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A Study on the Dimension Analysis of the End-of-Life Grid

Jae-Jun Lee*, Joung-Yeul Lee, Hyeong-Koo Kim, Yong-Hwan Kim
Nuclear Fuel Engineering Department, KEPCO Nuclear Fuel, 989 Beon-gil 242, Daedeok-daero, Yuseong-gu, Daejeon 305-353, Republic of Korea
**Corresponding author: jaejunlee@knfc.co.kr*

1. Introduction

The fuel assembly is influenced by the neutron irradiation and the high temperature coolant in the core. The grids, which are components of the fuel assembly, suffer dimensional changes because grids are also influenced by the effects of those. The changed dimensions are cell size, cell pitch, envelope width and others [1]. In this research, statistical analyses are performed for the components of cell dimension using the end-of-life (EOL) grids. The analyzed grids are the mid grids and the materials of the grids are the zirconium (Zr) based alloys.

2. Measurement of the Grid Dimensions

The cell size and cell pitch of grid were measured in the hot cell and Fig. 1 is the picture of the measurement of grid dimension. The cell size represents the distance between the spring and the dimple in a grid cell and the cell pitch represents the distance between the dimple in one cell and the dimple in neighborhood cell as shown in Fig. 2.

Five grids are measured which are 2 mid grids of Fuel A, 2 mid grids of Fuel B and 1 mid grid of Fuel C. The standard of burn-up level is the cycle 3 burn-up of Fuel A. The characteristics of each fuel are summarized in Table 1. The analyzed grid straps showed different dimensional changes because two kinds of Zr alloys and textures are used. Alloy II and transverse direction strap shows less growth of grid width than the others [1]. According to grid spring shape, the different contacts occur between the rod and grid spring.

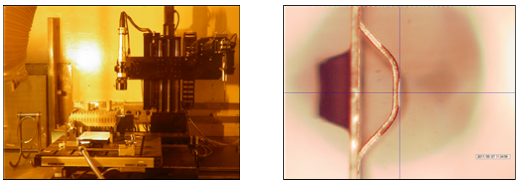

Fig. 1. Picture of the measurement of grid dimension

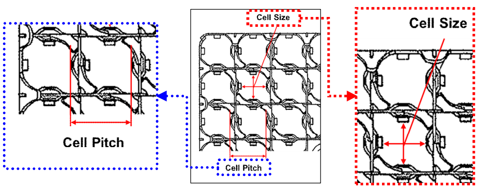

Fig. 2. Measurement method of cell size and cell pitch

Table I: Characteristics of the mid grid strap of each fuel

Fuel	Characteristic	
Fuel A	Zr Alloy type	Alloy I (General alloy)
	Texture	0° (Rolling direction)
	Grid Spring	Contour Spring
	Burn-Up Level	1.0
Fuel B	Zr Alloy type	Alloy I (General alloy)
	Texture	90° (Transverse direction)
	Grid Spring	I-Spring
	Burn-Up Level	0.96
Fuel C	Zr Alloy type	Alloy II (Low Tin alloy)
	Texture	90° (Transverse direction)
	Grid Spring	I-Spring
	Burn-Up Level	0.92

3. Analysis for the Grid Dimension

3.1 Analysis on Cell Size and Cell Pitch

EOL grids will show different cell size and cell pitch because the strap characteristics and the axial locations of grids are different and the fuels have the different burn-up. So, the dimension analyses are performed for the inner cell of each grid.

In this analysis, the non-dimensional cell size parameter and non-dimensional cell pitch parameter are used. The non-dimensional values are calculated from the measured values and the nominal values. The equations are as follows:

$$S_N = S_H / S_D \quad (1)$$

$$P_N = P_H / P_D \quad (2)$$

where, S is the cell size and P is the cell pitch. The subscript N means non-dimensional value and H means the measured data in hot cell and D means the nominal design value. The scatter plots and regression line of cell size vs. cell pitch are shown in Fig. 3 [2].

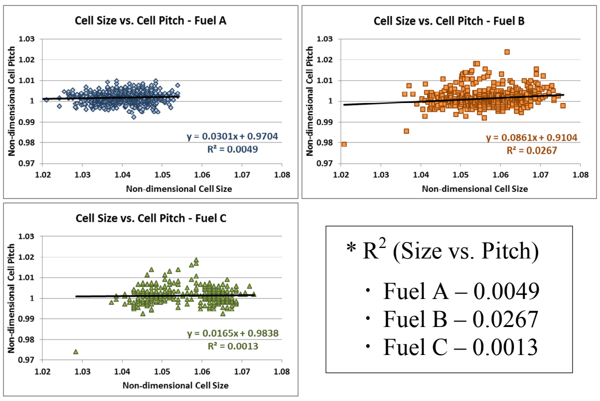

Fig. 3. Scatter plot and regression line: cell size vs. cell pitch

The regression analyses have the low R-square values. In other words, these analyses using the cell sizes and cell pitches are not significant and the correlations between two factors do not exist. Therefore, the analyses using new factors are necessary.

3.2 Analysis using Cell dimension and Cell Relaxation

It is known from section 3.1 that the analysis using the hot cell data is not significant. So, new factors are proposed to analyze the change of EOL grid dimension. The factors are the cell dimensional increment factors and cell relaxation factor. The cell dimensional increment factors are calculated from the hot cell data and nominal design values. The equations on the increment factors of cell size (S) and pitch (P) are as follows:

$$S_I = S_H - S_D \tag{3}$$

$$P_I = P_H - P_D \tag{4}$$

where, the subscript I means the incremental amount of each dimension.

The cell size is increased due to cell pitch increment and the height reduction of spring and dimple during burn-up. The increased and reduced values are obtained from comparisons of dimension between the nominal design values and the measured data of EOL grid. The proposed cell relaxation factor means the sum of the height reductions. So, the relaxation factor can be calculated from the difference between the cell size increment and the cell pitch increment. The non-dimension relaxation factor can be defined as follows:

$$R = (S_I - P_I) / D_D \tag{5}$$

where, R is the non-dimensional cell relaxation and D_D is total nominal deflection of spring and dimple when the fuel rod is inserted in the grid cell at as-built condition.

The regression analyses are performed using the non-dimension cell size and the non-dimension cell relaxation, and the analysis results are shown in Fig. 4: the used non-dimension cell size is calculated at section 3.1. The figures are the scatter plots and regression lines for all inner cells of each fuel. The regression lines can express the statistical significance of correlations between two factors due to the R-square values; Fuel A is 0.7155, Fuel B is 0.5812 and Fuel C is 0.6919, respectively [2]. However, the R-square values are not generally very large because the analyses have some high residuals due to outliers.

For this reason, the regression analyses are performed again after the residuals of top 5% level are removed, and the results are shown in Fig. 5. It is known that the R-square values from these results are larger than the R-square values using the whole data; Fuel A is 0.7721, Fuel B is 0.7229 and Fuel C is 0.8134, respectively [2]. From these values, the regression lines can describe the correlations between two factors. In other words, when the cell sizes are measured, the cell relaxation amounts and cell pitch increase amounts can be analogized using the proposed equations and the regression equations with the characteristics of each fuel.

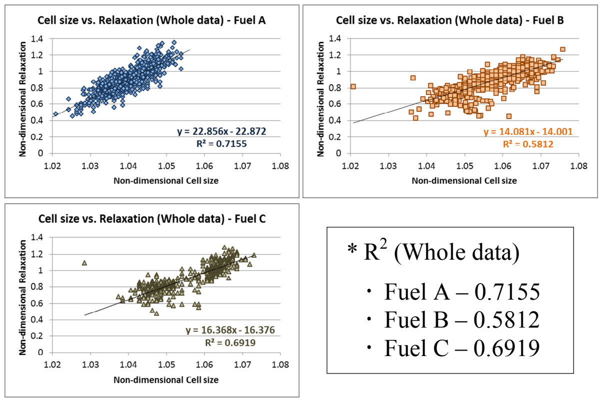

Fig. 4. Scatter plot and regression line: cell size vs. relaxation (Whole data)

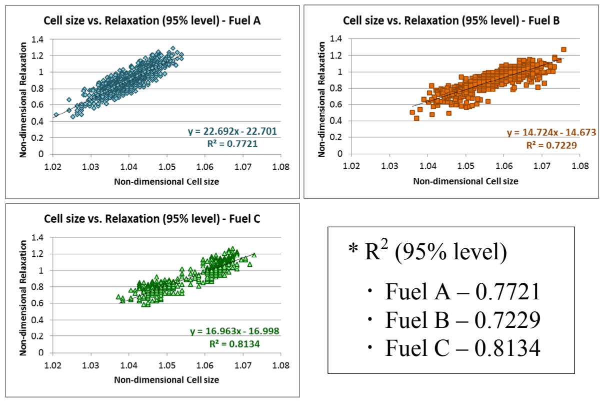

Fig. 5. Scatter plot and regression line: cell size vs. relaxation (95% level of whole data)

3. Conclusions

The analyses of grid dimensions are performed using the statistical method. The new factors are proposed and evaluated from hot cell data and nominal design values. It is worthy to note that the correlation between the relaxation factor and the cell size has the statistical significance and the cell relaxation and the cell pitch are analogized from the cell size. It is necessary in future that the analyses are performed between the grid width and these factors to obtain the effects for the grid width growth.

REFERENCES

[1] J. J. Lee, J. Y. Lee I. K. Kim, Y. H. Kim and J. C. Shin, A Study on the Growth of Grid width for the Manufactured Strap Conditions, Transactions of the Korean Nuclear Society Autumn Meeting, Oct.24-25, Gyeongju, Korea.

[2] W. C. Kim, J. J. Kim, B. W. Park, S. H. Park, M. S. Song, S. Y. Lee, Y. J. Lee, J. W. Jeon and S. S. Cho, "General Statics", Yongchi Publishers, Seoul, Korea, 2007.