Transactions of the Korean Nuclear Society Autumm Meeting
Gyeongju, Korea, October 25-26, 2012

Analysis method of deposit on steam generator tubes using eddy current

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1. Introduction

The steam generator tubes in operating nuclear power plants have an important problem during their operation time, an accumulation of corrosion products. Such corrosion products form from the secondary side of the plant system, such as carbon steel pipelines, heat exchange shell, and turbine. The accumulation position of corrosion product is mainly on the top of the tubesheet, the tube support structures of the steam generator. It is extinguished as sludge, and as a deposit of the corrosion product. The volume increase and hardening of the sludge eventually cause the tube deformation, and a blockage of the coolant flow of the tube supports. A deposit outside the tube results in reducing the heat transfer through the tube wall, and distorts the eddy current signals during an in-service inspection.

For the management of steam generator tubes from the problems mentioned previously, several methods were performed. The corrosion products could be reduced by chemical cleaning and sludge lancing [1, 2]. The monitoring of the quantity of sludge and deposit is very important data in the management of steam generator tubes. An eddy current testing (ECT) method is very useful to detect flaws and defects in the steam generator (SG) tubes of nuclear power plants (NPPs) during an in-service inspection. Recently, it was reported that deposit loading can be measured using eddy current test data, especially of a bobbin probe [3]. For a precision measurement using a non-destructive method, a calibration technique is required using the simulated deposit and signal characteristics from the deposit standard. In this study, a personal computer based device was developed for an analysis of ECT signals. The software program can convert the commercial eddy current data and measure the deposit amount from the calibration data.

2. Experimental and Results

Magnetite powder with an average size of 1 ㎛ and a purity of 99% was used to simulate and fabricate the deposit. Magnetite powder of 90% and a glue of 10% weight 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 consolidation, 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.

The digital data of the ECT signal was stored in the UNIX workstation system in the binary file format of the Zetec archive (ZArchive) algorithm, and the raw digital data was transferred to a Windows-based personal computer from a UNIX workstation system, and the data was parsed into an ASCII text file format. Data files created with ZAC contain several different segments of information. One segment will contain the raw eddy current data, and there are multiple segments that contain header data describing how the eddy current data was collected. Fig 1 shows an example of the program that analyzes the eddy current data on a personal computer.

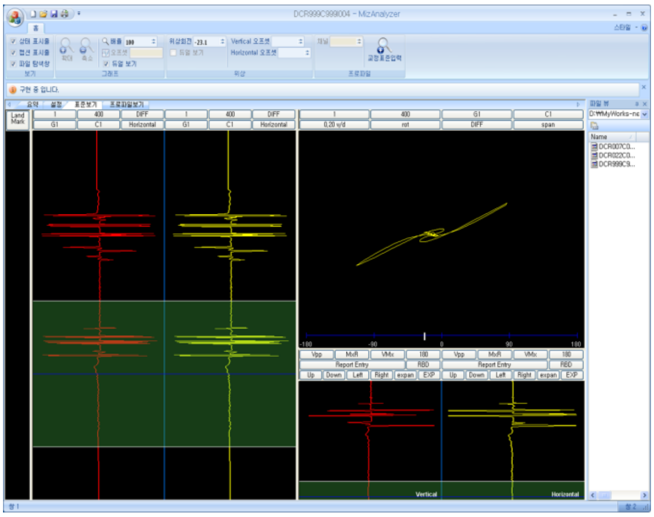

Fig. 1. Eddy current signal analysis program.

The program consists of windows including a summary, setup, standard view, and profile view. The summary window displays the information/configuration of the inspection. The eddy current data can be analyzed in a standard view window, which consists of a full data graph, zooming graph, and lissajous graph. The control and operation of the data are connected with each graph. The phase adjustment is performed on a lissajous graph by a rotating of the control bar. The phase angle determines the x and y axis components of the data.

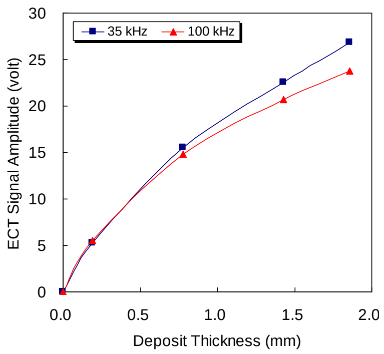

Fig. 2. Relationship between deposit thickness and bobbin signal amplitude.

Fig. 2 shows the relationship between the simulated deposit thickness and the bobbin signal amplitude. The deposition thickness at a certain location of the tube can be measured from this curve, and can be converted in the weight of the deposit. The magnitude of signal amplitude is a function of the deposit density. It is necessary to construct various calibration curves at several different densities of deposits.

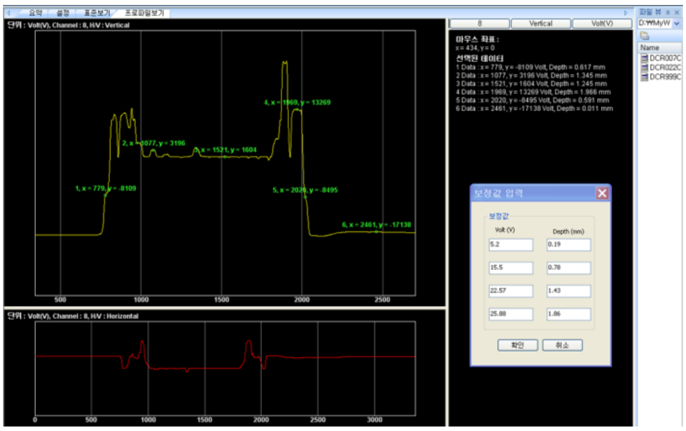

Fig. 3. Profile view of a deposit signal and setup of the calibration data.

Using the standard curve of deposit and a bobbin signal, users input the calibration data at the setup window. The profile view of the program displays the deposit thickness, which is calculated from the bobbin amplitude voltage (Fig. 3). The digital data of the deposit depth can be displayed on any selected position on the graph. The total amount of sludge and deposit loaded in a steam generator can be reasonably estimated using this program.

3. Conclusions

An analysis program of an eddy current signal was developed for a personal computer based operating system. Using the simulated deposit specimen, the relationship between the deposit thickness and the bobbin signal amplitude was constructed. The eddy current signal of the deposit on a tube can be converted into the thickness of the deposit using this program.

Acknowledgements

This work has been carried out under the nuclear research and development program of the Ministry of Science and Technology of Korea.

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