Transactions of the Korean Nuclear Society Autumn Meeting
Busan, Korea, October 27-28, 2005

Impedance Analysis of ECT Bobbin Probe for Steam Generator Tube Inspection

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1. Introduction

Eddy Current Testing (ECT) for steam generator (SG) tube inspection in nuclear power plants (NPP) is the most important non-destructive test during the plant outage [1]. Bobbin probe is the most commonly used for the SG tubing inspection. The impedance, important parameter related to the signal of ECT, depends on the characteristics of bobbin probe to be used for the inspection [2].

In this study, a system for acquiring the impedance data was made up and impedance analysis program was designed for effective data acquisition. Employing the system and program, the resonance frequencies were obtained and the impedance data were acquired for the bobbin probes for SG tube inspection. Experimental results are compared with the theoretical results and normalized impedance diagrams for the probes are offered in this paper. These experimental results gives not only a better understanding of impedance properties of the bobbin probes for SG tube inspection but also the information about the design and fabrication of the bobbin probe.

2. Methods and Results

The system and program for acquiring the impedance data of bobbin probes are described in this section. The results of impedance analysis are obtained and compared with the theoretical results. Also normalized impedance diagrams for the probes are offered.

2.1 The System for Acquiring Data

The system for acquiring the impedance data of bobbin probes consists of impedance analyzer (HP 4194A), cable terminal board (HP 16047), GPIB Board, SG tube and bobbin probes. ECT bobbin probe is a high-speed probe which the industry has demonstrated is capable of reliably detecting volumetric flaws and axially oriented crack [3]. These probes for SG tube inspection of NPP in Korea were imported from ZETEC in the whole quantity. The type of bobbin probe depends on the characteristics such as the material and geometry of the tube. In this paper the bobbin probe to be used for inspection is categorized with 4 models : WH-F, KSNP, Framatome and CANDU. In experiments, Cable terminal board in system was used to improve the signal to noise ratio. A schematic diagram of the system for acquiring data is illustrated in Figure 1.

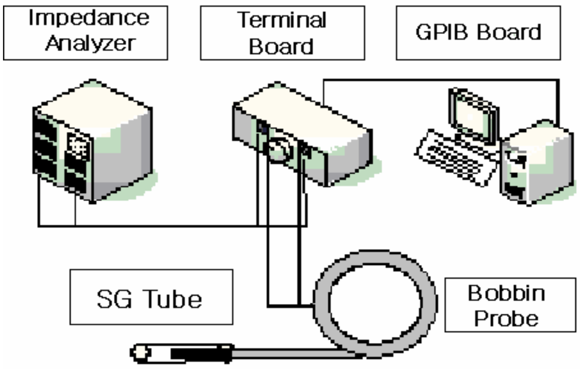

Figure 1. Schematic Diagram of the system for acquiring the impedance data of bobbin probes

2.2 Impedance Analysis Program

Impedance analysis program, coded by LabView, was developed to acquire the data such as resistance, reactance, impedance of each bobbin probe. For effective data acquisition, the program was designed to be easily accessed the results by typing the initial parameters such as test beginning frequency, test ending frequency, number of points. The data was obtained within frequency range of 100hz to 1Mhz. Figure 2. shows the main window of impedance analysis program.

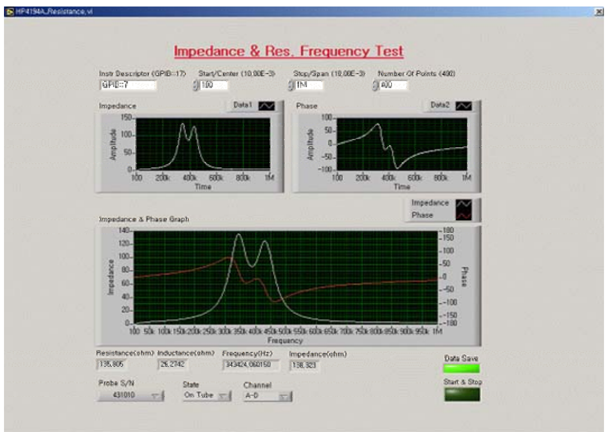

Figure 2. Main window of impedance analysis program for effective data acquisition within frequency range of 100hz to 1Mhz.

2.3 Results

Figure 3. shows impedance diagrams for KSNP of four categorized models. Left graphic illustrates the result of resistance, reactance, impedance measured on air as a function of the frequency. Right graphic is the result of the data measured on tube. As can be seen

from Figure 3, resonance frequency can be obtained at the peak point of impedance and each bobbin probe has resonance frequency of two points. The result of the resonance frequency and impedance peak of each probe categorized with SG type is shown in Table 1.

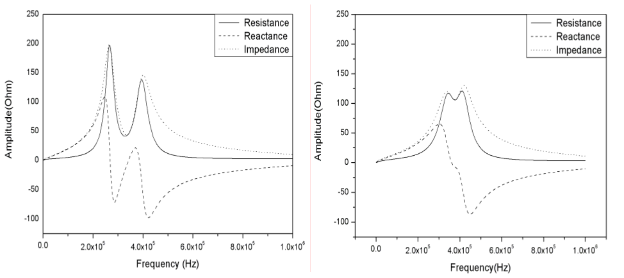

Figure 3. Impedance diagrams for KSNP : the result of resistance, reactance, impedance measured on air (Left graphic) and on tube (Right graphic) as a function of the frequency

Normalized impedance, the most important parameter for expressing the characteristic of the bobbin probe, is applied for analyzing probe characteristic by minimizing the effect of the material and geometry parameters affecting on the impedance variation [4].
This normalized impedance is calculated by impedance data of each probe of four categorized models using the following equation (1).

$$X = (R_L - R_0) / wL_0$$
$$Y = wL / wL_0 \qquad (1)$$

where X is normalized resistance, Y is normalized inductance. And R_L is the resistance of probe measured on air, R_0 is the resistance of probe measured on tube and w is angular frequency. L is the inductance of probe measured on air, and L_0 is the inductance of probe measured on tube.

Using equation (1), the result of normalized impedance of each probe categorized with 4 models is shown in Figure 4. Normalized impedance is independent of the change of the permeability and conductivity of SG tube materials such as Alloy 600TT, Alloy 600HTMA, Alloy 690 [5].

For this, as can be seen from Figure 4., normalized resistance of the probe is increased as the fill factor is increased. This property is the same as the theoretical result of numerical analysis [6].

Table 1. The test result of the resonance frequency and impedance peak of each probe categorized with SG type

SG Type	Peak	Resonance Frequency (kHz)		Impedance Peak (Ω)	
		On Air	On Tube	On Air	On Tube
WH-F	P1	293.30	343.30	187.55	139.86
	P2	426.12	438.65	142.40	135.49
KSNP	P1	265.74	340.92	198.65	119.85
	P2	401.06	421.11	146.09	130.36
Framatome	P1	233.16	303.33	245.70	130.71
	P2	363.47	383.52	174.78	140.06
CANDU	P1	320.87	355.95	185.14	149.60
	P2	426.12	438.65	142.40	135.49

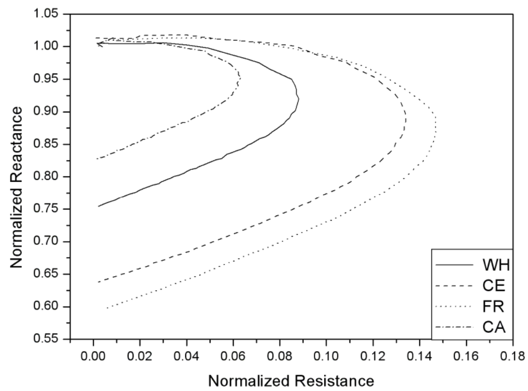

Figure 4. The normalized impedance diagram of each probe categorized with 4 models

3. Conclusion

In this paper, a system for acquiring the impedance data was made up and impedance analysis program was designed for effective data acquisition. Employing the system and program, the resonance frequencies were obtained and the impedance data were acquired for the bobbin probes for SG tube inspection. Experimental results are compared with the theoretical results and normalized impedance diagrams for the probes are offered. These experimental results gives not only a better understanding of impedance properties of the bobbin probes for SG tube inspection but also the information about the design and fabrication of the bobbin probe.

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