Transactions of the Korean Nuclear Society Autumn Meeting
Gyeongju, Korea, October 24-25, 2013

Performance Verification of the Lattice-type ECCS Sump Strainer to Prevent the Thin-bed effect

Je-Joong Sung, Chang-Hyun Kim and Sang-Jun Ha
KHNP CRI, 70 1312- gil Yuseong-daero Yuseong-Gu, Daejeon, 305-343, KOREA
**Corresponding author: sinclair@khnp.co.kr*

1. Introduction

In the event of a Loss of Coolant Accident (LOCA), a variety of debris could be generated under the post-LOCA conditions. The debris could block the Emergency Core Cooling System (ECCS) sump strainer, leading to a considerable head loss which in turn causes an abnormal ECCS and/or CS pump performance. The determination of strainer capacity is very important through the optimization of the head loss due to debris blockage. Especially, the thin-bed effect is a dominant factor to the design of the strainer.

This paper presents experimental head loss data to confirm an advantage of an advanced lattice-type strainer for the thin-bed effect and is compared to the results of NUREG/CR-6224 head loss correlation.

2. Methods and Results

Debris is generated from the LOCA cause the head loss on the ECCS. The required ECCS strainer capacity should be determined from the limiting head loss results between the thin-bed and possible maximum debris loading conditions on the screen of the strainer. If the thin-bed effect takes place which causes much higher head loss than that by the maximum possible debris loading conditions, the strainer capacity should be determined from the thin-bed effect [2]. To verify the thin-bed effect of a lattice-type strainer, a comparison has been performed between experimental data and NUREG/CR-6224 head loss correlation. Table I shows typical debris properties and the test conditions are summarized in Table II. The first case is performed to investigate experimentally the effect of the variation of the quantity of the insulation debris (NUKON). The second case is performed to calculate theoretically the same effect. The volume of NUKON ranges from 4.4 ft^3 to 21.9ft^3 and the same values are used for calculating the head loss by the correlation.

Table I: Summary of the debris properties

Category	Debris type	Size (μm)	Sludge Density (lbm/ft^3)
Fiber	Insulation	7	2.4
	Latent	7	2.4
Particle	Coating	10	39
	Latent	17.3	39
Miscellaneous		-	169

Table II: Matrix for the experiment and calculation

Case	Fiber debris		Particle debris	
	Insulation (NUKON)(ft^3)	Latent (ft^3)	Coating (lbm)	Latent (lbm)
Test cond.	4.4 ~ 21.9	0.07	82.9	1.01

2.1 Calculating the head loss by the Correlation

A semi-theoretical head loss correlation (so-called NUREG/CR-6224) for predicting head loss through a debris laden mixture was used for calculating the head loss. This general equation developed from the flat-plate experiment, valid for laminar, transient, and turbulent flow regimes, is formulated as follows.

$$dH/dL_0 = C\ [3.5\ S_V^2\ (1-\varepsilon_m)^{1.5}\ \{1+57(1-\varepsilon_m)^3\}\ \mu\ U + 0.66\ S_V \times \{(1-\varepsilon_m)/\varepsilon_m\}\ \rho_w\ U^2\ ]\ (dL_m/dL_0)$$

where, C = 4.1528 × 10-5 (ft-water/in.)/ (lbm/ft^2-s^2) [Units conversion constant]
Sv = specific surface area = 1.71 × 105 ft^2/ft^3 for NUKON
μ = dynamic viscosity (lbm/s-ft)
U = velocity (ft/s)
dH = head loss (ft-water)
ρ_w = water density (lbm/ ft^3)
dL_0 = fiber bed theoretical thickness (in.)
dL_m = actual bed thickness (in.).

The mixture porosity, ε_m, is given as

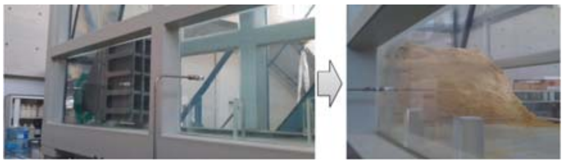
$$\varepsilon_m = 1-\{1+(\rho_f/\rho_P)\eta\}(1-\varepsilon_0)\ (dL_m/dL_0)$$

where, ρ_f = density of an individual fiber (175 lbm/ft^3 for fiberglass)
ρ_P = density of each individual particle
η = ratio of the mass of particulate to mass of fiber in the bed
ε_0= theoretical fiber bed porosity

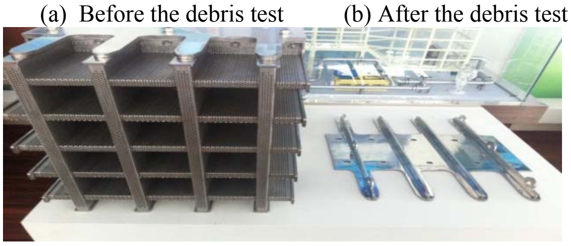
The solution of the NUREG/CR-6224 correlation and its supporting equations requires an iterative solution [1]. For better results of the correlation, the 6224 Correlation program (NRC, version 1.6B) was utilized to calculate the head loss due to the variation in the quantity of NUKON and coating debris.

2.2 Measuring the head loss on the lattice- strainer

To restrain the thin-bed effect on the screen, an advanced strainer with lattice-type is developed as shown in Fig. 1. This type strainer has advantages of increasing strainer area per unit volume and reducing the thin-bed formation by non-uniform debris loading on the screen. The strainer has been test in a closed-loop test facility to simulate the coolant flow near the sump in post-LOCA conditions. The facility consists of a flume, pool, recirculation pump, heater, piping and control system. The head loss is measured at a flow rate of 191 LPM and a water temperature of 105 °F. Table III shows the specification of the lattice-type strainer used in this study.



(a) Before the debris test (b) After the debris test



(c) Module of the lattice-type strainer

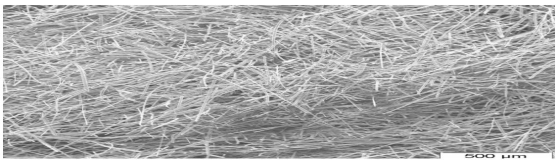
Fig.1 The experimental facility including the lattice-type strainer

Table III: Specification of the lattice-type strainer

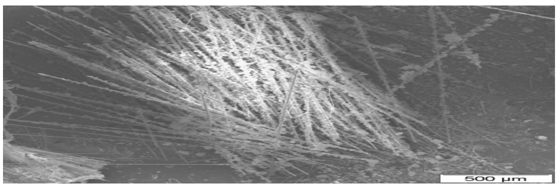
Contents	Specification
Size	0.87 × 0.89 × 0.64m
Effective Area	33.48 ft^2
Mesh Diameter	2.4 mm
Material	A304. Steel
Clean Head Loss	0.11 ft-water at 0.03 ft/sec

2.3 Analysis of Results

Figure 2 shows the Scanning Electron Microscope (SEM) image of the accumulated debris on the strainer surface and the porous media of the fiber debris layer blocked by the particle debris. The dramatic head loss arises when the porous media of the thin layer of fiber debris is blocked by the accumulated particle debris such as Fig. 2(b).



(a) Fibrous debris layer



(b) Particle debris on the Fiber debris layer

Fig. 2 The accumulated debris layers on the strainer.

Figure 3 shows the comparison of head losses from tests with those from the calculation of NUREG/CR-6224 correlation. As the volume of NUKON increases, the head losses from the experiment show a gradual increase but the head losses from the NUREG/CR-6224 correlation show a wide variation with maximum and minimum differences of 6.78ft-water and 0.72 ft-water, respectively. As shown in the result of the correlation, a considerable head loss could take place although a relatively small amount of fibrous debris is loaded in the strainer. This wide variation, apparently counter-intuitive head loss phenomenon, is known as the thin-bed effect.

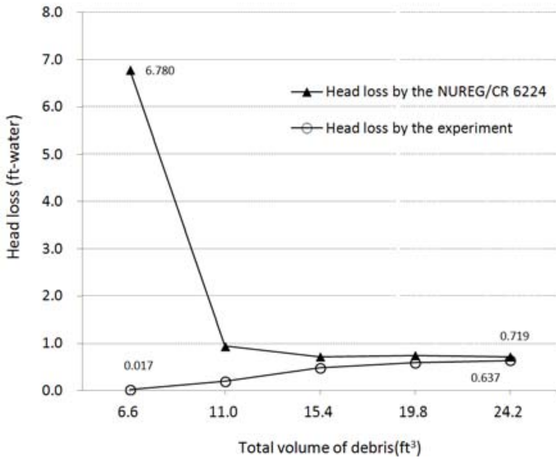


Fig. 3 Comparison between the experimental data at the test facility and NUREG/CR- 6224 correlation

NUREG/CR-6224 correlation developed from the flat-plate type screen could cause the thin bed effect in a debris loading condition with a small amount of fibrous debris. Because it is difficult to create an opened hole which could restrain the head loss. On the other hand, the lattice-type strainer could create many opened holes on the contact surface between debris layers and the strainer. The opened holes could reduce or prevent the thin-bed effect so that the head loss was gradually increased as the amount of debris rose. In case of the experiment, the head loss of the lattice-type strainer is converted into the compensated head loss for the flat-plate strainer by the correction factor. As shown in Fig. 3, it could be confirmed that the thin-bed effect didn't occur on the surface of the lattice-type strainer. Thus, the thin-bed effect which affected by the strainer screen shape is important factor to optimize the strainer.

3. Conclusions

The thin-bed effect is a dominant design factor because the head loss could increase drastically by the lack of available voids in the debris bed for coolant to pass through it. Though this study, the lattice-type strainer to reduce or prevent the thin-bed effect has been designed. As the experimental data shows, there is no thin-bed effect in the present lattice-type strainer. It is expected that the required capacity of the strainer to maintain the function of ECCS will be significantly reduced by the lattice-type strainer of the present study.

REFERENCES

[1] USNRC, Parametric Study of the Potential for BWR ECCS Strainer Blockage due to LOCA-Generated Debris, NUREG/CR-6224, 1995

[2] NEI, Pressurized Water Reactor Sump Performance Evaluation Methodology, NEI-04-7, 2004