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Comparison on Axial Cracks of Laboratory Grown SCC and Pulled Steam Generator Tubes

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1. Introduction

An eddy current testing (ECT) has been employed as an automatic testing method to measure a defect morphology on steam generator (SG) tubes in nuclear power plants. A feature of its evaluation capability not only to measure a crack location but also to estimate a crack depth is considered to be good. In this paper, laboratory grown SCC and natural SCC defects of pulled steam generator tubes were nondestructively analyzed by using the MPA (Multi Parameter Algorithm) which is operated in the MATLAB environment. The performance of the MPA has been benchmarked with experimental results of a nondestructive examination comparatively.

2. Experimental

2.1 Specimens preparation

We have developed laboratory grown SCC on tubes that were an Alloy 600 tube of which the outer diameter was 22.23mm (0.875in.) and the wall thickness was 1.27mm (0.05 in.). The tubes were sensitized at 600^{o}C for 48 hours in an inert gas (argon-hydrogen mixed gas) atmosphere to make a crack easily and to reduce the cracking time. Chemical compositions of the Alloy 600MA tubes are shown in Table 1. The outside of the tube was exposed to a 1M aqueous solution of sodium tetrathionate solution at room temperature by pressurizing the inside of the tube up to 15.17MPa (2,200psi). When a through-wall crack developed, the internal gas pressure was dropped, and the SCC process was completed. We also prepared pulled steam generator tubes from an operating plant. Main form of the degradation of the pulled SG tubes was a pitting, primary water stress corrosion cracking (PWSCC), outer diameter stress corrosion cracking (ODSCC) and inter granular attack (IGA). The selected tubes that were based on the ECT signal during an in-service inspection (ISI) were transferred to a hot laboratory at the Korea Atomic Energy Research Institute (KAERI).

2.2 Eddy Current Testing of SG tubes

The ECT data was collected by using the MIZ-30 acquisition system with a magnetically biased rotating pancake coil (RPC) probe. Before acquiring the ECT data for the tubes, a copper piece was attached on to the tube surface to identify the position of the flaws. The defect signals may be corrupted by noise and a non-defect or unwanted signals from a variation of the lift-off of the probe and the structures out side the tubes. These corrupted signals produce inaccurate signals from the tubes. The magnetically biased MRPC (Motorized Rotating Pancake Coil) probe was used to compensate for a distortion of the ECT signals. Though the sensitivity of this probe is less than a normal probe, it has a benefit for tubes where the ECT data was corrupted by a noise of the magnetic properties.

2.3 Destructive analysis of SG tubes

Prior to the destructive examination, the SG tubes were non-destructively examined to estimate the information on the defects such as the locations, directions and OD or ID, and then the crack morphology of the samples were observed macroscopically with an optical and scanning electron microscopy (SEM). Defect morphologies from the fractography were compared with those from the NDE results.

3. Results and discussion

3.1 Data analysis by MPA

The data from the eddy current inspection both laboratory grown SCC and pulled tubes was used to evaluate the performance of the multi parameter algorithm. Figure 1 shows a terrain plot of the relative OD depth profile for the crack zone which it is a part among several processing stages in an MPA when analyzing NDE data. As shown in Figure 1, this specimen has only one defect and there are two signals indicating Cu and TTS which can be specified to identify the location of defects randomly by a user. In order to obtain a depth profile, a cross-bar pointer was positioned on the images of a defect that had a maximum depth. The sample of the laboratory produced SCC had a maximum depth over 80% of the tube wall (TW) penetration and a 13 mm long axial crack in length. In order to confirm the MPA reliability, depth profiles (fractography) from the destructive examination were compared with results (EC NDE) analyzed from the multi parameter algorithm. Because the cracks were tight and a crack opening was not enough to produce a big ECT signal, it was hard to quantify the depth accurately. The analysis results are presented in Table 2. Due to this reason, the difference between the estimation results could be understandable.

4. Conclusions

- The data from an eddy current inspection of both an artificial SCC produced in a laboratory and pulled tubes were used to evaluate the reliability of a multi parameter algorithm.
- We have considerably good results by introducing a magnetically biased probe which is used to compensate for the corrupted signals by noise or artificial signals. But the sensitivity of this probe was less than a non-magnetically probe.
- The difference in the depth estimation could be explained as follows: the crack was so tight and the crack opening area (COA) was not enough to recognize the defect signals fully.

REFERENCES

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Table 1 Chemical compositions of alloy 600MA tube (wt %)

Alloy	C	Si	Mn	P	Cr	Ni	Fe	Co	Ti	Cu	Al	B	S	N
600MA	0.025	0.05	0.22	0.07	15.67	75.21	8.24	0.005	0.39	0.011	0.15	0.001	0.001	0.01

Table 2 Analysis results of DE and NDE for laboratory grown SCC and pulled steam generator tubes

	sepcimen	evaluation methods	Flaw ID	type	length [mm]	depth [%TW]	position from Cu	비고
laboratory grown SCC	# 9-SCC	metallography	A	axial(OD)	12.6	100	-	
		MPA			13	86	-	
	# 10-SCC	metallography	A	axial(OD)	8.8	100	-	
		MPA			9.6	83	-	
		metallography	B	axial(OD)	-	-	-	non intended flaw
		MPA			6.8	82	-	
pulled SG tubings	R28C45	onsite ECT	flaw-1	MAI(ID)	11.68	-	250°	
		metallography		MA crack(ID)	7.03	100	238.7°	
		MPA		axial(ID)	9.3	70	230°	
		onsite ECT	flaw-2	MAI(ID)	9.91	-	358°	
		metallography		MA crack(ID)	7.83	100	342.7°~351.9°	
		MPA		axial(ID)	8.56	75	350°	

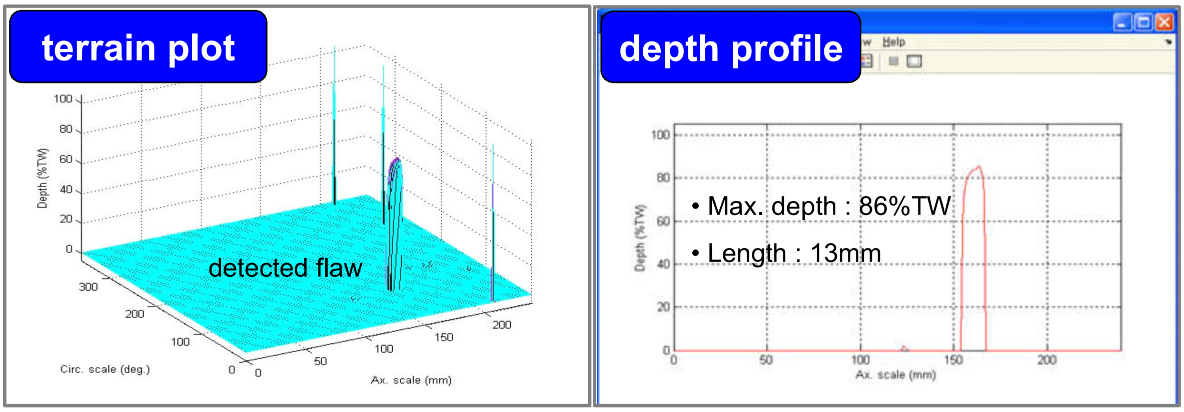

Figure 1 Terrain plot of relative OD depth profile (left) and flaw depth profile on a point with maximum depth (right)