

## Automated Analysis Technique Developed for Detection of ODSCC on the Tubes of OPR1000 Steam Generator

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**Abstract** A steam generator (SG) tube is an important component of a nuclear power plant (NPP). It works as a pressure boundary between the primary and secondary systems. The integrity of a SG tube can be assessed by an eddy current test every outage. The eddy current technique (adopting a bobbin probe) is currently the main technique used to assess the integrity of the tubing of a steam generator. An eddy current signal analyst for steam generator tubes continuously analyzes data over a given period of time. However, there are possibilities that the analyst conducting the test may get tired and cause mistakes, such as: missing indications or not being able to separate a true defect signal from one that is more complicated. This error could lead to confusion and an improper interpretation of the signal analysis. In order to avoid these possibilities, many countries have opted for automated analyses. Axial ODSCC (outside diameter stress corrosion cracking) defects on the tubes of OPR1000 steam generators have been found on the tube that are in contact with tube support plates. In this study, automated analysis software called CDS (computer data screening) made by Zetec was used. This paper will discuss the results of introducing an automated analysis system for an axial ODSCC on the tubes of an OPR1000 steam generator.

**Keywords:** Automated Data Analysis, Eddy Current Testing, Steam Generator, Bobbin Probe, POD

### 1. Introduction

The eddy current test is used to detect flaws on steam generator tubes during in-service inspection at nuclear power plants. Because an eddy current signal analyst for steam generator tubes continuously examines data over a given period of time, the analyst tends to get easily tired. Therefore, there are possibilities that the analyst could not discriminate the true defect signal from a complicated whole signal or makes wrong decisions.

A missed or incorrectly reported defect indication can lead to a plant shutdown or a tube rupture event. In order to avoid these possibilities, the analysis system demands forcibly three analysis teams. These teams are consisted of the primary, secondary and resolution. To maintain independence, the primary and secondary

analyses should be done separately without knowledge of the other team's results. A resolution team should review and resolve discrepancies between the results of the primary and secondary analysis teams. Generally in foreign countries, automated analyses are adopted for the secondary analysis (Fig. 1). Sometimes both a primary and secondary analysis is performed by the automated analysis tool.

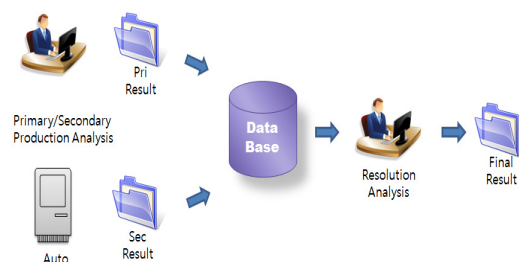


Fig. 1 SG ECT organization that includes automated analysis

A common problem that exists is when an axial ODSCC(outside diameter stress corrosion cracking) defects on the tubes of an OPR1000 steam generator have been found that came into contact with support plates. In this study, an automatic analysis technique for bobbin eddy current signal is introduced. This technique was devised to detect axial ODSCC on the OPR1000 steam generator tubes. Experiment results using practical data are provided and discussed in this paper.

## 2. Method and Results

### 2.1 Automated Analysis Software

Most foreign nuclear power plants utilize automated analysis software either from Westinghouse, Zetec, or AREVA. This software is qualified by EPRI(Electric Power Research Institute). The performance of the automated analysis software is verified through an EPRI AAPDD(automated analysis performance demonstration database) test before practical application.

Even if the software has passed the AAPDD it cannot be used directly for inspection of steam generator tubes at nuclear power plants. AAPDD qualification does not mean that the software is applicable to at nuclear site because the ECT signal appears differently depending on the characteristics of steam generator degradation

mechanism. In order to use this during a nuclear site inspection, the automated analysis software should be adjusted to fit such variables as, for example: defect location, detection frequency, signal degree, and voltage that are characteristic of steam generator model and its defect. In this study automated analysis software called CDS (computer data screening) made by Zetec was used as shown in Fig. 2 [1].

### 2.2 Analysis of Axial Crack Signal Characteristics

Inputting accurate variables in the automated analysis software is the most important factor in the ECT automated analysis, because the detection results depend on how the variables were selected. In other words, the selected variables strongly affect the inspection results such as the detectability and the number of detections.

Adequate variables for the automated analysis software can be obtained by analyzing the exact ECT signal characterization. To reduce miscalls and minimize the detection of falsecalls, the eddy current signal characteristics should be understood when carrying out a signal analysis for each channel. After completing this process, accurate variables can be set. Therefore, the ECT signal of axial cracks should be analyzed before setting the variables.

The axial cracks in an OPR1000 steam generator tube are mainly observed in the support area. The tube support structure of an OPR1000 steam generator consists of two and one inch height plates and has a lattice-like appearance, so it called the “eggcrate”. (see Fig. 3)

In the eddy current bobbin probe inspection, axial crack signals are reported by the DSI (distorted support indication). As illustrated in Fig. 4, The combined signal of the axial crack and the support plate within the DSI because axial crack exists in the support area.

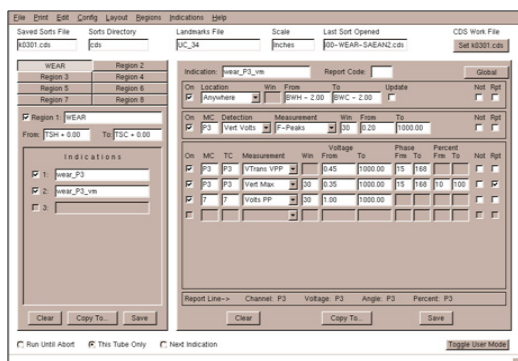


Fig. 2 CDS automated analysis software

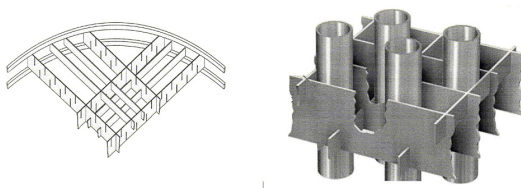


Fig. 3 OPR-1000 SG tube support(eggcrate)

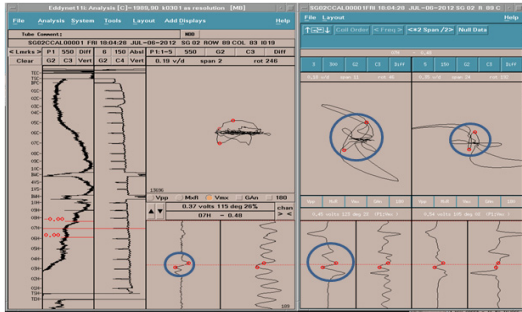


Fig. 4 Axial ODSCT ECT signal(OPR-1000 SG)

Generally, analysis channel at support plate region is selected process channel. Process channel minimize support plate signal so easily detect flaw signals in the support plate region. The results of DSI signal analysis, process channel P1 (550-150 kHz) is easy to detect for support plate edge region but channel 3 (300 kHz) is better for the other region.

2.3 Detection Criteria

Automated analysis results depend on the variable setting values so detection criteria is needed. So detection criteria for DSI was decided by referring to AAPDD and EPRI QDA (qualified data analyst) qualification acceptance criteria [2,3].

Table 1 AAPDD acceptance criteria

	≥ 40% TW(Through Wall)	<40% TW	Remarks
Detection	POD of at least 80% at a 90% CL	≥80%	
RMSE	≤ 10%		sizing

POD : probability of detection  
 CL : confidence level  
 RMSE : root mean square error

Table 2 QDA qualification acceptance criteria

	≥40% TW	<40% TW	Remarks
Detection	POD of at least 80% at a 90% CL	≥80%	
Minimum number of flaws	11	-	
False Call	≤ 10%		
RMSE	≤ 10%		sizing

The goal of automated analysis is to avoid missing the degraded signals of ECT data. Therefore, the detection criteria of DSI was not considered a false call rate, as in the same as case as foreign nuclear power plants. DSI signals are do not perform sizing. Automated analysis detection is criteria determined based on the as follow Table 3.

Table 3 Automated analysis detection criteria for DSI

	Detection Criteria
DSI	POD of at least 80%, at a 90% CL

2.4 Calculation of POD

As shown in Fig. 5, POD was calculated applying EPRI program based on the following equation[3,4].

$$P(x|n, p) = \frac{n!}{x!(n-x)!} p^x (1-p)^{n-x} \quad (1)$$

P : probability density function of binomial distribution  
 x : number of detection  
 n : number of data  
 p : probability of detection

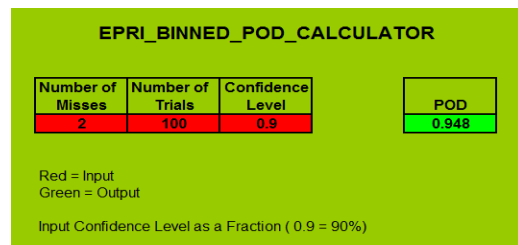


Fig. 5 POD calculator program(EPRI)

## 2.5 Results

In this study, the results of automated analysis meet more than the detection criteria (80% POD at 90% CL). First, an analysis was performed using EPRI AAPDD axial ODSCC variables of crack signals. In this case, the result of POD at 90% CL is 56.8%. This value was below the required detection criteria 80%.

Table 4 Number of detection on applying AAPDD variables

Set	Total	Detection	Missing	False call
AAPDD	109	69	40	271

Table 5 Results of applying AAPDD variables

Set	Detection rate(%)	Missing rate(%)	POD at 90% CL	results
AAPDD	63.3	36.7	56.8%	Fail

The analysis for detecting the cracks was performed by applying four sets of variables to decide variables satisfying the detection criteria. The variables of Set-4 met the criteria. The adjustments or additions of key variables were made to improve the detectability and reduction of falsecalls. Since the axial cracks only appeared in the hot-leg side of the steam generator, the detection area in Set-1 was limited. As a result the falsecall rate was reduced. The detection rate increased in the Set-2 by lowering the value of the signal amplitude after reflecting the results reviewed in the set. In order to reduce false calls channel 7 (20 kHz) was added in Set-3. Channel 7 (20 kHz) was used to separate eggcrate support contact regions and free-span. Support contact region signals were detected by Channel P1 (550 kHz-150 kHz) and other region signals were detected by Channel 3 (150 kHz).

In the case of Set-4 set, bandpass filter process channel P15 (550 kHz-150 kHz, band-pass), was added in order to reduce falsecall rates caused by signal noise. From the results of

performing the automated analysis with Set-4 set, the POD of over 80% at a 90% CL was obtained.

Table 6 History of set modifications

Set No.	Detection Channel	Modifications
AAPDD	3/P1	-
Set-1	3/P1	AAPDD + Limited detection area
Set-2	3/P1	Set-1 + lowered signal amplitude
Set-3	3/7/P1	Set2 + Channel 7(20kHz)
Set-4	3/7/P1/P15	Set-3 + Channel P15

Table 7 Number of detection on applying each set

Set No.	Total	Detection	Missing	False call
set1	222	181	41	1374
set2	222	184	38	1423
set3	222	184	38	680
set4	222	200	22	532

Table 8 Results of applying each set variables

Set	Detection rate(%)	Missing rate(%)	POD at 90% CL	results
set1	81.5	18.5	77.8	Fail
set2	82.9	17.1	79.2	Fail
set3	82.9	17.1	79.2	Fail
set4	90.1	9.9	87.1	Pass

Table 9 Set-4 variables

	Channel	Variable range
Signal amplitude $\leq 15$ volts at ch.7	ch.3	15~160°
	P1	$\geq 0.05$ volts at 10~170°
	P15	$\geq 0.03$ volts
Signal amplitude $\geq 15$ volts at ch.7	P1	$\geq 0.16$ volts at 20~170°
	P15	$\geq 0.07$ volts at 25~160°
Detection area	Hotleg side support plates	

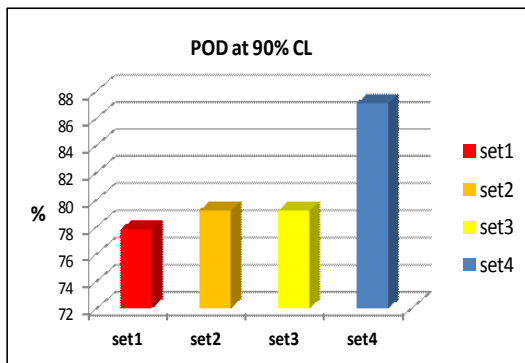


Fig. 6 History of set POD

Fig. 6 illustrates the POD of applying each set variables.

### 3. Conclusions

Automated analysis results depend on the variable setting values. In this study, the optimum variables are determined by detecting axial cracks on OPR1000 steam generator tubes. After applying these variables, an automated analysis was tried in order to detect the axial cracks. From the results of performing the automated analysis with Set-4 set, the POD higher than 80% at a 90% CL was obtained.

It is expected that an automated analysis system will be applicable in detecting axial ODSCCs on the steam generator tubes of

nuclear power plants in Korea. In the light of these results, an automated analysis could be considered as substitute for human analysts or identify missed indications. The automated analysis technique would increase the reliability of the ECT test.

### References

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