

Development of New ECT Probe Separating the PVC in the SG Tubes

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1. Introduction

Steam generator tube (SGT) in nuclear power plant is a boundary between primary side and secondary side, whose integrity is one of the most critical factors to nuclear plant safety. Multi-frequency eddy current inspection techniques are currently among the most widespread techniques for the rapid inspection of SGT in the nuclear power industry [1]. The eddy current (EC) tests are being applied in the nonferrous materials having relative permeability equals to 1 such as Inconel alloy because the magnetic permeability of magnetic materials severely limited by the depth of penetration of induced eddy currents. Although the EC technique is adopted widespread in the nuclear industry, it has the limitation to estimate size of the flaw accurately because the eddy current signal behavior depends on the total volume of the flaw. Furthermore, permeability variation clusters (PVC) such as the build-up of magnetite (Fe_3O_4) and magnetic phase on the secondary side of the SGT has no direct effect on the tube integrity but it cause spurious EC test results [2]. The relative permeability of the PVC is greater than 1, and with a number of ferromagnetic metals, a value of several thousands can be reached. Internal stresses caused by drawing, straightening and similar working of the material, creates the magnetic phase in the SGT, which can give rise to several fluctuations in the permeability. These fluctuations would always cause interference with the test signals. Since the ferromagnetic test piece of PVC is saturated by a strong magnetic field, in order to eliminate this interference effect during testing a suitable device such as magnetized ECT probe is employed. The magnetic properties of the ferromagnetic test piece become similar to those of a non ferromagnetic material and thus, the interference from permeability fluctuation is eliminated. Recently, to eliminate EC signal fluctuations, the magnetized probe with the built-in permanent magnet is being used in the SGT inspection, because a strong magnetic field of this probe reduces the variation of magnetic permeability, which improves the S/N ratio. However, these magnetized ECT probe could not saturate strong PVC having large permeability, and the strong magnetic field of magnetized ECT probe amplifies the ECT signal with noise by the interaction of magnetic filed of ECT probe and induced currents of probe coil. If we can separate PVC selectively from the flaws using magnetic sensor, Then the reliability of EC in SGT inspection will be

greatly enhanced. In this study, new ECT probe which separate PVC and ordinary defects created in SGT is developed, and its performance has been tested using I600 tube having artificial crack and PVC. Additionally, the hysteresis loops of PVC samples which were extracted from the retired SG of Kori-1 NPP in Korea were measured using Vibrating Sample Magnetometer (VSM) in order to analyze the magnetic properties of PVC.

2. The principle of new probe

The measuring principal of magnetic phase in Inconel alloy is based on the measuring magnetic flux density of sample as shown in Fig. 1. The schematic diagram of

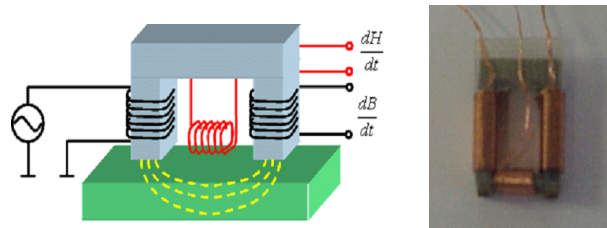


Figure 1. The measuring principle and probe for the measurement phase Inconel plate.

the measuring system and new ECT probe is shown in Fig. 2. The appearance of PVC in the SGT results in a

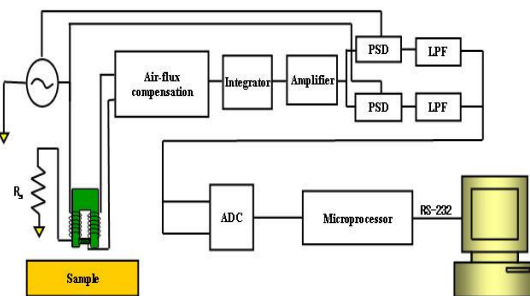


Figure 2. Block diagram of the measuring system and a new eddy current test probe.

field sensor, a silicon steel with two solenoids: the driving coil and the pick-up coil. The measured voltage is proportional to the magnetic field component perpendicular to the plane of the sample. This probe detects the voltage variation and phase shift induced by the magnetic field caused by the presence of the PVC in

the SGT. The measurement system which is constructed by using a waveform generator to excite the coil with sinusoidal current and lock-in amplifier to detect the response was inserted in the probe using a specialized electronics technique. The electronics which separate the induced signal from defects and PVC, and convert these signals from analog to digital and transmit to the computer are also inserted in the probe.

3. Results and discussions

Figure 3 shows the experimental results obtained by analyzing the Inconel 600 tube containing artificial flaws and magnetic phase with permeability detection probe. The sample have EDM slot with the width of 0.5 mm, length of 10 mm and the depth from 0.254 mm

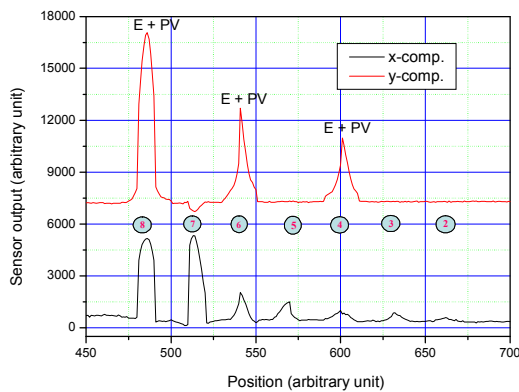


Figure 3. The change of magnetic flux density in the artificial flaws and magnetic phase.

to through hole as shown in Table 1. The ferromagnetic phases were inserted in the sample position 4, 6, and 8 to simulate the PVC effects.

Table 1. Dimensions of the artificial flaws and ferromagnetic phases as the sample positions in Inconel 600 tube.

Sample position	Width (mm)	Length (mm)	Depth (mm)
1	0.5	10	0.254
2	0.5	10	0.508
3	0.5	10	0.762
4	0.5	10	0.762
5	0.5	10	1.016
6	0.5	10	1.016
7	0.5	10	Hole
8	0.5	10	Insert

As shown in Fig. 3, the signals come from the defects and magnetic phase are appear in the x-component of signals. But, the signals come from magnetic phase are appear only y-component of the signals. Therefore, it is possible to separate the signal comes from defects and magnetic phase without ambiguity. In this experiment, with the permeability measurement based system we can detect the different size of cracks and magnetic phases.

The induced voltages are proportional to the sizes of artificial cracks, and the signal phase is reversed in the ferromagnetic fragments.

4. Conclusion

To eliminate the EC signal distortion due to ferromagnetic phase (PVC) in the SGT, new type of probe based on the magnetic flux measurement has been introduced. The magnetic phase created in the SGT can be selectively separated by a new permeability detection probe.

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