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Analysis of Volumetric Defect Signals from Eddy Current Test on the Secondary Side of Alloy 600 Steam Generator Tubes in the Sludge Pile Region above the Top of Tube Sheet

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1. Introduction

During the operation of nuclear power plants, magnetite scales from general corrosion of carbon steel components are accumulated in the secondary coolant system and forms thick sludge piles on the steam generator tubes above the top of tube sheet as shown in Fig. 1.

The operating experiences of steam generators with alloy 600 tubes have shown that the tube regions with sludge piles are very susceptible to the secondary side corrosive degradation such as stress corrosion crack (SCC) and intergranular attack (IGA), because the sludge increases the temperature of tube outer surface and also provide aggressive environment by the concentration of detrimental impurities in the coolant [1]. In this work, the volumetric defect (IGA) signals detected from the eddy current inspection of alloy 600 steam generator tubes with sludge piles in operating power plants were analyzed to investigate the effect of sludge pile distribution around the tube on the local evolution of IGA.

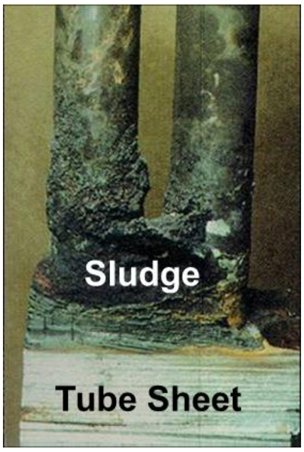

Fig. 1. Sludge pile above the top of tube sheet.

2. Methods and Results

2.1 Motorized Rotating Pancake Coil (MRPC) Probe

The tube regions with sludge piles were inspected with eddy current MRPC probes. The probe has three different coils, that is, a plus-point coil for crack and volumetric defect detection, a pancake high frequency coil for inner surface defect detection, and a basic pancake coil for defect detection and structure signal location. Also, multi-frequency signals of 20kHz, 100kHz, 300kHz, 400kHz, and 700kHz are obtained simultaneously in order to analyze the signals from different eddy current magnetic field changing with test frequency. The lower the frequency, the eddy current fields are induced around the outer region of tube, and the higher the frequency, the eddy current fields are induced around the inner surface of tube.

2.2 Analysis of MRPC Probe Eddy Current Signals

The detection of volumetric defect signals were performed by analyzing plus-point coil 300kHz signals. The distribution of sludge piles located outside of steam generator tubes were evaluated through pancake coil 100kHz signals in which the eddy current fields were spread out to the outside of tube and the signals from sludges could be mainly obtained. MRPC probe eddy current data acquired from one tube in plant A and three tubes in plant B were analyzed. The distribution of defect signals and corresponding sludge signals were displayed in each graph with the same axial and circumferential positions of tube for direct comparison.

2.3 Results and Discussion

Fig. 2 shows c-scan graphs of defect and sludge signal distribution of a steam generator tube in plant A. The magnitude of signals may reflect the size (depth) of defect and the quantity (thickness) of sludge in each graph. The volumetric defect signal was found at the middle of sludge pile signal height. Notable observation is that the volumetric defect signal is located on which the magnitude of sludge signal changes. This suggests that the preferential site of IGA evolution may be the location where the thickness of sludge changes, regardless of the size of thickness.

The analysis results of a steam generator tube I in Plant B were shown in Fig. 3. Even though the height of sludge pile signal was much higher than that of Fig.2, reflecting the different operation history between two plants, almost the same trend of results were observed in the location of defect signal (at the middle of sludge height) and preferential site of IGA evolution (where the sludge thickness changes).

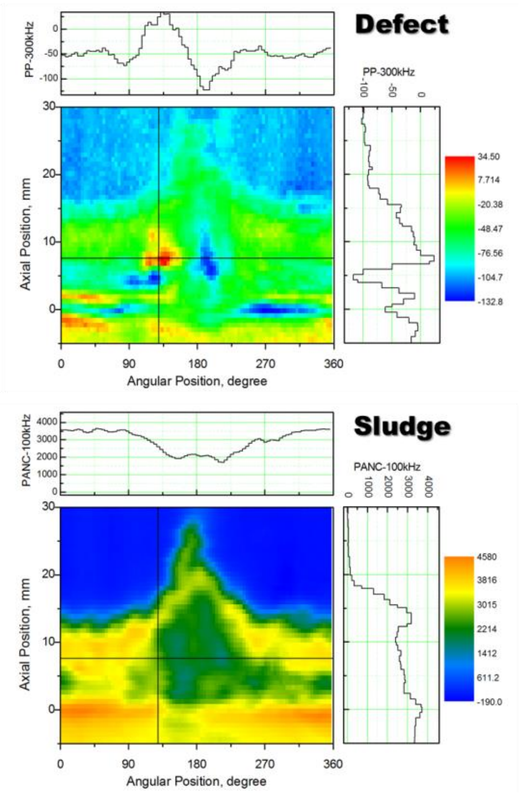

Fig. 2. Distribution of eddy current signal from defect and sludge in a steam generator tube of plant A.

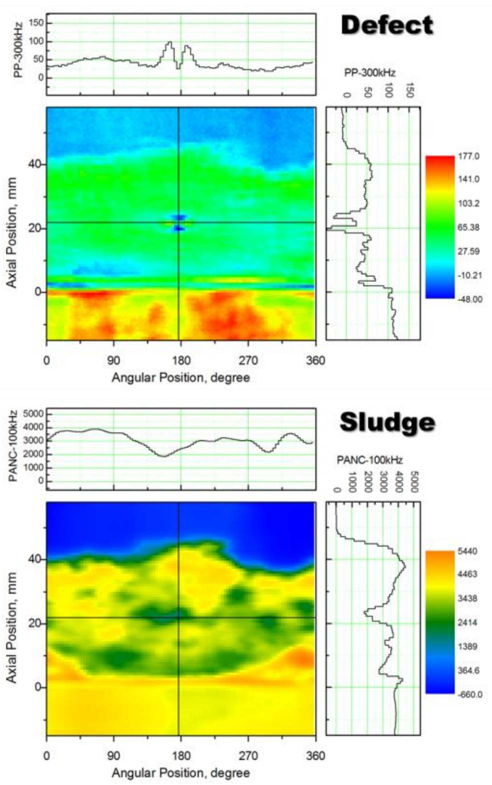

Fig. 3. Distribution of eddy current signal from defect and sludge in a steam generator tube I of plant B.

Fig. 4 shows c-scan graphs of defect and sludge signal distribution of a steam generator tube II in plant B. The height of sludge pile signals were uniform around the tube circumference, but the IGA was detected also on the location where the sludge thickness changes. The one more tube in plant B showed the same trend of results.

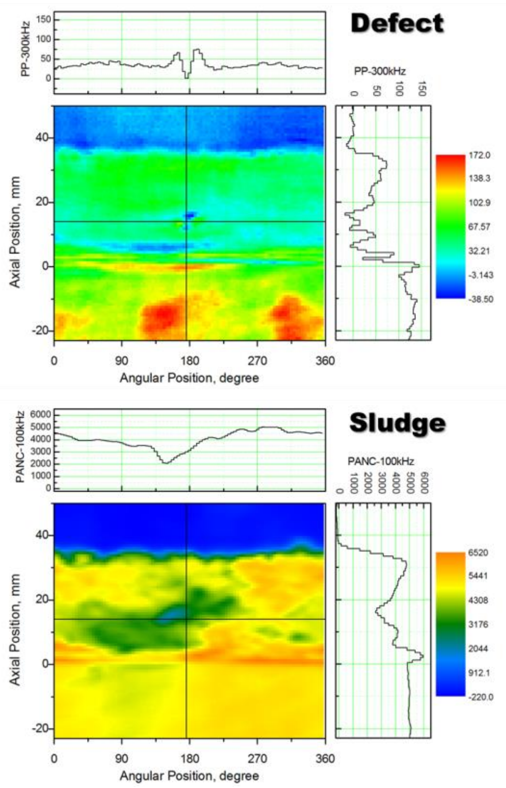

Fig. 4. Distribution of eddy current signal from defect and sludge in a steam generator tube II of plant B.

3. Conclusions

The sludge pile distribution around the secondary side of steam generator tube above the top of tube sheet and its effect on the evolution of IGA was investigated through the analysis of eddy current inspection data. The volumetric defect signals were observed at the middle of sludge pile regardless of its height. It was supposed based upon the analysis results of four steam generator tubes in two operating power plants that IGA would be preferentially developed on the tube location where the sludge thickness changes regardless of the size of sludge height and thickness. The present findings are presumed to be related with the concentration kinetics of impurities by the local boiling of coolant in the sludge pile. The further works are required to examine the root cause of these results observed.

ACKNOWLEDGEMENTS

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REFERENCES

[1] D.R. Diercks, W.J. Shack, and J. Muscara, "Overview of Steam Generator Tube Degradation and Integrity Issues," Nuclear Engineering and Design, 194, 19-30, 1999.