Remote Field Eddy Current Measurement of the Neighboring Tube Positions in CANDU reactor.

H.K. Jung [a], Y.C. Seo [a], D.H. Lee [b]
[a] Korea Atomic Energy Research Institute (KAERI), PO Box 105, Yusong, Daejon 305-600, Korea
[b] School of Mechanical Engineering, Sungkyunkwan University, Suwon, 440-746, Korea

1. Introduction

The fuel channels of a CANDU reactor are composed of pressure tubes (PT) and calandria tubes (CT). In addition to fuel channels, there are some other tubes horizontally or vertically installed for the safety operations. Liquid Injection Nozzle (LIN) tubes are installed horizontally and may encounter a contact from CT sagging. The LIN tubes are placed schematically as shown in Fig. 1. The sag measurement of cross aligned zirconium tubes for preventing contact is a safety concern in a CANDU reactor. [1, 2]

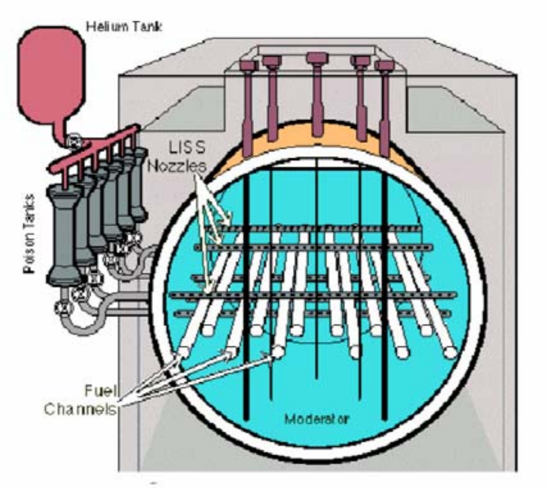

Figure 1. Schematic arrangement of fuel channels, LIN and vertical tubes.

In this study, we have evaluated the remote field eddy current (RFEC) technique for the gap measurement between the CT and LIN in a field inspection. The RFEC signals have also been identified based on the internal structure position.

2. Experiment and Results

2.1 Laboratory experiment

Under the condition of inserting the coil probe into the fuel channel, it is necessary to analyze the test conditions considering the electromagnetic field near the fuel channel. [3] The typical result for the contact condition is shown in Fig. 2. The exciter coil was fed a sinusoidal signal by a function generator to generate a voltage of 1 V at 1 kHz. The output signal was sent to the receiver coil and to a Stanford Research System SR 550 pre-amplifier and SR 830 lock-in amplifier. A LabView program controlled the RFEC data acquisition process and recorded the data, such as amplitude and phase of the RFEC signal. When the RFEC probe moved along the tube, a change of amplitude and phase angle occurs and the LIN signal is generated. As the sag of the CT increases, the gap between the CT and LIN tube decreases. As the gap is closer, the signal amplitude is higher exponentially in Fig. 3 which is called as the calibration curve. This is a high sensitivity method enough to alarm a contact situation.

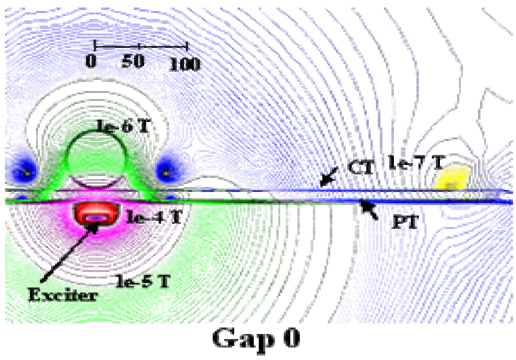

Figure 2. Electromagnetic field for the contact condition between the fuel channel and LIN.

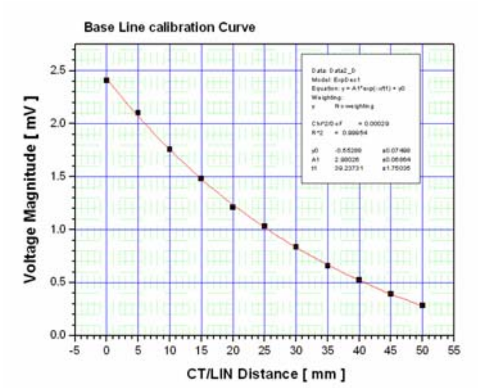

Figure 3. Calibration Curve for RFEC Measurement.

2.2 Field test and signal identification

The RFEC signals of the LIN tubes were acquired in Wolsung unit 3 during the fuel channels inspection. The LIN tubes were detected together with some vertical tubes in Fig. 4.

To identify the signals, we referred the design drawing and confirmed the number and position of vertical reactivity units. From the signal identification, the positions of LIN tubes were measured from the encoder readings. The gaps between CT and LIN were determined using the calibration curve. The results are 44 to 54 mm for LIN-4, 5 and 6 which show no sagging problem due to the short operation time.

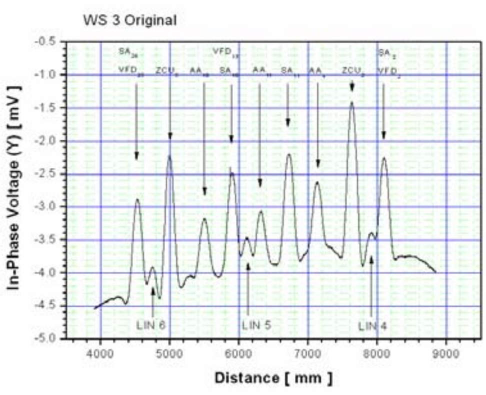

Figure 4. RFEC Signals from the field test.

3. CONCLUSIONS

The RFEC technique for detecting the LIN tube was successfully applied in CANDU fuel channel. The gap of a LIN tube showed an inverse exponential relationship with the RFEC signal amplitude as the calibration curve in the mock-up facility.

For the RFEC field signals of the fuel channels, the signals from the vertical tubes as well as the LIN tubes could also be detected. Therefore it is suggested that the RFEC technique is a useful tool for measuring the position of the neighboring tubes near the fuel channels.

Acknowledgements

This work was supported by the nuclear safety research project, as a part of long-term nuclear research program by the Korean Minister of Science and Technology.

References

1. T.R. Kim, et al, “Ultrasonic Measurement of sagging of Calandria Tubes and Liquid Injection Shutdown System Tubes Using Newly Developed Device” , 15th World Conference of NDT, Rome, Oct. 15-21, 2000.
2. D.L. Atherton, S. Sullivan, "The Remote Field Through-Wall Electromagnetic Inspection Technique for Pressure Tube", Materials Evaluation, 1986, 44, 1544-1550.
3. D.H. Lee, H.K. Jung, Y.M. Cheong, H. Huh, Y.S. Lee, “Electromagnetic Field Analysis and RFEC Signal Modeling for Gap Measurement between Liquid Injection Nozzle and Nuclear Fuel Channel”, 2004 Spring Conference of KSNT, Busan, May 14-15, 2004.