The Effect of Eddy Current Bobbin Coil Dimension Changes on Signal Quality of Steam Generator

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1. Introduction

The bobbin probe is now widely accepted as a basic and important ECT technique among various ECT techniques for steam generator tube integrity assessment that is practiced during each plant outage. The bobbin probe is also one of the essential components which consist of the whole ECT examination system, and provides us with decisive data for the evaluation of tube integrity in accordance with acceptance criteria described in specific procedures. Accordingly, the design of ECT probe is especially important to examination results because the quality of acquired ECT data is determined by the optimized probe design characteristics, such as coil geometry, electrical properties, operation frequency, and so on. In this study, the relationship between electric characteristic changes and differential coil gap variation for the optimization of the ECT probe signal was investigated.

2. Methods and Results

2.1 Design and Fabrication of Experimental Bobbin Probes

Experiments were performed to verify the optimal design parameters of differential bobbin probe for the steam generator tube in Nuclear Power plant. For these experiments, the variation of signals was measured as the differential coil gap was changed, and the coil turns and cable length were fixed during these measurements. The number of coil turn was determined by calculation using a principle equation. The experimental coil for the measurement of signal variation as the coil gap is changed is shown in Fig. 1.

2.2 Artificial Flaw Specimens

Two specimens which include a ASME type calibration standard described in ASME Section V, Article 8. The ASME type calibration standard has several flat-bottomed holes, I.D. & O.D. grooves, and through-wall hole.

2.3 Measurement of Probe Coil Electrical Characteristics

Electrical characteristics of bobbin coil, such as resonant frequency, impedance, resistance, and inductive reactance, were measured by using a measurement system which is composed of a LABVIEW data acquisition program, an impedance analyzer (HP 4194a), and a GPIB board.

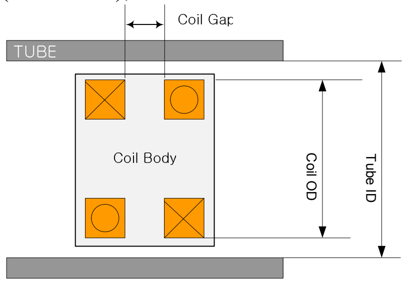


Fig.1 Nomenclatures of experimental coil for differential bobbin probe

Each coil resonant frequencies were obtained under “loaded” condition, i.e., probe coils placed inside a section of tubing. Normalized impedance curves were described as “bode plot”, i.e., x-axis represents frequencies, and y-axis represents probe coil impedance and phase angles.

2.4 Analysis of Eddy Current Signals

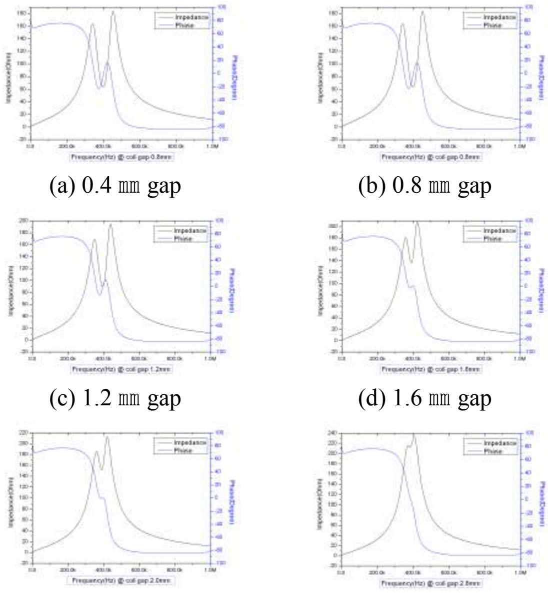
Eddy current testing system which is composed of a frequency generator, two workstation computers, and data acquisition & analysis program, was adopted to analysis the acquired signals. The frequency generator has a range of frequency from 10 kHz to 1 MHz, and total 64 channels. For this analysis, eddy current signals were acquired from specimen.

3. Results and Discussion

3.1 The Effect of Coil Gap Variation upon Resonant Frequency Characteristics

Bode plots which present the impedance variation for each coil gap were shown in Fig. 3. In these bode plots, it is recognized that the amplitude of each coil is commonly increased as the probe coil gap is increased, and also the two peaks of resonant frequency come close to each other. The peak of front resonant frequency is increased as the probe coil gap is increased, but the peak of rear resonant frequency is decreased as the probe coil gap is increased, and these two peaks forms finally one peak of resonant frequency. We estimate that this phenomenon is derived from the interactions of magnetic field between two coils.

However, the variation of resonant frequency is observed as insignificant.



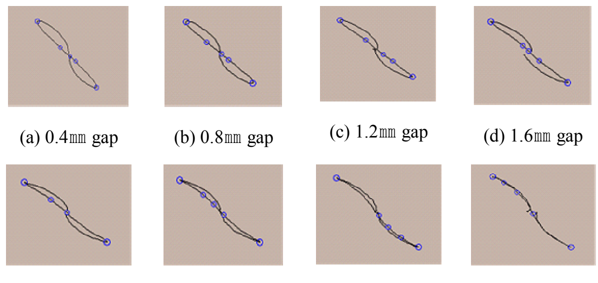
(a) 0.4 ㎜ gap (b) 0.8 ㎜ gap
(c) 1.2 ㎜ gap (d) 1.6 ㎜ gap
(e) 2.0 ㎜ gap (f) 2.4 ㎜ gap

Fig. 3 Impedance curves for each coil gap

It is also recognized that the distance between the highest point and the lowest point of resonant frequency is dramatically increased from the 1.2 mm coil gap. The lowest point of resonant frequency is equal to the end point of lobe signal, i.e., Lissajous signal. The distance between the highest point and the lowest point of resonant frequency have an effect on the shape of eddy current lobe signal. As the distance between the highest point and the lowest point of resonant frequency become longer, the shape of end point of lobe signal become also more round. This round shape of lobe signal has a bad effect on flaw sizing accuracy. That is, the round shape of lobe signals can decrease the flaw sizing accuracy. Conclusively, under the condition of below 1.2 mm coil gap, the accuracy of flaw sizing can be decreased.

3.2 The Effect of Coil Gap Variation upon Lissajous Signal Formation

The shapes of Lissajous signals for each coil gap are observed when the coil gap is varied from 0.4 mm to 3.2 mm. The through-wall hole in an ASME type standard is used for this observation. The observed Lissajous signals are shown in Fig. 4. The center axes of each signal are observed to analysis the effect of coil gap variation upon Lissajous signal formation. The straightness of center axes are changed as the coil gap is varied.



(a) 0.4㎜ gap (b) 0.8㎜ gap (c) 1.2㎜ gap (d) 1.6㎜ gap
(e) 2.0㎜ gap (f) 2.4㎜ gap (g) 2.8㎜ gap (h) 3.2㎜ gap

Fig. 4 Lissajous signal variation for each coil gap

The center axes of signal are slightly changed from straight line to curve at below the 0.8 mm coil gap, and also the center axes changed at above the 2.0 mm coil gap. The center axis only maintained straightness at the range of 1.2 mm ~ 1.6 mm coil gap. The straightness of center axis has effect upon the measurement of signal phase angle. As the center axis of signal become more distorted, the measuring accuracy of phase angle become worse. Generally the flaw sizing is achieved by measuring the phase angle, and phase angle is estimated by Max_R (maximum slope of center axis) measurement of the Lissajous signal.

4. Summary

In this study, we have observed the impedance curve and the Lissajous signal variation as the differential bobbin coil gap is changed, and estimated the optimal coil gap of differential bobbin probe that is used to examine the steam generator tube in nuclear power plants. As a result, we propose that the best Lissajous signal will be obtained when the coil gap of differential probe is approximately 1.2 mm~1.6 mm.

REFERENCES

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2. Hugo L. Libby, *Introduction to Electromagnetic Nondestructive Test Methods.* John Wiley & Sons, Inc (1971).