Sizing methodology of pipe wall thinning using inverse analysis with EMAT signal

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This paper proposes a method for sizing pipe wall thinning, using pulse-echo EMAT modes. First, the proposed method deploys a compact simulator model to efficiently reduce the computational cost of EMAT forward analysis. Then, an approach of signal processing based on peak values at back-wall echo and POD method is applied to EMAT signal are introduced. Finally, inverse analysis based on reduced POD basics is applied for defect parameters identification. Promising experimental results with high accuracy on both simulation and synthetic measurement data demonstrate the capability and effectiveness of the proposed method.

Keywords: Ultrasonic, non-destructive testing, elastic wave, proper orthogonal decomposition.

1. Introduction

In the field of non-destructive evaluation, electromagnetic acoustic transducers (EMATs) have emerged as an effective method for system integrity testing. This technique is effective for a wide range of application, such as thickness characterisation, flaw detection, etc because of its distinct advantages. The advantages include: operation without coupling fluid, non-contact operation, in-service inspection, high temperature operation, and the ability to utilize different type of acoustic wave.

One of the most important applications of EMAT is profiling cracks or damages in the test materials. Several methods have been introduced for detection and characterization of defect in different types, include surface and sub-surface cracks, interior holes or sub-surface corrosion by studying the interact of different types of acoustic wave with the faults or cracks.

This paper proposes a method to identify sub-surface defect parameters in plates, using pulse-echo EMAT modes. The proposed approaches include:

1. An EMAT simulation and reduced simulation model for analyzing back wall reflection of elastic wave produced by pulse-echo EMAT.
2. Signal processing method based on peak values of back wall echo in EMAT signal.
3. Proper orthogonal decomposition of extracted feature from EMAT signal for creation of simulation data based on reduced order POD basics in various defect parameters.
4. Inversion system for characterization of sub-surface defect.

The outcome of this research is to contribute an approach to detect and identify defect profile of sub-surface erosion in plates. With some certain improvement, this method can be used in detecting corrosion profiles in metal pipes of gas pipelines or boiled water tubes in nuclear power plants. Moreover, computational improvement in forward analysis and effective signal processing are other objectives of this research. The method of solving reduced simulation model introduced in this paper can be extended in different reducible simulation system, such as simulations related to eddy current problems.

2. Simulation setup and modelling of wall-thinning defect

This inspection system uses a single unit EMAT which performs both the sending and the receiving of the pulsed waves. Fig. 1 shows the principle of this EMAT method.

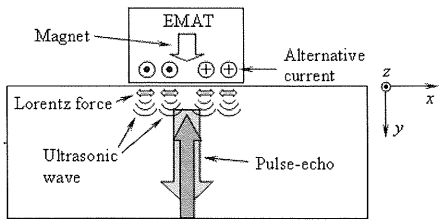

Fig. 1 Principle of EMAT pulse-echo mode

Wall thinning defects are simulated in semi ellipse shape. EMAT scans at top surface of speacimen in 1.0 mm pitch, as illustrated in Fig. 2. Extracted features of the reflected waveform from the back surface measured by EMAT are analized using POD method. Only a few POD basics are

needed in inverse analysis for identifying defect profiles.

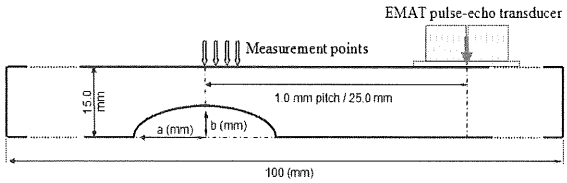

Fig. 2 Wall thinning model

3. Simulation results and proper orthogonal decomposition

Fig. 3 depicts typical extracted features of EMAT simulation results. The waveform varies in accordance with the defect parameters. Data constructed from reduced POD basics have well agreement with simulation data as shown in Fig. 4.

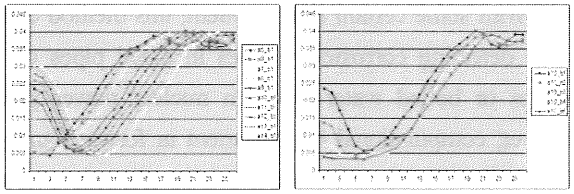

Fig. 3 Extracted features of EMAT simulation results with different defect parameters

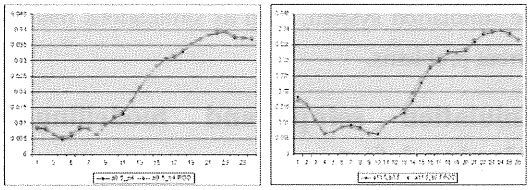

Fig. 4 Comparision between extracted features form POD basics and EMAT simulation

4. Inverse Analysis

Overall inversion system consists of three modules: (i) Virtual system, (ii) real system, and (iii) inversion process, as shown in Fig.5. In Virtual system, EMAT simulator is used to produce simulation signals on some certain defect parameters. After signal processing, extracted pitch-to-pitch values are used to construct POD basics. In real system, signal processing is also applied to measurement signal obtained by testing process. Before being used in inverse analysis, extracted features of measurement data are normalized with simulation data. Inversion process produces an optimized defect parameter set that minimizes error between measurement signal and simulation data created by POD basics.

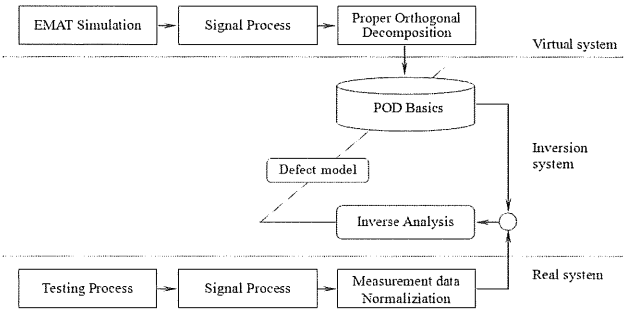

Fig. 5 EMAT Inversion system

5. Conclusions

A method to identify wall thinning defect parameters in plates, using pulse-echo EMAT modes has been proposed. Inverse analysis results on both simulation and synthetic measurement data confirm the reliability and applicability of the proposed method.

Acknowledgments

This work has been performed as a part of the National Research Project for Enhancement of Measures against the Ageing of Nuclear Power Plants sponsored by the Nuclear and Industrial Safety Agency (NISA).

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