Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 10-11, 2007

PLUS7^{TM} Growth Performance after Three Cycle Irradiation

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1. Introduction

Four(4) lead test assemblies (LTAs) for an advanced nuclear fuel, PLUS7^{TM}, which has firstly been developed in Korea in 2002, was irradiated in cycle 5, 6 and 7 at Ulchin unit 3. The LTAs were reached to fuel assembly burnup of 53,214 MWD/MTU, the maximum fuel rod average burnup of 58,139 MWD/MTU, and the duration of irradiation of 1406 effective full power days (EFPD). Poolside fuel examinations such as visual inspection and accurate measurement were performed in spent fuel pool to confirm the irradiation performance of the advanced fuel after each cycle[1,2,3]. Measurement items for the assembly performance due to irradiation were assembly growth, assembly bow, assembly twist, top nozzle-rod gap (for rod growth evaluation), rod-rod gap (for rod bow evaluation), grid width increase. As the effects of deformation, i.e., bow or twist due to irradiation were negligible, the irradiation growths of assembly, rod and grid width are described in this paper. As the result of evaluation related to irradiation growth, PLUS7^{TM} was irradiated successfully without any abnormal phenomenon.

2. Influences by Irradiation Growth

2.1. Fuel Assembly Length

Fuel assemblies in reactor are supported by the lower support structure on the bottom and the upper guide structure on the top not to be lifted off due to coolant flow. The excessive growth of assembly can contact to reactor internals solidly and then can cause assembly bow, and finally can change flow channel and prevent control rods from inserting guide tubes. Assembly length change in reactor is represented by eliminating compressive creep due to hold down force from irradiation-induced guide tube growth. In addition, the grid sliding force contribution due to rod growth can be added to assembly growth. In the meanwhile, irradiation growth, hydrogen absorption by structural corrosion, irradiation relaxations of hold down spring force and grid spring/dimple force are time dependent parameters. It is, therefore, necessary to get a lot of database related to irradiation to simulate and predict these fuel assembly growths.

2.2. Fuel Rod Length

Rod irradiation growth is represented by adding assembly growth mentioned above to top nozzle flow plate-rod gap decrease. In case that there is no gap between top nozzle and rod due to excessive rod growth, rod bow phenomenon can occur.

2.3. Spacer Grid Width

Spacer grid has important functional requirements to keep uniform flow channel and to prevent excessive rod vibration and wear. Excessive grid growth can cause an impact on assembly loading and unloading in reactor.

3. Measurement of Irradiation Growth

3.1. Fuel Assembly Length

Before measuring each elevation of the assembly, a calibrated measuring tape is matched to an encoder. A measuring tape of 10m in length is installed on the center of the assembly front face, and then 6 m in length covering the entire assembly by an increment of 40 cm is matched to an encoder. Each elevation of the assembly read from an encoder is converted to real length by scaling factor between a measuring tape and an encoder. Fig. 1 shows the measurement equipment on the UT elevator and a typical PLUS7^{TM} LTA grappled by the handling machine.

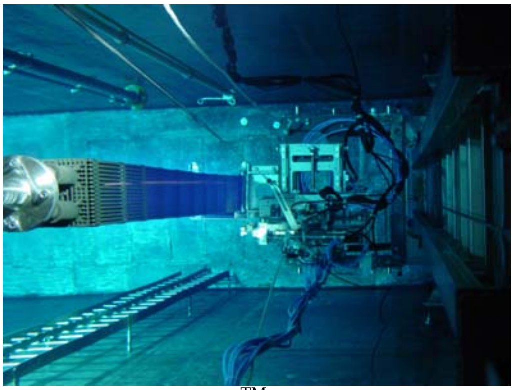

Fig. 1. Typical PLUS7^{TM} LTA and Measurement Equipment

3.2. Fuel Rod Length

As the fuel rods within PLUS7^{TM} assembly are positioned on the bottom nozzle, rod growth is represented by adding assembly growth to top nozzle flow plate-rod gap decrease. To evaluate top nozzle-rod gap, a videotape is recorded including top nozzle and top of fuel rod. By analyzing the recorded videotapes with a standard of a distance from top nozzle to rod measured in section 3.1 the outer rod- top nozzle gap can be obtained.

3.3. Spacer Grid Width

Before measuring the width of the grids supporting rods, the measuring equipment with LVDT is calibrated using the standards larger and smaller than the grid width. When the equipment contacts grids, the root of the equipment jaw is rotated left or right to contact the grid face. After the root contacts the grid face, a minimum value of grid width is measured by twisting the jaw up and down. Finally, the minimum value is compensated to the value at room temperature.

4. Evaluation of Irradiation Growth

4.1. Fuel Assembly Length

Fuel assembly growth which is calculated by eliminating the as-built data from the length after irradiation, is used to evaluate the compatibility to reactor internals and the interface between top nozzle and rod. Fig. 2 shows the growth increments of each cycle. From the figure, fuel assembly growths of PLUS7^{TM} LTAs were below design upper bound and they have still enough design margins in view of fuel assembly growth.

4.2. Fuel Rod Length

Rod growth is used to evaluate top nozzle-rod gap in liaison with assembly growth. Top nozzle-rod gap should be positive for the fuel life. As shown in Fig. 3, PLUS7^{TM} has enough design margin within the design limit from the top nozzle to rod gap point of view.

4.3. Spacer Grid Width

Excessive grid width can interrupt fuel loading and unloading. Even though the grid width is designed within the assembly pitch, the accumulated width of grids on row or column in reactor should be compared with the specified core shroud width in case that the expected grid width at end of cycle exceeds the assembly pitch. As shown in Fig. 4, PLUS7^{TM} is within the design limit from the spacer grid width point of view.

5. Conclusion

PLUS7^{TM}, the first advanced fuel developed in Korea, completed 3 cycles of irradiation in Ulchin unit 3. A result of the evaluation of the measurement data acquired from the poolside examination concludes as the following:

1) The effects of the deformation, i.e., fuel assembly bow, assembly twist and rod bow, etc. due to irradiation are negligible.

2) Even though the fuel growths such as fuel assembly growth, fuel rod growth and spacer grid width growth are increasing after each cycle, they have still enough margins.

It can be concluded that PLUS7^{TM} was successfully irradiated for three cycles in reactor.

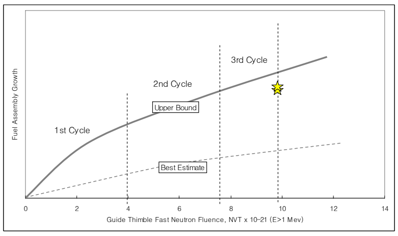

Fig. 2. PLUS7^{TM} Fuel Assembly Growth

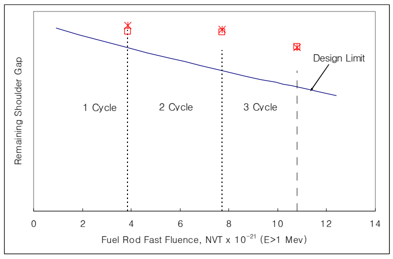

Fig. 3. PLUS7^{TM} Top Nozzle-Fuel Rod Gap

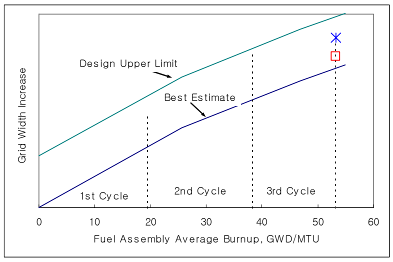

Fig. 4. PLUS7^{TM} Spacer Grid Width Irradiation Growth

ACKNOWLEDGEMENT

This study was carried out under the project "Development of the Major Design Codes for a Nuclear Power Plant" which was funded by the Ministry of Commerce, Industry and Energy.

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