Development of the analysis methods for eddy current signal of D-probe

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1. Introduction

Eddy current testing (ECT) method is very useful to detect flaws and defects in steam generator (SG) tube of nuclear power plants (NPPs) during in-service inspection. In spite of its technical improvements recently, typical ECT method has some shortcomings such as the low resolution in detection of small defects and it causes difficulty in analysis of the detect signals. The new diagnostic eddy current probe (D-probe) which was developed by KAERI [1], has the dual functions of the crack detection and a quantitative 3-dimensional profile measurement. It can measure a shape changes, and provides the information of the axial / circumferential location and magnitude of defect developed. The distribution of the defects and the shape changes on the SG tube surface could be acquired simultaneously from the analysis of an inspection signals with the D-probe. A stress corrosion cracking of the SG tubes in operating NPPs is supposed to have a relation with the residual stress existing in the local geometric changed region such as expansion transition, bend, dent and bulge, etc. Therefore the type and quantitative size of geometric anomaly existing in a tube is very important information to the activity of a nondestructive inspection, and it could provide a warning signal of an earlier defect in 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

The D-Probe is a rotary type eddy current coil probe and designed to have three eddy current coil units which are located at a circumference of the probe. Two coil units are surface riding type for crack detection and one is none-surface riding type for profile measurement. It has simultaneous dual function of the crack detection and a quantitative 3-dimensional profile measurement with a single pass of a probe movement into the SG tubes.

The D-probe was applied to the mock-up SG tube assembly containing natural defects and shape changes of expansion, dent or bulge with various type and size. The signal data of D-probe was acquired using the commercial eddy current test equipment, MIZ series digital data acquisition units (manufactured by Zetec Inc.). ECT signal data was obtained with a probe pulling speed of 0.2 inch/sec and rotating speed of 600 rpm.

The digital data of ECT signal was stored in the UNIX workstation system in the binary file format of Zetec archive (ZArchive) algorithm, then the digital raw data was transferred to a Microsoft windows based personal computer from the UNIX workstation system and data was parsed to the ASCII text file format. Data files created with ZAC contain several different segments of information. One segment will contain the raw eddy current data and there are multiple segments that contain header data describing how the eddy current data was collected. Each segment is different with the Miz unit models. Miz 30 and 70 contain segments that contain XML data, and an each segment is composed by a 32-byte header that describes the data within the segment. When a ZArchive file is created, the first element of the file will be a header that is used to identify the file as a ZAC generated file. This will then be followed by a header describing the first segment of data in the ZArchive file, which is the segment that contains the raw eddy current data. From the Miz-70 model, header describing the first segment was followed by XML syntax. Typically, a workstation systems using RISC processor has a storage method of Big-endian, the other hand, a personal computer using Intel processor uses the Little-endian method. A conversion routine between the Big and Little-endian format is needed to transfer the data from a workstation to personal computer. Fig 1 shows an example of the program that reads the ZArchive data in a personal computer.

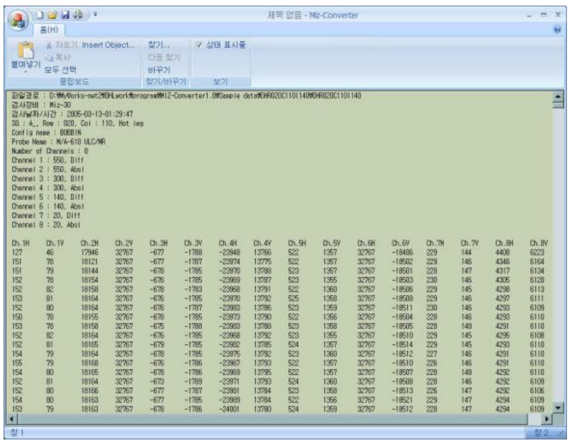
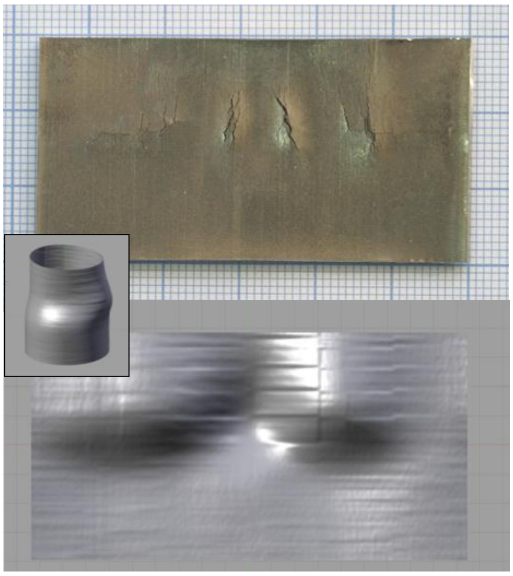


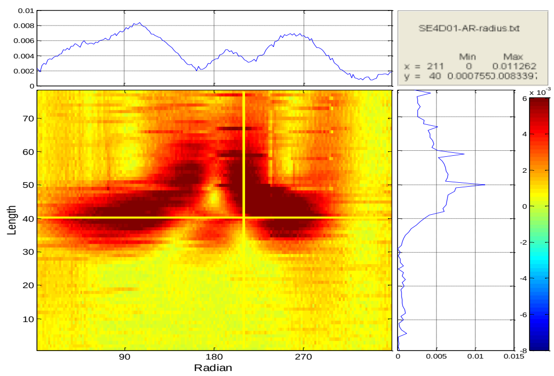
Fig.1 View of a Miz-Converter program parsing a ZArchive data.

A calibration curve was derived as a relative equation between the actual radius and the average circumferential digital counts of calibration standard specimens. Eddy current data was calibrated using this relative equation, and then it was analyzed the dimension size of the geometric anomaly.

Imported ECT data was arranged as an array of 2-dimension and it was converted to cylindrical axis of 3-dimensional. It was computed the vertices and faces from this 3-dimensional data and then the mesh was composed using the vertices and faces. The mesh for a surface of SG tube was rendered using the Blender software as shown fig. 2(a). [2, 3]



(a) Shape of a surface on the bulged expansion SG tube.



(b) Contour view of the radial & vertical differential data.

Fig 2. Geometric analysis the shape and defects on a SG tube with D-probe.

Upper photo in fig. 2(a) is a view of flattened surface of SG tube sample, which was locally expended (bulged) and cracked consequently by a stress corrosion cracking (SCC) due to the residual stress. The solid figure showed that the geometric anomaly of a local expansion and two dented regions could be recognized intuitively. The relationship between the crack occurrence and the shape change could be interpreted 3-dimensionally from this tube sample. The differential analysis of the 3-dimensional ECT data indicates the local regions where the SCC is the most susceptible (Fig. 2 (b)). These high resolution details of a geographic 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.

3. Conclusions

The computer programs for an ECT data handling and a geometric realization were developed as a tool of nondestructive inspection and analysis with D-probe. These programs are PC based so that the operation is easy and handy to process ECT data. The visualization of the real tube shape and the methods of differential data analysis for cracking prediction obtained by applying the new eddy current probe are expected to make an innovative contribution in both pre- and in-service inspection of SG tube in nuclear power plants.

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