EDM, SCC Defect Depth Analysis Using a Multi-Parameter Algorithm

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1. Introduction

Eddy Current Testing (ECT) is a nondestructive technique. It is used for an evaluation of a materials' integrity, especially, Steam Generator (SG) tubing in nuclear plants, due to its rapid inspection, safe and easy operation. For the depth measurement of defects, Electro Discharge Machined (EDM) notches that have several defects are prepared, and the Multi-Parameter Algorithm (MPA) was applied. We analyzed the Stress Corrosion Crack (SCC) of a tube pulled out from a Retired Steam Generator (RSG) of the Kori-1. The MPA is a crack shape estimation program developed in Argonne National Laboratory (ANL). To evaluate the MP algorithm, we compared the defect profile with the fractography of the defect. In the following sections, the basic structure of the computer-aided data analysis algorithm used as a means of a more accurate and efficient processing of the ECT data, and the defects depth analysis results of the EDM and SCC are described.

2. Basic architecture of the MP algorithm

The MPA was implemented under the Matlab environment and consisted of some routines assembled to carry out various stages of processing of the raw EC inspection results. Figure 1 shows the basic architecture of the algorithm to achieve on off-line analysis of data acquired with the ECT instrument, MIZ-30. [1], [2]

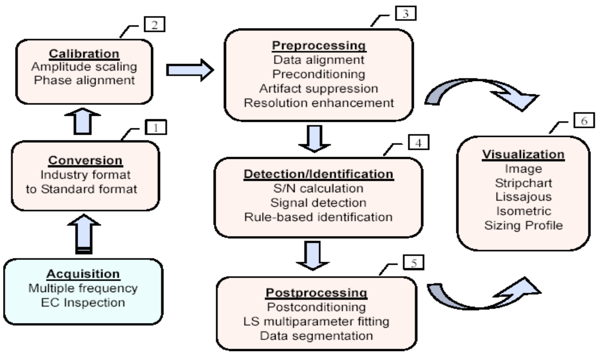

Figure.1 Schematic diagram showing a basic structure of computer-aided data analysis algorithm

The block diagram shown in Figure 1 can be divided into three components: data conversion, calibration, and analysis stage. In the conversion stage (block 1), digitized data is converted to a readable format for off-line manipulations. In the subsequent stage, multi-frequency raw EC data, shown in block 2, is calibrated for all the channels. Finally, in the data analysis stage (block 3~6) the calibrated data is processed to ultimately produce NDE profiles that represent the estimated defects depth along a selected test section of a tube. A detail description of each block is in Reference [4].

3. Data acquisition condition and coils for the ECT

The ECT data was acquired through 12 channels and used three coil rotating probes which included a 2.92-mm pancake, a mid-range +point, and 2.03-mm high-frequency pancake coil. For an analysis of the defect depth or length, the pancake coil signal at 400 KHz was used.

ECT Signal Acquisition Condition												
Used frequency[Khz]	400	400	400	300	300	300	200	200	200	100	100	600
Coil type	1	3	4	1	3	4	1	3	4	1	2	4
Number of channels	12											
Comment	1 : pancake coil 4 : high frequency coil					3 : +point coil 2 : trigger						

Table.1 Data acquisition condition

4. EDM, SCC defects depth analysis results

4.1. EDM defect analysis

EDM notches which have an axial and circumferential orientation originating from the OD and ID of the tube were machined. They ranged from a 20% tube wall (TW) to 100%TW in depth, from 2.5 mm to 25 mm in length, and 0.127±0.05mm in width. Table.2 shows the information of the test specimens.

Table.2 Information of the test specimens

EDM Defect Analysis using the Multiparameter Algorithm					
(22.23 mm OD,1.2 mm thickness, Alloy 600 MA)					
Specimen ID	ID/OD	Ax/Cir	Length, mm	Depth, %TW	Width, mm
MRPC Combo standard (14 defects)	OD, ID, Throughwall	Axial Circum. Irregular	2.5, 6, 10	20, 25, 40, 60, 75, 80, 100	0.127
#1 (18 defects)					
#2 (12 defects)					
#3 (8 defects)					
#4 (15 defects)					
Total : 4 tubes, 67 defects analyzed					

To get a more accurate depth measurement, it is necessary to have a better calibration curve fitting and a suitable noise level selection during the MP algorithm operation. Figure.2 shows the representative defect depth estimation results and the fractography by using a Scanning Electron Microscope (SEM). The defect depth analyzed by MPA agreed well with the depth by the fractography.

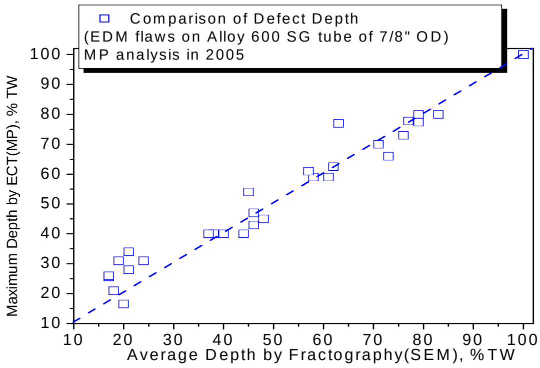

Figure.2 Comparison of defect depth inspected by SEM and MP algorithm

4.2. SCC defect analysis

The MPA was applied to a natural SCC defect obtained from a retired SG.

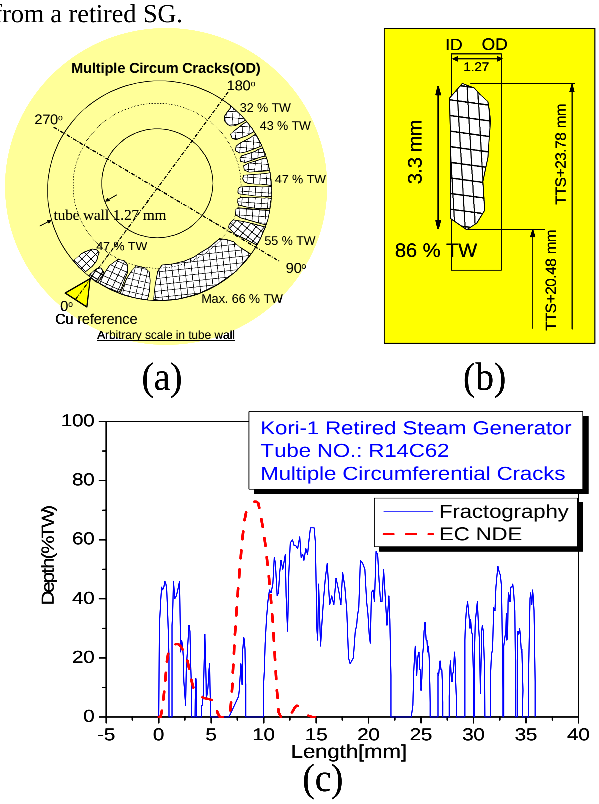

Figure.3 RSG SCC analysis results (a) OD, MCI crack (b) ID, SAI crack (c) comparison of SEM and MPA.

The depth and length of the SCC defect was analyzed by MPA and SEM fractography separately and then compared with each other. Figure.3 shows the analysis result of the R14C62 tube. This tube had cracks of multiple circumferential indications (MCI) on the outer diameter (OD) of the tube and a single axial indication (SAI) of the inner diameter at the top of the tube sheet (TTS). Defect depth and length measurement results by the MP algorithm (EC NDE) and a destructive inspection (SEM) are listed in Table.3. There are some difficulties in analyzing the ECT data: shallow cracks below about 40% TW were not detected, and the short axial crack was not detected too.

Analysis results of R14C62 tube				
flaw type	EC NDE		Fractography	
	flaw length [mm/deg.]	max. depth [%TW]	flaw length [mm/deg.]	max. depth [%TW]
OD, MCI*	14.9 / 77°	73%	35.7 / 184°	66%
ID, SAI**	X	X	3.3[mm]	86%
MCI* : Multiple Circumferential Indication			SAI** : Single Axial Indication	

Table.3 Analysis results of RSG tube, R14C62

5. Conclusion

Computer-aided data analysis techniques can provide an accurate and efficient processing of ECT data for EDM notches. There are some difficulties in analyzing the ECT data from natural SCC flaws.

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