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Characteristics Testing of the ECT Bobbin Probe for S/G Tube Inspection

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1. Introduction

The bobbin probe technique is basically one of the important ECT methods for the steam generator tube integrity assessment that is practiced during each plant outage. The bobbin probe also is the essential component which consists of the whole ECT examination system, and provides a decisive data for the evaluation of tube integrity in compliance with acceptance criteria described in specific procedures. The selection of probe is especially important because the quality of acquired ECT data is determined by the probe design characteristics, such as geometry and operation frequency, and has an important effect on examination results. The Electric Power Research Institute (EPRI) has recently defined the procedures for the qualification of eddy current hardware and technique. These procedures provide two basic methods for qualification. Flawed tube removed from operation, or artificial flaw is required for the original qualification of technique combined with related flaw mechanism. In case where the original qualification has been completed, the concept of equivalency may be used to extend the original qualification to similar probe designs. The qualified acquisition technique may be modified to substitute or replace instruments or probes without re-qualification provided that the range of essential variables defined in the examination technique specification sheet are met. In this case, both the original and replaced instrument or probe shall be characterized utilizing EPRI Guideline supplement "H1". This study is the result of the comparative performance evaluation of bobbin coil eddy current probes manufactured by KEPRI and a foreign manufacturer. As a result of this study, although there were minor differences between the two probe types, it was evaluated that the two probes were almost identical in the significant performance characteristics described in the EPRI guideline.

2. Test preparation

A bobbin probe used in this test is illustrated Fig. 1. For this test, five test specimens which contain several artificial flaw were manufactured. The probe impedance and phase were measured by the precision impedance analyzer 4294A, Agilent Inc. as shown in Fig. 2. In order to acquire and analyze ECT signals from the specimens, a test system as shown in Figure 3 has been configured. This test system consists of Miz-70 eddy current instrument and Eddynet software.

Figure 1. Bobbin probe designed by KEPRI

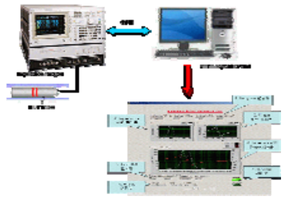

Figure 2. Impedance analyzer

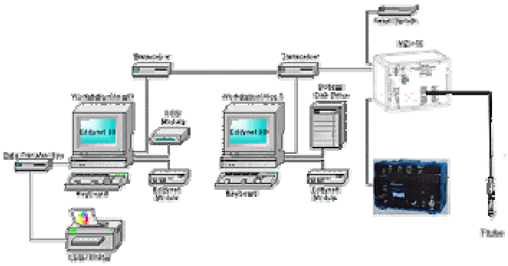

Figure 1. Test system configuration for eddy current characteristic measurement

3. Test methods and results

3.1 Impedance and phase angle test

Impedance and phase angle were measured for each coil at the test frequencies selected for the examination. Figure 4 and 5 show the impedance and phase angle comparison plots for KEPRI and foreign probes. These analysis plots of the impedance and phase angle show that the probe characteristics are very consistent for each manufacturer.

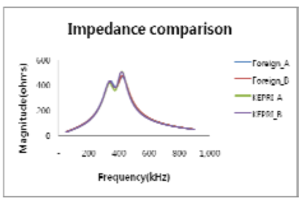

Figure 4. Impedance comparison plot for KEPRI and Foreign probe

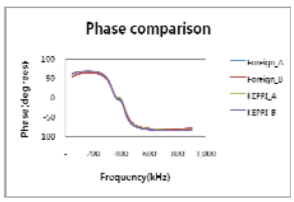

Figure 5. Phase comparison plot for KEPRI and Foreign probe

3.2 Center Frequency

The center frequency was measured with the full cable length between the coil and the instrument input connector. The measurement was performed using the precision impedance analyzer 4294A (Agilent Inc.) with the results being the peak values obtained during the impedance tests. The results summarized in Tab. 1 show that two probes have a minor difference. Although the center frequency is statistically different between the two probe manufacturers, the difference is near the resolution of the test instrument, and is considered to be insignificant.

Table 1 Comparison of center frequency

Manufacturer	Type	Center frequency(kHz)
KEPRI	MULC	337
Foreign	MULC	340

3.3 Effective scan field width (ESFW) test

The effective scan field width is a measure of the extent of the effective sensing area in the scanning direction. It is also a measure of spatial resolution. Fig. 6 and 7 show detected amplitude versus position for 30mm long axial EDM notch. Each channel was normalized for maximum response of 10 volts. The plots show that both probe types have a nearly identical axial field of view.

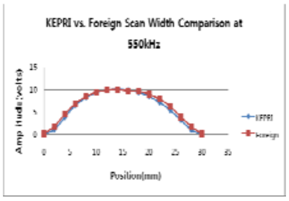

Figure 6. Scan width comparison plot for KEPRI vs. Foreign probe at 550kHz

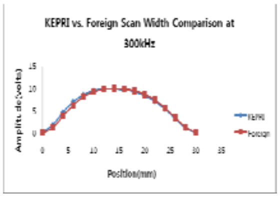

Figure 7. Scan width comparison plot for KEPRI vs. Foreign probe at 300kHz

3.4 Fill factor coefficient (FFC) test

The fill factor coefficient (FFC) is a measure of the drop in effective sensitivity due to the increase in the distance between the source of the eddy current inducing magnetic field and the inner surface of the tubing. The term fill factor is defined as:

Fill factor = $(\text{Probe OD})^2/(\text{Tube ID})^2$

Fig. 8 and 9 show the FFC comparison for the three tube ID (FF: 0.86, 0.82, 0.80) at differential and absolute mode. The response of KEPRI probe was less affected by fill factor than that of foreign probe.

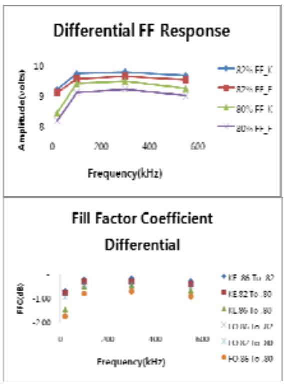

Figure 8. Fill factor coefficient comparison at differential mode

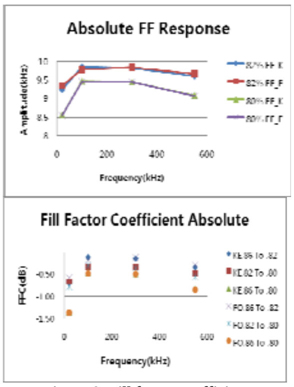

Figure 9. Fill factor coefficient comparison at absolute mode

3.5 Depth coefficient test

The depth coefficient (DC) is a measure of the depth-of-penetration and current density within the wall thickness of the tube. The measurement was performed at each coil configurations, and the modes of operation at the nominal fill factor being used in the steam generator tube. The response amplitude was compared for a series of ID and OD flaw depth. The depth coefficient values were calculated as decibel levels relative to the maximum amplitude flaw response. Fig. 10 and 11 show the depth coefficient plots of the two probes at differential and absolute mode. The test results showed that the depth coefficient comparison indicated that there was no practical difference between the two probe types.

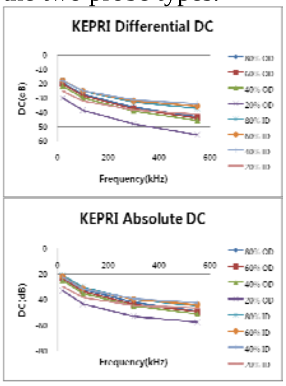

Figure 10. Depth coefficients plot of KEPRI probe at differential and absolute mode

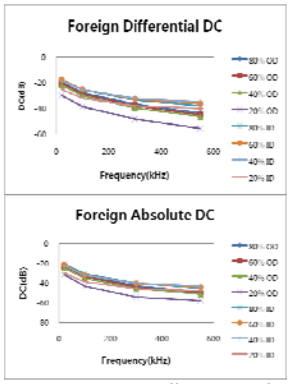

Figure 11. Depth coefficients plot of Foreign probe at differential and absolute mode

3.6 Phase angle-to-depth curve (PDC) test

The phase angle to depth curve measures the dependency of the eddy current signal phase angle on flaw depth. Fig. 12 and 13 show the phase angle to depth curve of the two probe types as the frequency changes. This test results showed that there was no practical difference between the two probes on the basis of the PDC measurement.

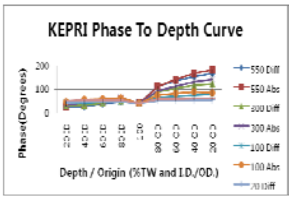

Figure 12. Phase to depth curve of KEPRI probe for frequency changes

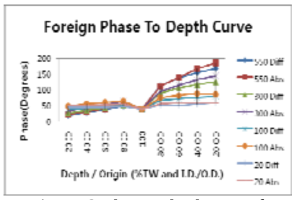

Figure 13. Phase to depth curve of Foreign probe for frequency changes

4. Conclusion

In this study, a series of test was performed to comprise the overall performance characteristics of bobbin probes as described in the EPRI Guideline supplement “H1”. As a result, it was found that the overall performance characteristics of KEPRI probe were equivalent to those of the corresponding foreign probe.

REFERENCES

[1] EPRI, Pressurized Water Reactor Generator Examination Guidelines: Rev. 7.

[2] ASME Boiler and Pressure Vessel Code Ⅴ, Non-Destructive Examination, 1995.