Guided Wave Inspection Using Magnetostrictive Principle For Cement Coated Pipe Lines And Rundown Pipe Lines

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Abstract
This work is based on use of unique method of generation of guided waves based on the Magnetostrictive effect (Joule Effect) and inverse Magnetostrictive effect (Villary Effect). This work provides and improves the defect detection capability of guided waves generated by Magnetostrictive effect, in high temperature, cement coated pipes, rundown pipelines especially in refineries and power plants at different conditions. MATLAB has been used as a tool for averaging the signals to improve SNR (Signal to Noise Ratio).

This works enables to improve sensitivity and resolution. For specific purposes in oil and power sector industries, many pipes are coated with the cement circumferentially either from inside or outside the pipe. To know the crack or working condition of cement coated pipelines guided waves have been used for defect detection.

Introduction

Guided waves (GW) or Long Range Ultrasonic Testing (LRUT) technique can be a very cost-effective technique for long-range piping and tubing inspection. Guided waves refer to mechanical waves in ultrasonic and sonic frequencies that propagate in a bounded medium (such as a pipe or rod) parallel to the plane of its boundary. These waves are called “guided waves” because these waves are confined with the geometry and travels along the medium guided by the geometric boundaries. One of the most pronounced advantages of GW is that the technique is capable of covering 100% of the component volume in a very short time.

The working principle of guided wave is described as shown in the Fig. 1. The guided wave probes generate guided wave which propagates inside the material though out the thickness of the material. The guided wave reflects back from any anomaly in the way of propagation of guided wave and can be received with the help of same guided wave probe. These signals are analyzed at the computer with the help of specific software.

Guided waves generation take place either based on conventional piezoelectric principle or advanced magnetostrictive principle. The magnetostrictive (MsS) effect is a small change in the physical dimension of ferromagnetic material caused by an externally applied magnetic field [1].

Guided wave generation based on the magnetostrictive principle is confined on the induction of ultrasonic guided waves into materials using different types of electromagnetic transducers for long-range inspection and structural health monitoring of pipes, plates, bridge cables, and tubes [2] compared to piezoelectric based generation, it is a lower frequency technology and effectively works in a frequency range below 300 kHz. Frequency selection depends on the thickness of the material to be tested, range to be covered and environmental conditions of the material. MsS also provides engineers with a fast, cost-effective means of inspecting steel pipes and tubes in processing and power generating plants for the oil, gas, and chemical industries.

Experimental Set up

Experimental arrangement for MsS System which consists of MsS Instrument, MsS probe and a computer as shown in the figure given below.
Fig 3: (a) Output of cement coated pipeline of diameter 8" with single probe; (b) Output of cement coated pipeline with two probes separated at distance equal to quarter of wavelengths; (c) Output of cement coated pipeline of diameter 6" with single probe; (d) Output of cement coated pipeline of diameter 6" with two probes separated at distance equal to quarter of wavelengths; (e) Output of 6" diameter pipeline LPG rundown.
The magnetostrictive sensor (MsS) probe uses the magnetostrictive effect to generate and detect guided wave in pipe. The MsS probe applies a time-varying magnetic field to the ferromagnetic material for guided wave generation and picks up magnetic induction changes in the material caused by the propagating guided wave for guided wave receiving.

The MsSR 3030 instrument used for the purpose generates tone-burst electric pulses to the MsS probes and detects induced voltage in the MsS probe that is generated when the ultrasonic guided wave passes through the probe. The signal received from both directions of pipe are analyzed and reported with data analysis and reporting software.

The MsS probe continuously covers the whole circumference (360°) of pipe as it covers all the circumference of the pipe structure so that MsS-generated guided wave has a short dead zone and minimizes flexural mode generation giving negligible near zone. The wave mode used for guided wave generation is torsional mode due to constant group velocity at different varying frequencies [3].

After cleaning the surface, a magnetic strip (Fe-Co) is mechanically coupled with the material or pipe to be tested through epoxy or wet couplant. A ribbon coil is wrapped over the pipe circumferentially and attached it to the laptop through adaptor of particular frequency. Frequency can be changed for the complete set up on changing the adaptor for different frequency.

**Sample Used**

Three samples have been used to carried out the experiments for LRUT using MsSR System based on magnetostrictive principle: 2 pipes of grade SA139 with cement coating inside with outer diameter 8" and 6" respectively and other was 6" diameter with LPG Rundown inside.

**Method Adopted**

Frequency selected for experiments were taken 32kHz, 45kHz, 64kHz, 90kHz, 128kHz and 250 kHz. For more distance lower frequency is used and for more sensitivity, higher frequency is used.

First at cement coated pipe line of 8" one magnetostrictive strip is used and the result obtained is shown as Fig. 3(a). For cement coated pipe lines 8" two magnetostrictive strips (2" wide each) have been installed with the gap between them equal to quarter of the wavelength which is calculated on the basis of thickness of the pipes. The final output of the image is shown in Fig. 3(b).

For cement coated line of 6" diameter, fig 3(c) is the output when only one strip is used while fig 3(d) gives the output when two probes are installed separated by quarter wavelength.

Fig. 3(e) shows the result for 6" diameter with LPG Rundown inside with a single probe.

**Results and Discussion**

Cement coated pipe can also be tested non-destructively by using guided wave MsS System. This coating may be outside or inside the pipe circumferentially.

On comparing fig. 3(a) with 3 (b) and fig. 3(c) with 3 (d), it is quite clear that on using two parallel probes which are wrapped circumferentially, separated by quarter of wavelengths gives more sensitivity and more clarity in the results.

From fig. 3(e) it is clear that on running liquid or gas inside the pipelines can be inspected with the help of guided wave with better sensitivity on using epoxy of higher delay time.

Guided waves are generated in the material to be tested, and propagate inside the material which attenuates guided waves more when other material with closer density to that of the parent material is attached to the parent material. In cement coated pipes, cement is fixed at the pipe of carbon steel. 2 parallel magnetic strips are mechanically coupled circumferentially with the pipe to be inspected as quarter wavelength separation generates the guided wave in the same phase in both the strips and gives more intensity to the pipe as reduces the attenuation effect on the guided waves.

**References**