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A Study on Electrical Characteristics for Coil Winding Number Changes of the ECT Bobbin Probe for S/G Tube Inspection in NPPs

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1. Introduction

Two kinds of eddy current probes are mainly used to perform the steam generator tube integrity assessment in NPPs. The first one is the bobbin probe using for inspection of volumetric defect like a fretting wear. The second one is the rotating probe using for inspection of non-volumetric defect like a crack. The eddy current probe is one of the essential components which consist of the whole eddy current examination system, and provides a decisive data for the tube integrity in accordance with the acceptance criteria described in specific procedures. The design of ECT probe is especially important to improve examination results because the quality of acquired ECT data is depended on the probe design characteristics, such as coil geometry, electrical properties, and operation frequency. In this study, it is analyzed that the coil winding number of differential bobbin probe affects the electrical properties of the probe. Eddy current bobbin probes for the inspection of the steam generator tubes in NPPs are designed and fabricated according to the results. Experiment shows that the change in coil winding number has many effects on the optimum inspection frequency determined by the tube geometry and material. Therefore, the coil winding number in bobbin probe is very important in the probe design. In this study, a basis of the coil winding number for the eddy current bobbin probe design for the inspection of the steam generator tubes in NPPs is established.

2. Test preparation and method

Bobbin probes used in this test are shown in Fig. 1. For this test, eight bobbin probes (N1~N8) which were designed in different coil turns were manufactured. The probes were fabricated with the coil winding numbers of $(N_4 \pm 5n)$, where N_4 is a calculated winding umber and n is natural number. Table 1 shows the design for coil winding numbers of the test probes.

The tube of Westinghouse model F steam generator is used in the test. In order to measure the impedance with the state of engaging the probe coil, reference specimen of sound tube was used. Reference specimen used in this test is illustrated Fig. 1.

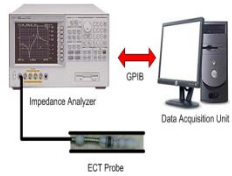
The probe impedance and phase were measured by the precision impedance analyzer 4294A, Agilent Inc. as shown in Fig. 3. Impedance analyzer can measure resonance frequency, impedance and phase angle of the bobbin probe.

Table 1. Design for coil winding numbers of the test probes

Probe No.	N1	N2	N3	N4	N5	N6	N7	N8
Winding No.	N4 -15	N4 -10	N4 -5	N4	N4 +5	N4 +10	N4 +15	N4 +20

Material	Inconel 600TT
OD	0.688 inch
Thick	0.040 inch

Fig.1 Test bobbin probes　　Fig.2 Reference specimen



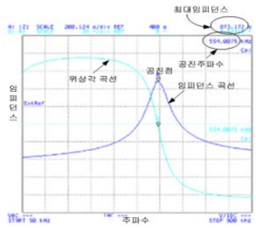
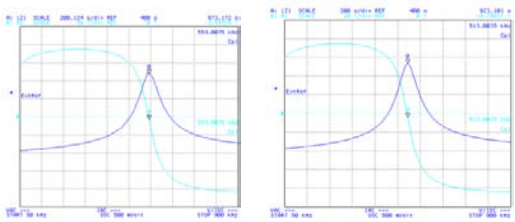


Fig.3 Electrical property test system　　Fig.4 Output of electrical property test system

3. Test results

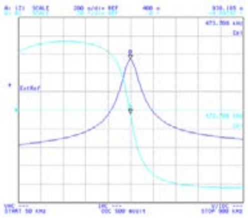
3.1 Impedance and resonance frequency test for coil winding variation

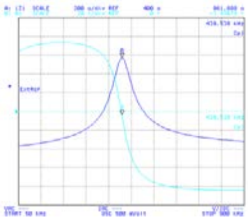
Impedance and resonance frequency were measured with the full cable length (100ft) between the coil and the instrument input connector. Figure 5 shows the impedance plots for absolute mode due to coil winding variation in inconel tube. As shown by Fig. 5, 6 and 7, the amplitudes of impedance are slightly increased and the resonance frequencies are linearly decreased as the coil winding numbers are increased.



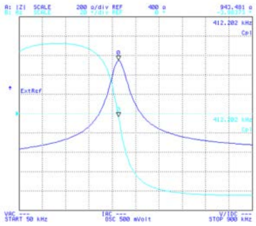
(a) N1　　(b) N2

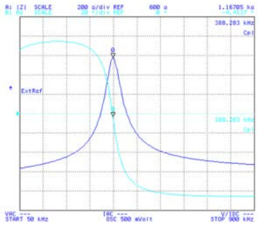
Fig.5 Impedance plots for absolute mode in inconel tube



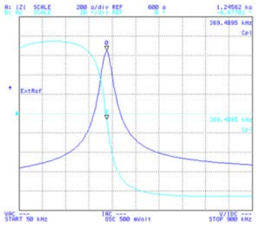


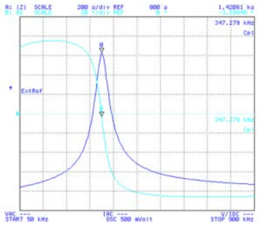
(c) N3 (d) N4





(e) N5 (f) N6





(g) N7 (h) N8

Fig.5 Impedance plots for absolute mode in inconel tube(continue)

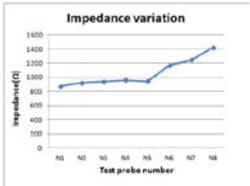


Fig.6 Impedance variation of test bobbin probes

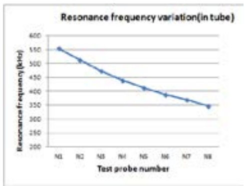
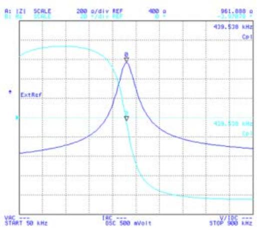
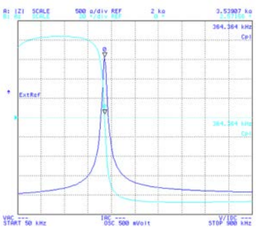


Fig.7 Resonance frequency of test bobbin probes

3.2 Effect on the test tube

Fig. 8 illustrates the impedance diagrams measured in the states that the probe coil is in reference tube and on air, respectively.





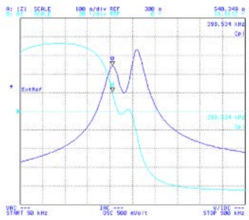
(a) Reference tube (b) Air

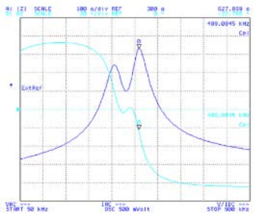
Fig.8 Impedance plots for absolute mode of N4 test probe in reference tube or on air

The impedance on air is over 4 times higher than that in the reference tube. The measured resonance frequency on air is lower about 70kHz than that measured in the tube. Therefore, at the design stage of the eddy current probe coil for Inconel 600 tube, a similar result is obtained for measuring the resonance frequency on air if the frequency is set up lower about 70kHz than the frequency in tube.

3.3 Characteristics test for probe coil modes

In the state that the probe coil of Fig. 5(a) is inserted in the test specimen, if one of two coils of differential type probe is short-circuited, the impedance diagram measured with one coil shows one resonance point. However, in the state that the probe coil of Fig. 12 is inserted in the test specimen, if two coils of differential type probe are connected, the impedance diagram measured with one coil shows two resonance points. The reason of existing two resonance points is that an induced current with opposite direction is produced in the adjacent coil by the electromagnetic induction phenomenon established by Faraday.





(a) The first peak (b) The second peak

Fig.9 Impedance for differential modes of N4 test probe in reference tube

4. Conclusion

Analyzing electromagnetic characteristics as changing the number of winding coil which is an important design factor for ECT bobbin probe for the inspection of the steam generator tube, following results are obtained:

The amplitudes of impedance are slightly increased and the resonance frequencies are linearly decreased as the number of winding coil is increased. In the state that the probe coil is inserted in the test tube, if one of two coils of differential type probes is short-circuited, the impedance diagram measured with one coil shows one resonance point. However, in the state that the probe coil is inserted in the test tube, if two coils of differential type probe are connected, the impedance diagram measured with one coil shows two resonance points.

REFERENCES

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