ULTRASONIC IN-LINE INSPECTION TECHNOLOGY AND FITNESS-FOR-SERVICE ASSESSMENT OF UNPIGGABLE PIPELINES

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The need to manage and maintain pipeline system integrity has become increasingly important to pipeline owners and operators in recent years. Accurate measurement and evaluation of the physical condition of oil and gas pipelines is critical to effective integrity management, as well as to assurance of sustained pipeline safety.

Conventional inline inspection (ILI) tools – commonly referred to as "pigs" – are frequently used to perform detailed inspections on pipelines. These tools are not designed for use on all pipelines, however. Valve restrictions, lack of launcher/receiver facilities, changing pipeline diameters, flow restrictions, or tight bend radii can deem a pipeline "unpiggable" if the inspection tool cannot physically pass through the line. Scaling up a pig for use in large diameter pipe is not as technically challenging as scaling down a pig for use in confined and restrictive pipe spaces. Until recently, little progress had been made in development of pigs for these circumstances, and consequently a large amount of piping, particularly within the fence line of refineries and other process plants, remained inaccessible.

Quest Integrity Group, a global provider of inspection and assessment solutions for the pipeline, process and power industries, is leading technology innovation in this area with its recent development and introduction of InVista™, an ultrasonic inline inspection tool designed to overcome challenges associated with pipeline configurations that until now have limited the capabilities of pigging systems. InVista, which is being utilized by Quest inspection teams on pipelines from the North Slope of Alaska to the Middle East, is designed to provide pipeline operators with highly accurate, quantifiable inspection data on non-traditional pipeline configurations. This data is used not only to identify corrosion and other defects, but also to provide a solid foundation for fitness-for-service assessments.

Although a number of small diameter smart pigs equipped with ultrasonic inspection technology have appeared in recent years, nearly all of them have limited capabilities to some extent. The ultrasonics of these small diameter pigs are not designed to be "free swimming" or are not fully self-contained and are adaptations of systems intended for relatively thick-walled pipe. These systems have experienced challenges navigating through tight bends (1.5D is generally the limit), and have limited inspection distances (less than 5km is common), often due to tethered configuration requirements.

The new InVista ultrasonic tool was designed to overcome these challenges. This inspection technology is a fully self-contained, free-flowing, smart pig ILI tool, equipped with sensors equally distributed around the circumference of the tool. The presence of corrosion or other three dimensional anomalies in a pipe disturbs the ultrasonic pulse sequence, and is picked up by the receiver and recorded onboard. Time of flight is then used to compute the piping wall thickness, diametrical, and shape dimensions based on the known acoustic propagation properties of the couplant and the piping material.

InVista's ultrasonic sensors are capable of direct measurement of anomaly characteristics, which leads to superior pipeline integrity assessment in comparison to indirect measurement techniques. Important attributes of the InVista tool include:

- Ultrasonic sensors provide 100% internal and external pipe inspection coverage as well as geometry inspection
- Inspection distance of greater than 100 miles (160.93 km)
- Circumferential and longitudinal positioning data, providing location of defects
- Conformability to pipe diameters of 3 to 14 inches (76.2 to 355.6 mm)
- Ability to navigate through short radius 1D pipe bends
- Ability to navigate through back-to-back 90° "S" bends
- Ability to navigate through reduced port valves and unbarred tees
- Ability to operate under low-flow conditions
- Ability to discriminate between defects on interior and exterior pipe surfaces
- Bi-directionality (ability to enter and exit the pipeline at one location)
- Data tagging with GPS coordinates through above-ground markers

The InVista tool detects and measures wall thickness and changes in internal and external diameter dimensions caused by anomalies. The tool is comprised of multiple modules and is propelled with water or hydrocarbon fluid throughout the length of a pipeline. The fluids in the pipeline also provide acoustic coupling for the ultrasonic transducers. Because of the unique sensor configuration, the system operates within tighter tolerances, providing a more accurate and more confident measure of defect dimensions than conventional magnetic flux leakage tools, and superior resolution and accuracy than comparable ultrasonic systems. Overall, for the smaller diameter pipelines for which it was designed, InVista produces a higher quality ILI data set than that available from any other comparable inspection system.

The use of custom ultrasonic sensor technologies, combined with a powerful graphical data analysis package such as Quest's LifeQuest™ Pipeline, results in high resolution, digital, quantitative inspection data for the entire pipeline, viewable in two-dimensional (2D) or three-dimensional (3D) formats. Data can be obtained in a matter of minutes after being collected without removing tight bends or modifying the pipeline with special launcher and receiver facilities. Additionally, the InVista tool has bi-directional capabilities such that access to the pipeline can be limited to one location. This is an important feature when under space and/or modification cost constraints. Today's designs are capable of inspecting Schedule 20 to 160 pipelines with nominal diameter dimensions of 3 to 14 inches (76.2 to 355.6mm). Other size designs are currently under development and will have onboard inertial measurement units (IMUs) to enhance the inspection of complex piping configurations.

The primary applications for InVista intelligent pigs in a pipeline system include:

- In-plant piping and pipelines
- Transfer and storage lines
- Loading lines, both onshore and offshore
- Production and gathering lines
- Compressor and pump station piping
- Process and refining pipelines
- Short transmission lines or road crossings
- Tank farm lines

InVista in the Field

Following is an example of how the InVista technology is being applied in the field. In this instance, a refinery in one of the world's most crowded pipeline corridors needed to inspect a configuration containing a pipeline which consisted of three different piping diameters, leading from the process facility to the delivery location of another pipeline operator. The challenge was that the pipeline had several diameters (4-inch, 6-inch and 8-inch) and the operator needed to have a thorough internal and external inspection that would require the least number of mechanical changes.

In addition to the differing pipe diameters, the location and configuration was a significant challenge. There was one above-ground valve setting allowing access to the pipeline. In one direction, an 8-inch section transitioned to a 6-inch section, then transitioned to a 4-inch section inside the process facility and flowed in an overhead rack to a manifold. On the other side of the valve setting was a three-and-a-half mile length of 4-inch pipeline that teed into another operator's line.

It might have been possible to perform a hydrostatic test on the line, but it would have been expensive and would have only provided an instant snapshot rather than comprehensive data required for longer term management of the line. Likewise, above-ground inspection methodology in the dense pipeline environment would have provided only qualitative data which could have been erroneous or misleading.

Using InVista, with its unique bi-directional and multiple size configuration capabilities, Quest performed the inspection and required only one mechanical change to the above-ground valve setting. The result was a quantitative data set which allowed for a fitness-for-service analysis, inspection time of only one day, and a significant cost savings for the operator.

FFS Assessment Procedures

Fitness-for-service (FFS) assessment is a multi-disciplinary approach to evaluate structural components to determine, as the name suggests, if they are fit for continued service. FFS is particularly applicable for pipelines because there is a high likelihood of flaws or other damage being present. In addition, pipelines may be subject to more severe operating conditions than for which they were originally designed. The typical outcome of an FFS assessment is a go/no-go decision on continued operation. An evaluation of remaining life and/or inspection intervals may also be part of such an assessment. FFS assessment protocols have been updated recently to address a wider variety of damage mechanisms and component geometries, incorporate use of more powerful analytical tools, and leverage the ability to analyze a linear section of pipe rather than just individual flaw locations. Two FFS protocols discussed here are API 579-1/ASME FFS-1 and ASME B31G (original and modified).

For pipelines, FFS assessment has traditionally been performed on identified flaws in pipe wall or welds, focusing on whether a particular flaw exceeds established criteria for safe and reliable operation, or if it is likely to worsen during the next operating interval such that it will exceed the criteria. These assessments have historically been performed on a flaw-by-flaw basis in conjunction with field verification (prove-up) studies and are known to be computationally intense. However, recent advances in analytical software and computing power make it possible to perform sophisticated FFS assessments rapidly on the entire pipeline using complete ILI data sets, thus making it feasible to use some forms of FFS assessment as a screening tool prior to field verification, as well as an evaluation tool for pre- and post-remediation of defects.

The FFS corrosion assessment approach of many, if not most, pipeline operators is based primarily on ASME B31G (original or modified). These are established methods that seek to determine the remaining strength of pressurized pipe based on maximum dimensions (length/depth) of reported indications in inspection data. Newer and more broadly applicable assessment methods have been available for some time, such as those in DNV-RP-F101 and API-579-1/ASME FFS-1. These are considered to be more appropriate for modern pipeline steels, and use of API 579-1 procedures in pipelines that are less than fifteen years old is generally recommended. API 579-1/ASME FFS-1/2007 is the second edition of the FFS standard, and it incorporates a number of important changes and additions from previous versions. The API standard includes three levels of analysis that differ primarily in regard to the data considered at each level. LifeQuest Pipeline allows for a rapid and automated Level 1 and Level 2 assessment of the entire line utilizing 100% of the inspection data.

Historically and presently, most ILI inspections of extensive pipeline systems are performed using magnetic flux leakage (MFL) technology. MFL data sets can be interpreted to describe the dimensions (depth and length) of flaws, and modern software enables analysts to estimate the geometry of flaws (e.g., parabolic or river bottom shape) to create a richer characterization of individual flaws in the analytical algorithms. On the other hand, the compilation programs applied to raw MFL data typically use very broad signal interpretation tolerances, such that the interpreted data sets (the starting point for ASME or API assessment) are considered to be very conservative. While software manipulation of MFL data to characterize the shape of individual flaws is a good thing conceptually, it does nothing to reduce the inherently broad tolerances in the data or increase an operator's confidence that an indicated flaw merits excavation and further study. The challenge of MFL technology, well-known to all who use it, is to understand the ILI data well enough to decide where prove-up and remediation should be undertaken, and get it right most of the time.

Newer ILI tools such as InVista, using direct measurement capabilities of ultrasonics, produce higher resolution raw data than MFL tools and produce data sets with tighter tolerances and more accurate flaw sizing. Additionally, ultrasonic tools easily differentiate between interior and exterior corrosion, and yield precise measures of wall thickness. When UT data are assessed with ASME B31G and API 579 Level 2 protocols, the theme of the results will be roughly the same (safe maximum pressure for ASME, and a calculated reduced maximum allowable operating pressure for API 579), but the confidence levels will be inherently higher because the raw data are better.

Summary

Pipeline integrity management depends to a large degree on understanding the physical condition of the pipe and the unique degradation mechanisms affecting it. For many years the norm has been to gather huge volumes of ILI data of suboptimal quality, interpret this information conservatively to identify numerous locations where significant flaws cannot be ruled out from inspection of the data, excavate the pipe in these locations to confirm and characterize the flaws, and then perform calculations to determine whether the flaw must be repaired or how much longer the pipe can remain in service.

Three innovations to the pipeline integrity management field offer material improvements over the status quo:

- New and advanced ILI inspection tools that produce more accurate and less ambiguous data in pipelines previously considered “unpiggable”
- Rapid assessment and analysis techniques using API 579/ASME FFS-1 to assist in the management of very large data sets and yield important insights into “unpiggable” pipeline condition.
- New FFS assessment procedures which, in combination with new analytical software such as LifeQuest Pipeline, offer highly efficient and highly confident evaluations of pipeline corrosion damage and remaining strength, reducing unnecessary pipeline excavations and repair, in addition to allowing for the confident establishment of inspection intervals.