Depth analysis of mechanically machined flaws on steam generator tubings using Multi-Parameter Algorithm

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1. Introduction

The eddy current testing (ECT) is a nondestructive technique. It is used for evaluation of material's integrity, especially, steam generator (SG) tubing in nuclear plants, due to their rapid inspection, safe and easy operation. For depth measurement of defects, we prepared Electro Discharge Machined (EDM) notches that have several of defects and applied multi-parameter (MP) algorithm. It is a crack shape estimation program developed in Argonne National Laboratory (ANL). To evaluate the MP algorithm, we compared defect profile with fractography of the defects. In the following sections, we described the basic structure of a computer-aided data analysis algorithm used as means of more accurate and efficient processing of ECT data, and explained the specification of a standard calibration. Finally, we discussed the accuracy of estimated depth profile compared with conventional ECT method.

2. Basic architecture of the MP algorithm

The MP algorithm is implemented under the Matlab en-vironment and consisted of some routines assembled to carry out various stages of processing of the raw EC inspection result. Figure 1 shows the basic architecture of the algorithm to achieve for off-line analysis of data acquired with ECT instrument, MIZ-30. [1], [2]

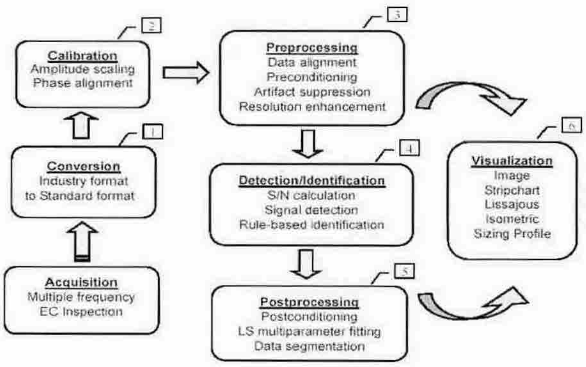


Figure 1. Schematic diagram showing a basic structure of computer-aided data analysis algorithm.

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 are converted to readable format for off-line manipulations. In the subsequent stage, multi-frequency raw EC data, shown as block 2, are calibrated for all the channels. Finally, in the data analysis stage (block 3~6) calibrated data are processed to ultimately produce NDE profiles that represent estimated defects depth along a selected test section of a tube. More description of each block is provided in the following sections.

2.1 Conversion and Calibration Routines

The data conversion routine extracts the essential header information, such as the number of channels and their associated frequencies, from the original Eddynet-formatted files. The extracted header information is used to sort out raw EC readings. Normalization values which include amplitude scaling factors, phase angle rotations, and null values are calculated by using the inspection results from a calibration standard tube. Calibration of raw data plays an important role in data analysis procedure. Because conventional phase angle calibration procedures are carried out manually, and routinely involve visual alignment of the lissajous plot with respect to reference indication, the background fluctuations and S/N ratio, analyst judgment could affect the calibration process. So it is expected that computer-aided data calibration routines will play an essential role in uniform and accurate normalization of raw EC data. [1], [2]

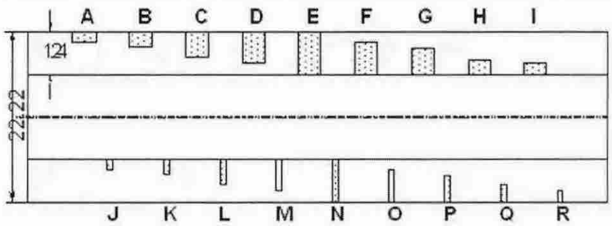
2.2 Signal Processing, Data Analysis, and Display Routines

The data analysis section (block 3~6) is composed of three basic stage : pre-processing, flaw detection and identification, post-processing of data. These blocks perform the calculation of S/N ratio for all available channels, apply filters for pre-and post processing of data, and ultimately combine multiple-frequency information from all processed channels to provide an estimate of the depth profile for the tubing test section. Flaws and their origin are identified by a series of rules that are applied to the multiple-frequency EC data. Both amplitude and phase relationships are used at this stage. Finally, the phase information is combined to calculate the depth profile in reference to known indications on a calibration standard tube. Various stages of data analysis process are visualized on the display. Lastly, the estimated values of defects are displayed in a form that is converted to percent of tube wall thickness. [1], [2]

3. Configuration of standard tube and probe for ECT

The EC NDE data were acquired with three coil rotating probe which includes a 2.92-mm pancake, a mid-range +point, and 2.03-mm high-frequency pancake coil. For analysis, we used pancake coil data. The machined calibration standard contains 18 EDM notches which have axial and circumferential orientation originating from the OD and ID of the tube and ranging in depth from 20% tube wall (TW) to 100%TW. All defects are 6.0-mm in length and 0.127±0.05-mm in width. Figure 2 shows that the dimension of calibration standard specimen.

18 holes standard tube, 22.23mm, Alloy 600 MA									
	A	B	C	D	E	F	G	H	I
axial/circ	Ax	Ax	Ax	Ax	Ax	Ax	Ax	Ax	Ax
OD/ID	OD	OD	OD	OD	Thru	ID	ID	ID	ID
depth(%TW)	20	40	60	80	100	80	60	40	20



	J	K	L	M	N	O	P	Q	R
axial/circ	Circ	Circ	Circ	Circ	Circ	Circ	Circ	Circ	Circ
OD/ID	ID	ID	ID	ID	Thru	OD	OD	OD	OD
depth(%TW)	20	40	60	80	100	80	60	40	20

Figure 2 Flaw geometries of calibration standard specimen and flaw dimensions.

4. Data analysis result

MP algorithm has various stages for analyzing EC NDE data as explained above. Figure 3(a) is a terrain plot of OD depth profile, upper part is axial defects and lower part is circumferential defects. Through this picture, we can know the location and types of the defects approximately. Figure 3(b) is cross-sectional plot, taken over a point with maximum depth, of estimated flaw profile on the same test section of tube. In the analysis result of figure 3(b), we can estimate that each crack has a maximum depth of >30%TW, >50%TW, >70%TW. To demonstrate the performance of MP algorithm, Figure 3(c), the processed data is compared with original data (fractography).

5. Conclusion

Computer-aided data analysis techniques can provide accurate and efficient processing of EC NDE data for EDM OD notches. Comparison of NDE results with fractography is presented to benchmark the MP algorithm. In the Figure 3(c), we confirmed that the estimated depth profile approximately similar to actual crack depth (difference about less than 5%TW). We will experiment and analyze ECT signals of laboratory grown SCC and retired SG tunings in nuclear power plants using this program.

REFERENCES

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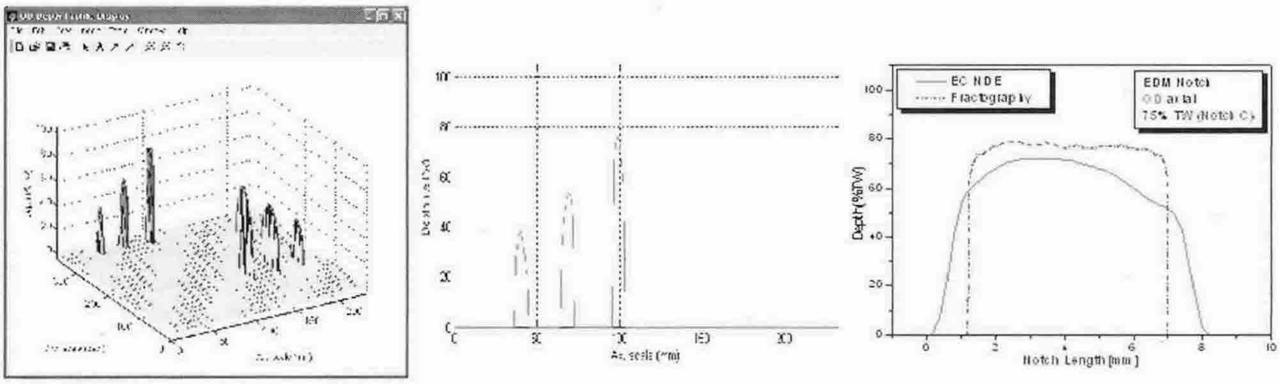

(a) (b) (c)

Figure 3 Representative displays of data analysis results. (a) terrain plot, (b) cross-sectional plot, (c) comparison of NDE and factography profile for OD axial 75% EDM notch