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Ultrasonic Sensors Supervision of Petrochemical and Nuclear Plant

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Abstract

Piping in the oil and nuclear plants are subject to erosion or corrosion inside pipe wall. This corrosion or erosion depends on chemical aggressively of fluids, operational conditions and pipeline materials. In many cases inspection become tough when pipes are mounted several meters above the ground for a human testing personnel. Sometimes, inspection done during shut- down of plant or removal of surrounded armatures. For in service maintenance or inspection of these plants, there is always a desire for optimal solution. The NDT (Non Destructive Testing) developments for measuring flow accelerated corrosion or thickness degradation. Our first task is to deploy and connect ultrasonic sensor for measuring pipe wall thickness in such a design, their values can be evaluated at accessible point.

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Keywords

Non Destructive Testing (NDT), Flow Accelerated Corrosion (FAC), Ultrasonic Testing (UT), Pipe Inspection Gauge (PIG), Piezoelectric Transducer (PZT), Electromagnetic Acoustic Transducers (EMAT), Strong Static Magnetic Field (SSMF), Liquid Coupled Method (LCM), Wheel Coupled Method (WCM).

Introduction

In present scenario there is no single system which measures all pipelines. In present era commonly used tool is PIG (pipe inspection gauge) that moves inside the pipe. Crawler move down to the pipeline independently and stop if major defect assessment. The sensors are mounted on crawler; they are almost small in size, lightweight and required low power consumption. Therefore, the distance between measurement and evaluation can be bridge by cable (in order of 100 meters). Pipe wall thickness degradation due to flow accelerated corrosion gave a birth to leaks and raptures in piping system which cannot be identify at early stage. Ultrasonic examination methods are typically used to monitor pipe conditions in terms of thickness, erosion and corrosion. In this paper we focus on design issues of ultrasonic system for rapid scanning of sample model. Ultrasonic testing is completed with the help of ultrasonic waves (Primary wave) which uses 20 KHz to 200 KHz high frequency sound energy for making accurate measurements of thickness, corrosion and erosion with the help of sensors. Ultrasonic examinations can be conducted to known the properties of material including castings, forgings, geometry, welds, and composites. We collect a considerable amount of information related to turbine, boilers with the help of instrument where human being approach is impossible. In this technique first we generate guided wave with the help of ultrasonic generators than we collect information with the help of receiver (sensor). This gathered information passed from Micro-channel plate detector for resolution and getting more accurate readings. Pipelines are worldwide used for distributing energy to end users. The pipeline deployment is well designed and required in service monitoring for natural degradation to overcome sudden failures. A mostly failure in pipeline occurs due to ageing factor of pipe system for examples leak, corrosion, erosion and raptures etc.

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Ultrasonic System for Pipe Wall Measurement

In 1980s high frequency sound waves are used for sample object inspection. The basic principle is shown in the figure 1. The working model of hand-held

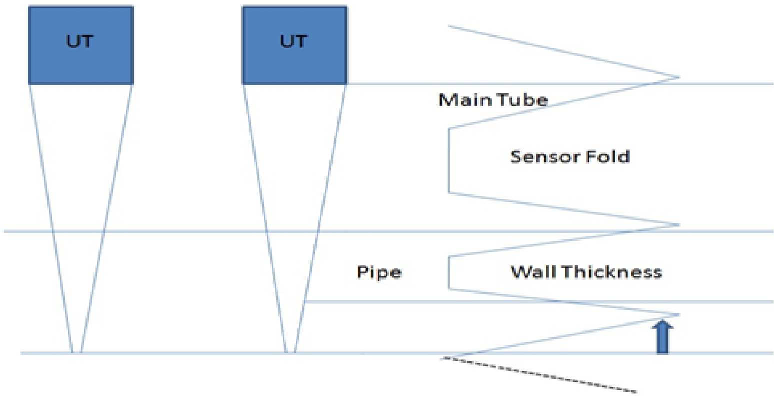

Figure 1: *Pulse echo Ultrasonic System for pipe wall measurement*

ultrasonic gauge based on the principle of pulse echo method to determine accurate pipe sample thickness and raptures. Pulses of ultrasonic energy are launched with the help of piezoelectric transducer, angle beam etc. Energy band of ultrasonic testing varies 1-10 MHz. These energy pulses are reflected by inside and outside wall of the sample object. The thickness is measured by calculating reflection time and speed of sound in steel pipe. For industrial perspective thickness measurement accuracy required 0.001" (0.025 mm). Especially in case of noisy areas we prefer high frequency transducers for more accurate results. To overcome pipeline surface roughness challenges we use lower frequency transducers (5 MHz) for accurate results. The typical accuracy for in service inspection is 0.020" (0.5 mm). Ultrasonic tools require a large number of tiny sensors, in the order of ten per inch diameter. Data processing and storage time directly affect the speed of inspection. In early years (1989) inspection speed of ultrasonic system in the range of 3.0 mph. Now recent state of art in electronics pushes up speed of inspection. Ultrasonic Testing gave an accurate reading in noise free pipes; lamination and inclusions on a pipe reduce accuracy. In ultrasonic testing misses to catch out defects lying behind laminations. Therefore applying ultrasonic gauge system we make a pipe free from debris or deposits.

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Ultrasonic Crack Detection System

Most common methods which are used to determine cracks in pipeline:

1. Liquid Coupled Method.
2. Wheel Coupled Method.
3. Electromagnetic Acoustic Transducers.

These above methods are capable for crack detection but all have some limitations:-

In case of wheel coupled method numbers of sensors are limited to number of wheels. The number of sensors in liquid coupled methods has many more in comparison to wheeled tool. Two common tools are:

1. Liquid Coupled Angle Beam Tool
2. Wheel Coupled Angle Beam Tool

Difficulties in angle beam tools are same as difficulties arise in wall thickness measurement tool. For example:

1. Speed Restriction
2. To differentiate cracks from lamination and inclusion

After several attempts to above system EMAT (Electromagnetic Acoustic Transducers) inspection system came in focus for determine cracks in pipe wall thickness. EMAT ultrasonic testing technique operates at lower frequency (200-800 KHz) in comparison to PZT (1-20 MHz). The waves generated by EMAT are bounded by the geometry of sample object. The waves generally generated by EMAT are shown in figure 2. For generating above waves two things are essential:

1. Strong Static Magnetic Field
2. Coil

Coils are used for creating localized eddy current in the sample object. Eddy current oscillates at the designed inspection frequency. Wave mode directly depends on pipe wall thickness. If we make a small change in variable cause a different wave mode, which affects result of inspected sample object. The coil near to sample object are generate sufficient amount of energy required to determine cracks even hidden by laminations. For long distance pipe wall

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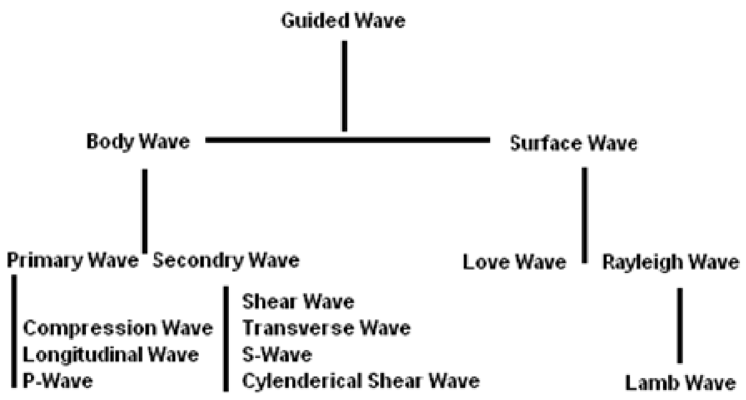

Figure 2: *Waves generated by EMAT*

inspection, the coil is covered by thin polymers.

Advantages of EMAT in comparison to Liquid Coupled Method and Wheel Coupled Method:

1. No need for liquid coupling media.
2. Bounded waves propagate in sample object.

Disadvantages of EMAT in comparison to Liquid Coupled Method and Wheel Coupled Method:

1. Many modes.
2. Different results by different mode.
3. Implementation Challenges.

Simulation Models

Ultrasonic testing simulation models use numerous methods and physical equations for predicting results of an experiment. The potential uses of simulation model classified into three categories as shown in Table ??. All above queries except last three are cracked by UTSIM (Measurement model). Last three queries are related to scan coverage modelling, scan coverage problems are sort out by a beam model.

Table 1: *Simulation Model Parameters*

Ultrasonic reach the region of sample object?	**Properties of the field in region of sample object?**	**Response from the incident field of sample object?**
What is amplitude?	Shape of beam?	Time domain waveform?
Beam passes through concave interface?	Phase curvature?	Flow response change?
Beam spread when it propagates into material?	Focal point?	–X–
Beam bend?	–X–	–X–
Amplitude loses due to coupling?	–X–	–X–
–X–	–X–	–X–

Scan Optimization

Industrial objective towards scan optimization is to minimize in-service inspection cost for accomplishing a specific task or optimum in service inspection under specified cost. Modelling objective towards scan optimization is to maximum sensitivity for a given scan spacing. In scan optimization we focused on following points:

1. Best location to place a probe.
2. Optimum wedge angle.
3. Optimum transducer coverage.

Scope of Modelling in Ultrasonic

Automated scans using longitudinal waves at normal incidence, automated scans for deterministic and repeatable of accurate motion. Contact scans are excluded due to variability in coupling. Two important spacing parameters index and scan spacing are beneficial for chosen a coordinate system for example optimum change in beam width along index direction. Qualities of coordination

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direction they are orthogonal by nature. Index coordinates direction used for radial cross section of the sample object. Scanning of sample object is modelled in lower dimension.

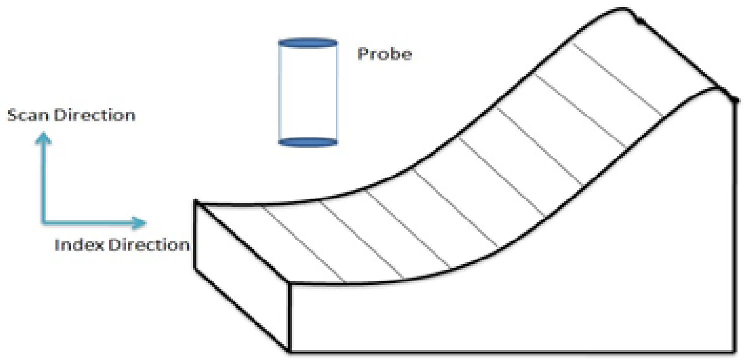

Figure 3: *Scan Direction v/s Index Direction*

Result and Conclusion

The above system reduce cost of non destructive testing and required time in petrochemical plant, also increase operating safety, minimized processing cost, reduce testing intervals and this system make easy continuous supervision possible. Advantages of above system in comparison to other models are: No need for liquid coupling media and Bounded waves propagate in sample object. Disadvantages of above system in comparison to other models are: Many modes, Different results by different mode, Implementation Challenges, etc.

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