Measurement of the Deposit Loading on the Tube Outer Diameter of Nuclear Steam Generator Using ECT

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1. Introduction

Corrosion products formed from the secondary side system are accumulated on the top of the tubesheet, the tube support structures and the tube surfaces of a nuclear steam generator. The resulting deposits mainly consist of magnetite (Fe_3O_4). Chemical impurities concentrate in this sludge and corrosively attack the steam generator tubes and tube support structures. The sludge progressively increases in volume and density, eventually deforms the tubes beyond the yield stress and/or blocks the flow holes of tube supports, resulting in denting and water level oscillation. In addition, sludge adhering to the steam generator tubes not only reduces heat transfer properties from the primary to secondary side but also distorts eddy current signals from the tubes during in-service inspection.

Therefore effective managements for sludge are essential to preserve the operation safety of the secondary side. As an active strategy, several sludge removal techniques such as chemical cleaning and sludge lancing were developed and implemented in plants [1,2]. In order to determine cleaning method, cleaning point and removal effectiveness, however, a reliable technique for measuring deposit loading on the secondary side is very important. Recently, it has been reported that the deposit loading can be measured using eddy current test (ECT) data, especially of bobbin probe [3].

We at KAERI are developing a technique for deposit mapping at any locations or intersections of a steam generator using ECT data. To simulate consolidated hard deposit on the outer diameter (OD) side of tube, a method of deposit attachment is developed. Signal characteristics from deposit standard for calibration are also presented.

2. Experimental Methods

Magnetite powder with an average size of 1 ㎛ and a purity of 99% was used to simulate and fabricate deposit. Magnetite powder of 90% and a glue of 10% in weight percent were mixed to reach a complete wetting condition. The mixture was placed on the tube, which was a high temperature mill-annealed Alloy 600 material with a nominal outer diameter of 19.05 mm and a nominal wall thickness of 1.07 mm. After consolidated, the deposits were machined to have an axial length of 25 mm and a thickness of 0.19, 0.78, 1.43 and 1.86 mm.

The ECT signals of the deposit tube specimen were obtained by the Zetec MIZ-70 digital data acquisition system with a bobbin probe (M/A-610-ULC/MR) and a 3-coil motorized rotating probe (M/+Point-610). In the case of the bobbin probe, the pulling rate was 304.8 mm/sec and the test frequencies were 35, 100, 300 and 550 kHz. In the case of the rotating probe, the specimens were inspected at a pulling speed of 5.08 mm/sec and at a rotating rate of 600 rpm.

3. Results and Discussion

The deposits had an excellent adherence property and a good workability, so we could control to get a target thickness by machining them using lathe. Fig. 1 shows a deposit tube specimen with 4-different thickness of deposit and the corresponding ECT signals from the bobbin probe at a frequency of 35 kHz. Each deposit signal was similar to a typical characteristic of plant sludge obtained during in-service inspection. The magnitude of signal amplitude also increased with increasing the deposit thickness.

Fig. 2 shows the C-scan of the deposit with a 0.19 mm thickness, which was obtained using a 3-coil motorized rotating +Point probe at a frequency of 35 kHz.. It can be seen that the signal magnitude have a nearly similar value at every location, indicating that the deposit was evenly distributed around the tube surface. Therefore a technique to simulate hard deposit and to control a thickness of the deposit even below 200 ㎛ was successfully established.

Fig. 3 shows the relationship between the deposit thickness and the bobbin signal amplitude. From the curve, therefore, the deposit thickness at a certain

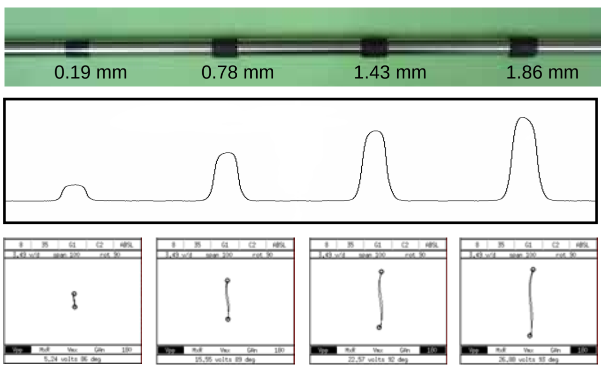

Fig. 1. Deposit specimen and the corresponding ECT signals from a bobbin probe at a frequency of 35 kHz.

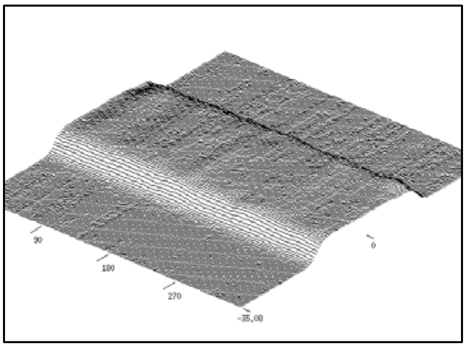

Fig. 2. C-scan by a 3-coil motorized rotating +Point probe at a frequency of 35 kHz.

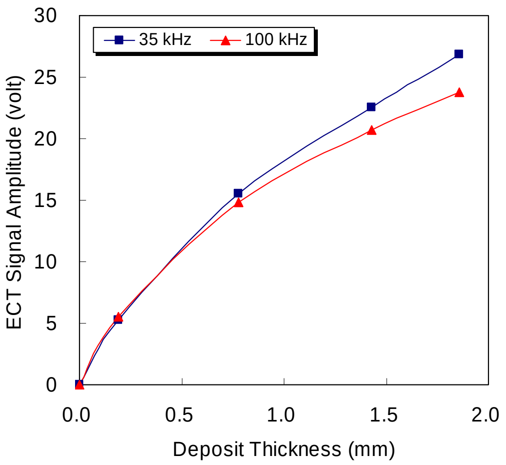

Fig. 3. Relationship between deposit thickness and bobbin signal amplitude.

location of tube can be measured using bobbin probe data, which in turn can be converted in the weight of the deposit.

It should be noted that the magnitude of signal amplitude is a function of deposit density. That is, it increases with increasing deposit density even though at a constant thickness of deposit. So, we need to construct various calibration curves at several different densities of deposits.

The density of pure magnetite is 5.2 g/cm^3. However, actual deposit density will vary greatly. Determining factors include deposition location, solidification period, temperature of the deposit location and deposit composition. Therefore, in order to quantify deposit loading more exactly, a research on the typical density range of actual steam generator deposits should be conducted.

3. Conclusions

The deposits to simulate a hard deposit on the OD tube showed an excellent adherence property, a good workability and an even distribution. Using this deposit specimen, a relationship between the deposit thickness and the bobbin signal amplitude was constructed, which is useful for calibrating plant deposit signals to estimate a deposit loading. For future work, research on the typical density range of actual steam generator deposits is proposed.

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