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A development of Techniques Detecting Foreign Objects in the Secondary Side of Steam Generator

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1. Introduction

Foreign objects remaining in steam generator (SG) would make significant damage to steam generator tubes. In recent years, tube wear damage, caused by loose parts, has been the primary reason of forced outage in oversea NPPs. Although inspections adopting foreign object search and retrieval (FOSAR) system are implemented during every outage for detecting foreign objects, it is not easy to identify them because FOSAR equipment access is limited due to the tube arrangement. If the damage due to foreign objects is not identified at the time of inspection, it is hard to detect the foreign object using general techniques because techniques finding the foreign object are not currently well defined in ECT guidelines and most analysts focus on detecting tube degradation. To determine the effectiveness of foreign object detection, in this study, Techniques for detection of loose parts causing degradation is provided using bobbin data. Foreign objects retrieved from a steam generator by FOSAR during Pre-Service Inspection (PSI) are used as a specimen. The experiments were simulated that foreign objects are on the top of tubesheet because most foreign objects have been found on the tubesheet. The maximum distance from the tube surface to the foreign object to be detected is introduced in this paper. Moreover, the optimum frequency to find the foreign objects is presented with phase angle and voltage values for the frequency.

2. Test preparation and method

Table 1-1 shows the results of specimen's material analyzed by using portable XRF Analyze equipment.

Table 1. Material specifications of specimens

Specimen 1 Material	Specimen 2 Material
SA193 Gr B7	Inconel 690
	

Specimen 1 was found to be carbon steel, which is the most common material of foreign objects and Specimen 2 is the same material as the tube material (Inconel 690). The experiments were conducted with the same equipments and probe with frequency configuration as those of real field inspection. Table 2 illustrates examination systems. Figure 1 shows pictures of the test equipment set for the foreign object test. Test calibration is conducted using ASME standard.

Table 2. Examination system for experimental

Tube	Equipment	Test probe	Frequency Configuration
Inconel 690	Miz 70	Bobbin	600/300/150/20kHz

Fig 1. Test equipment set

The mockup utilized had tube samples inserted into a tubesheet. It is simulated the tubesheet part of the actual steam generator. Data were collected for each of the foreign object specimens. In addition the spacing from the tube and the foreign object was controlled using spacers.

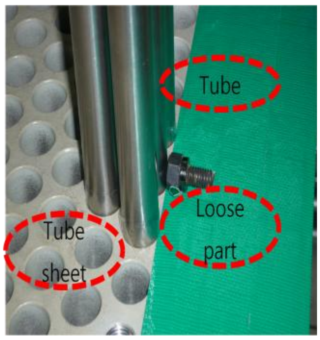

Fig 2. Mockup and Specimen 1

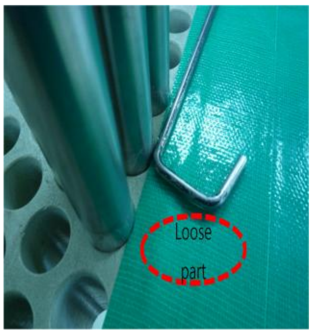

Fig 3. Mockup and Specimen 2

3. Test results

The first set of data reviewed contained the bobbin data from the foreign object specimens. The analysis setup is determined by an examination technique specification sheet (ETSS) applied at the steam generator tube. Figure 4, and 4-1 illustrate an analysis displays with the foreign object specimen 1 and specimen 2 in contact with the same tube, respectively. For the case of specimen 1, the optimal frequency and phase angle for foreign object detection were 20 kHz (CH 7 Diff.) and nearby the 90°, respectively. The amplitude of the foreign object signal decreased when the distance between the tube surface and each specimen was increased due to the sharp decline in current density. However, the phase angle didn't change. For the case of specimen 2, the optimal frequency and phase angle for foreign object detection were 150 kHz (CH5 Diff.) and nearby the 270°, respectively.

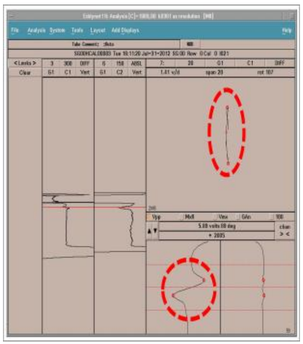

Fig 4. Analysis display when specimen 1 contacts with tube

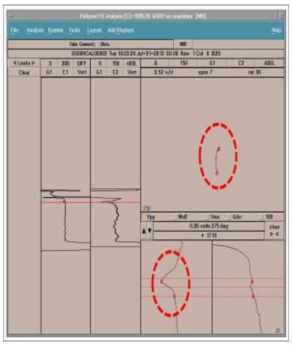

Fig 4-1. Analysis display when specimen 2 contacts with tube

Figure 5, and 5-1 illustrate analysis displays of critical detectable distances for each specimen. It is easy to know by comparing Figs. 4 and 4-1 and Figs. 5 and 5-1 that the magnitudes of signals in the analysis windows are quite different. The critical detectable distances are 6mm for specimen 1 and 1.5mm for specimen 2, respectively.

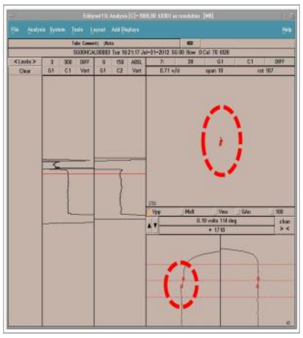

Fig 5. Analysis display when specimen 1 offset 6 mm from tube

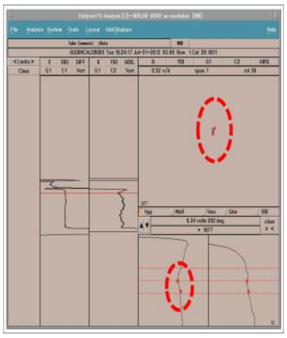

Fig 5-1. Analysis display when specimen 2 offset 1.5 mm from tube

The results of the voltage measurements depending on offset distance of specimens are shown in Figure 6. The red line and blue line represent the amplitude changes of each specimen. When the tube and specimen are contacted, the amplitude of the signal for the specimen 1 is 6 times larger than that for specimen 2 due to the material properties of the specimens. Eddy current signal can be affected by three main factors: electrical conductivity, permeability, and geometry. In this study, the permeability of the three main factors between specimens 1 and 2 displays the greatest different factor. The permeability of specimen 1 is 500 times higher than that of specimen 2. The effects of the permeability are the most predominant at lower frequencies. Therefore, the detection frequency and angle for finding each specimen are different.

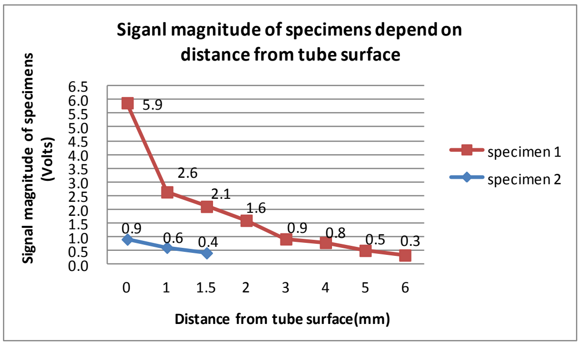

Fig 6. Experimental result of detecting loose parts

4. Conclusion

Frequencies having the greatest amplitude of signal detected form specimen 1 and specimen 2 were 20 kHz (CH 7 Diff.) and 150 kHz (CH5 Diff.), respectively.
Table 3 shows the effective techniques for detecting foreign objects. Tech. 1 and Tech. 2 provide optimal methods for the detection of magnetic and nonmagnetic foreign objects. However, more careful analysis is needed adopting Tech. 2 because its amplitude of signal is very small.

Table 3. Effective techniques for detecting foreign object

	Detection material	Detection freq.(kHz)	Phase angle	Detectable maximum distance
Tech. 1	Carbon steel	20kHz	85°≦ Ang. ≧95°	6mm
Tech. 2	Inconel 690	150 kHz	265°≦ Ang. ≧275°	1.5mm

REFERENCES

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