Transactions of the Korean Nuclear Society Autumn Meeting
Gyeongju, Korea, October 29-30, 2009

A study of parameters affecting debris filtering effectiveness

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1. Introduction

Debris in the reactor have been a significant contribution to fuel rod damage. Debris trapped in a grid region may vibrate against the fuel rod to wear through, result in leaking fuel rods. The size and shape of the debris capable of causing severe damage are quite variable ranging from fine wire segments to rather long strips or chunks of metal.

PWR fuel vendors have taken steps to reduce the debris-induced damage with the debris filtering devices such as the protective grid. The objective of the protective grid is to trap debris at the entrance to the fuel assembly, thus avoid passing through the protective grid and loading in the fuel assembly grids where it could damage fuel rods.

The purpose of this paper is to study the key design parameters of the debris filtering effectiveness such as the gap between the protective grid and the bottom nozzle, debris-through width, and debris-through length. In order to investigate the debris filtering effectiveness of these parameters, we have performed a lot of debris filtering tests using standardized debris specimens which are able to simulate the debris' behavior in the reactor.

2. Test of Debris Filtering

2.1 Test Configuration

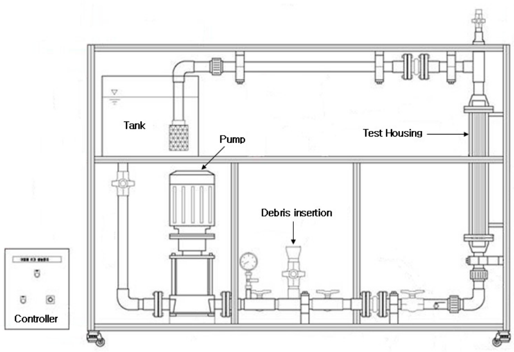


Figure 1. Test configuration of debris filtering effectiveness

The test configuration of debris filtering is shown in Figure 1. The test components are consisted of flow loop with transparent test housing, debris insert valve, pump, water tank, controller, and so on. With this test housing, we can perform the debris filtering test using 6X6 partial assembly with approximately 3 spans length of commercial fuel assembly which is enough to investigate the debris filtering efficiency of each design parameter.

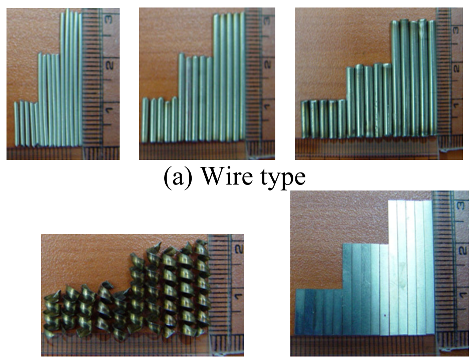
Debris were dropped into the debris insert valve located in the bypass line for entering the main flow loop. The flow velocity was measured by ultrasonic flowmeter at the vertical flow loop pipe.

2.2 The Debris Specimens

We have applied the three kinds of debris specimens such as wire, metal chip, and flat types. The key dimensions of each debris specimens are presented in Table 1. And Figure 2 displays the typical configuration of each debris type.

Table 1. Key dimensions of each debris specimens

Type	Groups	Length	Dia. / Width	Thickness
Wire	18	10~30mm	1.0~3.5mm	-
Metal chip	4	10~15mm	< 8.5mm	> 0.35mm
Flat	6	10~30mm	2mm	0.27~0.89mm



(a) Wire type

(b) Metal chip type (c) Flat type

Figure 2. Some debris shapes of each type

2.3 Test Performance

Debris were 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 pieces to prevent from being caught by other debris and to find them easily within the partial assembly. If a few pieces of debris injected into the test loop did not leave the by-pass line or were never located, these pieces were excluded from the calculations. Flow is maintained until the debris are all trapped or passed at the partial assembly or for minimum of 5 minutes.

3. Analysis of Test Results

The test results can be expressed as the percentage of debris specimens trapped at the protective grid.

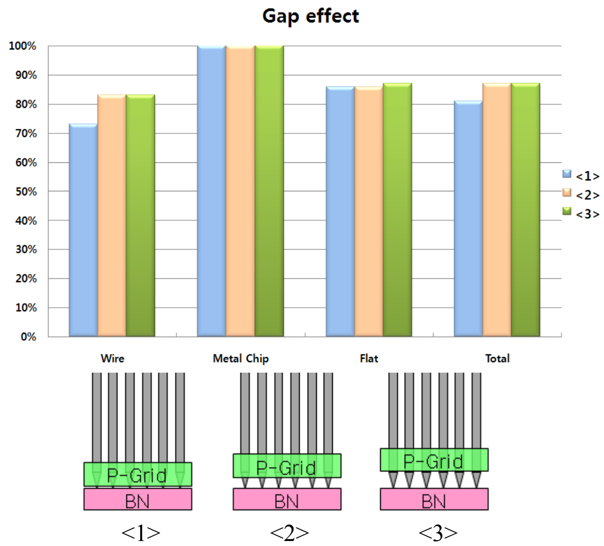


Figure 3. Filtering efficiency for gap effect

As shown in Figure 3, we can infer that the filtering efficiency is improved when the bottom of the protective grid is located above the end of the fuel rod' fillet, compared that located below the end of the fuel rod's fillet. It is that the fillet guides the debris to pass through the protective grid easily.

And the more gap between the protective grid and the bottom nozzle increases, the better the filtering effectiveness is. It is because debris have more chances to be strained with lying state as the gap increases.

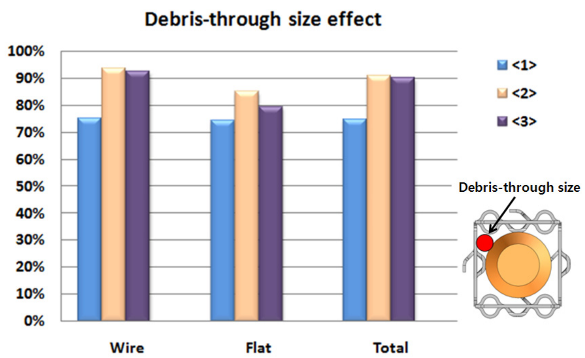


Figure 4. Filtering efficiency for debris-through size effect

In Figure 4, the debris-through size of <1> is bigger than <2> and <3>, and the size of <2> is similar to <3> as the debris filtering grids' shapes are different.

As the debris-through size grows lager, the filtering performance gets worse at seeing Figure 4. So, we can see that the smaller debris-through size is good for filtering effectiveness.

If debris' size is lager than debris-through size, it can't pass the protective grid. We can check out that fact at seeing debris for metal chip. At Figure 3, all cases of the filtering efficiency of debris for metal chip type are 100%. It is that the width of metal chip type debris is larger than the protective grid's debris-through size.

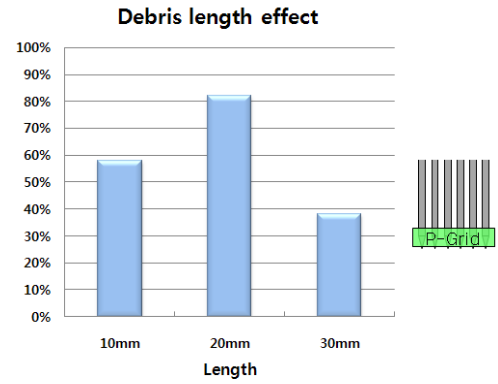


Figure 5. Filtering efficiency of protective gird on wire type debris with dia. 1.5mm after passing the bottom nozzle

As shown in Figure 5, the filtering efficiency of debris' length at 20mm is better than at 30mm after passing the bottom nozzle. Because the more the debris are long, the more they tend to stand vertically at passing the bottom nozzle's holes, so the long debris are easy to pass through the protective grid compared to the short debris.

However, the filtering efficiency of debris' length at 10mm is worse than at 20mm. Because the cell pitch of the protective grid is 12.9mm that the 10mm debris have few filtering probability with their lying state.

4. Conclusions

This study discussed the parameters affecting debris filtering effectiveness. We can find out filtering efficiency is changeable for various parameters; protective grid to bottom nozzle gap, debris-through size, debris length, etc.

As the gap between the protective grid and the bottom nozzle increases, the filtering effectiveness is improved.

Debris-through size is the dominant parameter for the filtering efficiency.

When the debris' length are longer than the grid's pitch, we can infer that the more the debris are long, the less the filtering effectiveness they have.

The test results of the debris filtering effectiveness of each design parameters are expected to understand the debris filtering mechanism and to be applied to enhance the debris filtering efficiency of fuel assembly.