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Effects of magnetic phase on the ECT signal 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 safety. Multi-frequency eddy current inspection techniques are currently among the most widespread techniques for the rapid inspection of SG tubing in the nuclear power industry [1]. Although the eddy current (EC) technique is adopted widespread in the nuclear industry, it has the limitation to size the flaw accurately because the eddy current signal behavior depends on the total volume of flaw and permeability variation clusters (PVC). The EC tests are being applied in the nonferrous materials having relative permeability 1 such as Inconel alloy because the magnetic permeability of magnetic materials severely limits the depth of penetration of induced eddy currents. Furthermore, the PVC inherent in SGT can 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 thousand can be reached. Internal stresses caused by drawing, straightening, and similar working of the material, can give rise to severe fluctuations in the permeability. These fluctuations would always cause interference with the test signals. In order to eliminate this interference effect during testing, the ferromagnetic test piece is magnetized by a suitable device such as magnetized ECT probe. The relative permeability will approach unity by a suitable device. 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 fluctuation, the magnetized probe with the built-in permanent magnet is being used in the SG tube inspection, because a strong magnetic field of this probe reduces the variation of magnetic permeability, which gains S/N ratio. If we can separate PVC selectively from the flaws using magnetic sensor, the reliability of EC in SGT inspection will be greatly enhanced. This paper shows the possibility that the permeability sense can be applied to detect the magnetic phase in the steam generator tubes and to measure them quantitatively.

2. ECT signal fluctuation due to PVC (magnetic phase)

The RPC test data from the Younggwang 4 are presented in Fig. 1 provides the flawed tubes location on the tubesheet map. Note that the flawed tubes are not in the conventional sludge zone. Fig. 1 (a) shows the result of bobbin probe, and (b), (c) represent the results of MRPC pancake and plus point, respectively. Where Fig. 2 (d,e,f) represent those of magnetized probe. Bobbin data of the ISI for the tube (R47 C34) shows the indication of PVC, and its size is conformed by RPC data. The prior inspection of PVC measurement indicates continuous distribution of PV signal up to 1 m. However the PVC signal was not eliminated by magnetized probe as shown in Fig. 1 (d, e, f), and the S/N ratio was reduced contrary to our expectation. The magnetized probe was introduced to saturate the ferromagnetic nature of PVC, but the saturation field depends on various factors such as demagnetization coefficient of the PVC. If the magnetic field of magnetized probe can not saturate the PVC, the distortion of the ECT signals increases by the interaction of the magnetic filed of probe and PVC, which results in a low S/N ratio.

3. Experimental

The detection principal of magnetic phase in Inconel alloy is based on the variation of magnetic flux density due to magnetic phase. The schematics and probe for magnetic phase measurement are shown in Fig. 2. The appearance of PVC in the SGT results in a change of magnetic flux density of the pick-up coil. The variation of flux density due to PVC can be obtained by measuring the applied field and induced field. The probe consists of a exciting coil and a magnetic field sensor, a SiFe 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 structure under test. The measurement system was constructed by using a waveform generator to excite the coil with a sinusoidal current and a lock-in amplifier to detect the response. Inconel 600 plate specimen containing various artificial slots and magnetic phase was used in this experiment.

3. Results and discussions

Figure 3 shows the experimental results obtained by analyzing the Inconel plate containing artificial flaws and magnetic phase with permeability detection probe.

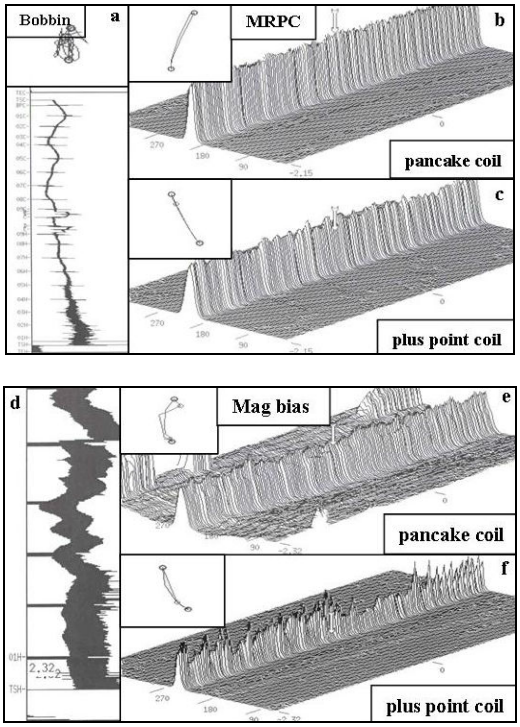

Figure 1. The bobbin and RPC data of R47 C34.

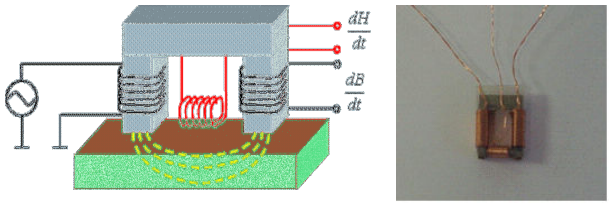

Figure 2. The measuring principle and probe for the measurement of magnetic phase in Inconel plate.

In this figure, A2 is the EDM slot with the width of 0.127, length of 4.013 and the depth of 0.229 mm, respectively. The flaws B2 and C2 have the same area but depths are 0.457 and 0.686 mm, respectively. In D2 and E2 positions, the slice of ferromagnetic materials having the size of 0.15x1.6x0.2 mm and the permeability of 510 and 780 were inserted in the Inconel plate, respectively. The measurements have been carried out at a frequency of 10 kHz. The lift-off was varied from 0.25 to 0.75 mm. Experimental results on the Inconel 600 plate having the artificial flaws (A2, B2, C2) and ferromagnetic phase (D2, E2). In this experiment, with the permeability measurement based system we can detect the different size of crack and magnetic phase. The induced voltages are proportional to the sizes of artificial cracks, and the signal phase is reversed in the ferromagnetic fragments.

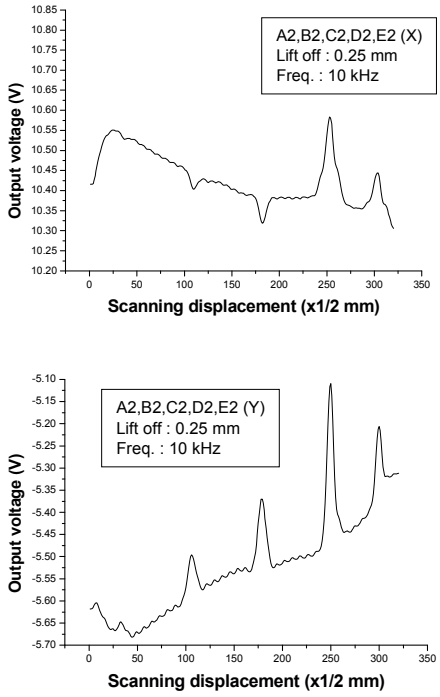

Figure 3. The change of magnetic flux density in the artificial flaws and magnetic phase

4. Conclusion

To eliminate the EC signal distortion due to ferromagnetic phase (PVC) in the SGT, new technology based on the magnetic permeability measurement has been introduced. The use of magnetized probe in the SGT inspection decreases the S/N ratio when the ferromagnetic phases of PVC's are not saturated by the built-in permanent magnetic of probe. The magnetic phase created in the SGT can be selectively separated by permeability sensor.

REFERENCES

[1] T. Sakamoto, et al., Journal of the Japanese Society for Non-destructive Inspoection, Vol. 42, No.9, 1993
[2] S. Takahashi, Y.Sato, Y. Kamada, T. Abe, Journal of Magnetism and Magnetic Materials, Vol. 269, p. 139, 2004