A Study on the Growth of Grid width for the Manufactured Strap Conditions

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1. Introduction

The grid, which is located in the nuclear fuel assembly, is influenced by the neutron irradiation. The mid-grid envelope has to take into account the material growth during burn-up. Because the material of mid-grid strap made of the zirconium based alloy, and the Zr alloy grows due to irradiation and hydrogen pickup [1]. The excessive deformation of the grid width from the material growth can lead to the defect, which occur due to the tear at grid-to-gird interface for fuel assembly hang-up during core loading and unloading. For this reason, the grid is designed considering grid-to-grid gap. In this research, the analysis, prediction and evaluation is performed for the grid growths according to the materials of grid straps. The materials are classified by directional properties on rolling process and tin content in manufactured strap.

2. Grid Growth Equation and Growth Requirements

Generally, the widths of irradiated grids are changed due to hydrogen pickup and irradiation growth of material. The grid growths according to materials of grid straps are different because the material growth factors are different. The factors are the hydrogen content, rolling direction, tin content and burn-up. The grid growth equation is as follows:

$$\%\varepsilon = F_1(H) + (1 - f_i) \times F_2(NVT) \qquad (1)$$

where, $\%\varepsilon$ is percentage of growth and F means function for growth factor. H is hydrogen content of Zr alloy material and F_1 is the function of hydrogen pickup. f_i is Kearns number which is material coefficient for texture and tin content and the classification of the used straps in this research is summarized in Table 1 [2]. *NVT*, which is mean fast fluence, is a characteristic equation on fuel type and depends on burn-up. F_2 is the function of *NVT*.

Table I: Classification of the manufactured strap

Content	Mark	Character
Direction(Texture)	0°	Rolling direction
	90°	Transverse direction
Zr Alloy type	Alloy I	General alloy
	Alloy II	Low Tin alloy

The requirements for growth of irradiated grid exist to prevent the tear of grid during loading and unloading of fuel assembly.

[Requirement 1]
The growth of Zr alloy grid width is less than or equal to 0.048 inches.
[Requirement 2]
The minimum cold grid-to-grid row average gap for all grids is more than or equal to 0.020 inches.

The grid-to-gird gap is 0.048 inches which is calculated the difference between the nominal fuel assembly pitch and grid envelope. In other words, the growth of grid width is limited to grid-to-grid gap. The criterion value 0.020 inches is to provide sufficient margin for unloading of the core.

3. Measurement of the Grid Width

The grid widths were measured during the Pool-Side Examinations (PSE). All mid-grids were measured in each fuel type, and 4 points were measured in each grid. The measured fuel A is manufactured using the strap with Alloy I and transverse direction, and the measured fuel B is manufactured using the strap with Alloy II and transverse direction. Fig. 1 is schematic of measurement method of the irradiated grid width.

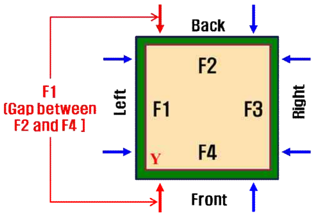
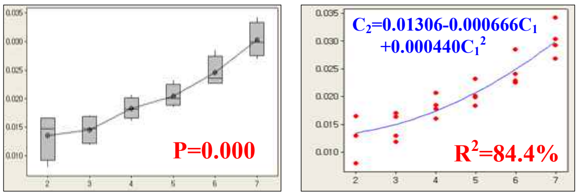


Fig. 1. Schematic of measurement method of grid width

4. Analysis and Prediction for the Grid Width

4.1 Analysis on growth for Grid Locations and Measured points

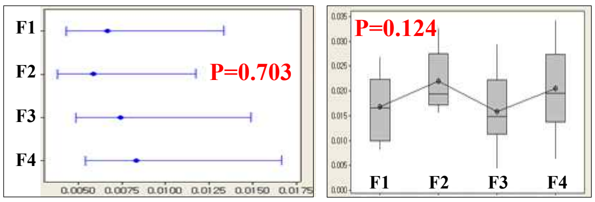
Each grid is located at different height position in fuel assembly and the grids have different thermal effects for the positions. The growth of grid width is influenced by temperature, so the analysis on the grid height locations should be necessary. The variance analysis and the regression analysis were performed to evaluate the growths for the each located grid and the analysis results for growth of grid width are shown in Fig. 2. It is known from these analysis results that the difference of growth for grid locations exist; the P-value is 0.0 from variance analysis result, and the regression curve is significant because the value of R-square is 84.4% [3]. From these analyses, top mid-grid of each fuel type is used in analysis and prediction of grid growth for each manufactured strap condition.



(a) Variance analysis (b) Regression analysis

Fig. 2. Analysis results of growth for the grid locations

The analysis on the measured points was performed using the homogeneity of variance test and the variance analysis. The results are shown in Fig. 3. The measured points are not significant because the P-value from result of homogeneity of variance test is 0.703 and the P-value from variance analysis result is 0.124 [3]. In other words, it is known that the widths of measured points are similar. From this, the average of widths can be used in the analysis, prediction and evaluation of the growth of grid width.



(a) Homogeneity of variance test (b) Variance analysis

Fig. 3. Analysis results of growth for the measured points

4.2 Analysis on growth of top mid-grid width for each fuel type

Table II: Maximum growth of grid width for each strap condition

Fuel type	Alloy Type	Direction	Burn-up (MWD/MTU)	Max. growth (in)	Difference (in)	Measurement / Prediction
Fuel A	Alloy I	0°	51,137	0.0318	-0.0162	Prediction
	Alloy I	90°	51,137	0.0238	-0.0242	Measurement
	Alloy II	0°	51,137	0.0278	-0.0202	Prediction
	Alloy II	90°	51,137	0.0178	-0.0302	Prediction
Fuel B	Alloy I	0°	48,878	0.0532	0.0052	Prediction
	Alloy I	90°	48,878	0.0445	-0.0035	Prediction
	Alloy II	0°	48,878	0.0453	-0.0027	Prediction
	Alloy II	90°	48,878	0.0343	-0.0137	Measurement

The grid widths of one strap condition for each fuel type and measured during PSE. The maximum growth of the widths is calculated from the measured data and the dimension of grid envelope. The growths of the other strap conditions are predicted from Eq. (1) and the growths of the measured grid. The growths for each strap condition and fuel type are shown in Table II. One case should not be used to produce the grid because the maximum growth is larger than criterion value; the growth of fuel B-Alloy I-0° direction is 0.0532 inches and the criterion value is 0.048 inches from requirement I. From predictions and measurements of two fuel types, the best strap condition is the Alloy II-90° direction strap.

The maximum average gap criterion between grids in a core is that the gap is more than or equal to 0.020 inches from requirement II. The gaps are reduced when the width grids are increased due to hydrogen pickup and irradiation. Table III shows the prediction values of average gap for each power plant and fuel B's are used in these plants. These prediction values are calculated using the measured average growth of grid width and each average burn-up of fuel assembly in core. Alloy I-0° direction strap should not be used at these power plants from this prediction result because the average gaps of two plant are smaller than criterion value 0.020 inches. From predictions of two plant types, the best strap condition is the Alloy II-90° direction strap.

Table III: Prediction of average gap for each strap condition

Plant type	Alloy type	Direction	Avg. Growth (in)	Avg. Gap (in)
Plant A	Alloy I	0°	0.035	0.015
	Alloy I	90°	0.024	0.025
	Alloy II	0°	0.028	0.022
	Alloy II	90°	0.018	0.031
Plant B	Alloy I	0°	0.033	0.017
	Alloy I	90°	0.026	0.024
	Alloy II	0°	0.029	0.021
	Alloy II	90°	0.020	0.030

4. Conclusion

The test of significance is performed to analyze on growths of grid width for grid location in fuel assembly and measured point in grid. The height position influences the growth and the measured point does not influence the growth. From these results, the top mid-grid is used in the analysis of grid-to-grid gap and average width is used in the analysis of grid-to-grid average gap in core. The evaluation results for these analyses are the same. The strap with low tin zirconium alloy and transverse direction is the best material of manufactured strap.

Four widths are used in this research because 4 points are only measured when the measuring device is used in PSE. It is necessary in future researches that the number of measured points is increased to consider the detail outer shape of grid.

REFERENCES

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