Electromagnetic Testing Rod Cluster Control Assembly in Pressured-Water Reactor Power Plant

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1. Introduction

In pressured-water reactors (PWRs), control rods are used in the control and emergency stop operations of the reactor core. The control rods include an absorbing substance consisting of Ag(80%)-In(15%)-Cd(5%) in an STS304 tube, which has an external diameter of 9–11 mm and a thickness of 0.47–0.49 mm. Further, the tube end is welded using an end plug. If the absorbing substance falls into the reactor core owing to the existence of a faulty rod, the reactor will become unstable. Usually, a rod cluster control assembly (RCCA) consists of 16 (14 × 14 type), 20 (16 × 16 type), or 24 (17 × 17 type) control rods. An RCCA is supported by eight guide cards located at the upper-side of the reactor core, which are visible after the nuclear fuel is withdrawn during the operation of the nuclear reactor. The vibrations of the guide cards caused by the flowing coolant in the reactor core result in fretting wear of the control rods. Further, the sliding wear becomes apparent when the RCCA moves along the guides for reactivity control. In addition, intergranular stress corrosion cracking (IGSCC) often occurs around the welded parts of the end plug because of the neutron irradiation [1]. Thus, the nondestructive testing of the RCCA is necessary.

Several eddy current testing systems have successfully developed such as encircling bobbin probe system and multi-array (8×1) pancake probe system [2, 3]. However, they are limited in scan resolution due to limitation of sensor elements. Therefore, this paper presents an inspection system using Hall sensor array which has higher spatial resolution. The actual 17 × 17 type RCCA will be tested, which was produced artificial cracks. Totally 24 sensor probes will be used and each sensor probe has 16 Hall sensor elements.

2. Experimental Setup & Results

Fig. 1 shows the inspection stage and a Hall sensor array probe. The sensor probe has 16 Hall sensor elements arrayed in 11.2 mm – cylindrical supporter at an interval of 22.5^{o}. The bobbin coil has 168 turns in 13 mm width using 0.1 mm copper wire. The inner diameter of the bobbin coil is 13.8 mm. The bobbin coil is assembled outer the Hall sensor array.

When an alternating current is supplied to the coil, eddy current will be distorted and concentrated around flaws in the control rods specimen. This distorted eddy current will produce an alternating magnetic field which radial component of this magnetic field could be measured by the Hall sensor array. Thus, the flaws could be detected.

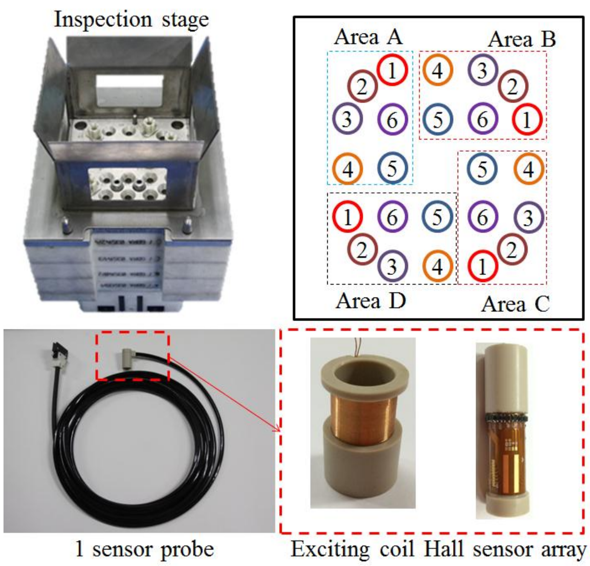

Fig. 1 Inspection stage for 17 × 17 type RCCA and a Hall sensor array probe

The 17 × 17 type RCCA is a set of 24 control rods, which is divided into four groups (A~D) as shown in Fig. 1. There are 24 sensor probe will be setup in the inspection stage for inspecting the control rods by a switching circuits. At each switching process, signal of one sensor probe in the each group will be processed by filters, amplifiers, root-mean-square circuits, and converted to digital by an A/D converter [4]. Totally, 64 sensor channels will be transferred to the computer at each switching.

Fig. 2 shows the experimental results in waterfall graph of short circumferential grooves and sliding wears. The control rods have diameter of 9.68 mm and 0.47 mm thickness of cladding tube (STS304). The flaws depths are from 10%~100% of the tube thickness as indicated in the left side in each figure. The current supplied to the coil was 200mA-15kHz. The results show that all the short circumferential grooves from 10% depth were inspected.

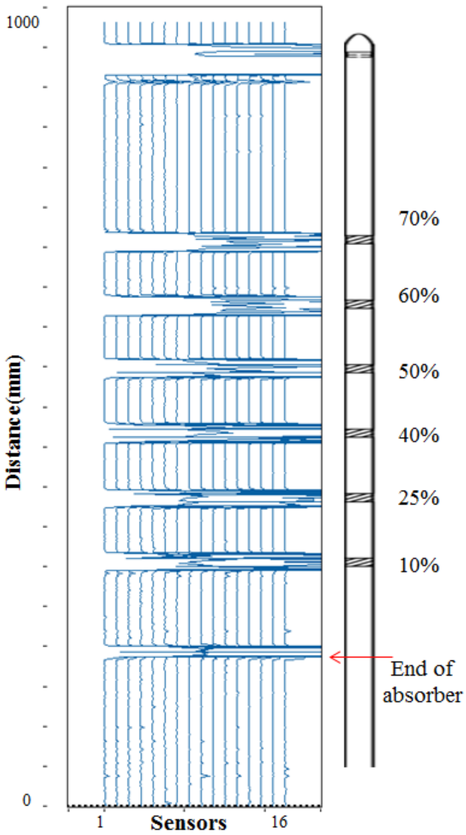

Fig. 2 Inspection results of short circumferential grooves

Acknowledgment

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