Application of Ultrasonic Guided Wave to Heat Exchanger Tubes Inspection

Ik-Keun PARK [1,a], Yong-Kwon KIM [2,b], Sae-Jun PARK [1,c], Yeon-Shik AHN [3,d], and Doo-Song GIL[3,e]

[1] Dept. of Mechanical Engineering, Seoul National University of Technology, Seoul 139-743, Korea

[2] Graduate school of Energy and Environment, Seoul National University of Technology, Seoul 139-743, Korea

[3] Korea Electric Power Research Institute, Daejeon 305-380, Korea

[a] ikpark@snut.ac.kr, [b] younggun76@snut.ac.kr, [c] saejune@hanmail.net, [d] ysas@kepri.re.kr, [e] kds6801@ kepri.re.kr

Abstract

Ultrasonic guided wave is one of the maintenance inspection techniques which ensure integrity of various facilities in power plants. The power plant parts are operated continuously for long time except the overhaul period and under severe condition such as high temperature, high pressure, corrosion, mechanical stress and vibration. Therefore, defects such as a crack or early fracture before the life-time of the parts can break out easily.

In this study, a preliminary study of application of the ultrasonic guided waves to the heat exchanger tubes inspection from the inside surface has been verified experimentally. And various types of defects such as corrosion, transverse cracking and wear or thinning defect in heat exchanger tubes support regions is considered. Although the present experiment is mostly restricted to the guided wave technique, this method will be fully verified either by comparing with a conventional ECT or by comparing with an Ultrasonic Internal Rotary Inspection System (IRIS).

Keywords: Ultrasonic guided wave, Ultrasonic Internal Rotary Inspection System, Eddy current test, Heat exchanger tubes

1. Introduction

General heat exchangers are used for high pressure and high temperature applications and consist of many tubes supported by Tube Sheets and Support plates for preventing deflection of an Exchanger tube. When a high pressure and high temperature fluid runs over tubes for heat transfer from one medium to another, tubes are vibrated and the tube surface is contacted with Support plates. This vibration cause damage of tubes like crack, wear and so on. To detect defects on the tubes An Eddy current testing (ECT) has been proposed and demonstrated. This method is attractive in the exchanger tube inspection with internal diameter probes because of the speed of test, ability to automate and lack of any other NDT technique.

However, The ECT faces serious problems in their application to support plates, tube sheets and U-bend pipe regions, because such regions cannot be inspected due to ferromagnetic materials, edge effects and liftoff. Especially it is difficult to apply ECT to support plate regions with a defect, because ECT probe responds not only to a defect, but also to liftoff variations and to the unwanted material properties related to magnetic permeability.

We propose an alternative method using an ultrasonic guided wave that solves the above problems. In the proposed method, Ultrasonic guided waves are excited using an internal transducer probe from a single position at the end of the tube. In this paper, we present a preliminary experimental verification using a titanium tube.

2. Experimental Setup and Specimens

2.1 Test Specimens

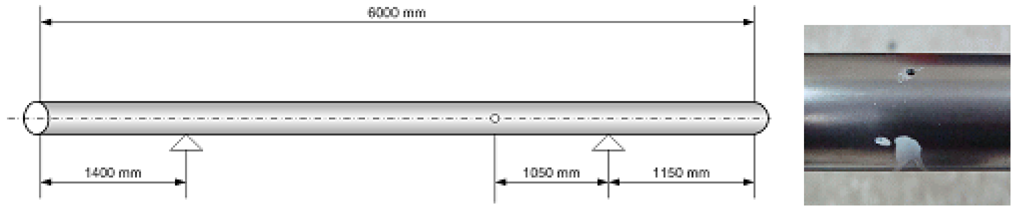
Two titanium tubes were developed for the detectability and sizing performance of the ultrasonic guided waves technique as shown in Fig. 1. Two specimens, as shown in Fig. 1, are titanium pipes of 19.05 mm OD, 0.889 mm thickness, and 6 m length. These are the same type of the tubes which are used in power plant facilities. One specimen, as shown in Fig. 1(a), contained through-thickness defects with varying diameters. Five through-thickness defects with diameters of 1 mm to 5 mm were machined into the specimen. Second specimen, as shown in Fig. 1(b), contained wear defects with varying depth of thickness reduction. Five wear defects with depth about 20% to 80% of the thickness were machined into the specimen. Fig. 1 is a schematic showing the location and geometry of each defect on the specimens.

2.2 Support ring

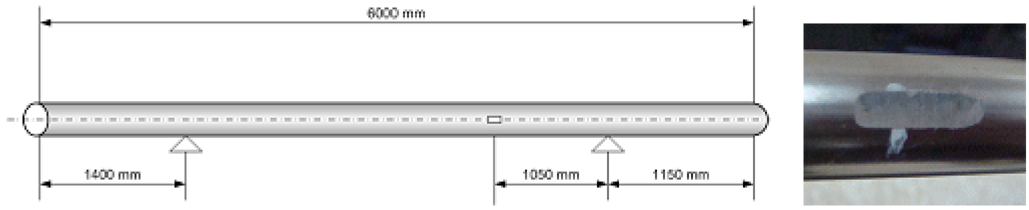
A support ring simulating a support plate region is developed for the detectability and sizing performance of the ultrasonic guided waves technique against ECT technique. Fig. 2 shows shape of a support ring.

2.3 Test Equipment

Longitudinal mode(0,1) are generated in tube specimens using the long range guided wave inspection system, Wavemaker G3, Guided Ultrasonic Ltd. Fig. 3 shows the configuration



(a)



(b)

Fig. 1 The shape of specimen and drillhole and wear defects

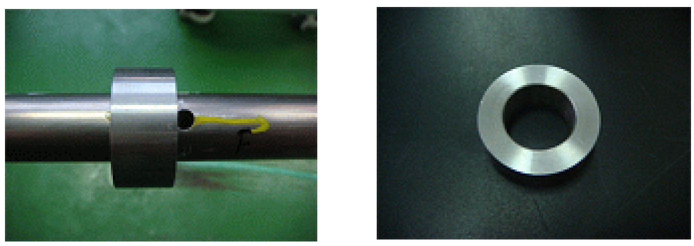
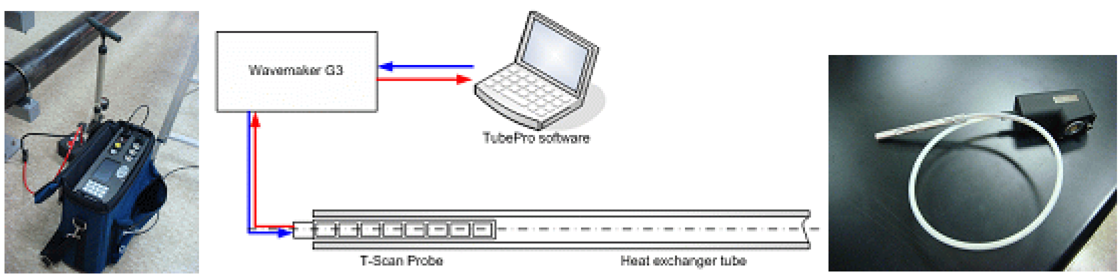


Fig. 2 The shape of a support ring

of test setup. The test setup is comprised of a pulse generation and reception unit and a portable computer with control software, and internal transducer probe. Ultrasonic guided waves are excited using an internal transducer probe from a single position near one end of the tube as shown in Fig. 3(a). The probe consists of an array of piezoelectric transducers, which are dry-coupled to the inside of the tube wall through a pneumatic system. The frequency range of probe is 30-90 kHz. Fig. 3(b) shows the internal transducer probe.

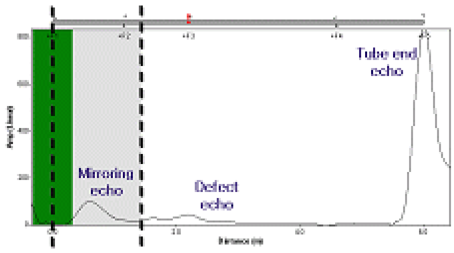


(a) (b)

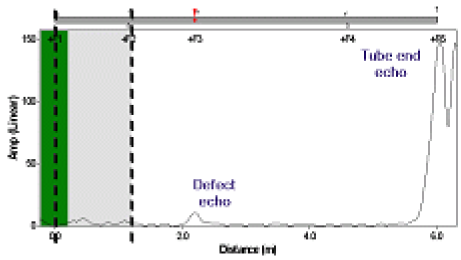
Fig. 3 Experimental setup of (a) Guided wave inspection system with (b) internal transducer probe

3. Test Results and Discussions

For the study presented, longitudinal mode (0, 1) was generated by the array transducer as shown in Fig. 3(b). The frequency range of longitudinal mode is about 25-47 kHz. Fig. 4(a) and (b) show the experimental results of defect detection in the exchanger tube specimens at 25 kHz and 39 kHz respectively. The x-axis represents the distance away from the ring. The green and grey areas near zero distance represent the dead zone and the near field respectively. Reflections from within the near field can be analyzed, however, special care must be taken since amplitudes are artificially low and false echoes can appear. One of false echoes is mirroring echo as shown in Fig. 4. When the direction of the transmitted and received wave is not adequately controlled, a small copy of a reflection can appear in the 'wrong' direction. This normally happens within the near field. For the above reason the mirroring echo appeared as shown in Fig. 4(a), and defect echo also observed. But it is difficult to distinguish defect echo from unwanted signals. For solving this problem we propose frequency tuning for reducing amplitude of mirroring echo and enhancing S/N ratio. It is easy to distinguish the defect echo from unwanted signals as shown in Fig. 4.



(a) defect detection at 25 kHz

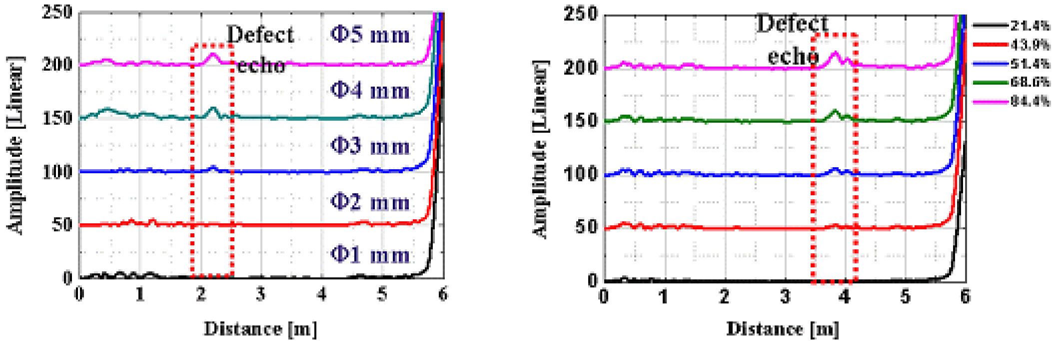


(b) defect detection at 39 kHz

Fig. 4 Experimental result in a titanium tube(19.05 mm O.D., 0.889 mm thickness)

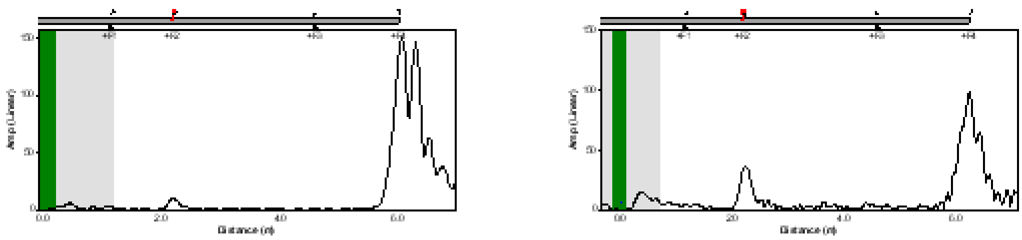
The Amplitudes of intended signals are plotted in Fig. 5 as a function of the distance away from the ring. It is noted that the amplitudes increases as a diameter of drillhole defect or a depth of thickness reduction increases only in a limited condition. For example, The defect signal of 3 mm drill hole and wear defect with depth about 50% of the thickness are detected. According to the test result, it is found that the limit of detection of the drillhole defect and wear defect is more than 3mm diameter and depth about 50% of the thickness respectively.

Fig. 6(a) and 6(b) shows the experimental results of the 5 mm drillhole defect with support ring or without support ring respectively. In this result the most important finding is that the amplitude of defect echo differs between two figures. The amplitude of defect echo with support ring markedly increases as compared with the left of Fig. 6, though at present we do not know the reason for it. According to the experimental results, it seems to be feasible to distinguish a defect echo from a support plate signal. However, the most important steps in carrying out a successful job is obtaining sufficient prior information about all the features in a tube should be known from either technical drawings or visual inspection.



(a) Drillhole defect echo (b) Wear defect echo

Fig. 5 Experimental result in a titanium tube at 39 kHz



(a) without support ring (b) with support ring

Fig. 6 Experimental result of defect detection in a titanium tube at 39 kHz

4. Conclusions

In this paper, we proposed and experimentally verified an ultrasonic guided wave technique that can discriminate a defect echo in support plate region. Though we do not know the reason for it, this is the advantage of the present method over the ECT technique. As possible application of this interesting feature, change of Amplitude of Longitudinal mode will provide a qualitative measurement of defects. Although the present experiment is mostly restricted to the guided wave technique, this method will be fully verified either by comparing with a conventional ECT or by comparing with a Ultrasonic Internal Rotary Inspection System (IRIS)

References

[1] Park Ik-Keun et al, Long Range Ultrasonic Guided Wave Technique for Inspection of Pipes, Key Engineering Materials, Volume 321-323, 2006, P 799-803

[2] H. J. Shin et al, Inspection of Heat Exchanger Tubing Detects with Ultrasonic Guided Waves, Journal of the Korean Society for Nondestructive Testing, Volume 20 Number 1, Feb. 2000, P1-9

[3] J. L. Rose et al, Ultrasonic Guided wave NDE for Piping, Materials Evaluation, Volume 51 Number 5, May 1996, P1310-1313
[4] T. Nagai et al, Guided Ultrasonic Testing as a Practical Technology, Journal of the Japanese Society for Non-Destructive Inspection, Volume 52 Number 12, Dec. 2003, P667-671
[5] S. Kameyama et al, Ultrasonic Test Instrument Using Guided Wave, Journal of the Japanese Society for Non-Destructive Inspection, Volume 52 Number 12, Dec. 2003, P672-678