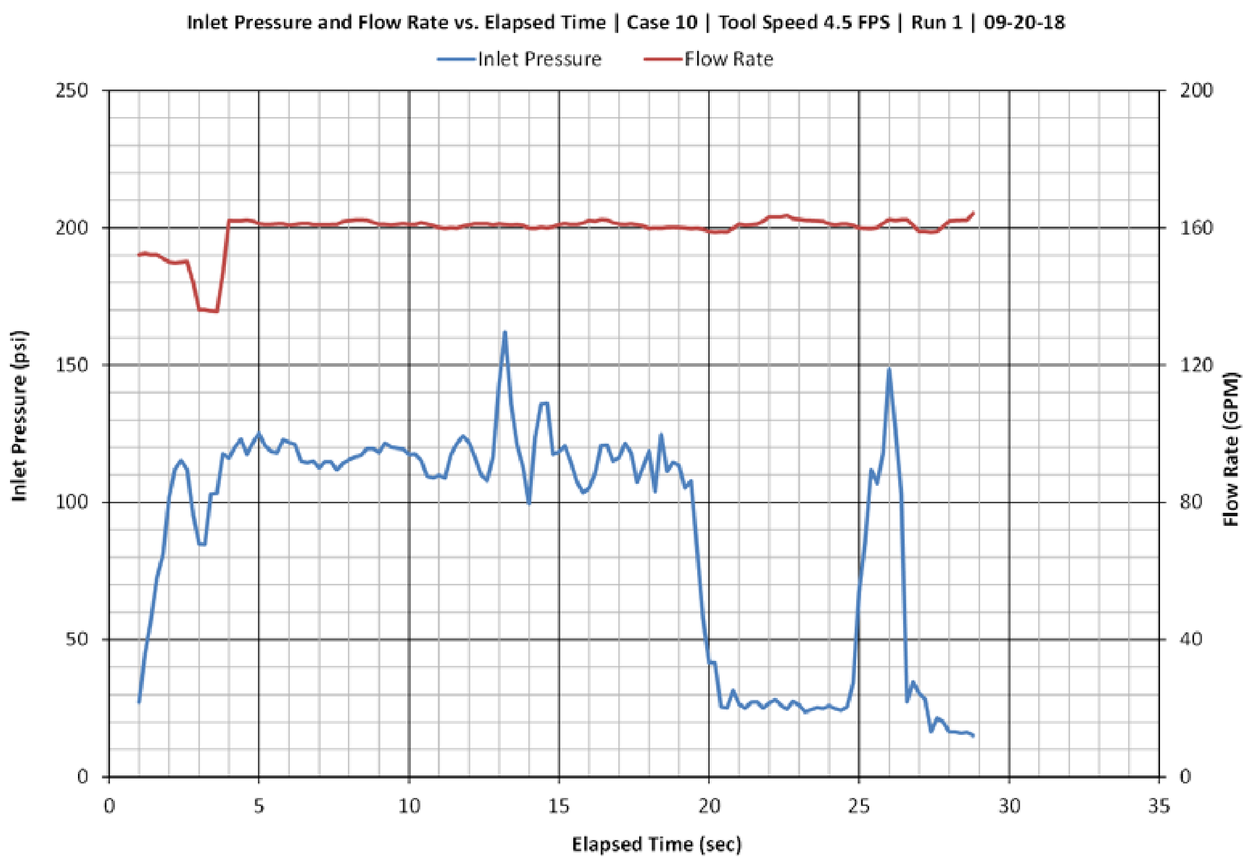

Figure 5 Pressure and Flow of Test Pipe with 3.55 Diameter Rings, with No Stopping

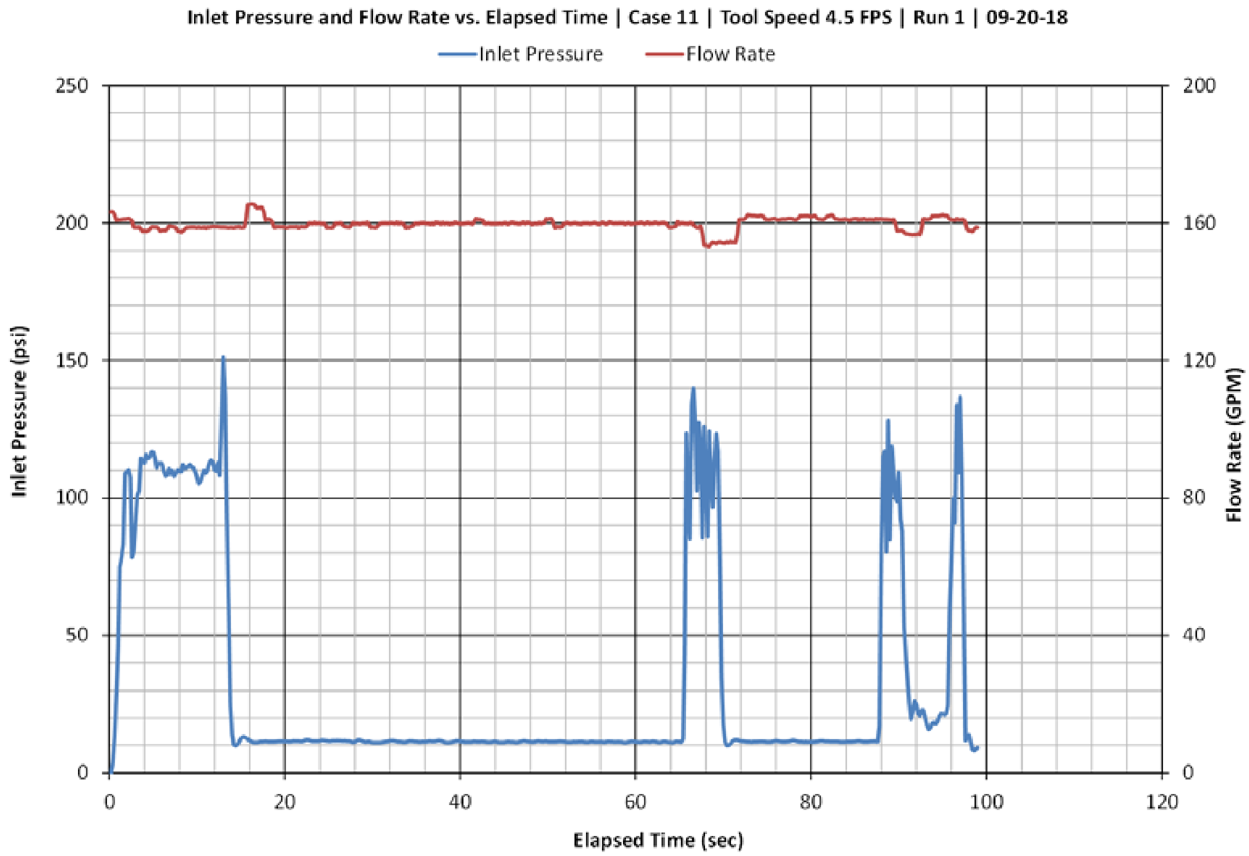

Figure 6 Pressure and Flow of Test Pipe with 3.55 Diameter Rings, with Two Stops

Throughout all the test scenarios the ILI tool never stuck in the restrictions. At the conclusion of the testing phase the operator had a very high confidence level the ILI tool would not stick in their pipeline and recommended that we move forward with the inspection of the 4", 10-mile-long pipeline.

The pipeline operator still wanted to be prepared for the possibility of sticking a tool in their line. They came up with a plan to have "one calls" made for both valve sites and have tested replacement pipe on hand prior to running the ILI tool to minimize down time on the pipeline should the ILI tool get stuck in the line.

Figure 7 One Call Stakes at Valve Site

The pipeline operator created a calibration spool of 4" schedule 40 pipe that contained both internal and external metal loss features as well as dents. The spool was brought to the launcher and prior to launching the ILI tool, the pipeline operator pulled the ILI tool through the spool with a strap using a pickup truck. This spool would allow the operator to validate the performance of the ILI tool.

Figure 8 Calibration Spool of 4" Sch. 40 Pipe

The ILI tool was run through the pipeline. Both valve sites were closely monitored to make sure the ILI tool made it through the restrictions. The tool passed both valve sites with a constant speed and never stopped or slowed down.

When the ILI tool was removed from the receiver, it was covered in a lot of ferrous debris from the pipeline. The pipe had been cleaned with foam and brush cleaning pigs but had never had a magnetic cleaning pig run through the pipeline. The tool was downloaded, and the data evaluated. There were several MFL sensors that were damaged during the ILI tool run. A review of the data also revealed that the background magnetic level of the ILI tool diminished over the length of the pipeline due to the ferrous debris collecting on the ILI tool.

Because the damaged sensors and sensor coverage did not meet the customer's acceptance criteria for ILI tools, a rerun was necessary. A rerun was rescheduled and performed. The ILI tool was closely monitored through all valve locations. The tool passed through these all sections with no difficulty.

Lessons learned

Over 3 years of inspecting pipelines with this system has allowed the ILI system to evolve and improve. There are several lessons learned and to be shared. First, these small diameter pipelines are difficult to inspect. While every effort is made to make a system that is robust, sensor failure occurs. The evolution of the sensor system has constantly been changed and improved. In small diameter tools, there is not a lot of room to protect sensors from the pipe line environment. Last year over 50% of the lines inspected by the KMAX system were unable to be inspected by other ILI vendors' tools.

Most of the inspections with the KMAX system have been in pipelines that have never had an ILI tool run through the pipeline. Cleaning the pipeline is very important, especially if the line has never had a magnetic cleaning pig or MFL tool run through the pipeline. Ferris debris can remain inside a pipeline segment even after running a foam or cup pig through the pipeline segment.

Our experience with inspecting these pipelines compelled KMAX to develop its own cleaning pig. The goal was to develop a multi-bodied cleaning tool that would contain brushes, magnetics and gauge pig to detect restrictions in the line. We feel that this type of cleaning tool is import to the successful inspection of these small diameter pipelines.

References

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