Characteristic Testing of Eddy Current Array Coil for Steam Generator tubes of the Nuclear Power Plant

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1. Introduction

The eddy current testing (ECT) is commonly used to inspect the integrity of steam generator (SG) tubes of the nuclear power plant, and bobbin and motorized rotating probes are widely used as the ECT coil. The bobbin probe has two coils circumferentially wounded around the probe, and used to detect pit, thinning, wear and axial flaws of the tube, has a high speed of inspection (24~40 inch/sec) as a basic inspection. The motorized probe has pancake and (or) plus (+) point coil, and rotated with go through the tube inside during inspection, has low inspection speed (0.1~0.8 inch/sec) because the motorized coil scan on the surface of the tube inside rotating by motor device (180~1200 rpm).

Due to the low speed and high detection ability, the motorized probe is used to detect small flaw as crack and to confirm abnormal signal from bobbin probe. Because of its advantage from both bobbin and motorized probe (high speed and detectability) array probes were developed and are used in some countries. The array probe has many coils around the probe, transmit and receive the ECT signal sequentially, so it works as rotated electrically as it move inside the tube at a higher speed (20 inch/sec) than motorized probe.

KHNP has developed array probe that has 2 row×16 coils, and applied KEPIC code and US EPRI guideline to verify the characteristic testing of the probe. This paper shows test equipment, method, specimens, and results of the prototype array probe.

2. Experiments and Results

The ECT equipment and acquisition specification for array probe are used as Figure 1 and Table 1.

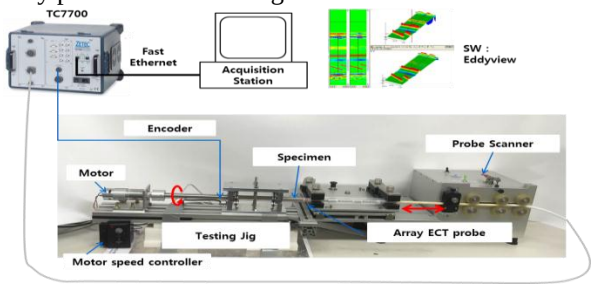


Figure 1. System configuration for characteristic test

Table 1. Signal acquisition specification.

Items	Specification
Tube material	Inconel 600MA
Tube outer/inner diameter	19.05/16.92mm
Tube thickness	1.065mm
Frequency	400/300/200/10kHz

2.1 Effective Scan Field Width (ESFW)

The ESFW is a measure of the drop in the signal amplitude when the sensing area scans past the defect at increasing sensing distances. A 100% TW notch of 0.2mm width and 30mm long is scanned perpendicular to the direction of the induced eddy current.

The signal amplitude drop is used as dB, and it means that how long the eddy current signal measure the notch length at a certain amplitude relatively to the peak.

$$Decibel = 20 \times \log(\frac{Measure}{Peak})$$

Table 2. ESFW(mm) comparison according to frequency

dB drop	100kHz	200kHz	300kHz	400kHz
-2 dB	21.56	21.35	23.77	21.00
-4 dB	23.08	22.77	22.45	22.35
-8 dB	24.85	24.54	24.18	23.97
-12 dB	26.05	25.77	25.35	25.10

Table 2 shows that the measured length of eddy current signal becomes longer as the higher signal drop regardless of the frequency.

2.2 Diametral Offset Value (DOV)

The DOV is a measure of the drop in the effective sensitivity increasing the distance between eddy current source and the inner surface of the tube. Three (3) 100% TW notches of 0.2mm width and 30mm long with different tube inner diameter (17.3/17.1/16.9mm and has fill factor 92/91/90% separately).

$$Fill\ Facter(FF) = \frac{Probe\ outer\ diameter}{Tube\ inner\ diameter}$$

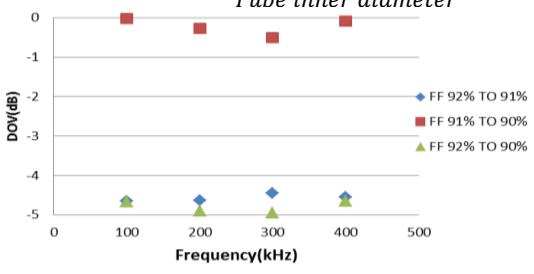


Figure 2. Diametral Offset Value according to the fill factor of the tube

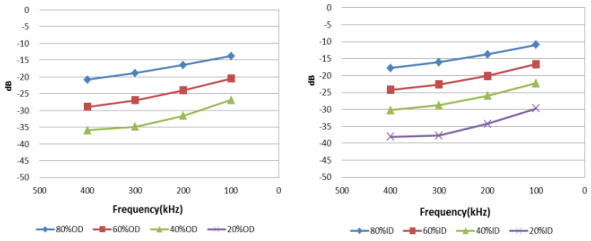
Figure 2 shows the fill factor change from the max point (92%) affects the signal drop more, the change of fill factor (from 91% to 90%) is little because the eddy current signal is decreased according to the distance between the coil and tube inner surface.

2.3 Depth Coefficient (DC)

The DC is a measure of the flaw depth and eddy current density within thickness of the tube. The following notches have 0.2mm width and 30mm long with different depth and arrangement on inner and outer surface of the tube.

- One notch of 100% through wall (TW) depth
- One notch of 80% TW depth
- Two notches of 60% TW depth with 180° apart
- Four notches of 40% TW depth with 90° apart
- Six notches of 20% TW depth with 60° apart

(All apart notches are on the same cross section)



(a) OD Notches (b) ID Notches

Figure 3. Depth Coefficient according to the notch depth

Figure 3 shows the deeper of the notch depth the lesser of the signal drop, and inner notches (b) has less signal drop than outer notches (a).

2.4 Axial Length Coefficient (ALC)

The ALC is a measure of the influence of the axial notch length on the amplitude of the eddy current signal. Six notches have 0.2mm width with different length.

- length(mm) : 15 / 12.5 / 10 / 7.5 / 5 / 2.5

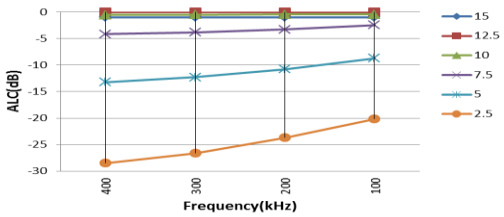


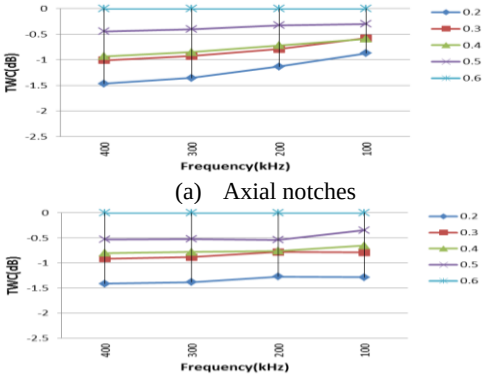
Figure 4. Axial Length Coefficient according to the notch length

Figure 4 shows the higher the frequency the more of the signal drop, and the longer of the notch length the less of the signal drop.

2.5 Transverse Width Coefficient (TWC)

The TWC is a measure of transverse crack width on the amplitude of the eddy current signal. All notches have 100% TW depth and are scanned perpendicular to the sensing area direction, axial notches have 8.2mm long and circumferential notches have 5.9mm long with different width.

- width(mm) : 0.2 / 0.3 / 0.4 / 0.5 / 0.6



(a) Axial notches

(b) Circumferential notches

Figure 5. Transverse Width Coefficient according to the notch width

Figure 5 shows the wider of the notch the smaller of the signal drop, and the axial notches has more signal drop (a) as the frequency is lowered.

3. Conclusion

This paper shows the characteristic test result of the prototype array probe followed by the Steam Generator Management Program and EPRI guideline.

The signal amplitude drop in this test shows the relative decrease of the signal as compared with the peak amplitude. In addition the relative trend, it is important for array probe to have good absolute signal amplitude because of the high signal-to-noise ratio.

This test shows meaningful results which variables of the prototype probe have to be modified to upgrade the performance, and the upgraded version of probe modified by the coil variables (distance between coils, coil dimension) has been developed to get better signal response.

And in order to have equivalent performance with foreign qualified array probe, it will be the next step to compare the characteristic result between qualified and the KHNP probe.

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