Single Phase Pressure Drop Tests in TROI Particulated Debris Bed

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1. Introduction

If a reactor vessel fails during severe accident situation of PWR, the molten core material can be released to the reactor cavity. Because pre-flooding strategy is adopted for ex-vessel corium cooling in Korean PWR, melt will be poured to wet cavity and fragmented into particles with various shapes and sizes. Finally fragmented corium particles will form a debris bed which should be properly cooled to ensure containment integrity. The debris bed coolability is affected by the pressure drop of debris bed depending its characteristics such as debris bed porosity, particle morphology, particle size distribution and bed stratification and so on[1, 2].

A pressure drop test facility has been built for pressure drop tests using corium particles which were collected from non-explosive TROI experiments at KAERI[3].

This paper deals with single phase pressure drop tests in TROI particulated bed with air and water.

2. Methods and Results

2.1. Particle characteristics assessment

Non-explosive TROI experiment particles are sieved again to get a detailed size distribution. The particle size distribution is shown in Fig. 1.

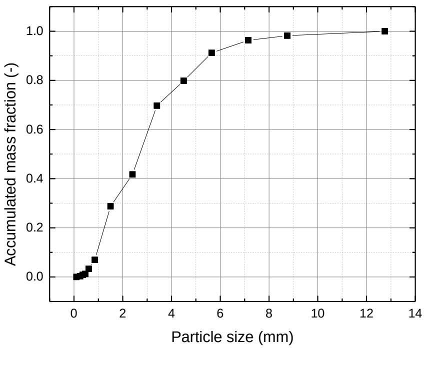

Fig. 1 Particle size distribution of non-explosive TROI particles

Mean diameters are also calculated. They are shown in Table 1.

Table 1 Mean diameters of non-explosive TROI particles

Mass mean	Area mean	Length mean	Number mean
3.498 mm	2.240 mm	1.227 mm	0.644 mm

The porosity of TROI particulated debris bed is measured and shown as 0.47. Details for particle characteristics assessment are described in Ref. [4].

2.2. Test facility

Recently, the facility was moved to TROI building. Test facility is described in Ref. [3]. A photo of the test facility is shown in Fig. 2. Three T-type thermocouples are added to provide more information of temperature. In the test facility, some of instruments are changed from the previous ones for the convenience of measurements. Equipment shown in Table 2 is used for the test.

Fig. 2 Pressure drop test facility

Table 2 Specification of equipment

Equipment name	Measurement or control range
Mass flow controller	0 ~ 1000 sl/min
Differential pressure transmitter	0 ~ 1.5 kPa
	0 ~ 37.3 kPa
Thermal mass flow meter	(Air) 0 ~ 1000 Nl/min
Coriolis mass flow meter	(Water) 15 ~ 3000 kg/hr
Pump	Revolutions: 720 ~ 3600 rpm Head: 35 m Flow rate: ~ 33 l/min

2.3. Experimental condition and result

Pressure drop test is performed for several steps of fluid flow rate. Each step is maintained at least 5 minutes(300 s). For calculation of pressure gradient using experimental data, the steady state data of differential pressure and fluid flow rate is used. All experimental data was recorded by NI-cDAQ-9174 through LabVIEW.

2.3.1. Air single phase pressure drop test

Air velocity range of the test is 0.1 ~ 0.9 m/s(60 ~ 420 l/min). Air velocity, i.e., air flow rate is controlled by mass flow controller and measured by thermal mass flow meter. Experimental result is shown in Fig. 3.

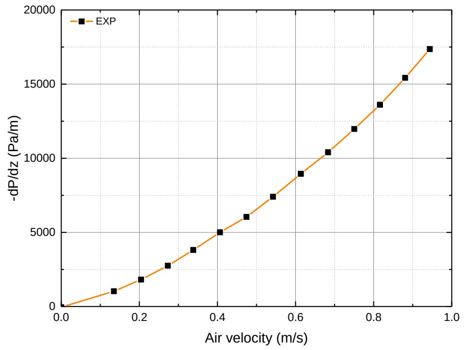

Fig. 3 Air single phase pressure drop test result

2.3.2. Water single phase pressure drop test

Water velocity range of the test is 0.01 ~ 0.05 m/s(4.5 ~ 22.5 l/min). Water velocity, i.e., water flow rate is controlled by changing pump speed and measured by Coriolis mass flow meter. Experimental result is shown in Fig. 4.

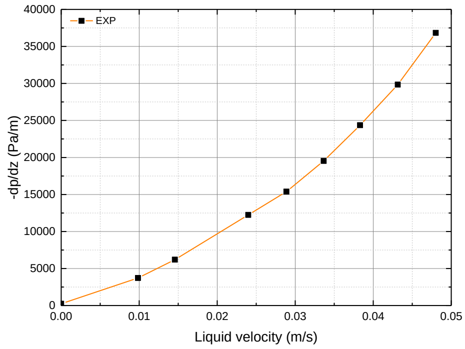

Fig. 4 Water single phase pressure drop test result

2.4. Experimental result analysis

Using experimental data, effective diameter of TROI particles is calculated based on Ergun equation, namely, Eq. (1) ($C_1 = 150$, $C_2 = 1.75$) [5]:

$$-\frac{\mathrm{dp}}{\mathrm{dz}} - \rho_i g = \frac{\mu_i}{K} V_{si} + \frac{\rho_i}{\eta} V_{si}^2$$
$$= \frac{C_1 \mu_i (1-\epsilon)^2}{\epsilon^3 d_p^2} V_{si} + \frac{C_2 \rho_i (1-\epsilon)}{\epsilon^3 d_p} V_{si}^2 \qquad (1)$$

Through comparison between experimental data and calculated ones, it is shown that effective diameter is in the range of 0.91 and to 1.04 mm. These are shown in Fig. 5 and 6. It is noted that the effective diameter is between number mean and length mean diameter.

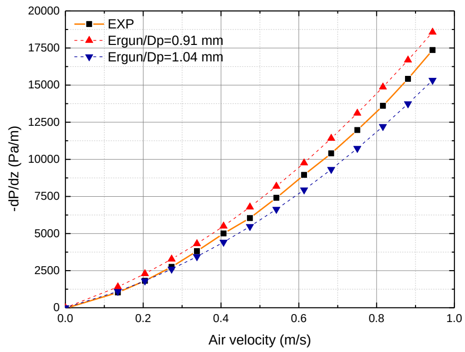

Fig. 5 Effective diameter estimation of TROI particles(Air single phase pressure drop test result)

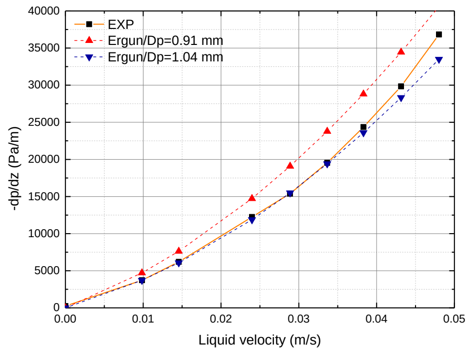

Fig. 6 Effective diameter estimation of TROI particles(Water single phase pressure drop test result)

2.5. Further work

Air-water two phase pressure drop tests will be performed in the same TROI particulate debris bed. Results of the experiments will be used to develop pressure drop model for debris bed coolability analysis code so called COLAS[3].

3. Conclusions

Single phase pressure drop tests with real corium particles are carried out. Air single phase pressure drop test is performed in velocity range of 0.1 ~ 0.9 m/s. And water single phase pressure drop test is performed in velocity range of 0.01 ~ 0.05 m/s. With experimental data, effective diameter of non-explosive TROI particles is calculated using Ergun equation. The effective diameter is in the range of 0.91 mm and 1.04 mm.

ACKNOWLEDGEMENTS

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