An Investigation on Irradiation-induced Grid Width Growth in Advanced Fuels

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1. Introduction

The spacer grids for fuel assembly are fabricated from preformed Zircaloy or Inconel strips interlocked in an egg crate fashion and welded or brazed together. The spacer grid is the important component to maintain the fuel rod array by providing positive lateral restraint to the fuel rods but only frictional restraint to axial fuel rod motion.

To improve economy and safety aspects, advanced nuclear fuels of PLUS7, 16ACE7 and 17ACE7 were developed. The former is for Optimized Power Reactor of 1000 MWe (OPR1000) and Advanced Power Reactor of 1400 MWe (APR1400) and the latter two are for 16x16 and 17x17 Westinghouse type reactors, respectively. The material for top and bottom spacer grids on these advanced fuels are Inconel and the mid grids are Zirlo patented by Westinghouse.

For neutron economy, the fuel assemblies are arranged very closely and the gaps between assemblies are kept to around 1 mm based on the worst case. The Zirconium-based alloys grow during irradiation in reactor. The large growth may cause some difficulties in loading and unloading fuel assemblies during refueling outage in reactor. The severe growth may cause some problems that fuel assemblies may be stuck within the core shroud and a modification of loading pattern is required. In addition, the grid growth with grid spring relaxation may cause different rod vibration behavior and results in the different wear mechanism.

The grid width growth on the advanced fuels were predicted by using the growth models before the irradiation in reactor and were examined using lead test assemblies (LTAs) after each cycle in Ulchin unit 3 and Kori units 2&3, respectively. To reconfirm irradiation performance results using LTAs, the additional examinations are being performed through the surveillance programs on the commercially supplied fuels in Yonggwang unit 5 and Kori units 2&4 [1,2]. It is investigated on this study whether the grid widths on the advanced fuels meet their criteria and the predicted models describe the measured data well.

2. Poolside Examination (PSE)

In this section, the devices and methods to measure grid width of the irradiated fuel assembly in poolside are described.

At first, an LVDT (Linear Variable Differential Transformer) device for grid width measurement is fabricated on X-Y table that can be remotely controlled and then is installed on the elevator as shown in Fig. 1. The LVDT is calibrated by using the standard hanged on grapple as shown in Fig. 2(a). The four width values are obtained as a function of voltage and a curve is obtained. Every mid grid is measured by using LVDT shown in Fig. 2(b) and the grid widths are obtained by the interpolation method. After the measurement of grid width, LVDT calibration using the standard is repeated for verification of LVDT calibration values. When the difference between LVDT calibration and LVDT verification provide the acceptable levels, the measured grid widths are obtained.

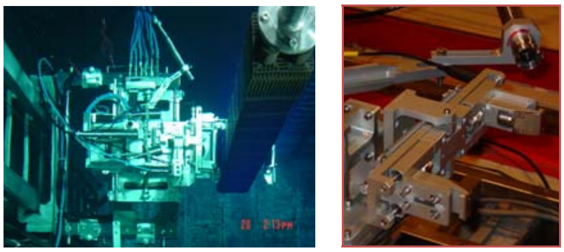
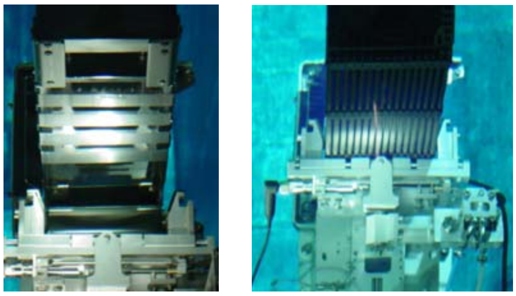


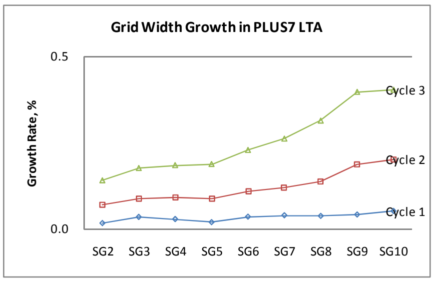
Fig. 1. Setup of LVDT for Grid Width Measurement



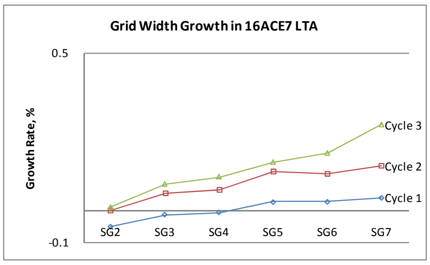
(a) Calibration of LVDT (b) Measurement of Mid Grids
Fig. 2. Measurement of Mid Grid Width

3. Evaluation of Grid Width Growth

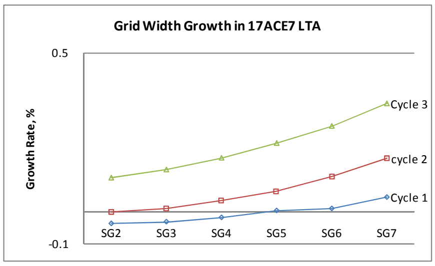
The grid widths are measured at four faces on all mid grids. These values are measured three times and then averaged. Fig. 3 shows the face averaged growth at the grid locations on three advanced fuels. The grid widths increase as a function of burnup and the grids at the upper region have more increase than those at the lower region. The grids for 16ACE7 and 17ACE7 on the lower region were decreased during cycle 1 irradiation due to the transversely stamped grid straps in comparison to longitudinally stamped strips at PLUS7 grids. The grid widths at the upper region grew larger than those at the lower region obviously at the higher burnup.



(a) PLUS7 LTA (KU3HA06)



(b)16ACE7 LTA (KK2W94)



(c) 17ACE7 LTA (KK3T93)

Fig. 3. Axial Distribution on Grid Width Growth (Face Averaged)

If the grid width exceeds the assembly pitch, it should be checked whether the sum of the expected grid widths in each row exceeds the corresponding shroud width or not. If exceeded, assembly arrangement in loading pattern for the next irradiation should be modified not to exceed the shroud width. Fig. 4 shows the maximum grid widths based on the worst case for several types of assemblies as a function of burnup. Zirlo grids and Zry-4 grids stamped transversely satisfy their grid width criterion while Zry-4 grids stamped longitudinally exceed its criterion and another action considering the second step or assembly rearrangement can be required for higher burnup.

Since the grid width growth by the previous methodology may under-predict, the methodology considering corrosion as well as irradiation based on the measured database in Westinghouse was developed. Fig. 5 compares the predicted values by the current methodology based on PSE data on the grid width growth rates for three advanced fuels. The model for 16ACE7 grid width growth predicts the measured values conservatively while the grid width growth model for PLUS7 under-predict the measured values still. The measured values for 17ACE7 shows the different trend comparing to the predicted line by the model. The careful reviews of the model for these two fuels are required.

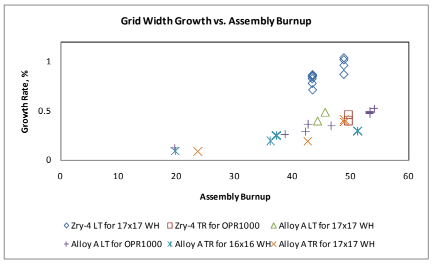


Fig. 4. Maximum Grid Width Growth

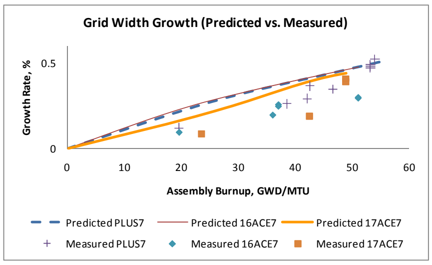


Fig. 5. A Comparison between Grid Width Growth Prediction and Measured Values

4. Conclusion

The grid width performance for three advanced fuels was verified using LTAs in reactors and is being confirmed through the surveillance program during the commercial supply. It was found from PSE that the mid grids grow as a function of burnup and the mid grids at the upper region grow larger than those at the lower region. As all mid grids for advanced fuels meet their criteria, the second action like loading pattern change is not required under the current burnup level. However, the minor correction on the grid growth models for PLUS7 and 17ACE7 is required after the further examinations.

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