Demonstration for the Applicability of the EPRI ETSS on the SG Tube Wear Defects Formed at the Tube Support Structure

Ki Seok Shin [a*], Keun Young Cheon [a] ,Min Woo Nam [a], Kyong Mahn Min [b]
[a]*Central Research Institute, Korea Hydro & Nuclear Power Co. Ltd, Dae-Jeon, KOREA, 305-343*
[b]*Universal Monitoring & Inspection(UMI) Inc., Dae-Jeon, KOREA, 305-811*
[*]*Corresponding author: shinsks@khnp.co.kr*

1. Introduction

One of the major flaw mechanisms detected in the currently operating domestic OPR-1000 pressurized water reactors(PWR's) steam generator(SG) tubes is wear defect. In general, wear defect has been constantly detected in the upper tube bundle imposed to the flow induced vibration interaction between tube and its support structure, and the quantity of the affected tubes has also shown the tendency to increase as plant operation life is added. In order to take appropriate measures and maintain the structural integrity for the SG tubes, wear defect is currently categorized as active damage mechanism and the tubes containing 40% or greater wear depth of the nominal tube wall thickness shall be plugged per SGMP(SG Management Program)

Recently, a fairly large amplitude of wear defects on the Batwing(BW), one of the upper tube support structures in the SG tubes of domestic OPR-1000 were found by Eddy Current Testing(ECT) and those abnormally greater defects were not expected considering the known growth rate of the wear defects. To obtain the precise depth and profile of the wear defect, specific wear scar standard tube containing a variety of wear depth was fabricated and Bobbin coils and MRPC®(Motorized Rotating Pancake Coils) were applied to the STD tube and subsequently the SG tubes were examined by those probes.

In this paper, the authorized EPRI ETSS #27906.2 applied to the detection of tapered wear volumetric indications and depth sizing within the free span area, loose part not present was reviewed and applied to the site SG tubes for getting the actual value of the wear depth and providing structural integrity interpretation based on engineering evaluation. The experiment to demonstrate the applicability of EPRI ETSS was performed by the employment of the newly prepared STD tube and resulted in ensuring the effectiveness and equivalency of the EPRI ETSS as well.

2. Methods and Results

In this section, the data analysis results of the wear defects were described by applying two types of wear scar STD tubes. And the experiment to demonstrate the applicability of the EPRI ETSS and the detailed description of EC graphics showing the profile of the wear defects are to be introduced.

2.1 Site Wear Defects and Newly Designed STD Tube

The wear defects assumed to be abnormally greater than 40%tw was noticed while performing ECT of SG tubes. In order to get an accurate value of the defect depth, the new wear scar STD tube(CRI) containing 60, 70, 80, 90%tw was designed to complement the currently being applied wear STD tube(ZETEC), holding up to 50%tw wear defects. Table 1 lists Bobbin coil data analysis results of the abnormal wear defects. The table confirms that the second inspection results is estimated to be relatively close to the actual defect depth, due to the accuracy of STD tubes applied in the inspection. Fig. 1 shows the ECT instrument including MRPC and newly fabricated STD tube drawing with actual tube, respectively.

Table 1. Bobbin coil data analysis results of the abnormal wear Defects(1st:ZETEC, 2nd:ZETEC+CRI STD tubes applied)

SG	Tube		Loc.(in.)	Defect Depth(%tw)	
	Row	Col.		1st Insp.	2nd Insp.
01	28	66	BWH+1.36	47(17.6V)	66(18.9V)
	37	85	BWH-0.90	46(14.6V)	61(15.1V)

Fig. 1. ECT instrument w/MRPC(L) and newly designed wear STD tube(R)

2.2 Applicability Testing for ETSS Equivalency

In order to provide wear depth profile data for the structural integrity assessment on those wear defects mentioned in the above, the qualified EPRI ETSS(#27906.2) was introduced. Basically, there is a fundamental difference between the ETSS(#27906.2) and the OPR-1000 SG tube wear. In this testing, an attempt was made to demonstrate the applicability of the ETSS to the support structure wear. Table 2 and Fig. 2

compare the test application technique and MRPC® C-scan of ETSS(#27906.2) and OPR-1000 SG wear, respectively.

Table 2. Comparison the application of ETSS(#27906.2) and OPR-1000 SG wear

Application Items	*EPRI ETSS(#27906.2)*	*OPR-1000 SG wear*
Tube mat'l	Inconel690	Inconel600
Wear shape	Tapered(w/ LP*)	Tapered(w/ BW**)
Location	w/o TSP***	w/ TSP(BW)

*:Loose Part, **:Bat Wing, ***: Tube Support Plates

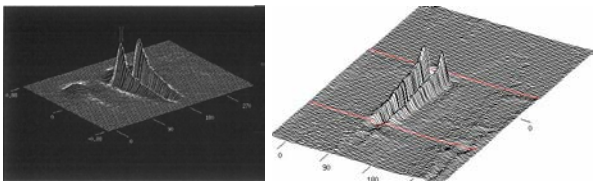

Fig. 2. MRPC C-scan Graphics of Wear Defect

The testing was performed with the same equipment and procedure as applied in the site. The STD tubes used in the testing were EDM notch with TSP ring and Inconel 600/690 wear scar.

2.3 Testing Results and Remarks

The testing results were reviewed with the influences of SG tube material and the support structure. In conclusion, the impact of the tube materials was insignificant and that of the tube support structure showed somewhat conservative results. Therefore, the testing resulted in successful demonstration of applicability of the EPRI ETSS on the SG tube wear defects at the tube support.

2.3.1 SG Tube Material

By comparison of the measured wear defect depth between Inconel 600 and 690 SG tubes, no significant differences were noticed. Table 3 shows the wear depth comparison results with respect to the SG tube materials.

Table 3. Wear Depth Comparison wrt Tube Material

Inconel 600		*Inconel 690*	
Amp.	Wear Depth	Amp.	Wear Depth
1.82V	22%	1.825V	23%
2.73V	31%	2.73V	32%
3.86V	41%	3.86V	42%
4.55V	47%	4.55V	47%
5V	50%	5V	50%

2.3.2 Tube Support Structure

The effects of being free of or equipped with tube support structure were reviewed. The significant deviation from the testing variables was not found and even rather conservative results were noticed. Table 4 shows the wear depth comparison of being with or without tube support structure.

Table 3. Wear depth comparison w/ or w/o support structure

w/ Support Structure (+PT 300kHz, raw)		w/o Support Structure (+PT 400/100kHz, Mixing)	
Amp.	Wear Depth	Amp.	Wear Depth
1.82V	22%	1.82V	25%
2.73V	31%	2.73V	34%
3.86V	41%	3.86V	43%
4.55V	47%	4.55V	47%
5V	50%	5V	50%

3. Conclusions

1. The authorized EPRI ETSS #27906.2 for getting the actual value of the wear depth and providing structural integrity interpretation based on engineering evaluation was reviewed and applied to the site SG tubes.

2. The testing results were reviewed with the influences of SG tube material and the support structure. The impact of the tube materials was insignificant and that of the tube support structure showed somewhat conservative results.

3. The testing resulted in successful demonstration of applicability of the EPRI ETSS on the SG tube wear defects at the tube support.

REFERENCES

[1] SG Tube Eddy Current Testing Final Examination Report, KHNP-SGECT-ER-2012YG6-8, 2012
[2] SG Tube Support Structure Wear Integrity Assessment Report, KHNP-SGMP-WearCM-2012Y6-8, Rev. 0, 2012
[3] PWR Steam Generator Tube Fretting and Fatigue Wear, EPRI NP-6341, 1989
[4] EPRI Performance Demonstration Database, ETSS# 27906.2, Rev. 0, June 2007
[5] C. H. Lee, Vibration and Structural Analysis of Tubes and Tube Supports, 10287-SS-302, ABB-CE, 1991