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The Effects of Nuclear Fuel Geometry on Debris Filtering Efficiency

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1. Introduction

In Pressurized Water Reactor (PWR), the damage of nuclear fuel assemblies due to the debris has been found continuously. Pieces of debris involuntarily enter the fuel assembly, which may be trapped between fuel rods. If these are trapped for a long time, it can wear the fuel rod by fretting [1]. Thus debris filtering in fuel assemblies is important issue for the operation of nuclear power reactor.

Fuel damage by debris can be occurred at the bottom part of assemblies. Therefore, the fuel assemblies were equipped with the structure of debris filtering such as Debris Filtering Bottom Grid (DFBG) or Protective Grid (P-Grid). In order to design a structure of debris filtering on the DFBG or P-grid, it is necessary to derive geometric parameter of bottom nozzle and grids. The geometric parameters were selected as flow area of grid, configuration of grid, flow area of bottom nozzle, configuration of bottom nozzle. The maximum passable size of debris is determined by using the diameter of circle which is able to pass through the grid or flow holes of bottom nozzle.

In this paper, the design parameters were derived based on test results of debris filtering effectiveness. The effects of each parameter on the debris filtering efficiency were evaluated.

2. Debris Filtering Test

2.1 Test Configuration

The configuration of debris filtering test was shown in Figure 1. The test components consisted of PVC (Polyvinyl chloride) flow loop with transparent test housing, pump and tank. The test housing had 84mm square test section. Debris was inserted between two ball valves in a bypass line for entering the main flow path.

2.2 Test specimens

The 3-models of KNF's commercial fuel assemblies and 7-models of candidate models for new fuel assembly were used to the test. The size of all grids was 6X6 array partial fuel assembly. The size of bottom nozzles was same as the used grid.

Since the efficiency was affected by the type of debris and size, it is necessary to standardize the type of debris filtering and size for an objective and conservative evaluation [1].

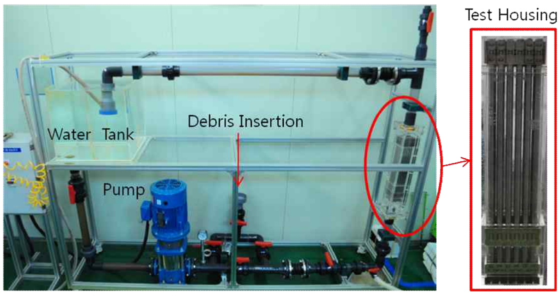

Fig. 1. Configuration of debris filtering efficiency test loop.

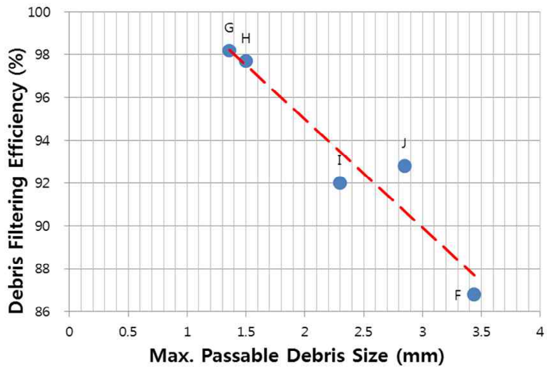

Fig. 2. Test result of maximum passable size of debris with same bottom nozzle (F to J Model).

The three type of debris shapes were used such as wire type, flat type, metal chip type. All debris specimens consist of 22 groups according to the type and size. These consisted of 12 groups of wire, 4 groups of metal chip and 6 groups of flat shape.

2.3 Test Method

Debris was inserted into the test loop step by step after dividing into each group according to debris type and size. The number of debris for each group was limited to five piece of debris to prevent from being caught by other debris and find them easily within the partial assembly. Flow was maintained until the debris was trapped in the partial assembly or for a minimum of 5 minutes.

3. Analysis of Test Results

Simulation test was performed according to their set of grid and bottom nozzle in the debris filtering facility. Test result was expressed as the percentage of debris trapped at debris filter grid and bottom nozzle in Table I. The G-model had the best efficiency of debris filtering,

Table I: Test Result of Debris Filtering Efficiency

Unit (%)

	A	B	C	D	E	F	G	H	I	J
Wire	88.3	85.6	94.5	86.9%	91.7	85.7	95.6	97.6	92.2	93.3
Flat	83.7	88.3	90.0	83.4%	90.0	81.3	96.4	96.7	86.3	86.7
Total	89.0	88.2	94.3	90.4%	92.5	86.8	98.2	97.7	92.0	92.8

Table II: Geometric Parameter of Bottom Nozzles (BN) and Grids

	A	B	C	D	E	F	G	H	I	J
Max. passable size of debris on BN(mm)	10.7	5.6	10.2	7.7	10.5	7.4	7.4	7.4	7.4	7.4
Flow hole area ratio of BN	0.38	0.38	0.45	0.30	0.30	0.36	0.36	0.36	0.36	0.36
Max. passable size of debris on grid(mm)	2.5	3.3	2.5	2.9	2.9	3.4	1.36	1.5	2.3	2.9
Flow hole area ratio of grid	0.41	0.47	0.40	0.39	0.38	0.51	0.42	0.43	0.42	0.44

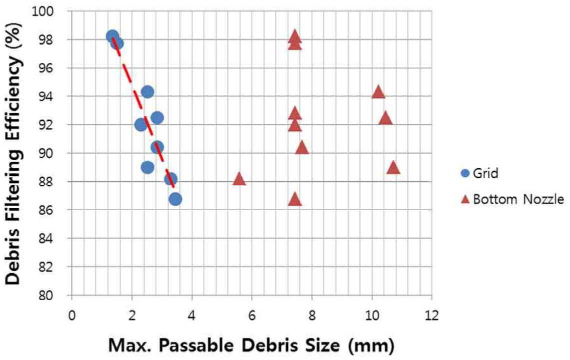

Fig. 3. Test result of maximum passable size (A to J model).

98.2%. On the other hand, F-model was the worst case, 86.8%.

The geometric parameter of bottom nozzle and grids was summarized from the designed hardware of fuel assemblies in Table II. The figure 2~4 was derived to compare the values of debris filtering efficiency and geometric parameter.

The test specimens of F to J model were using same bottom nozzle and different grids. The result of debris filtering efficiency in Figure 2 showed roughly inverse proportion to maximum passable debris size. As the maximum passable size of debris was getting smaller, the filtering performance was obtained better result. We used the different set of grid and bottom nozzle for expanding the meaning of the result. Although different set of grid and bottom nozzle was used in Figure 3 respectively, the filtering effect was similar tendency of Figure 2. The maximum passable size of bottom nozzle was the bigger than the maximum passable size of grid in Figure 3. Thus the maximum size of grid was more dominant on the debris filtering efficiency. However, the results of maximum passable size of bottom nozzle and flow area per total area ratio did not showed any trend in Figure 3~4. Therefore, we could know that the parameters apart from maximum passable size of debris did not affect the debris filtering.

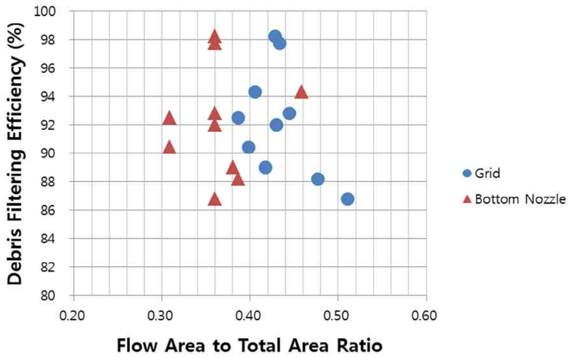

Fig. 4. Test result of flow area to total area ratio (A to J model).

Consequently, the results of parametric study showed that the debris filtering efficiency was determined dominantly by the maximum passable size of debris at grid.

4. Conclusion

The parameters on the debris filtering efficiency were derived from geometry of fuel design and then the effects were evaluated. The debris filtering test was performed to obtain the effect of debris filtering.

As a result of analysis, the flow area to total area ratio and maximum passable debris size of bottom nozzle did not affect the debris filtering efficiency, while the parameter of maximum passable debris size at grid was in inverse proportion to the debris filtering efficiency.

In conclusion, the debris filtering efficiency could be mainly determined by the maximum passable debris size at grids.

REFERENCES

[1] Joon-Kyoo Park, Jin-Seok Lee, Jung-Min Suh, Kyu-Tae Kim, Kyeong-Lak Jeon, Application of Statistic Evaluation Method for Debris Filtering Effectiveness, Transaction of the Korean Nuclear Society Spring Meeting, p. 363-364, 2008