The Cause of an Eddy Current Signal Noise from a Steam Generator Tube and its Effect on the Detectability of a Crack

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1. Introduction

An eddy current inspection has been applied for a pre-service and in-service examination of a steam generator in nuclear power plants. The experience from the inspection of steam generators showed that many plants had an excessive number of tubes with eddy current noise signals over several hundreds, which originated from manufacturing anomalies. The plants in U.S suffered significant downstream inspection costs, history reviews, and diagnostic testing because some signals resembled flaws and others masked a flaw. These lessens learned resulted in issuing the guidelines for steam generator tubing specifications and repair, in order to reduce the number of anomalous signals in the tubes and also to provide the requirement of a signal to noise ratio by applying a field type examination with bobbin coil eddy current probes at a manufacturing process [1].

Besides the noise signals of a bobbin coil eddy current probe from manufacturing anomalies, the excessive background noise of the rotating coil eddy current probe signal is frequently observed from a tube and it negatively affects the detection and sizing estimate of a defect. Since the inspection intervals are being extended up to 60 months for the more recent steam generator of corrosion resistant alloy 690TT tubing, the detection of an earlier crack and an accurate sizing are becoming more important in the activity of a non-destructive examination.

In this study, the cause of an eddy current signal noise of a rotating coil probe from a steam generator tube was examined and its influence on the detectability of a crack was analyzed.

2. Experimental

2.1 Steam Generator Tubes with Natural Cracks

The steam generator tubes with high and low level of background signal noise were chosen and designated as the tube A and B, respectively. The magnitude of the background noise, measured from the signal of +point coil in a rotating coil eddy current probe was 0.10V and 0.05V for the tube A and B. In order to analyze the effect of background signal noise on the detectability of a crack, two circumferential cracks were manufactured on a circumference of the outer surface in each tube. The length of each crack and the gap between the cracks were intended to be about 3mm. The depth of a crack into the tube wall was controlled to have the amplitude of the +point coil signal equal to and two times larger than that of the background noise for the two cracks in each tube.

2.2 Topography of Tube Inner Surfaces

The eddy current noise of the rotating coil probe is suspected to originate from the irregular inner surface of the steam generator tube. So, the topographs of the inner surfaces were examined for the two tubes by the 3-dimensional laser profile measurement method. LTC LP-2000 laser profilometry system, used for the measurement, has a rotary laser sensor with a spot size of 0.13mm and a resolution of 0.013mm. The data in terms of radius value was obtained at intervals of 1 degree in the circumferential direction and 0.4mm in the axial direction of the tube.

2.3 Eddy Current Tests and Destructive Examinations

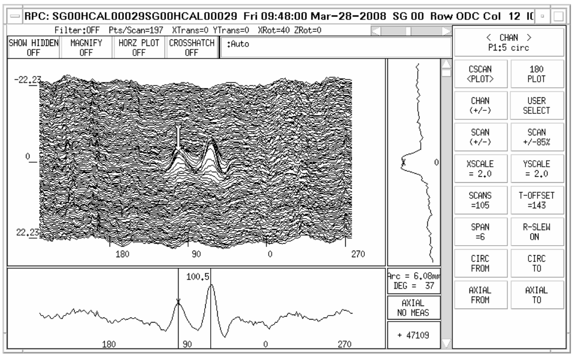
For the selection of the tubes with a high and low background signal noise and the evaluation of the effect of a background signal noise on the detectability of a crack, Zetec MIZ-70 eddy current data acquisition system and a motorized rotating 3-coil (+point, pancake, and pancake high frequency coils) probe was used. The amplitude of the +point coil signal from the axial EDM notch of a 9mm length was calibrated to be 20V.

The length and depth of the cracks in tube A and B were measured on the fracture surface by cutting into the segment with a crack and pulling the crack off.

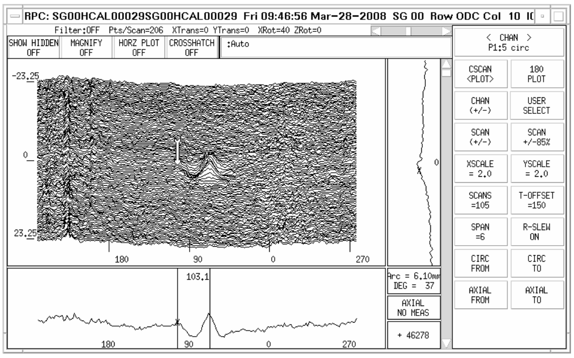
3. Results and Discussion

3.1 Eddy Current Inspections of Tubes

The c-scan graphs of eddy current signals from the +point coil for tubes A and B containing circumferential cracks manufactured on the OD surface are shown in Fig. 1-a and Fig. 1-b, respectively. It can be clearly seen from these figures that tube A has a lower background signal noise compared to tube B. The cracks were successfully manufactured so that the amplitudes of a signal from the two cracks were approximately equal to and two times larger than that of the background noise in each tube. The eddy current signal amplitude of the background nose, smaller crack (on the left in the figures) and larger crack (on the right in the figures) were measured to be 0.10V, 0.11V and 0.22V in the tube A (Fig. 1-a) and 0.05V, 0.06V and 0.10V in the tube B (Fig. 1-b), respectively.



(a)

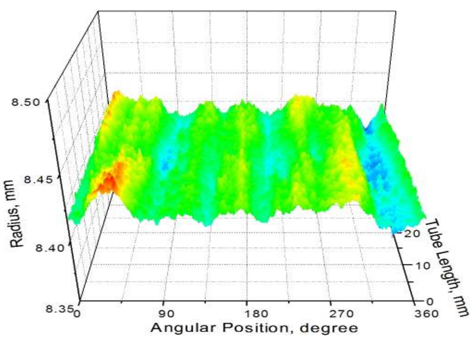


(b)

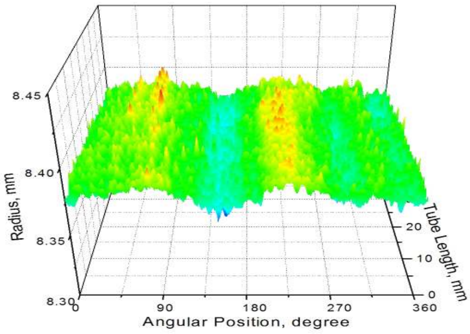
Figure 1. C-scan graphs of eddy current signals from the +point coil for (a) tube A and (b) tube B containing circumferential cracks manufactured on the outer surfaces.

3.2 Topographs of Tube Inner Surfaces

The background signal noise from the +point coil was suspected to originate from the irregularity of the tube inner surfaces, and the topograph of each tube was investigated. The results for tube A and B are shown in Fig. 2-a and Fig. 2-b, respectively. The topographs were shown in terms of radius changes along the circumferential and axial directions of each tube. In Fig. 2-a, obtained from tube A, an axial irregularity of the inner surface was observed, and the number of sharp axial ridges was six, which was coincident with that in the background noise pattern of Fig. 1-a. For tube B in Fig. 2-b, two round axial ridges were observed and it was interpreted to reflect the oval shape of the tube.



(a)



(b)

Figure 2. Topographs of the tube inner surfaces in (a) tube A and (b) tube B measured by the laser profilometry.

From these results, it can be concluded that the cause of the eddy current signal noise originats from the irregular inner surface of the tube. The variation of the micro-scale dimension with the pattern of the sharp axial ridges observed in tube A is thought to be introduced by the cold pilger rolling stage of the tube manufacturing process.

3.3 Detectability of Cracks

A defect signal with an amplitude smaller than that of the background noise level can not be called an indication of a defect in the eddy current inspections. In this regards, the detection limit for the best and general evaluation can be assumed to be a signal amplitude equal to and two times larger than that of the background noise, respectively. Based upon this assumption and from the destructive examinations of the cracks, the detection limits for the best and general evaluation were 47% and 51% for tube A with a higher background noise, and 32% and 45% for tube B with a lower background noise, in terms of the crack depth into the tube wall thickness for the circumferential cracks on the outer diameter with a length of about 3mm.

4. Conclusion

The background signal noise from the +point coil originates from the irregularity of the tube inner surfaces, related to the cold pilger rolling process. The increase in the background signal noise of a steam generator tube drastically reduced the detectability of the crack in the eddy current inspection.

REFERENCES

[1] A.R. McIlree, "Guidelines for PWR Steam Generator Tubing Specifications and Repair," EPRI TR-016743-V2R1, 1999