Sensitivity Study of Fiber Length Effect on Pressure Drops in the Mockup PLUS7 Fuel Assembly

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1. Introduction

There has been a concern that following a loss-of-coolant accident (LOCA), particulates, fibrous material and chemical precipitate could be ingested into the emergency core cooling system (ECCS) and flow into the reactor coolant system (RCS). This phenomenon could be harmful for a long term core cooling (LTCC) when the debris accumulates on the core inlets and blocks the flow of cooling water.

The in-vessel downstream effect tests for the APR1400 have been performed to address this generic safety issue (GSI) 191 [1]. In this study, we performed sensitivity tests using a fiber grinded for 10 seconds and 8 seconds. When the fiber is grinded for shorter time, the fiber length is increased.

2. Description of the Tests

2.1 Test Facility

A photo of the test loop is shown in Figure 1. The test loop is composed of four main parts; mixing tank system, circulation system, test pool, control and monitoring system. Detailed descriptions of the test facility are given in Reference 2.

Fig. 1. Photo of the test loop

2.2 Debris Preparation

Particulate

The particulate debris is represented by grinded silica powder (SiO_2) that has 10μm ± 5μm of diameter. The U.S.NRC safety evaluation for NEI 04-07 identified particle size as a key parameter for the selection of representative debris [3].

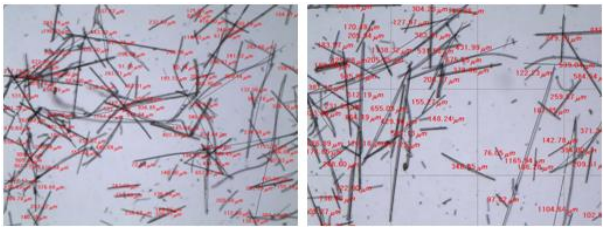
Fiber

A NUKON fiber is used in a baked and coarse chopped form. Sample A and B in Table 1 were grinded for 10 seconds and 8 seconds, respectively. The fiber length in Sample B is larger than that in Sample A. The fiber length distributions in both Samples meet the test protocol developed by the PWR Owners Group (PWROG) [4]. Figure 2 shows the grinded, and Figure 3 shows an image of the fiber grinded for 10 seconds and 8 seconds, respectively.

Table 1: Sample fiber distributions

Description	Sample A (10 sec.)	Sample B (8 sec.)
Fiber length<500 ㎛	75.9 %	73.4 %
500 ㎛≤fiber length≤1000 ㎛	18.7 %	20.7 %
Fiber length≥1000 ㎛	5.4 %	5.9 %

Fig. 2. Grinded fiber



(a) Grinded for 10 sec. (b) Grinded for 8 sec.

Fig. 3. An image of grinded fiber

Chemical Precipitate

The test uses AlOOH as chemical debris, which has been shown by Argonne National Laboratory to produce the highest pressure drop among all of the chemical precipitates.

2.3 Test Conditions

In this test, we chose a particulate-to-fiber mass ratio of 1:1. This ratio caused most limiting results. Test conditions are shown in Table 2. After the flow rate (77.6 lpm) and temperature (22 ^{o}C) conditions are stabilized, tests are run. Test ID SK34-205 is the reference tests, and test ID SK34-221 is a test which has an increased fiber length condition.

Table 2: Test condition of SK34-205 and SK34- 221

Test ID	SK34-205	SK34-221
Particulate(g)	100	100
Fiber(g)	100	100
Chemical(g)	300	300
Grinded time of fiber(sec)	10	8

3. Test Result and Discussion

Test results in the condition of increased fiber length are shown in Figure 4. The maximum pressure drop (dP) is 32.18 kPa, which is higher than that of reference condition (19.4 kPa) as shown in Figure 5. The fiber with increased length could more easily accumulate on the bottom nozzle and the fuel grids. The debris beds caused more resistance to flow, and increased pressure drop.

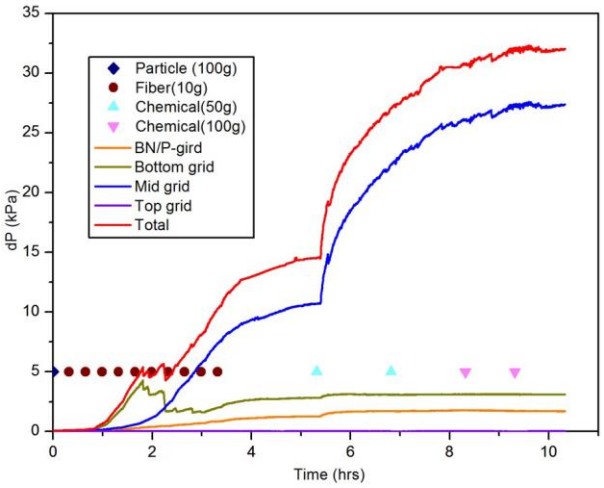


Fig. 4. Pressure drop results (SK34-221)

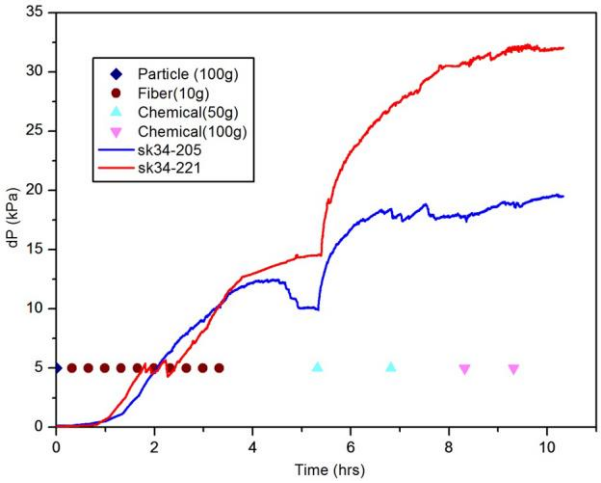


Fig. 5. Comparison of total FA dP (SK34-205 and 221)

4. Conclusions

In this study, sensitivity study of fiber length effect on pressure drops has been performed using a mockup PLUS7 FA. Particulate-to-fiber mass ratio of 1:1 was chosen, because the condition caused most limiting results. The fiber grinded for 8 seconds was used, and the result showed higher differential pressure than the condition of 10 seconds grinded. Because, both cases meet the fiber length distribution in the test protocol developed by the PWROG, the tests should be run using the fiber grinded for 8 seconds which gives more limiting results. However, all the test results meet the acceptance head loss (91.8 kPa) of the APR1400 with a sufficient margin.

REFERENCES

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[4] WCAP-16793-NP, Rev. 2, "Evaluation of Long-Term Cooling Considering Particulate, Fibrous and Chemical Debris in the Recirculating Fluid," 2011.