Development of Data Analysis Software for Diagnostic Eddy Current Probe (D-probe) for Steam Generator Tube Inspection

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1. Introduction

Occurrences of a stress corrosion cracking in the steam generator tubes of nuclear power plants are closely related to the residual stress existing on the region of a geometric change, that is, expansion transition, u-bend, ding, dent, bulge, etc. Therefore, information on the location, type and quantitative size of a geometric anomaly existing in a tube is a prerequisite to the activity of a non destructive inspection for a root cause analysis, alert detection of an earlier crack, and the prediction of a further crack evolution. KAERI developed an innovative eddy current probe, D-probe, equipped with the simultaneous dual functions of a crack detection and a 3-dimensional quantitative profile measurement [1]. Its excellent performance has been verified through the sampling inspections in several domestic nuclear power plants where the various types of the steam generator tube cracking were observed in operation [2]. The qualified data analysis software should be furnished in order to deploy D-probe to pre- and in-service inspection of commercial power plant. This paper introduces the PC-Windows based eddy current data analysis software which is being developed for D-probe in cooperation with Zetec Inc.

2. Development of Eddy Current Data Analysis Software for D-probe

2.1 Diagnostic Eddy Current Probe (D-probe)

D-probe has two surface riding eddy current coils for a crack detection and sizing, and a non-surface riding eddy current coil for a 3-dimenstional quantitative profile measurement, as shown in Fig. 1.

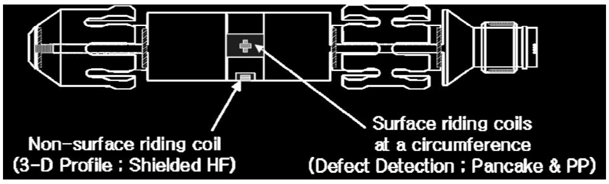

Figure 1. Design diagram of D-probe.

From this configuration, two streams of eddy current signal from each coil for crack detection, and one stream of eddy current signal from a coil for profile measurement are acquired simultaneously with a single pass of a probe movement into the steam generator tubes, and recorded into a digital data file. Considering the purpose and characteristic of each signal acquired from different coils, various modes of graphic user interface (GUI) for data analysis are developed; i) GUI for crack detection and sizing, ii) GUI for standard tube calibration for a 3-dimensional quantitative profile measurement, iii) GUI for 3-dimensional tube profile illustration, and iv) GUI for crack detection and corresponding illustration of 3-dimensional tube profile.

2.2 GUI for Crack Detection and Sizing

The basic GUI for crack detection and sizing is designed to represent multiple graphs of a 1-dimensional strip chart, a 2-dimensional scan and 3-dimensional block scans with lissajous from each coil signal. Fig. 2 shows an example of analysis for a standard tube specimen with axial and circumferential EDM notches. The signals from pancake and plus-point coils are shown simultaneously in the upper and lower 3-dimensional scan, respectively.

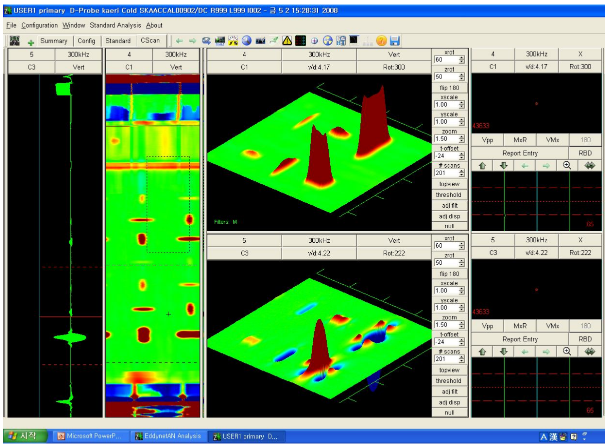

Figure 2. Example of data analysis for an EDM notch standard tube.

2.3 GUI for Standard Tube Calibration for a 3-Dimensional Quantitative Profile Measurement

In order to convert the value of the eddy current signal from a coil for 3-dimensional profile to the quantitative radius value, a calibration should be done with a standard tube containing multiple segments of uniform radial changes of known values. The GUI for the calibration process is shown in Fig. 3. The 3-

dimensional geometry of the standard tube is illustrated in order to locate the position of radial changes and the corresponding values of radius can be inputted correctly. Also, the calibration process is validated with the graph of curve fitting results as shown in Fig. 4.

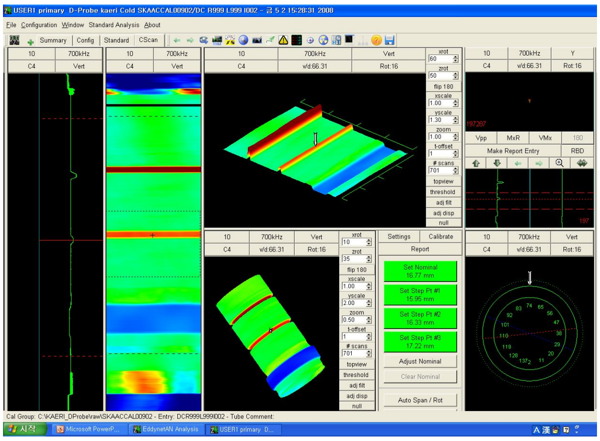

Figure 3. GUI for calibration for 3-dimensional tube profile measurement.

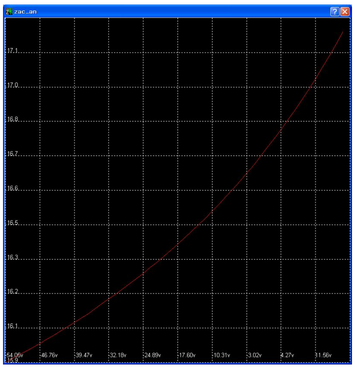

Figure 4. Example of calibration curve fitting result.

2.4 GUI for 3-Dimensional Quantitative Tube Profile Illustration

The GUI for 3-dimensional quantitative profile illustration is shown in Fig. 5 for a tube with two dents, caused by the collision with support structures. The 3-dimensional geometry of tube is illustrated in both the rectangular and the cylindrical coordinates. Also, the quantitative size of a dent can be measured directly by the radial scan graph on the right side of Fig. 5, along the axial direction of a tube.

2.5 GUI for Crack Detection and Corresponding 3-Dimensional Quantitative Tube Profile Illustration

The root cause of cracking in steam generator tube could be examined by comparing the evolution of cracking with the geometric changes of tube, at which the residual stress is developed. Therefore, the GUI for crack detection and 3-dimensional tube profile illustration is developed, in which the location of a crack and its corresponding geometry of a tube can be interpreted. Fig. 6 shows an example of analysis for a tube with axial ODSCC (outer diameter stress corrosion crack) at the eggcrate intersection in a steam generator of operating power plant. It is evidently seen that the cracking is accelerated by the spiral geometric changes introduced by the roll-straightening in the tube manufacturing process.

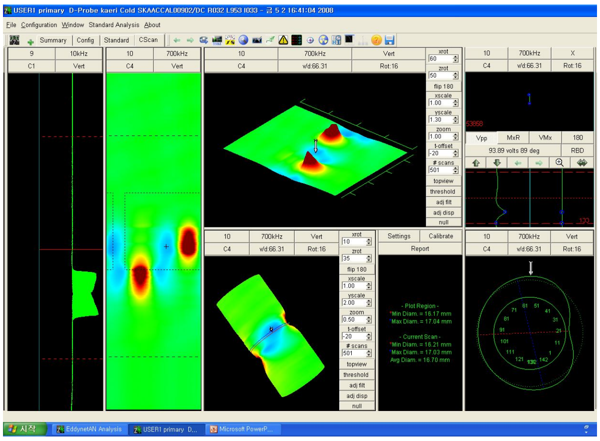

Figure 5. GUI for 3-dimensional tube profile.

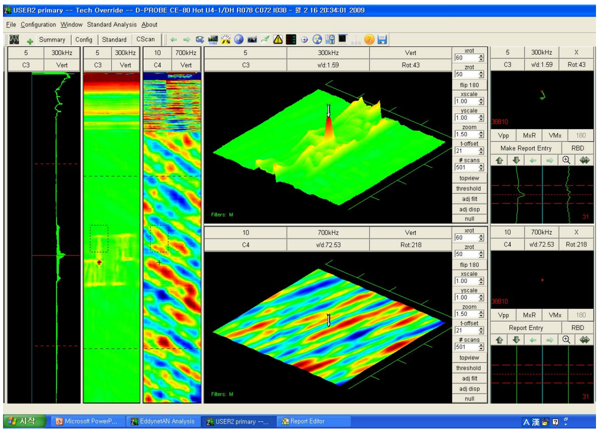

Figure 6. Example of data analysis for a tube with ODSCC at eggcrate intersection in an operating plant.

3. Summary

The PC-Windows based eddy current data analysis software for D-probe has been developed. Various modes graphic user interface (GUI) for data analysis and its performance has been successfully demonstrated.

REFERENCES

[1] D. H. Lee et al, US Registered Patent No.7,242,201, KAERI/KHNP, 2007.
[2] D. H. Lee et al, Optimization of D-probe and Development of Visualization Program, 2009 ZETEC Symposium, Taejeon, Korea, 2009.