

Improved Methodology to Identify the Location of a Stuck Pig Using Large Standoff Magnetometry Technology

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ABSTRACT

Pipeline operators regularly run pigs for various applications, such as cleaning, batching, and integrity inspections. These runs are often completed without the aid of transmitters or pig tracking, making it difficult and problematic to pinpoint the location of a pig if it happens to get stuck in the pipeline.

This paper will discuss recent research and advancements in locating stuck pigs using a non-intrusive technique with a technology known as large standoff magnetometry (LSM). Additionally, the influence that operational and pipeline conditions, operating factors, and technical calculations have on the process will be deliberated; likewise, the collection and analysis method, and future developments will be presented. Finally, a case study from a recent project will present the cost-effectiveness, process efficiency, operating procedures, and reduced environmental impact of the LSM technique when compared to standard methods of identifying the location of a stuck pig.

Key words: Pig, Inline Inspection, LSM, Project Management, Operational Efficiency, Stuck Pig, Cost Effective, Wax Buildup, Transmitter, Tool Monitoring, PWA.

INTRODUCTION

Pigs are currently available in varying size and type and are run in pipelines for a wide variety of applications. The common types deployed into pipelines are cleaning pigs, batch pigs, purge pigs, and smart pigs which are also called inline inspection (ILI) tools. There are substantial costs involved in an integrity assessment completed using pigs, these costs are from the overall inspection, throughput loss due to pump or compressor station bypass, and tracking. The factors that influence the success of a pig run are pipe cleanliness, fluid medium, flow rate, pressure, temperature, speed of the product, and total

run time.¹ Pig tracking plays a crucial role in a pig run as it aids in controlling some of the success factors and the overall inspection cost. When pig tracking is used during pig runs a pipeline operator is provided with the following information: near real-time location of the tool, estimated time of arrival (ETA) to above ground references (AGR) or critical sites along the line, and estimated pig velocity. This information aids pipeline operators in efficiently planning pump or compressor station bypassing which minimizes throughput loss, reduces operational risk, and increase revenue.² Some pipeline operators use an alternative method referred to as “batch tracking” to approximate the pig’s location during a pig run, this is accomplished using pump rate and product throughput information.¹ This method is not conducive for knowing the precise location of a pig, communicating ETAs to downstream sites, monitoring the pig’s near real-time velocity, and efficiently bypassing pump or compressor stations. Batch tracking is commonly used during short runs or runs involving cleaning or batch pigs. When pig tracking is not used there have been instances where pigs have been stuck, lost, or have damaged valves at stations. In the absence of pig tracking there is an improved and cost-effective methodology to identify stuck pigs or obstructions in a pipeline by using large standoff magnetometry (LSM) technology.

LSM technology works by measuring the effects of inverse-magnetostriction. Magnetostriction is characterized when a ferromagnetic material changes in size, volume, type, age, etc. during magnetization.³ LSM technology detects inverse magnetostriction which is the “change of the magnetic susceptibility of a material when subjected to mechanical stress”.⁴ LSM technology is a non-intrusive, passive, aboveground, indirect inspection, geo-magnetization flux leakage measurement technology that traditionally identifies and locates stress concentration zones on steel pipelines.⁵⁻⁶ For example, the technology has been used to successfully identify dents, buckles, cracks, casing ends, and taps by measuring changes in the magnetic field across the buried pipeline and identifying a signal characteristic of a dipole.³⁻⁷

Using a recently developed methodology, LSM has been used to locate stuck pigs in buried pipelines efficiently, cost-effectively, and with limited environmental impact. A commercial implementation of LSM, Spectrum XLI-PWA[†] (Pipe Wall Assessment), has successfully located stuck pigs on multiple occasions, further demonstrating the value of this impressive technology.

METHODOLOGY

When a pipeline’s flow is severely restricted or blocked due to a stuck pig, product build up, or both (“obstruction”), the location must be identified to facilitate remedial action. When the location cannot be located by conventional means, segments of the pipe are fully exposed, and a pressure gauge is installed to verify if that exposed location is before or after the obstruction. An obstruction can be identified through observations and comparisons of pressure changes. This process requires a large excavation and a process called hot tapping, all while the pipe is full of a petroleum product.⁸ Each excavation and hot tap can cost tens of thousands of dollars, and as many as a dozen or more may be required to adequately pinpoint the location of the obstruction.⁸

There is a need to accurately locate an obstruction in a pipeline without requiring repeated pipeline excavation, exposure, and tapping. The advanced LSM technology can be used to pinpoint the location of obstructions (e.g. stuck pigs or wax buildup) in a section of pipe by detecting change in the magnetic field due to pressure-induced stress in the pipe wall. The magnitude and direction of the change in the magnetic field is dependent on numerous factors, including the diameter, wall thickness, grade of steel, and current level of magnetism on the pipe.

An LSM sensor is positioned on the ground above a buried pipeline. Ideally, where possible, the sensor can be positioned directly on the pipe, or as near as possible to the pipeline to minimize signal to noise ratio and the occurrence of false positives. The precise positioning standoff requirement of the sensor is

[†] Trade name.

determined by factors such as pipeline diameter, pipeline pressure specifications, and strength of the magnetic field generated by the pipe under stress from internal pressure.

Detection Feasibility Calculation

The pipeline should be cycled from maximum allowable pressure to zero pressure, or as high and low as possible, to create a gradient that allows for the detection of an obstruction. The aim is to create a change in pressure within the pipeline whereby the change is above a predetermined threshold. First, Barlow's formula (Equation 1) is used to find the maximum internal pressure that the pipe can withstand. With P_{BARLOW} calculated, Equation 2 is then used to determine the pressure change that is required on the pipeline. The result (P_{TEST}) should be greater than 10%, and ideally greater than 30%, of P_{BARLOW} . A pressure change that meets this criterion ensures that changes in the magnetic field are easily discernable with the LSM sensor. If P_{TEST} is under 10%, the ability to detect magnetic field deviations using LSM is reduced and may have limited success. This specification was derived from proprietary research, SME knowledge, and repeated experiments on test and live pipelines, and is part of a pending patent application.

$$P_{BARLOW} = \frac{2\sigma_t s}{D} \quad (1)$$

where

$$\begin{aligned} P_{BARLOW} &= \text{max internal pressure (in psi)} \\ \sigma_t &= \text{allowable stress (in psi)} \\ s &= \text{wall thickness (in inches)} \\ D &= \text{outside diameter (in inches)} \end{aligned}$$

$$P_{TEST} = \frac{(P_{MAX} - P_{MIN})}{P_{BARLOW}} \quad (2)$$

where

$$\begin{aligned} P_{TEST} &= \text{percentage of Barlow} \\ P_{MAX} &= \text{maximum pressure of test (in psi)} \\ P_{MIN} &= \text{minimum pressure of test (in psi)} \end{aligned}$$

Data Analysis

Figure 1 depicts an example of the two types of indications that can be seen at a testing location during a pressure cycle. The graph on the left shows a visible shift in the magnetic field which indicates that the obstruction is downstream of the location and away from the pressure source. By comparison, the graph on the right does not have a clear or visible shift in the magnetic field and this indicates that the obstruction is upstream of the location and towards the pressure source.

The visible magnetic shift is due to inverse magnetostriction caused by the hoop stress created in the pipe wall when the pressure is increased within the test segment. The absence of a magnetic response indicates that the obstruction has isolated the pressure from the test segment. The LSM pressure detection test is more conclusive when consecutive pressure cycles can be produced from both the upstream and downstream direction (e.g. from pig launcher and from pig receiver). The consecutive test from each end confirms the position of the LSM sensor in reference to the obstruction. In addition, the magnetic data must be examined for evidence of unusual or unexplained steps or shifts in the trends of all three axis to confirm that the obstruction is not moving when under pressure. The magnetic change

should correspond with the pressure increase, being held steady, and decrease. Correlation of the time that the pressure change starts and ends, as well as, the time that maximum and minimum pressure is achieved is required to confirm that the LSM response corresponds to the pressure cycle changes.

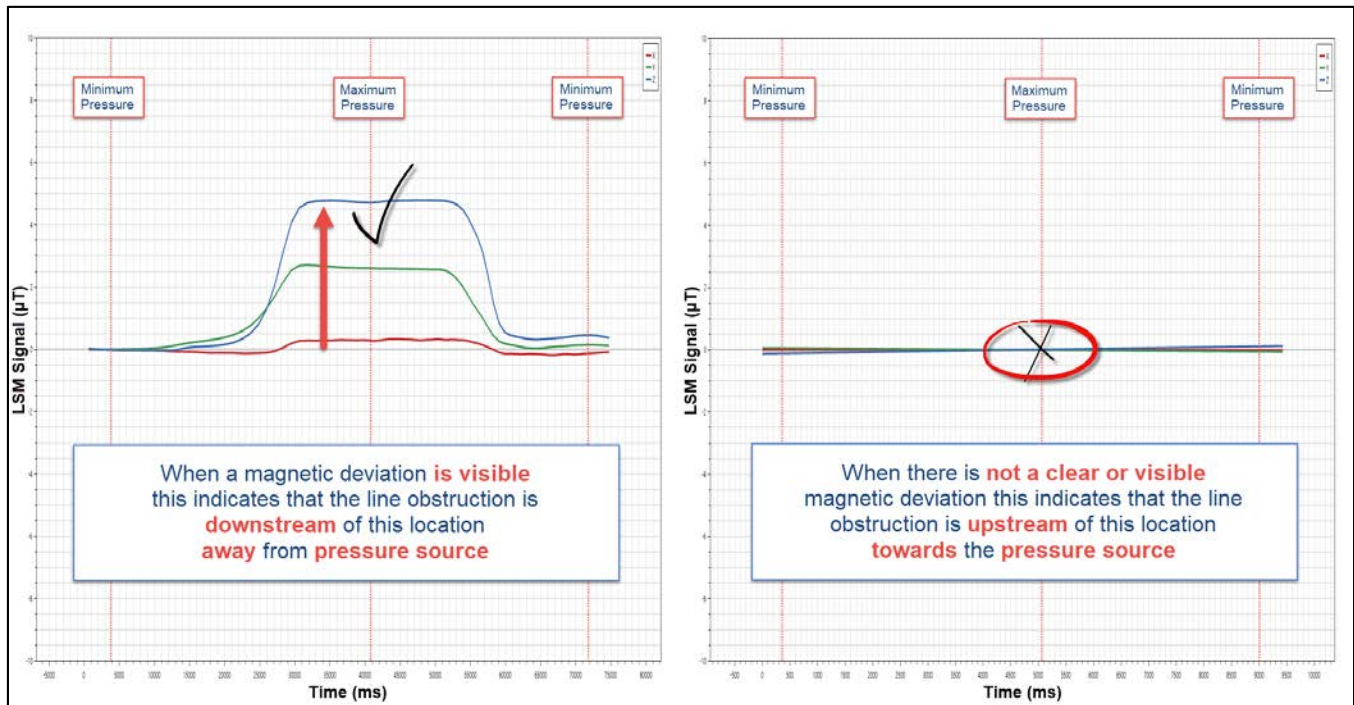


Figure 1: Analysis of the Effect of Pressure Cycles on the Magnetic Field of a Pipeline

Identifying a Stuck Pig in a Pipeline

- 1) Place the LSM sensor on subject's pipeline near pressure source to verify strength of magnetic field by cycling from maximum to minimum pressure (or minimum to maximum). The technician will be able to confirm the maximum standoff distance that the LSM sensor can be from the pipe to detect magnetic field deviations caused by the pressure cycles.
- 2) The sensor is then moved to the mid-point (Location A in Figure 2) of the section of pipeline where the blockage is suspected (50% of the distance from start to end). The sensor is placed over the pipeline within the maximum standoff distance previously established in step 1, and the pressure is cycled again.
- 3) Using the analysis methodology shown in Figure 1, the search area is further reduced by determining the direction of the obstruction (upstream or downstream) and setting the next inspection location as the mid-point of the current location and the previous location. Effectively, the search area is halved after every pressure cycle test as shown in Figure 2.
- 4) Repeat step 3 until:
 - a. The search area is narrowed down to a desired distance; or
 - b. There should be no magnetic field deviation when pressured from either the upstream or the downstream sources. This indicates that the LSM tool is on the blockage or pig.
- 5) The LSM tool operator will provide the exact location or narrowed down area of the stuck pig to the pipeline operator.
- 6) The Pipeline operator will plan to remove the pig using a method appropriate to the situation and standard procedures.

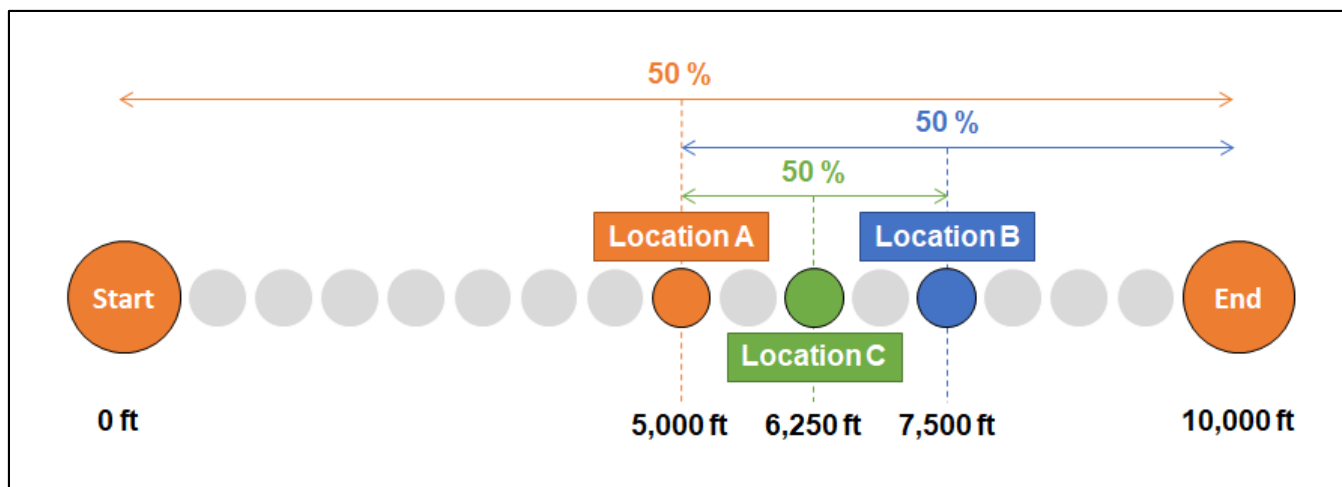


Figure 2: Method of Reducing Search Area

Advantages

Some of the key advantages of identifying an obstruction in a pipeline using LSM technology instead of traditional methods (e.g. hot tapping at multiple spots) are:

- Cost savings and efficiency: a technician can locate an obstruction quickly, often within a single day;
- Environmental impact: reduced impact due to minimal excavation and corresponding need for land rehabilitation; and
- Operational risk, health and safety: reduced number of hot works and field workers days onsite and at remote locations.

Disadvantages

There is no obvious disadvantage in using LSM technology to identify an obstruction when compared to traditional methods. The LSM technology is still in early stages of research and development and is a low-resolution scanning tool not a pressure gauge; it does not provide accurate pressure information (psi measurement). Based on multiple field trials, the need for psi measurements directly from the LSM tool is not required to identify an obstruction, as the aim is to identify a corresponding change in the magnetic field due to an internal pressure change in the pipe.

If the pipeline depth of burial is significantly high, the LSM technology may require removal of cover to reach the maximum detection distance; this can be done by hand excavation or hydro-vac and does not require exposing the pipe. Exposing the pipeline is necessary when using traditional hot tapping methods, hence, this is not actually a disadvantage.

CASE STUDY

Problem: A cleaning pig was launched in a 6", ~8.96 km long, condensate pipeline. The pipeline operator did not have any issues historically on the line with pigging, but despite previous success the pig became stuck and blocked flow of the pipeline. Multiple attempts by the pipeline operator to move the stuck pig were unsuccessful. Since a 22 Hz transmitter or pig tracking had not been used, the pipeline operator had to rely on alternatives. Batch tracking was used but due to an expectation of product build up (wax) during the pigging operation the calculations may have been inaccurate. The pipeline operator had historical samples of wax buildup from the pipeline that was confirmed by taking additional samples from the pig receiver. The batch tracking indicated that the pig should be ~3 kms upstream of the pig receiver.