Per lustration on Defects in Oil and Gas Tubular Industry

Dipak K. Banerjee

Abstract— Pipelines are used for transportation of Oil and gas across various nations. Some of these pipelines are concealed or overhead. The extent and usage of pipelines depends upon transportation substance. It is evident that material and safety of pipeline are of pertinent nature for erroneous transportation and hazard free environment. The pipeline under discussion on this paper generally as Submerged Arc Welded Pipes which produced by fabrication process .The governing specification for the manufacture of these pipes accentuated by American Petroleum Institute (API) and American Society of Testing and Metallurgy (ASTM).Pipeline the management plays a vital role to estimate the life cycle of embedded structure. Crack or Leakage are the most vulnerable discontinuities in pipeline. Piping discontinuities capped in this paper are labeled as sub surface (Cracks-Porosity-inclusions-Lack of penetration-Incomplete Fusion-Burn through-Undefill) and surface defects (Lamination -Scabs).Tabular form of sub surface discontinuity propagation study is also included. The Non Destructive System includes for ease of measurement of the discontinuities, pictorial view of advanced methods comprehended to improve the process resulting in better quality of product and high yield for the manufacturing organizations.

Keywords— Pipeline, Weld Defect, Non Destructive Testing (NDT), Acoustics, Magnetic Flux, Radiography Testing, X-Ray Testing.

1 Introduction

Pipeline network is most effective way of transporting Oil-Gas for long distances. In Oil and Gas industries the pipelines are perhaps used commonly in Gathering System which reserves raw crude, from different wells later transmitted through the pipe line to various refineries. After refining the raw crude, it is transferred to various business or distribution centers for the usage. The advent of pipeline goes back to 1859 and continues till date with no exceptions. There is an urge in demand of pipelines to transport oil and gas from an remote areas to various business centers. Initial days a long span of times intended to increase the material development of the pipelines [1-8].

Extended analysis on pipe raw materials and manufacturing process such as forming and welding is intending to alter the prevailing limitations. Pipe manufacturing cost is of vital significance with the growing demand and complexity in material properties.

There is a growing agility in the existing pipeline structure and it has become a subject of discussion across the globe. It is impertinent and tough measure, to evaluate the discontinuities for subsurface pipelines. The common reason for agility of the surfaced pipelines is the corrosion .Corrosion leads to loss of pipeline the material resulting in leaks and low transmission capacity. Operators concerned for continuous corrosion and extended studies are in progress to measure the pipeline reliability with time change [1-3],[9].

The objective of research is the reliability and residual life monitoring of the existing pipeline structures. The aim is to segment the pipeline as a whole or a cross section of pipeline in which a set of defects is located. An objective of characterizing the pipeline state can attain if the surface and subsurface defects are diagnosed. The procedures for evaluation of pipelines known as Nondestructive methods and inspection mechanism termed as Nondestructive Inspection (NDI). Allegorizing discontinuities in pipes during manufacturing and in process is better established by Non Destructive Evaluation (NDE). It is even noticed that the large diameter pipes are even manually inspected from the inside by human crawling throughout the section [3].

The various techniques envisaged to study the discontinuities in the pipes or plates are Ultrasonic Technique (UT) [10], Radiography (RT) [11], Acoustics Emissions Technique (AET) [12], Magnetic Flux Leakage (MFL) [13] and Image Processing [14].

Ultrasonic technique is one of the nondestructive techniques highly practiced in the pipeline industry. Higher frequency sound waves used to measure the discontinuities in the structures. The object is being exposed to beam of high ultrasonic energy .The beam passes the matter beyond any loss reproduced back for discontinuities. This method uses a coupling fluid namely water or oil is used depending upon the conductivity .Continuous on line inspection, of small diameter pipes-6"(SMLS or ERW) immersion chamber with ultrasonic probes of the special designs are preferred. The weld seam area is exposed to these probes to measure the intensity of the discontinuities. However, for large diameter pipes probe guidance is of persistence significance. The probes mounted, on a series with the probe holder which guides along the pipe surface by roller or shoes. Curved shoes preferable for better exposed of pipe surfaces to these probes. Dual element probes recommended for the front and back end of pipes leaving small untested zones [1],[10],[11],[15].

Ultrasonic testing incapacitated in dual ways during inspection in service pipe lines and while during manufacturing.

- *Dipak K. Banerjee is currently pursuing PhD degree program in engineering Science and Systems / Mechanical and Materials Engineering Track in University of Arkansas at Little Rock, Little Rock, Arkansas, USA E-mail: dkbanerjee@ualr.edu*

A detail of pipeline insulation depends upon getting, ultrasonic transducers in contact with pipes to test [10],[16-18].

In this paper we go through Radiographic Technique (RT), Ultrasonic Technique (UT), Acoustic Emission Techniques, Magnetic Flux Leakage Signals (MFL), and Image Processing Technique. Also we have demonstrated sub surface defects (Cracks-Porosity-inclusions-Lack of penetration-Incomplete Fusion-Burn through-Undefill) and surface defects (Lamination -Scabs)

The main reason of this paper is to feature the conventional and advanced NDE techniques commonly practiced in the tubular industry .The goal is disseminate all surface and subsurface discontinuities which will be latent beneficial to the researcher contractors and asset managers of piping industry. All the discontinuities described with a diagrammatic representation for in-depth understanding.

2 Industrial Radiography

Industrial radiography is another reliable defect detection method practiced highly in Oil-gas industry .It uses the incident electromagnetic energy (Gamma or X-rays passing through the specimen which in turn attenuates a greater effect at the detector .More often used detectors are X-ray films which possess a very high contrast and are extremely fine grain. Film image is obtained by incident x-rays travelling in a straight from source to the object passing through the X-ray tubes. X-ray films are later interpreted by the experts based upon their experience and knowledge to drill downs the various discontinuities in the structures. This system exercised to sublimate the sub surface discontinuities as porosity, cracks, lack of penetration etc [19].

Inverse Square Law [19]:

Radiography method includes that magnitude of radiation expands as it travels X-ray or Gamma sources. An Intensity (I) for a given radius(r) at any point is the source strength over area of the sphere.i.e. “Intensity of X-rays is inversely proportional to the square of the distance” [19], E. Mundry.

This is illustrated as below.

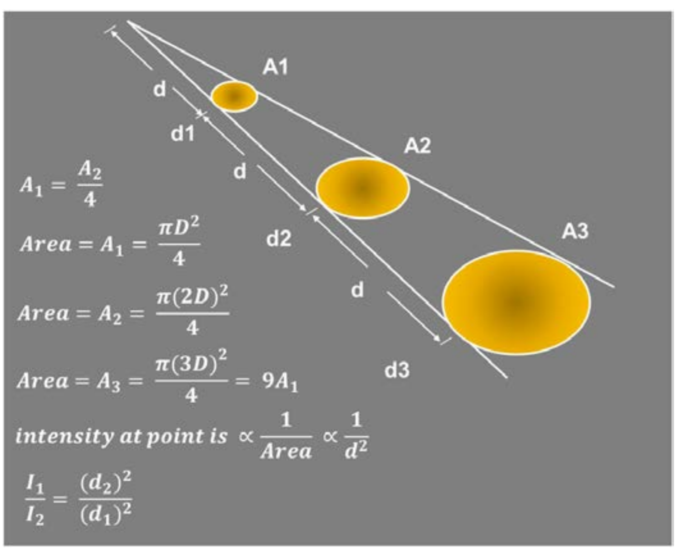


Figure 1. “Inverse Square Law” [19].

I1-Intensity at Point1; d1-Distance at Point 1.

I2 -Intensity at Point2 ; d2-Distance at Point 2.

Enumerate Inverse Square Law of Radiation.

Weld discontinuities [20] are abeyance of the archetypal construct of a weldment such as a paucity of continuity in its visible, metallurgical or mechanical characteristics. The notable discontinuities are in the base metal, weld metal and heat affected zone. The heat affected zone (HAZ) is part of base material adjacent to homogenous weld which remains unmelted and has its microstructure and properties altered by welding or heat intensive cutting operations [20].

Discontinuities origination can be ascertained due to.

A) Technological: Related to metallurgy and welding process.

B) Execution: Welding Personal skill in following the procedure and specifications.

Table 1. The Summary of type and location of the weld Discontinuities.

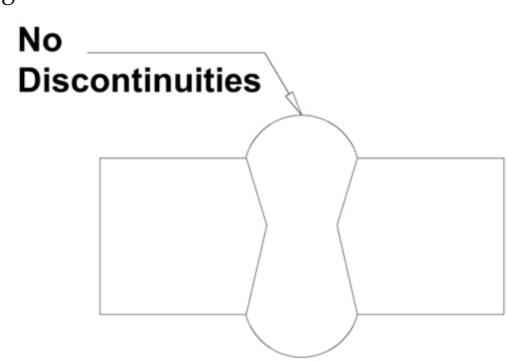
Type	Location Of Defect
Cracks	Weld
	Heat Affected Zone (HAZ)
Lamination Seams & Laps	Base Metal(BM)
Lamellar Tears	BM
Porosities	Weld
Inclusions	Weld
Lack Of Fusion OR Penetration	Weld
Undercut	BM
Overfill	Weld

Radiography is way to detect volume based defects .This is best used for the products manufactured by casting, welding forging and rolling. It is an ideal technique for the inspection of items which have been welded or exposed to temperature above the AC3 temperatures. The sensitivity is affected by the sample specimen, film alignment and size-location of the discontinuity [11],[20].

3 Defects and Interpretation of the Radiographs

3.1 Sound Weld

Sound weld for steel pipes is characterized by well-defined microstructure of the heat affected zone. It brings adequate mechanical and metallurgical values with weld joints appear brighter an since it is thicker than the base metal [9],[21].



ISSN 2229-5518

Figure 1. Represent an outline of Sound Weld for a steel pipe [1],[3],[19],[22].

3.2 Cracks

Cracks generated due to thermal contraction during phase change of metal. This depends upon metallurgical content i.e. for Carbon Equivalent an greater than 0.2% in welded pipes with rapid cooling developed, cracks. Hot cracks generated during process or completion of welding due to Sulphur and Phosphorous for high Carbon equivalent. The low mechanical strength of weld bead at the time of cooling thwart the contraction stresses is notable reason for these cracking. Commonly these cracks developed in the weld metal and are visible with naked eye. Cracking reduced with low carbon and phosphorous, Sulphur should be 0.06%.Owing an Hydrogen presence filler metal or weld pool hydrogen induced cracking developes at Heat Affected Zone, at weld toe or under weld bead during fabrication [1][3].

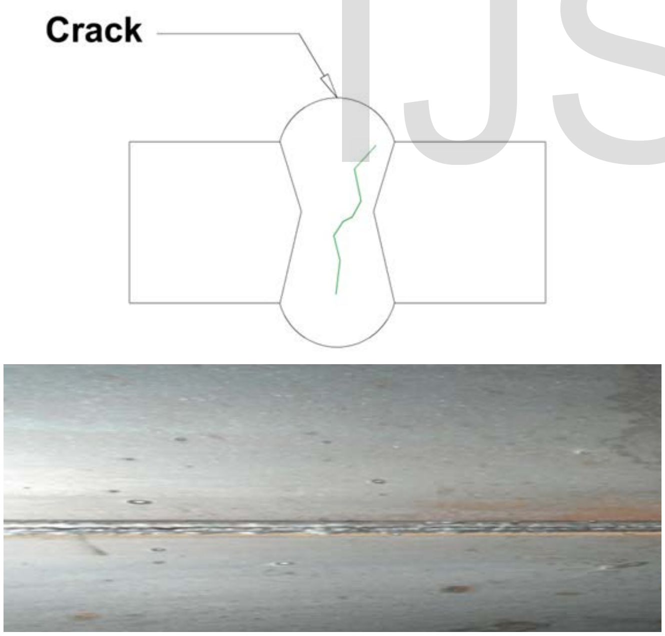


Figure 2 Delineative outline exemplication of longitudinal cracks in welded pipes [1],[3].

3.3 Porosity

Porosity occurs due to gasses being cornered at the time of crystallizing the weld metal. Commonly, these are round-spherical or cylindrical in shape. The underlying reason is due to improper welding, technique accompanied by leaving behind the uncleaned welding area an apart from the lubricants in conveyors. They are categorized as Linear porosity as in the straight line occurs due to contaminations along joint, root or inter bead boundaries, Cluster porosity, is defects in one spot due to improper start and stop techniques [1][3].

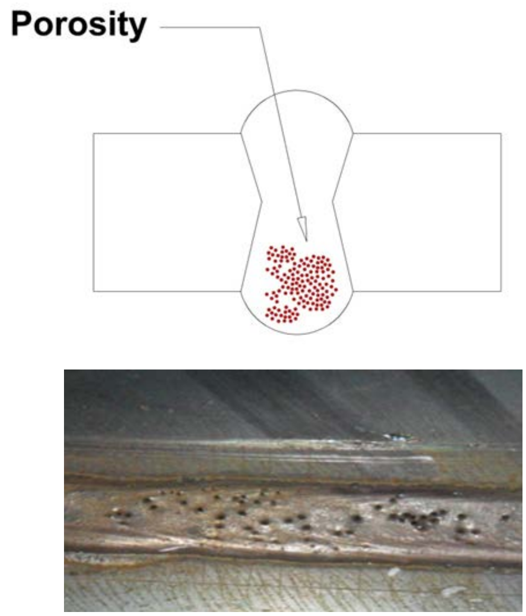


Figure 3 Delineative outline exemplication of linear, cluster porosities in welded pipes [1][3].

3.4 Inclusions

Inclusions are generated due to left over slags/oxides and the nonmetallic materials which get trapped in the weld metal between weld beads and base metal. This developes undue stresses and reduces bonding strength of the weld .This may also arise due to high voltage fluctuations [1],[3].

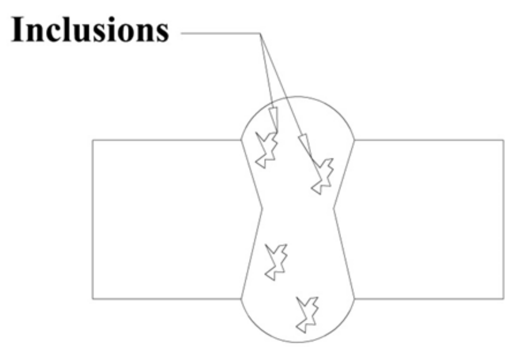


Figure 5 Delineative representation of Lack of Fusion in weld-

ed pipes [1],[3].

3.5 Incomplete Fusion

Incomplete fusion occurs due to unfusion of joint in the root during welding. This leaves behind uneven root gap more root face leading to improper weld with imprudent joint design .It also arises owing to an inadequate heat to melt the base metal resulting in a low bevel angle [1],[3].

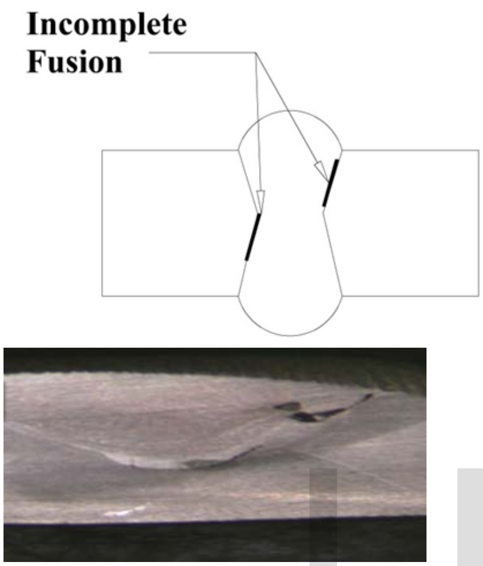


Figure 5 Delineative representation of Lack of Fusion in welded pipes [1],[3].

3.6 Undercut

Undercut is generated due to molten base material curving alongside of the weld owing to expeditious solidifications [1],[3].

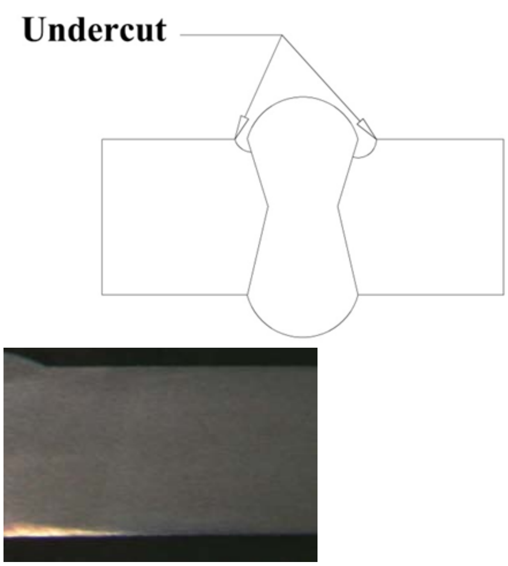


Figure 6 Delineative representation of Undercut in welded pipes [1],[3].

This results in centralizations of stresses at one point emanating in poor welds. The underlying reason for undercut may be due to the fast welding head travel speed accompanied by more current-voltage [1],[3].

3.7 Lack of Penetration

Incomplete penetration is owing too low welding head travel speed resulting in low amperage and voltage and imprecise torch angle. These avert the weld bead perveate the thickness of base metal which culminates a natural stress and leads to poor weld and crack [1],[3].

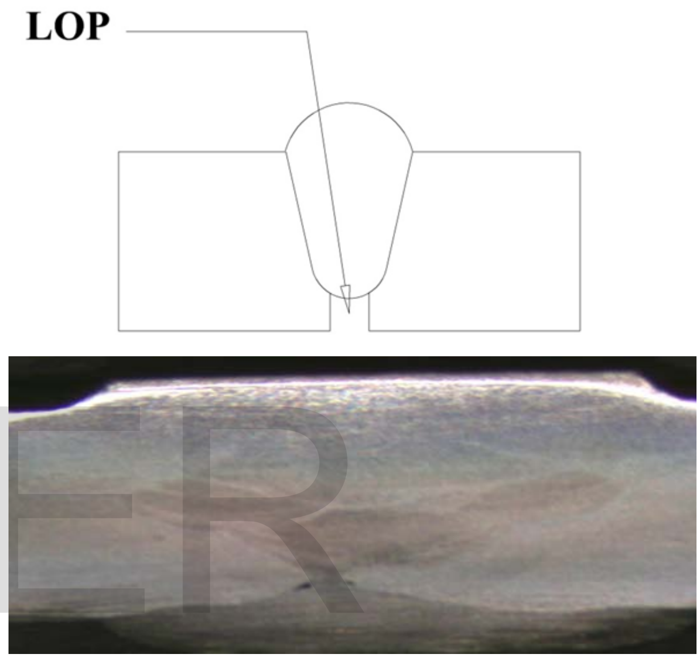


Figure 7 Delineative representation of Lack Of Penetration in welded pipes [1],[3].

3.8 Underfill

Undercut is generated due to inadequate deposition of filler metal and eroding of the base metal while welding .Common cause is excessive temperature at the welding area [1],[3],[21].

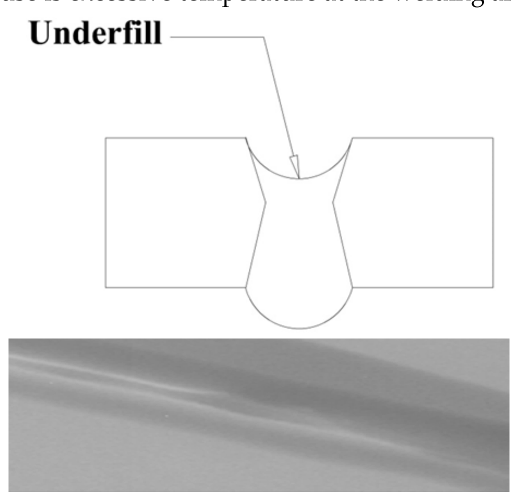


Figure 8 Delineative representation of Underfill in welded pipes [1],[3].

Another discontinuity which arises due to an extension of the root face in the base metal is termed as Underfill. This develops an internal concavity and can be avoided by modifying the welding speed [1],[3],[21].

3.10 Excessive Penetration

Excessive penetration ensues when weld metal bulges on one side of the root face. This exaggerated due to excessive high amperage or a miniature root face. It provides a good location for crevice corrosion, and minute spots are a considered to reduce the integrity of weld [1],[3].

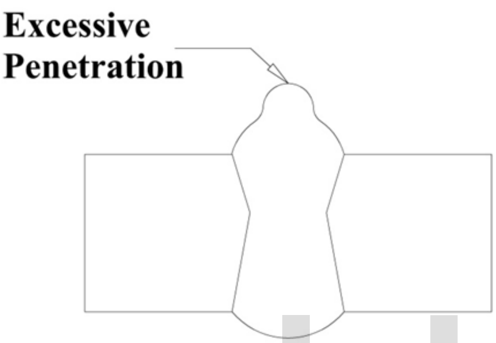
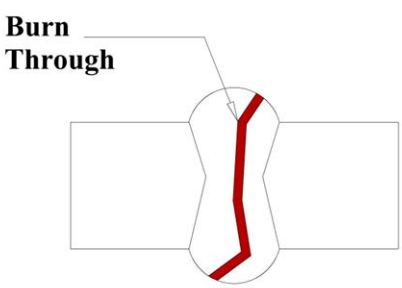


Figure 10 Delineative representation of Excessive Penetration in welded pipes [1],[3].

3.11 Burn Through

Burnthrough generated owing confined eruption of the molten metal to superfluous infiltration at the time of welding. The common logic is exorbitant flow of current and improper welding technique [1],[3].



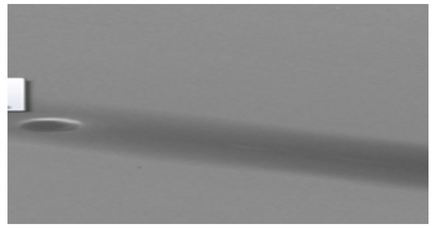


Figure 11 Delineative representation of Burn through in welded pipes [1][3]

Agglomeration of metal droop through the weld causing a dense annular position on rear of the weld [1],[3].

3.12 Surface Defects

These defects are raw material which caused owing uncontrolled cooling of slabs, leaving some foreign particles e.g nails during rolling-casting of these slabs .These results leaving sliver marks, cracking resulting in improper welding and other defects with uncontrolled wastages Most likely causes for the defects were either high voltage, or a long enough wire stick-out, or the welder moved expeditiously through these areas [1],[3].

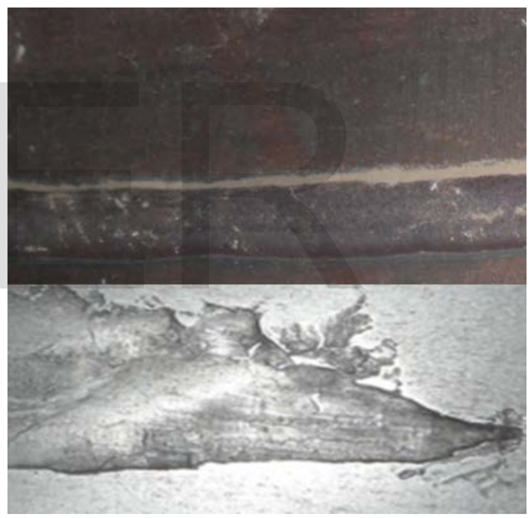


Figure 12 Delineative representations of Surface Defects in welded pipes.

4. Magnetic Flux Leakage Signals (MFL)

Magnetic Flux Signal (MFL) is another nondestructive method to find the surface and subsurface discontinuities in the pipelines. This process involves the magnetic leakage field to locate the discontinuities both in axial and circumferential directions. The concept of MFL is that magnetic field applied to a Ferro magnetic material till it becomes magnetized .If a defect noted in the object magnetic resistance magnified and magnetic field gnarled. Thus the magnetic leakage field will develop at the areas and the electrical signals will displayed which amplified for extended research. It's hard to detect the interior and exterior defects of the pipelines [22].

5. Acoustic Emission Techniques:

Acoustics Emission Technique (AET) is an acceptable method of NDT which relies mostly on high frequency stress waves. It provides the detailed information of the origination of discontinuity including developmental part .This technology utilizes high range Ultrasonic sensors (20Khz-1Mhz) which records the defects or discontinuities in the structure . Any waves or oscillation received sensors, converts electrical energy into voltage that electronically amplified into AE data.AE applied on an object initiates the latent forces which developes local stress resulting in plastic deformation of the object at specified locations. These deformations, generates acoustic or elastic waves which propagates from the body till it strikes a remote sensors. These sensors converts electrical signals for research .It is noted that amount on energy dissipated and the amplitude of resulting wave calculated on the dimension and source of the discontinuity i.e. emission amplitude is the directly proportional to crack velocity [23],[24].

6. Image Processing

Image Processing is an advanced nondestructive method in Oil-Gas industry. This system works on the principle of pattern recognition and requires volume of data to train the same. A complete algorithm train the system nomenclature of the defects including its dimensions, chances of occurrences and its suspect able positions in the pipeline. After training the sample data system tested with the actual data. The actual data compared with the conventional NDT system to measure the effectiveness [25].

7. Summary

Radiography is an traditional and widely acceptable nondestructive method in Oil-Gas industry for ages. This system traces a most of the pipeline sub surface discontinuities and images overlaps. Porosity labelled as the major defects and its appearance as a linear, cluster or single. It appears as circular black dark spots in the images. Cracks resembles as thin dark or broken lines under radiography. Surface defects due to chipping tool marks, Salver, pitting marks also generate images and often mislead with internal defects.

Magnetic Flux Linkage (MFL) is nondestructive method capable of measuring the defects in all directions. This system uses online inspection and unaltered by the transportation medium. However the system has a limitation owing to the quality of the required signal, impurities presence in the pipelines, magnetic field development etc. Though research is in progress to mark the system popularity, however asset managers are using robotic tools for low pressure pipelines without masses.

Acoustic Emission Technique (AET) recognized as nondestructive test method to measure defects for objects under stress. AET works better for a remote sensing method, low sensitive to any geometry configuration and global monitoring practices. AET is a passive technique since it depends on the object under test for the initiation of energy. This system possesses limitation of attenuation, subjected noisy and effective results achieved with predefined material property and fewer repeatability.

8. Conclusion

Welding plays a dominant role in giving the structural integrity for the pipes. Any discontinuity generated during the process must be detected by an NDT system to avoid any harmful effect to the environment .It is also noticed that a some of the defects generated are permissible as per manufacturing specifications .As per recommended specification, some defects are allowed to be repaired and accepted . They need be within the tolerable limits, specified by the quality control code used during the weld inspection.

9. References

[1] W. M. Alobaidi, "Application of microwave and ultrasonic techniques for defect detection in pipes," Dissertation. *University of Arkansas at Little Rock*, 2017.

[2] M. Ahammed, "Probabilistic estimation of remaining life of a pipeline in the presence of active corrosion defects," *International Journal of Pressure Vessels and Piping*, vol. 75, no. 4, pp. 321–329, 1998.

[3] W. Alobaidi, E. Sandgren, and H. Al-Rizzo, "A Survey on Benchmark Defects Encountered in the Oil Pipe Industries," *International Journal of Scientific & Engineering Research*, vol. 6, no. 2, pp. 844–853, 2015.

[4] W. M. Alobaidi, H. M. Al-Rizzo, and E. Sandgren, "NDT Applied to the Detection of Defects in Oil and Gas Pipes: A Simulation-Based Study," in *ASME 2015 International Mechanical Engineering Congress and Exposition. American Society of Mechanical Engineers*, 2015, p. V02BT02A008.

[5] W. M. Alobaidi and E. Sandgren, "Classification of the Extent of Wall Thinning in Pipes Based on Simulations in the Time and Frequency Domain," in *ASME 2016 Pressure Vessels and Piping Conference. American Society of Mechanical Engineers*, 2016, p. V005T10A005.

[6] W. M. Alobaidi, E. Sandgren, and H. M. Al-Rizzo, "Waveform Pattern Recognition Applied to Rapid Detection of Wall-Thinning in Pipes: A Simulation-Based Case Study," in *2016 11th International Pipeline Conference. American Society of Mechanical Engineers (ASME)*, 2016, p. V003T04A038.

[7] W. M. Alobaidi and E. Sandgren, "High-Efficiency

Remote Measurement of Pipe Defect Using RF/UT Technologies: A Theoretical Analysis Part One—Straight Beam UT," in *ASME 2016 Pressure Vessels and Piping Conference. American Society of Mechanical Engineers*, 2016, p. V005T10A006.

[8] W. M. Alobaidi, Z. A. Nima, and E. Sandgren, "Localised surface plasmon-like resonance generated by microwave electromagnetic waves in pipe defects," *Nondestructive Testing and Evaluation*, no. April, pp. 1–10, 2017.

[9] W. Alobaidi and E. Sandgren, "Detection of Defects in Spiral/Helical Pipes Using RF Technology," in *11th Pipeline Technology Conference*, 2016, no. May, pp. 22–33.

[10] W. M. Alobaidi, E. A. Alkuam, H. M. Al-Rizzo, and E. Sandgren, "Applications of Ultrasonic Techniques in Oil and Gas Pipeline Industries: A Review," *American Journal of Operations Research*, vol. 5, no. 4, pp. 274–287, 2015.

[11] W. M. Alobaidi, E. A. Alkuam, E. Sandgren, and H. M. Al-rizzo, "Enhancing Production Efficiency of Oil and Natural Gas Pipes Using Microwave Technology," *Energy and Power Engineering*, vol. 7, pp. 440–450, 2015.

[12] M. F. Haider and V. Giurgiutiu, "A Helmholtz Potential Approach to the Analysis of Guided Wave Generation During Acoustic Emission Events," *Journal of Nondestructive Evaluation, Diagnostics and Prognostics of Engineering Systems*, vol. 1, no. May, pp. 21002-1-21002–11, 2018.

[13] L. Clapham, V. Babbar, T. Rahim, and D. Atherton, "Detection of Mechanical Damage Using the Magnetic Flux Leakage Technique," in *ASME, 2004 International Pipeline Conference, Volumes 1, 2, and 3*, 2004, no. October 4–8, pp. 983–990.

[14] O. Duran, K. Althoefer, and L. D. Seneviratne, "Automated Sewer Pipe Inspection through Image Processing," in *IEEE International Conference on Robotics and Automation*, 2002, vol. 3, no. May, pp. 2551–2556.

[15] W. M. Alobaidi, C. E. Kintner, E. A. Alkuam, K. Sasaki, N. Yusa, H. Hashizume, and E. Sandgren, "Experimental Evaluation of Novel Hybrid Microwave/Ultrasonic Technique to Locate and Characterize Pipe Wall Thinning," *Journal of Pressure Vessel Technology*, vol. 140, no. 1, p. 11501, 2018.

[16] I. H. Griffin, E. M. Roden, and C. W. Briggs, *Welding Processes*, 3rd ed. Ed. elmar Thomson Learning, 1984.

[17] W. A. DEUTSCH, P. SCHULTE, M. JOSWIG, and R. KATTWINKEL, "Automated Ultrasonic Pipe Weld Inspection," in *17th WCNDT World Conference for Nondestructive Testing*, 2008, pp. 1–10.

[18] W. A. Deutsch, P. Schulte, M. Joswig, and R. Kattwinkel, "Automated Ultrasonic Pipe Weld Inspection," 2008.

[19] E. Mundry, *Non Destructive Testing on Industrial Radiography*, vol. USAGE NOTE. .

[20] N. Bailey, *Faults in fusion welds in constructional steels*. The Welding Institute, Abington Hall, Abington, Cambridge CB1 6AL, UK, 1986.

[21] V. Gunaraj and N. Murugan, "Prediction of Heat-Affected Zone Characteristics in Submerged Arc Welding of Structural Steel Pipes," *Welding Journal*, vol. 81, no. 3, pp. 94–98, 2002.

[22] Y. Shi, C. Zhang, R. Li, M. Cai, and G. Jia, "Theory and Application of Magnetic Flux Leakage Pipeline Detection," *Sensors*, vol. 15, no. 12, pp. 31036–31055, 2015.

[23] "Acoustic Emission Technique," in *Copy Right 2003, The McGraw-Hill Companies, Chapter 10*, 2003.

[24] R. K. Miller, *Nondestructive Testing Handbook "Acoustic Emission Testing,"* 2nd ed. Columbus, OH: American Society of Mechanical Engineers (ASME), 1987.

[25] H. I. Shafeek, E. S. Gadelmawla, A. A. Abdel-Shafy, and I. M. Elewa, "Automatic inspection of gas pipeline welding defects using an expert vision system," *NDT and E International*, vol. 37, no. 4, pp. 301–307, 2004.