Heat Exchanger Tube Inspection of Nuclear Power Plants using IRIS Technique

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1. Introduction

Inspection of heat exchange tubing include steam generator of nuclear power plant mostly performed with eddy current method [1]. Recently, various inspection technique is available such as remote field eddy current, flux leakage and ultrasonic methods. Each of these techniques has its merits and limitations. Electromagnetic techniques are very useful to locate areas of concern but sizing is hard because of the difficult interpretation of an electric signature. On the other hand, ultrasonic methods are very accurate in measuring wall loss damage, and are reliable for detecting cracks [2]. Additionally ultrasound methods is not affected by support plates or tube sheets and variation of electrical conductivity or permeability. Ultrasound data is also easier to analyze since the data displayed is generally the remaining wall thickness. It should be emphasized that ultrasound is an important tool for sizing defects in tubing. In addition, it can be used in situations where eddy current or remote field eddy current is not reliable, or as a flaw assessment tool to supplement the electromagnetic data. The need to develop specialized ultrasonic tools for tubing inspection was necessary considering the limitations of electromagnetic techniques to some common inspection problems. These problems the sizing of wall loss in carbon steel tubes near the tube sheet or support plate, sizing internal erosion damage, and crack detection. This paper will present an IRIS(Internal Rotating Inspection System) ultrasonic tube inspection technique for heat exchanger tubing in nuclear power plant and verify inspection reliability for artificial flaw embedded to condenser tube.

2. Methods and Results

2.1 IRIS Based Tubing Inspection System

The operating principle of IRIS is based on pulse-echo detection. An axially mounted transducer excited by a high frequency pulse produces an ultrasonic wave that propagates in water. A mirror deflects the wave to produce a normal incidence beam on the tube ID. Echoes, reflected back from each metal-water interface, are digitized and processed to extract the time of flight and amplitude of the front wall echo and back wall echoes. Figure 1 depicts the turbine/mirror and associated UT signals. Further processing is applied to calculate the tube ID, OD, and wall thickness.

Complete tube inspection is obtained by rotating the mirror, which is driven by a hydraulic turbine. The beam, striking an ultrasonic target, performs synchronization of the rotation. In this study KEPRI developed IRIS probe and inspection procedure for tubing inspection.

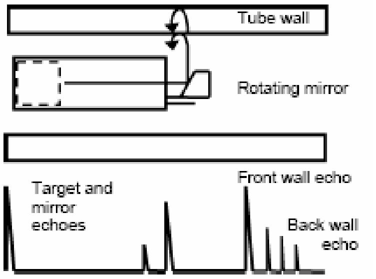

Figure 1. IRIS Sensor configuration and associated signal

The experimental system is configured with pulse-receive (TC5700, RD-tech) and rotating turbine, water pumping system. A schematic diagram of IRIS system is illustrated in Figure 2.

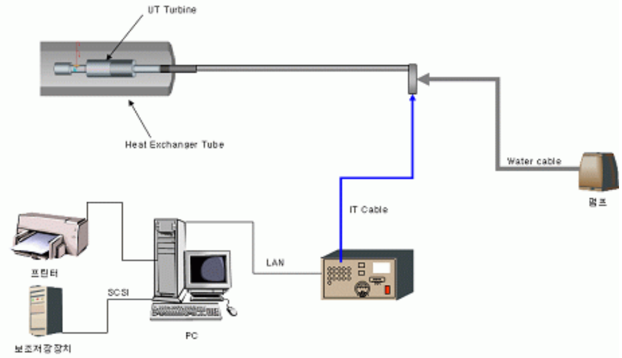

Figure 2. Schematic diagram of the IRIS system

2.2 Data analysis and reliability evaluation

To study the IRIS system for exchanger tubing, the artificial flaws machined along the condenser. The tube made of Titanium Gr. 2 was 24mm outside diameter with 0.7mm wall thickness. The tube contains OD grove and flat bottom hole. OD grove is machined 3 different depth 25%, 50% and 75%. And flat bottom hole is four 25% depth and 50% in depth. The water pump for couplant pumped water with $5kg_f/cm^2$ pressure. The frequency of ultrasonic probe is 10Mhz and focused to tube outer surface.

The data in figure 3 demonstrate the result from artificial flaws. The layout of the IRIS presentation shows the C-scan on the upper left, the B-scan, or circumferential section, on the upper right, and the D-scan, or horizontal section, on the lower left. The C-scan represents the circumference of the tube laid open in the vertical direction. The horizontal direction is along the tube axis. True top of the tube is unknown due to the fact that the location of the ultrasonic trigger may move relative to the tube. From this, it is clear that the wall loss area is completely around the circumference.

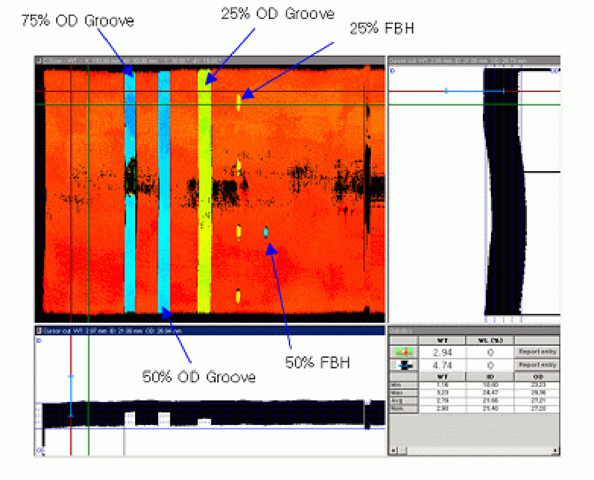

Figure 3. IRIS signal from condenser tube included groove and flat bottom hole.

Data analysis is preformed with analysis software [3]. Fig 4 shows measurement error with respect actual flaw depth.

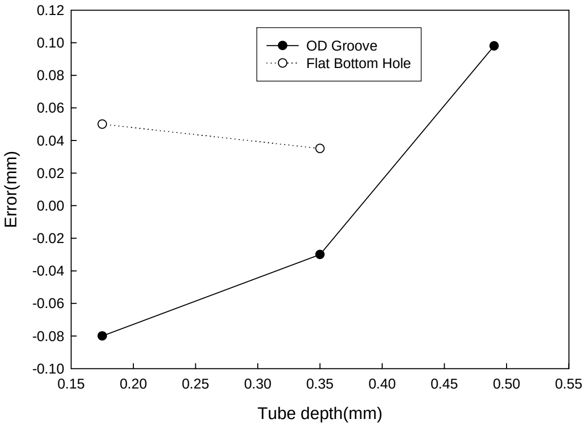

Figure 4. Flaw depth measurement error for OD grove and flat bottom hole as a function of flaw depth

As can be seen Figure 4, measurement accuracy is very close to actual flaw dimensions. The measurement result for FBH more accurate compared to OD groove. But the most of measurement result errors are within ± 0.1mm range.

4. Conclusion

The IRIS inspection technique for heat exchanger tube flaw sizing was suggested. Using IRIS ultrasonic technique as a sizing tool to supplement eddy current or RFT is desirable in situations where the flaw depth and extent detection is unreliable by electromagnetic techniques. IRIS technique using ultrasonic probe is possible accurate flaw sizing and measuring wall loss damage for heat exchanger tube. When we apply to field application, we have to consider pulling speed and IRIS probe centering between tube and mirror.

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