Visualization and Analysis of Eddy Current Data from D-Probe

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1. Introduction

Eddy current testing (ECT) method is widely used as the non-destructive evaluation (NDE) of the various kinds of material degradation occurring in nuclear power plants (NPPs) components including steam generator (SG) tubes. Detection of any defects or flaws in the steam generator tubes in the early stage is very important in maintenance of NPP for its primary role as the pressure boundary with thin wall thickness. Although the ECT technique provides lots of information for a SG management, it has a generic problem in its reliability due to a low ability in detect of small defects and some difficulty in a signal analysis. For the improvement of these shortcomings in conventional ECT, profile-MRPC (motorized rotating pancake coil) ECT technology was developed in KAERI [1]. The key of this new technology is the development of new eddy current probes, designated as a diagnostic probe (D-probe). The D-probe is furnished with a simultaneous dual function of a defect detection and shape changes (expansion, dent and bulge, etc.) measurement, and provides the information and three-dimensional analysis of the axial/circumferential location, magnitude and distribution of both the defects and the shape changes in the SG tubes.

In this study, the personal computer based software program was developed for the analysis of the advanced D-probe ECT signals. The function of this software program includes the 3-dimensional quantitative evaluation and visualization of the geometric anomaly in a SG tube such as its type, location, magnitude and distribution.

2. Methods and Results

For the diagnosis of the defects and shape changes with the D-probe ECT technique, SG tubes of high temperature mill-annealed Alloy 600, which was the same tube materials as that in OPR 1000 SGs, were used. These tubes have the dimension of a nominal outer diameter of 19.05 mm and a nominal wall thickness of 1.07 mm. The D-probe was applied to the mock-up tube assembly containing natural defects and shape changes of expansion, dent or bulge with various type and size. MIZ-70 model data acquisition system (manufactured by Zetec Inc.) was used for the data acquisition. Inspection frequency and the function of each coil in D-probe are listed in table I. ECT inspection was performed with a probe pulling speed of 0.2 inch/sec and rotating speed of 600 rpm. After ECT signal calibration, the digital raw data was transferred to a personal computer from the UNIX workstation system into text file format.

Table I: ECT inspection frequency and remarks on the D-probe test coils.

D-probe test coil	Frequency (kHz)	Remark
Pancake Coil	400, 300, 100, 10	Detection of defects and tube support structures Distribution of sludge
Plus Point Coil	400, 300, 100	Detection of defects
Profile Coil	400, 700	Detection and sizing of geometric anomaly

The D-probe ECT signal was visualized in 3-dimension using the Blender software which was released with general public license (GNU) by Blender Nation Inc. This program is a very useful tool for the three-dimensional design art and animation [2-3]. To visualize the matrix data, we developed the ECT signal process script using the python program with numpy which was a plug-in numerical package [4]. The script program processed the high frequency and low frequency ECT data using an each independent algorism. In order to illustrate the high frequency data for tube expansion region into a 3-dimensional graphic form, the two signal values at unexpected and expanded zone was used for calibrating the extent of the tube expansion. An example of the program execution is shown in Fig. 1.

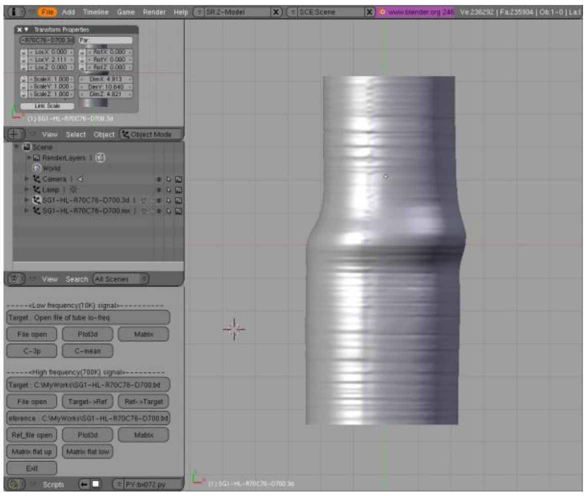
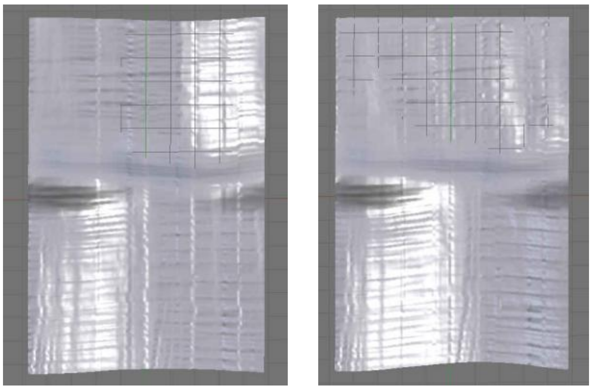


Fig. 1. Illustrate in a developed shape of the 3D tube shape.

We developed the filtering algorithm for a matrix flat to calibrate a distortion phenomenon of a curved surface due to an eccentricity of the tube expansion region (Fig. 2(a)). After the filtering process, the tube surface showed a flat shape in the region of free span above the expansion region (Fig. 2(b)).



(a) (b)

Fig. 2. Calibration with matrix flat filter (a) before filtering (b) after filtering.

The 3-dimensional visualization of the ECT data showed that the geometric anomaly of an eccentric expansion and dents could be detected intuitively, and the relationship between the crack occurrence and the shape change could be interpreted 3-dimensionally. The visualization of the data obtained by applying the new eddy current probe is expected to make a contribution to manage and repair of a SG in NPPs.

3. Conclusions

A 3-dimensional visualization program was developed for a D-probe signal analysis. This program is PC- based so that the operation is easy and handy to process ECT data. The high resolution details of a geographic surface shape provide an intuitive evaluation for a SG tube anomaly and it can be applied in an analysis of ECT data from a tube which has any defect, dent or bulge etc., even with a very small magnitude in its size at an initial stage

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