Advancements in Pipeline Girth Weld Inspection

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Abstract

Historically, girth weld inspection of Oil and Gas transmission pipelines has been carried out by film-based radiography. This technique provides easy-to-interpret, two-dimensional grayscale images of the weld and, with minimal training; an operator can interpret the image and determine the relative quality of the weld. While film based radiography is still widely used, like any other technique, it does have its drawbacks and disadvantages.

Today, girth welding of large diameter pipe is more likely to be carried out by mechanized or “automatic” welding processes rather than by manual techniques. This conversion has also seen an accompanying conversion to automated inspection techniques and particularly to Automated Ultrasonic Testing or AUT in similar fashion as seen in pipe manufacturing where both ultrasound and radiography techniques are now highly automated.

This paper compares the strengths and weaknesses of various inspection modes as well as discusses current advancements that provide improved technical capability and inspection efficiencies.

Figure 1, Spiral Weld Pipe Testing System
1. Historical Background

The enabling technology facilitating the science of Non Destructive Testing (NDT), X-rays, was discovered in Germany in 1895 by Professor Wilhelm Conrad Roentgen. For much of the early 20th century x-ray use was limited mostly to medical applications as the cathode ray tubes used to generate x-rays were not capable of being driven by the voltage levels required to produce x-ray levels adequate to penetrate metals. It was not until the advent of the Coolidge tube in 1913 by William Coolidge of the General Electric Company that industrial x-ray applications began to be a reality. The Coolidge tube is still the foundation of x-ray tubes in use to this day.

Since the early days of radiography, silver halide films have been the mainstay of radiographic imaging. When x-rays strike this film Bromine ions are liberated and captured by positive Silver ions. Subsequent processing of the film through a reducing agent yields black metallic silver creating the familiar gray scale radiographic image.

While the principles of sound propagation were well known in the late 18th and early 19th centuries, their use as an industrial inspection method were not considered until the late 1920’s when Soviet scientist Sergei Sokolov postulated that sound could be used to detect irregularities in homogeneous solids. Sokolov’s work and subsequent work conducted by others in Europe in the early days focused on through transmission of ultrasound. In the early 1940’s American scientist Floyd Firestone demonstrated the reflection technique using a modified radar instrument, which he went on to name the Reflectoscope. Taking the lead form Firestone various others including German Physicists Josef and Herbert Krautkramer of Cologne Germany began developing commercially available industrial ultrasonic testing instruments.

2. The Advent of Automated Ultrasonic Girth Weld Testing

Some of the first endeavors into using ultrasonics as a replacement for radiography were by RTD b.v. in the late 1950’s and the first semblance of a modern day Automated Ultrasonic Testing (AUT) system was developed by Vetco Offshore in 1971. Being a conservative industry, large-scale change from a proven, familiar technology to something new in NDT is often slow to develop and AUT was no exception. It took nearly twenty years from these first developments to achieve industry acceptance. Arguably the start of modern mechanized inspection of pipeline girth welds came in the late 1980’s with the award of the first commercial on-shore contract using AUT by TransCanada Pipelines.

The driving forces in facilitating this transformation were mechanized welding, and the inspection challenges it created as well as the ever-increasing need for inspection productivity. Early mechanized welding attempts using the newly developed Gas Metal
Arc Welding process proved problematic due primarily to the lack of understanding of bevel design and joint fit up. The early leader in mechanized welding, CRC, introduced a process involving an internal alignment clamp and a special bevel design that included a flat to help register each pipe end – the Land of Cross Penetration or LCP. This design dramatically improved weld ability but created inspection issues with radiography, specifically, the 45° Hot Pass and Fill Pass fusion zones.

During the early days in AUT several approaches were taken to develop the optimum ultrasonic testing method for pipeline girth weld inspection. The Krautkramer approach focused on finding general weld anomalies including defects in the volume of the weld while others focused their work on identifying and sizing fusion face defects. The resultant standard was documented in ASTM E 1961 released in 1998. The fundamental assumptions of planer defects oriented along theoretical bevel lines, sizing algorithms based on zonal discrimination and signal amplitudes referenced to known standards and the more recent inclusion of Time of Flight Diffraction have resulted in AUT being a robust inspection method with POD’s documented in excess of 90%.
3. Digital Conversion

The basic science of Non-Destructive Testing has remained essentially unchanged since the early days. What have changed dramatically, especially in the least several years, are the methods used to acquire and store inspection data. A fundamental shift from analog batch processes to more real time digital solutions is taking place now with the largest impact being seen in the field of radiography. Digital radiography solutions currently exist in two forms – Computed Radiography and Direct Radiography. Both methods eliminate the need for radiographic film and create a true digital image of a radiograph.

Computed Radiography (CR) is the closest to conventional film based radiography and employs an imaging plate containing photosensitive storage phosphors. When exposed to x-rays, these phosphors create and retain a latent image that when scanned via laser in the digitizer release visible light, which is captured, reconstructed and saved as a digital image. CR imaging plates are reusable and require no chemical processing unlike their x-ray film counterpart. Other benefits of CR over conventional film radiography are:
- Wide dynamic range and a higher tolerance for varying exposure conditions resulting in less retakes and reduced x-ray doses.
- Reduced granularity of the image
- Higher absorption efficiency and excellent homogeneity of the phosphor material resulting in improved image sharpness.
- Digital archiving capability.

Direct Radiography (DR) provides an immediate conversion from radiation exposure to digital image creation. Since the exposure and image creation occur simultaneously, images can be reviewed within seconds of an exposure with no further processing required. DR’s ability to provide extremely high quality images in real time eliminates the need for batch processing providing significant improvements in productivity in addition to cost savings by eliminating consumables.

In general radiography relies on the visual acuity of the operator to identify and interpret anomalies in a weld. Taking advantage of the processing power of today’s computers, a host of tools are available to the operator to facilitate proper evaluation of an image. Zoom features, edge identification algorithms, sizing cursors, etc. all have one purpose – to optimize probability of detection and ensure operators make the right calls.

4. Advancements in AUT

There is little doubt that for the majority of pipelines being constructed, AUT has the potential of providing a higher quality, higher productivity pipeline girthweld inspection than any of the radiographic methods discussed. The fundamental variable in the quality of an AUT inspection is the technical competence of the operator. AUT provides orders of magnitude more information to the operator with greater potential for variation. Recognizing the need for continued advancement in the technologies that improve
detection and sizing of anomalies, most of the advancements in AUT over the last ten years have been and will continue to be directed at improving the overall robustness of the technique and simplifying an AUT inspection for the operator.

The inclusion of phased array into AUT is a good example. A pair of phased array transducers essentially replaces all of the pulse echo transducers on a conventional multi-probe AUT system. Changes to probe angles and pulse echo setups are now done in software and not by changing wedges and physical locations of the probes in the probe pan. More sequences can be added to interrogate smaller zones improving the operator’s ability to determine the z-axis depth and size of a defect.

Advancements in electronic design and miniaturization now allow ultrasonic pulsers and receivers to be located on the scanner itself as opposed to a remote cabinet. The main benefit of this architecture is the elimination of long coaxial cables being run from the electronics to the scanner head – cables that act like antennas and are prone to receiving electrical noise from the welding operation. It is now feasible for an AUT crew to follow close behind the weld crew providing them with detailed information on quality so the welding process can be kept in control and eliminate defects before they occur. AUT can now be thought of as a process control tool as opposed to just an inspection method.
Setting up an inspection plan and creating a reference block drawing can take an operator days to manually create. Setup wizards now automate much of this process by providing virtual images of an ultrasonic shot and generating calibration blocks and technique sheets directly from information captured during creation of the inspection plan. Such tools reduce the planning stage of a project from days to an hour or two at the same time removing opportunities for error.

5. Conclusions

Conservatism is a natural part of nondestructive testing and change has historically been slow to come. Developing economies around the world are putting a strain on energy demand resulting in expansion of transmission pipeline infrastructure. Lack of qualified inspection technicians to meet this demand is driving a need to simplify the operation of NDT systems and improve inspection productivity. Technology providers are investing heavily and products are now coming on line that provide a step change in overall productivity.

Figure 6, Wizard generated phased array UT Shots