Transactions of the Korean Nuclear Society Autumn Meeting
Busan, Korea, October 27-28, 2005

In-Bay Dimensional Measurements of Post-Irradiated CANDU Fuel Bundle

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1. Introduction

This paper intends to provide the results of dimensional measurements of post-irradiated (PI) CANDU fuel (37-element) bundle [1]. The in-bay measurements of eight PI bundles are performed in spent fuel reception bay of Wolsong-3 reactor by the measurement system [2]. The detail measurements are performed for the outer rod profile (including the bearing pad), the diameter of bundle, the bowing of bundle, the rod length and the surface profile of end plate (waviness). Eight test bundles had been located at the 11^{th} and the 12^{th} bundle positions of four fuel channels (O-07, Q15, G-13, D-06). Four channels are selected in the proposed high power and low power test channels [3], where the in-air measured fresh bundles [4] are planned to be loaded for the purpose of the estimation of the integrity of fuel bundle in two-phase flow in the CANDU-6 fuel channel [5]. The PI bundles have been cooled for a 6 months in spent fuel reception bay of Wolsong-3 reactor after they were discharged on 22 April 2004 when the in-air measured fresh bundles were loaded in the channels. The results are compared with the design values [1] because the in-air measurements were not performed for these bundles prior to loading in the reactor by using the same equipment.

2. Measurement procedure

The setup of the measurement system is needed to calibrate all the LVDT sensors and compensate the mechanical error of the system in-bay as well as in-air. The in-bay measurements of PI CANDU bundle are checked by the quality assurance (Q/A) list, which requires the detail test procedure to ensure the reliability, the repeatability and the consistency of the test. The measurements are performed by the following test procedures ; lifting the PI bundle from the tray, checking the serial number of bundle by the underwater camera (R981 model), installing the bundle on the system, setting the DAS (data acquisition system) program of the system, checking the position of LVDT, aligning the bundle, measuring the endplate waviness and the rod length, saving the measured data on the disk, measuring the rod profile, saving the rod profile data and all the graphic files on the disk, and then performing the visual inspection by the underwater camera. All procedures are controlled remotely by the DAS program, while the bundle is installed manually on the system by bundle lifting tool [1].

3. Results and discussion

All the PI bundles were manufactured by KNFC Q/A procedure for satisfying the reference design [1] prior to loading into the reactor. Figure 1 shows the outer rod profile including the surface of bearing pads for the PI bundle, which was located at the 12^{th} bundle position in the O-07 channel. The average height of bearing pads is measured by about 1.26mm～1.28mm for eight PI bundles. The maximum height of bearing pads is less than 1.3582mm (maximum design value of 1.385 mm for fresh bundle) for all the PI bundles. The PI bundle had the sliding of a maximum distance of 15.7 m on the pressure tube and 6.7 m on the liner tube due to the on-power refueling features of CANDU reactor [1]. It requires that the wear of bearing pads should be less than 0.25 mm and the minimum height of the worn bearing pads should be greater than 0.87 mm to provide an adequate element to the pressure tube clearance for heat transfer. The results are regarded as satisfying these two requirements of bearing pad height for the PI bundle although the wear of bearing pad could not be estimated because the measurements were not performed for

these bundles prior to loading in the reactor by using the same equipment. Figure 2 shows the profile of endplate with a periodic waviness at the welding points on the ribs. Unfortunately, the right LVDT could not scan data between 260 to 360 degrees due to the insignificant mechanical problem. Anyway, the maximum waviness of PI bundle is measured by about 0.4 mm (0.14 mm for fresh bundle). In this study, the waviness is defined as a deviation from the reference LVDT position of each ring. Rods may be bowed radially outwards/inwards (Figure 1) or be S-shaped. Based on the profiles of 18 outer rods, the bowing of bundle is examined at the positions of 1/4, middle and 3/4 planes as shown in Figure 3. The bowing at the middle plane is slightly greater than other positions. The maximum bowing of PI bundles for high power channels (G-13, Q15, O-07) is measured by about 0.80mm～2.50mm. But, the bowing of PI bundle for low power channel (D-06) is similar to that of the fresh bundle(less than 0.50mm). The S-shaped bowing, where the direction of bowing at 1/4 plane is opposite to that of bowing at 3/4 plane, is not found in these PI bundles. It is achieved through these tests that the technology of the in-bay measurement system is verified by obtaining the first in-bay precise measurement data of PI bundle in the world.

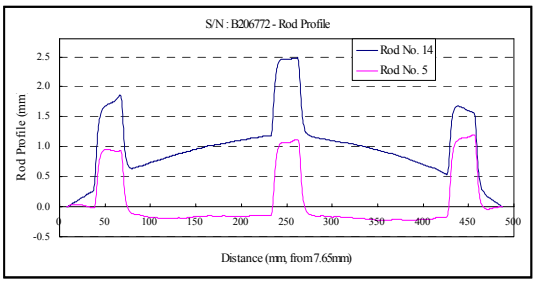

Fig1 Outer Rod Profile of B206772 PI Bundle

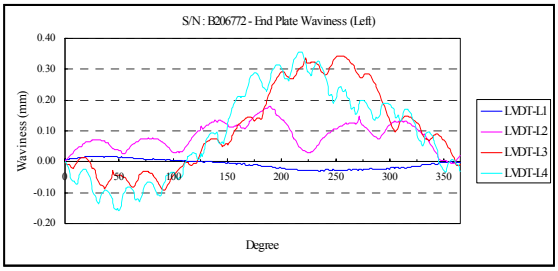

Fig.2 Waviness of B206772 PI Bundle

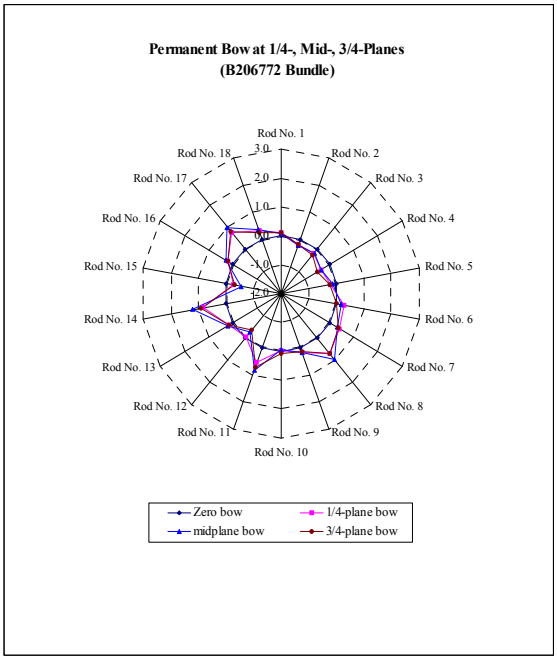

Fig.3 Bowing of B206772 PI Bundle

ACKNOWLEDGEMENTS

This work has been carried out under the Nuclear Research and Development Program of the Korea ministry of science and Technology.

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