Irradiation Growth Performances of Advanced Fuels in Nuclear Reactors

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1. Introduction

The irradiation performances on three types of advanced fuels, PLUS7™, 16ACE7™, and 17ACE7™ are being verified in Korean reactors. The PLUS7™ is for Optimized Power Reactor-1000 MW class (OPR1000) and Advanced Power Reactor-1400 MW class (APR1400) while the 16ACE7™ and 17ACE7™ are for 16x16 Westinghouse type plant in Kori 2 and 17x17 Westinghouse type plants, respectively. The design targets were to get the batch average burnup up to 55 GWD/MTU, to obtain over 10% thermal margin increase, to improve neutron economy, to improve the mechanical performances such as higher seismic capability, higher debris or grid fretting wear resistance, prevention of incomplete rod insertion and spring screw failure issue, etc. and to improve of manufacturability.

For the PLUS7™ lead test assemblies (LTAs), three times of poolside examinations (PSEs) after each cycle, fuel rod inspection after discharge and the examination in hotcell for fuel rod were completed and the hotcell test on skeleton was left. For the 16ACE7™, three times of assembly-wise examinations after each cycle and fuel rod inspections after irradiation in the pool side were completed. For the 17ACE7™ twice of poolside examinations (PSEs) after each cycle were completed. The in-reactor verification for these two kinds of advanced fuels will follow the similar procedure as that for the precedent, PLUS7™.

The irradiation performance parameters for assembly-wise examination were assembly/rod/grid growths, assembly/rod bows, assembly twist, rod diameter, and cladding oxidation, etc [1]. The marginal one among the irradiation performance parameters were assembly growths even though it still has the design margin. The excessive assembly growth can induce the interference to the reactor internals to support the fuel assemblies, then have an effect on assembly bow and eventually injure the mechanical and thermal integrity. In this study, the measurement and evaluation on the assembly growth characteristics are described.

2. Calibration and Measurement

Measurement of assembly positions in the poolside is accompanied by the several restrictions such as time limitation and inaccuracy due to the variation of temperature, etc. Sometimes, another error may be caused by using a measuring tape to measure the assembly positions in this environment. It is very economical to use an encoder after calibration. In this section, the piece-wise calibration of encoder using a calibrated measuring tape and the measurement of the specified assembly positions using the calibrated encoder are described.

2.1 Calibration of ten meter tape and encoder [2]

First of all, a measuring 10 m tape is calibrated using the length standard at the room temperature (20 degree centigrade) at an agency for calibration. And a record sheet reading the graduations by 40 cm is issued. Table I shows the typical calibration record on a measuring 10 m tape.

Table I. Calibration values of a 10 m measuring tape (typical)

Nominal graduation of 10 m measuring tape	Calibrated graduation value
6000	6000.4795
5600	5600.5223
5200	5200.3419
…	…
800	800.4939
400	400.3196

In the poolside, a measuring tape is installed vertically at the distance of 425 mm from the camera which is the same distance between assembly and camera. In the meanwhile, one hand of an encoder is hooked on the measurement equipment and the other hand fixed on the poolside. The encoder transmits data for movement distance of the equipment. The encoder values do not indicate the real length because it is not installed vertically. The encoder should, therefore, be calibrated using a calibrated measuring 10 m tape by considering the temperature of pool. Fig. 1 shows the typical pictures for calibrating an encoder using a calibrated measuring 10 m tape and Fig. 2 compares a values indicated by a calibrated measuring 10 m tape and an encoder typically.

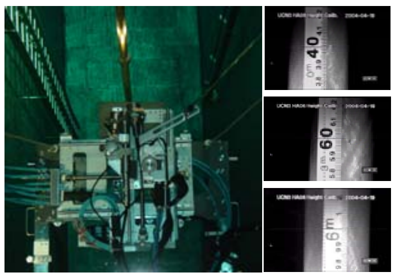

Fig. 1. Piecewise calibration of an encoder using a calibrated measuring 10 m tape

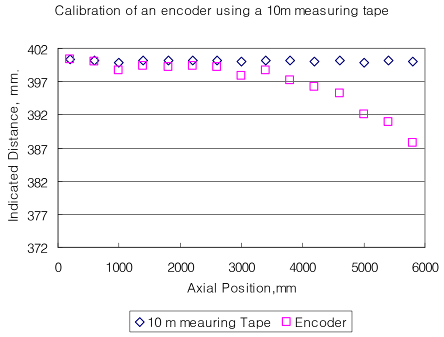

Fig. 2. Piecewise calibration of an encoder using a calibrated measuring 10 m tape (typical)

2.2 measurement of assembly growth

After calibrating an encoder using the calibrated rule, the specified elevations of assembly are measured using the encoder as shown in Fig. 3. Then, the values obtained by the encoder are converted to real values by interpolating one-to-one correspondence relationship between the measuring tape and the encoder linearly.

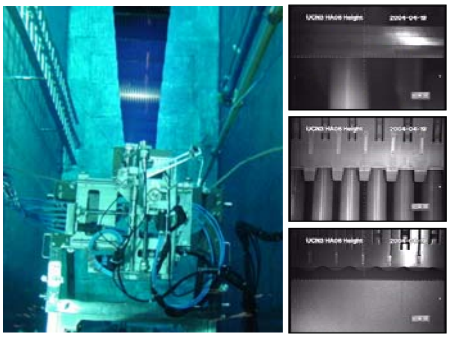

Fig. 3. Measurement of each elevation using an encoder

3. Assembly growth characteristics

The excessive assembly growth can induce the interference to the reactor internals which support the fuel assemblies, then have an effect on assembly bow and eventually injure the mechanical and thermal integrity. It is known that the fuel assembly growth in reactor is dependent on guide tube irradiation, guide tube compressive creep by holddown spring force, and holddown spring force relaxation. The irradiation effect can be smaller due to fewer irradiation exposed beyond the active region and the strong holddown spring force at the early time can induce the larger compressive creep while the small force due to spring relaxation near the end of life can induce the smaller compressive creep.

Fig. 4 compares the accumulated grid span growth along the elevation on three types of advanced fuels. For PLUS7^{TM}, the compressive creep term is dominant due to the higher spring force during the cycle 1 and then the relatively smaller growth was happened. After cycle 2, the spring force was relaxed and the irradiation growth term in SRA material is dominant, and then the assembly is grown continuously.

For 16ACE7^{TM} and 17ACE7^{TM}, the irradiation induced growth is dominant due to the comparatively smaller spring force during the cycle 1 and then the relatively greater growths were happened. After cycle 2, the spring force was comparatively higher as the assemblies grow and the compressive creep term is dominant, and then the assembly growths are saturated.

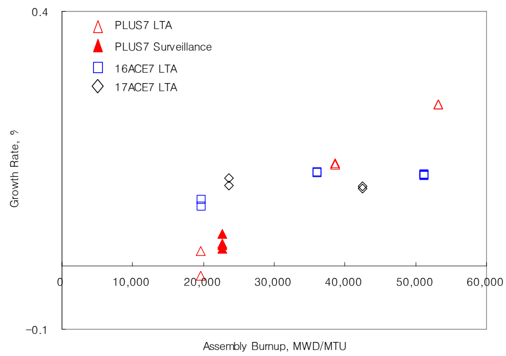

Fig. 4. Comparison of the accumulated grid span growth rates for advanced fuels

4. Conclusions

The excessive assembly growth can induce the interference to the reactor internals to support the fuel assemblies, then have an effect on assembly bow and eventually injure the mechanical and thermal integrity. The measurement related to assembly growth and the growth evaluation results on the advanced fuels irradiated in Korean reactors were described. The growth measurement using encoder was reasonable by considering the uncertainties. The comparison of the assembly growth performances shows design-dependent. The PLUS7^{TM} having initially big holddown spring force has comparatively lower growth during 1st cycle and grows continuously during 2nd and 3rd cycles due to spring force relaxation

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