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Applications of Specific NDT Methods for Pipeline Inspection and Testing

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ABSTRACT

The importance and criticality of the processes and equipments within the Oil & Gas industry highlights the requirement for more reliable, available and maintainable production activities and facilities. These requirements can be fulfilled by prevention of failures through reducing the downtime and wastage of material. Besides, prevention of failures helps the companies to stay away from their unwanted catastrophic consequences. Therefore, having effective and efficient inspection and maintenance management programs seems to be of paramount importance to keep all these facilities in process. Among all the inspection methods, the use of Non-Destructive Testing (NDT) methods is increasing rapidly due to their remarkable advantages such as high quality, accuracy, flexibility, and etc. which are of interest for those who are involved with inspection and maintenance programs. All the advantages of NDT methods encourage companies to apply them for the inspection of flowlines which have the most criticality among all the processingequipment's.Among all NDT methods, Radiographic Testing and Ultrasonic Testing are among the most used ones for the inspection of flow lines. These methods are explained within this thesis to see their limitations, advantages and disadvantages. Thereafter, all NDT methods applied for the inspection of flow lines on offshore production facilities are evaluated to see which ones have had more accurate and reliable results. The frequency of these methods is also investigated in this dissertation. Aforementioned evaluations reveal the most important influencing factors that can affect the frequency and accuracy of each particular NDT method. Underlying reasons of some exotic results which companies may confront within their inspection plans and programs are also pointed out in this manuscript. All these factors and influencing parameters can be used in developing matrixes and frameworks for the selection of the proper NDT method(s) which should be used for inspection purposes. Some of the matrixes that are in-use by one of the leading companies in Oil & Gas industry are updated regarding the results of mentioned evaluations.

KEYWORDS: NDT, simulation, Ultrasonic Testing, Magnetic Particle Testing, Radiographic Testing, Liquid Penetratant Test

I.INTRODUCTION

Non-Destructive Testing (NDT) interchangeably known also as Non-Destructive Evaluation (NDE) has proven to be a cost saving and beneficial technique to be used in oil & gas industry.Hellier (2001) defined NDT at Non-destructive Evaluation Handbook as a test or evaluation performed on any kind of equipment to test the material integrity without changing its characteristics or destroying it in anyway. Any kind of defects and discontinuities within the material can affect its efficiency, maintainability and serviceability.NDT can be used to determine the physical and mechanical characteristics of the material. For example eddy current testing can be used to measure the changes in the impedance of a carbon reinforced plastic composite in order to assess fiber volume fraction in it (Li et al., 2008). Estimating the grain size of the material using ultrasonic attenuation measurement can be another example of applying NDT for determining the physical characteristics of material (Mc Clements).NDT methods can be appliedfor: Thickness measurements (Crouzenetal 2006; Baltzersen et al.,2007);Classification of materials (e.g. Magnetic Flux Leakage (MFL) can only be used for magnetic material) (Classifying into e.g. Magnetic, Plastic, Polymeric.);Assessment of the chemical composition (changes in chemical composition caused by e.g. corrosion can change the material response to the NDT);Evaluation of surfacecharacteristics; Determining areas with high stress concentration (Zhang and Yang and Xu,2009) and prediction of materialbehavior.Magnetic Particle Testing (MPI) is more efficient in detecting cracks, while Thermography is better to be used for the detection of cracks, corrosion and leaks.(Bøving,1989).

LITERATURE SURVEY

Sanjay Kumar et al [1] stated that Non-destructive testing techniques typically use a probing energy form to determine material properties or to indicate the presence of material discontinuities (surface, internal or concealed). It was also found that most of the non destructive testing techniques are primarily being used in many places such as in the aerospace industry, manufacturing industries and have likely to be used for evaluating civil work and infrastructures.

S.Gholizadeh [2] reviewed the non-destructive testing (NDT) methods for the evaluation of composites. Composite tools are mostly used in critical-safety applications in aircraft primary construction. So to know the incipient faults in composite material, the non destructive testing techniques are very much essential.

Malcolm K. Lim et al [3] describes the use of different non destructive techniques. Some time from one NDT method we could not get the required result so that we use the combination of the NDT techniques to get more detail information and result. In this paper two NDT ultrasonic testing and impulse Response method has been used to evaluate the condition of concrete and defect on concrete structure. By using these techniques together we find out more accurate condition of concrete

MR Jolly et al [4] describes the highly reliable and cost effective non destructive testing technique for the thick walled carbon fiber component that can detect delamination, cracks and other defects and can be applied in series production at an acceptable cost point.

YANG Zhan-feng et al [5] describes the nonlinear ultrasonic testing technique for micro-damage of TATB based Polymer Bonded Explosive (PBX). Ultrasonic non-destructive testing technique is used to evaluate the defects inside explosive parts.

M. Rojek et al [6] explained the Fatigue and ultrasonic testing of epoxy-glass composites. Epoxy-glass composites are useful and apply more and more frequently as high performance engineering materials. Also they find applications in such demanding and challenging fields as civil engineering, car industry, electronic industry, aerospace technology and many others.

Eiichi Sato et al [7] explained the ultrasonic testing method for detection of planar flaws in graphite material. An ultrasonic inspection method was used for graphite ingot to detect internal planar flaws that are oriented in various directions.

Chunguang Xu et al [8] describes the non-destructive testing residual stress using ultrasonic critical refracted longitudinal wave. As we know that residual stress has significant and major impacts on the performance of the mechanical components, especially on its strength, fatigue life and corrosion resistance and dimensional stability.

Tirupan Mandal et al [9] describes the non-destructive testing of cementitiously stabilized materials (CSMs) using ultrasonic pulse velocity instrumentation. Here flexural strength and flexural modulus tests were conducted on CSMs and their constrained modulus were recorded.

Gabriel Dan Tasca et al [10] described research regarding ultrasonic examination of complex parts. Non- destructive evaluation process established and recognized in order to observe cracks and delamination's that occur below the surface in titanium parts and in particular in complex shaped parts. Although X-rays technique might be an obvious choice, but they are not effective in many cases, mostly when the defect has the same density as the surrounding material.

OBJECTIVES

To find out a specific Non-Destructive Testing method for the pipelines inspection and testing.

To explore the various NDT methods from the various sources and to find out the best methods.

To investigate upon the existing methods and to propose the suitable and specific methods that could be considered as the simplified and standardized procedure for the NDT.

To conduct a study on the category-I NDT :Radiographic Testing (RT), Ultrasonic Testing(UT), Magnetic Particle Inspection (MPI) known also as Magnetic Particle Testing(MPT), Liquid Penetrant Testing(PT), Visual Testing(VT) and Thermal/Infrared Inspection(IRI).

To conduct a study on the category-II NDT : Advanced Electromagneticmethods -Eddy Current Testing,Remote Field Technique(RFT),Externally Referenced Remote Field Technology(XRFT),Saturated Low Frequency Eddy Current(SLOFEC) and Electromagnetic Acoustic Transducers(EMAT).Advanced Ultrasonic Technologies-PhasedArray,Time-of-Flight Diffraction (TOFD),Creeping Head wave Inspection Method (CHIME), M-Skip (Complementary method ofCHIME)and Guided Wave UltrasonicTesting.

EXISTING AND PROPOSED METHOD FOR UT AND LPT EXISTING METHOD OF UT

Prior to World War II, sonar, the technique of sending sound waves through water and observing the returning echoes to characterize submerged objects, inspired early ultrasound investigators to explore ways to apply the concept to medical diagnosis. In 1929 and 1935, Sokolov studied the use of ultrasonic waves in detecting metal objects. Mulhauser, in 1931, obtained a patent for using ultrasonic waves, using two transducers to detect flaws in solids. Firestone (1940) and Simons (1945) developed pulsed ultrasonic testing using a pulse-echo technique. Shortly after the close of World War II, researchers in Japan began to explore the medical diagnostic capabilities of ultrasound. The first ultrasonic instruments used an A-mode presentation with blips on an oscilloscope screen. That was followed by a B-mode presentation with a two dimensional, gray scaleimage.

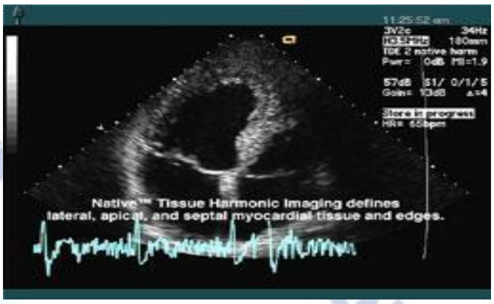
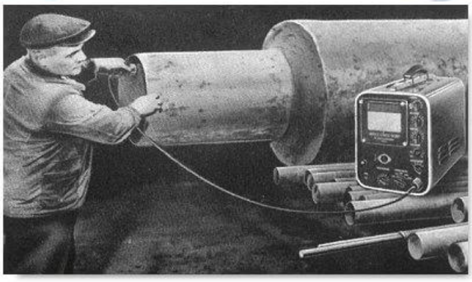


Fig-1 Ultrasonic Testing



Graph-1 Ultrasonic Testing

Japan's work in ultrasound was relatively unknown in the United States and Europe until the 1950s. Researchers then presented their findings on the use of ultrasound to detect gallstones, breast masses, and tumors to the international medical community. Japan was also the first country to apply Doppler ultrasound, an application of ultrasound that detects internalmoving objects such as blood coursing through the heart for cardiovascular investigation. Ultrasound pioneers working in the United States contributed many innovations and important discoveries to the field during the following decades. Researchers learned to use ultrasound to detect potential cancer and to visualize tumours in living subjects and in excised tissue. Real-time imaging, another significant diagnostic tool for physicians, presented ultrasound images directly on the system's CRT screen at the time of scanning. The introduction of spectral Doppler and later colour Doppler depicted bloodflowinvariouscolours to indicate thespeedanddirectionofthe flow. The United States also produced the earliest hand held "contact" scanner for clinical use, the second generation of B-mode equipment, and the prototype for the first articulated-arm hand held scanner, with 2-Dimages.

PROPOSED METHOD FOR UT

PRESENT STATE OF ULTRASONIC TESTING

Ultrasonic testing (UT) has been practiced for many decades. Initial rapid developments in instrumentation spurred by the technological advances from the 1950's continue today. Through the 1980's and continuing through the present, computers have provided technicians with smaller and more rugged instruments with greater capabilities. Thickness gauging is an example application where instruments have been refined make data collection easier and better. Built-in data logging capabilities allowthousands of measurements to be recorded and eliminate the need for a "scribe." Some instruments have the capability to capture waveforms as well as thickness readings. The waveform option allows an operator to view or review the A-scan signal of thickness measurement long after the completion of an inspection.Also, some instruments are capable of modifying the measurement based on the surface conditions of the material. For example, the signal from a pitted or eroded inner surface of a pipe would be treated differently than a smooth surface. This has led to more accurate and repeatable field measurements.

Many ultrasonic flaw detectors have a trigonometric function that allows for fast and accurate location determination of flaws when performing shear wave inspections. Cathode ray tubes, for the most part, have been replaced with LED or LCD screens. These screens, in most cases, are extremely easy to view in a wide range of ambient lighting. Bright or low light working conditions encountered by technicians have little effect on the technician's ability to view the screen. Screens can be adjusted for brightness, contrast, and on some instruments even the colour of the screen and signal can be selected. Transducers can be programmed with predetermined instrument settings. The operator only has to connect the transducer and the instrument will set variables such as frequency and probe drive. Along with computers, motion control and robotics have contributed to the advancement of ultrasonic inspections. Early on, the advantage of a stationary platform was recognized and used in industry. Computers can be programmed to inspect large, complex shaped components, with one or multiple transducers collecting information. Automated systems typically consisted of an immersion tank, scanning system, and recording system for a printout of the scan. The immersion tank can be replaced with a squitter systems, which allows the sound to be transmitted through a water column. The resultant C-scan provides a plan or top view of the component. Scanning of components is considerably faster than contact hand scanning, the coupling is much more consistent. The scan information is collected by a computer for evaluation, transmission to a customer, andarchiving.

Fig-2: Accessories for UT

Fig-3: Couplants for UT

Fig-4: Transducers for UT

Fig-5: Coaxial Cables for UT

Fig-6: V-I

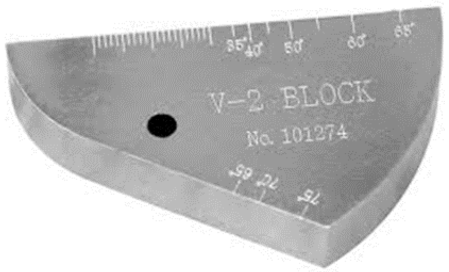


Fig-7: V- II

Fig-8: Machines for Calibration

EXISTING OF PENETRANT INSPECTION

Liquid penetrant inspection is a method that is used to reveal surface breaking flaws by bleed out of a coloured or fluorescent dye from the flaw. The technique is based on the ability of a liquid to be drawn into a "clean" surface breaking flaw by capillary action. After a period of time called the "dwell," excess surface penetrant is removed and a developer applied. This acts as a blotter. It draws the penetrant from the flaw to reveal its presence. Coloured (contrast) penetrants require good white light while fluorescent penetrants need to be used in darkened conditions with an ultraviolet "blacklight".

Fig-9: Defects for LPT

A very early surface inspection technique involved the rubbing of carbon black on glazed pottery, whereby the carbon black would settle in surface cracks rendering them visible. Later, it became the practice in railway workshops to examine iron and steel components by the "oil and whiting" method. In this method, heavy oil commonly available in railway workshops was diluted with kerosene in large tanks so that locomotive parts such as wheels could be submerged. After removal and careful cleaning, the surface was then coated with a fine suspension of chalk in alcohol so that a white surface layer was formed once the alcohol had evaporated. The object was then vibrated by being struck with a hammer, causing the residual oil in any surface cracks to seep out and stain the white coating. This method was in use from the latter part of the 19th century to approximately 1940, when the magnetic particle method was introduced and found to be more sensitive for ferromagnetic iron andsteels.

A different (though related) method was introduced in the 1940's. The surface under examination was coated with a lacquer, and after drying, the sample was caused to vibrate by the tap of a hammer. The vibration causes the brittle lacquer layer to crack generally around surface defects. The brittle lacquer (stress coat) has been used primarily to show the distribution of stresses in a part and not for findingdefects.

Many of these early developments were carried out by Magnaflux in Chicago, IL, USA in association with Switzer Bros., Cleveland, OH, USA. More effective penetrating oils containing highly visible (usually red) dyes were developed by Magnaflux to enhance flaw detection capability. This method, known as the visible or color contrast dye penetrant method, is still used quite extensively today. In 1942, Magnaflux introduced the Zyglo system of penetrant inspection where fluorescent dyes were added to the liquid penetrant. These dyes would then fluoresce when exposed to ultraviolet light (sometimes referred to as "black light") rendering indications from cracks and other surface flaws more readily visible toinspectors.

PROPOSED METHOD FOR LPT

Fig-10: Developer, Pre-cleaner, Penetrant

There are six basic steps to follow when using the dye penetrant solvent removable method.

Pre cleaning

This can range from grinding and wire brushing to merely wiping the part with a rag moistened with the cleaner/ remover. The surface needs to be free of dirt, rust, scale, paint, oil, and grease,

and be smooth enough to wipe off the penetrant without leaving residue.

Fig -11: Precleaner

Apply penetrant.

This is generally done by spraying penetrant from the aerosol can or applying it with a brush. A dwell (soak) time needs to be observed to allow for the penetrant to permeate into cracks and voids. This is typically 5 to 30 minutes but should never be long enough for the penetrant to dry. The penetrant manufacturer's recommendations and written procedure should be followed.

Fig-12: Penetrant


Fig-13: Penetrant

Remove penetrant

All penetrant should be removed with clean, dry, lint-free rags until thoroughly clean. The part or material should be rubbed vigorously until the penetrant is not visible on the dry rags. Next, cleaner/ remover should be sprayed on another clean, dry, lint-free rag and used to vigorously rub the part again until there is no penetrant visible on the rag.

Apply developer.

A thin, light coating of developer should be sprayed on the part being examined. A dwell time needs to be observed to allow time for the dye to exit the flaws and create an indication (flaw) in the developer. The dwell time for developer is typically 10 to 60 minutes. The d

Fig-15:Penetrant Removal

developer Manufacturer's recommendations and written procedure should be followed

Evaluate indications.

It is critical to examine the part within the time frame designated in the written procedure. Length of an indication can grow over time as penetrant bleeds out, causing an acceptable indication to be a rejectable defect. Length of indication is measured for evaluation, not length of the flaw. Here, the two linear indications are rejectable defects. The round indication is nonrelevant.

Fig-16 : Defects in LPT

Post-clean part.

The part needs to be cleaned to remove all developer after it has been evaluated.

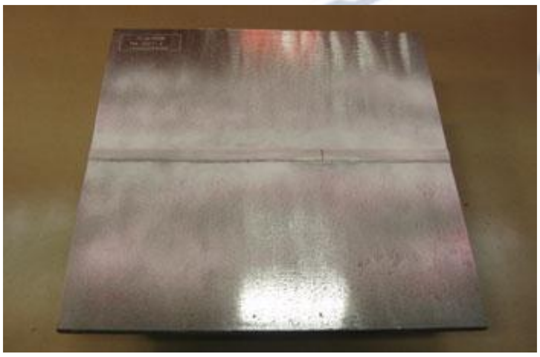


Fig-17: Post-cleaning

DATA COLLECTION AND INTERPRETATION

Some of the advantages of ultrasonic inspection that are often cited include the below mentioned:

- It is sensitive to both surface and subsurface discontinuities.
- The depth of penetration for flaw detection or measurement is superior to other NDTmethods.
- Only single-sided access is needed when the pulse-echo technique is used.
- It is highly accurate in determining reflector position and estimating size and shape.
- Minimal part preparation is required.
- Electronic equipment provides instantaneous results.
- Detailed images can be produced with automated systems.
- It has other uses, such as thickness measurement, in addition to flaw detection.
- Ultrasonic inspection also has its limitations, which include:
- Surface must be accessible to transmit ultrasound.
- Skill and training is more extensive than with some other methods.
- It normally requires a coupling medium to promote the transfer of sound energy into the test specimen.
- Materials that are rough, irregular in shape, very small, exceptionally thin or not homogeneous are difficult to inspect.
- Cast iron and other coarse grained materials are difficult to inspect due to low sound transmission and high signal noise.
- Linear defects oriented parallel to the sound beam may go undetected.
- Reference standards are required for both equipment calibration and the characterization offlaws.

RESULTS AND DISCUSSION

The proposed methods that had been adapted were found to be specific for the application as they had been proved to be providing better quality of the products,reduction in costs and increase in production, helpful in the detection of unwanted failures in the very beginningphase,provide the ability to inspect the equipments in the operationalstate, reachto the higher levels ofreliability, gain consumersatisfaction and avoid or reducethe downtime and wastage ofmaterial.

CONCLUSION

- In this present study, it was found that Liquid Penetrant Testing (LPT) is more effective in detecting surface cracks and discontinuities. Ultrasonic Testing is effective in detecting internal cracks and discontinuities in the material.
- LPT works even on complex geometricshapes.
- Ultrasonic testing has high sensitivity allowing it to detect extremely smallflaws.
- LPT and UT are less hazardous to the inspector as well as the material that is to be inspected.
- LPT can be used even at a temperature of 50^{0}C reducing dwell time ofpenetrant.
- It helps in reducing costs and time taken in the testing area in variousindustries.
- Materials required for testing are easily portable and it ischeaper.
- Ultrasonic Testing using automation is the future of NDT in the industry. This helps in reducing man-made errors with high precision and accurate testing of materials within a limited period oftime.
- The quality of the product increases automatically due to high precision and accuracy in finding the type of errors and preventing defective products handed over to thecustomers.

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