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Analysis of Non-Explosive TROI Particles for Debris Coolability Study

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Motivation

Background

- According to Korean SAMG, reactor cavity is flooded before a break of reactor vessel in case of a severe accident.
- Molten corium is fragmented into fine particles and accumulated on the cavity surface in a form of debris bed.
- How to secure the coolability of debris bed is an important safety issue for the mitigation of severe accident.

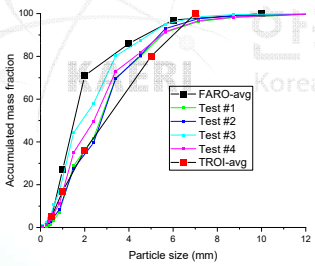
Scope & Objective

- Two-phase pressure drop test in TROI particle bed is planned at KAERI in 2021.
- Non-explosive TROI particles were sieved and analyzed to get the major parameters for an analysis of two-phase pressure drop test; i.e., PSD (Particle Size Distribution), porosity, and effective diameter of the particles.

Sieving and PSD of non-explosive TROI particles

- Among many TROI tests, non-explosive particles obtained from the Tests #1 ~ #4 are chosen.
- PSD for Tests #1 ~ #4 lies well between average FARO and average TROI.

Particle size(mm)	Test #1 (kg)	Test #2 (kg)	Test #3 (kg)	Test #4 (kg)
0~0.2	0.045	0.145	0.24	0.12
0.2~0.3	0.05	0.095	0.275	0.135
0.3~0.425	0.1	0.14	0.445	0.245
0.425~0.5	0.065	0.09	0.29	0.155
0.5~0.71	0.375	0.415	1.055	0.58
0.71~1	0.665	0.65	1.385	0.83
1~2	3.94	3.425	5.97	4.44
2~2.8	2.345	2.16	2.955	2.715
2.8~4	5.06	5.405	4.865	4.34
4~5	1.825	1.92	1.55	1.62
5~6.3	2.06	2.29	1.705	1.82
6.3~8	0.925	0.84	0.745	0.955
8~9.5	0.335	0.215	0.22	0.32
9.5~16	0.33	0.21	0.1	0.3
Total	18.12	18	21.8	18.575



Porosity of non-explosive TROI particles

- Porosity of the particles was measured for Test #1 and #2; 0.470 for test #1 and 0.476 for Test #2

Mean diameter of non-explosive TROI particles

- For a packed bed with multi-sized and irregular particles, various mean diameters are applied in the analysis of debris bed coolability.

mass mean diameter; $d_m = \sum x_i m_i = \sum \left(x_i \frac{x_i^3 f_i}{\sum x_i^3 f_i} \right) = \frac{\sum x_i^4 f_i}{\sum x_i^3 f_i}$

area mean diameter; $d_a = \sum x_i a_i = \sum \left(x_i \frac{x_i^2 f_i}{\sum x_i^2 f_i} \right) = \frac{\sum x_i^3 f_i}{\sum x_i^2 f_i}$

length mean diameter; $d_l = \sum x_i l_i = \sum \left(x_i \frac{x_i f_i}{\sum x_i f_i} \right) = \frac{\sum x_i^2 f_i}{\sum x_i f_i}$

number mean diameter; $d_n = \sum x_i n_i = \sum \left(x_i \frac{f_i}{\sum f_i} \right)$

- Mean diameters for Tests #1 ~ #4 are calculated for the whole particle size ranges.

Mean diameter (mm)	Test #1	Test #2	Test #3	Test #4
Mass mean	3.49	3.43	2.75	3.24
Area mean	2.13	1.87	1.35	1.7
Length mean	0.77	0.44	0.38	0.49
Number mean	0.2	0.14	0.15	0.16

- Particles in the small size range can play a major role in the calculations, because of many numbers. Mean diameters are also calculated excluding minimum particle size in the range of 0 ~ 0.2 mm.

Mean diameter (mm)	Test #1	Test #2	Test #3	Test #4
Mass mean	3.5	3.46	2.78	3.26
Area mean	2.24	2.19	1.57	1.9
Length mean	1.23	1.08	0.78	0.93
Number mean	0.64	0.53	0.45	0.5

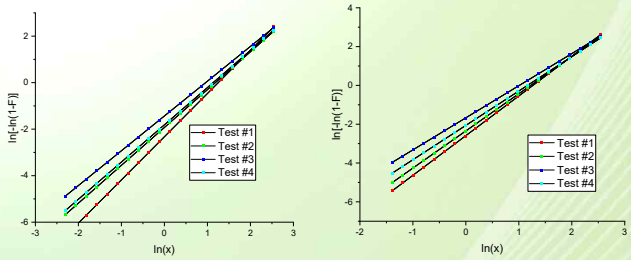
Rosin-Rammler distribution of non-explosive TROI particles

- For many irregular particles, the mass distribution is found to follow Rosin-Rammler distribution.

$$ln\left[ln\left(\frac{1}{1-F}\right)\right] = n\ln(x) - n\ln(x_0)$$

F: cumulative weight fraction less than size x
n: uniformity constant
x: particle size
x_0: characteristic particle size

- Rosin-Rammler distributions for Tests #1 ~ #4 are obtained including all particle size ranges (left) and excluding minimum particle size in the range of 0 ~ 0.2 mm (right).



- Uniformity constant (n) and characteristic particle size (x_0) are calculated. Characteristic particle size (x_0) is almost the same as the mass mean diameter for the case of excluding minimum particle size (0~0.2 mm).

		Test #1	Test #2	Test #3	Test #4
Including all particles	n	1.86	1.63	1.5	1.6
	x_0 (mm)	3.5	3.27	2.61	3.1
Excluding minimum particle size	n	2.05	1.92	1.65	1.77
	x_0 (mm)	3.55	3.4	2.74	3.2

Conclusions

- Coolability of debris bed in wet cavity is of great safety issue for the mitigation of severe accident. For the resolution of this issue, two-phase pressure drop test using non-explosive TROI particles is planned at KAERI.
- Analysis of non-explosive TROI particles is conducted to get the information of PSD, porosity, and mean diameters.