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Introduction of DEFCON Facility for Providing the Empirical Shape of Fragmented Ex-vessel Debris Bed in a Pre-flooded Reactor Cavity

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1. Introduction

As coolant injected in a reactor cavity according to the SAMG (Severe Accident Management Guideline) of Korean PWRs (pressurized water reactors), ex-vessel corium falls into the pre-flooded reactor cavity [1]. The falling corium becomes the form of liquid jet or liquid droplets or solidified particles, and then accumulates on the bottom of the cavity. Among them, this study is especially interested in the case of full fragmented debris bed by a deep water pool. Since the geometric shape of debris bed has an effect on its coolability [2], it is important to provide the empirical shape of fragmented debris bed.

The geometric shape of the debris bed is determined by several factors such as particle shape, falling velocity, falling time and so on. Nevertheless, it is obvious that the driving factor affecting the bed shape is the steam generation by sensible heat and decay heat. The former will spread the falling particles and have an effect on the initial shape of the debris bed. And the latter will affect the bed shape in the long-term perspective such as self-leveling phenomenon. Thus, it is necessary to synthetically simulate the steam generation by both heats so as to study the resulting debris bed shape.

In this paper, the experimental facility constructed in KAERI to provide the empirical shape of fragmented debris bed by simulating the steam generation close to real situation is introduced with the description of other facilities related to studying the bed.

2. The Facilities from Previous Researches

2.1 DAVINCI (POSTECH)

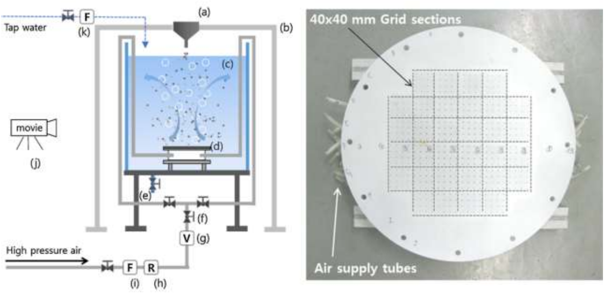

Fig. 1. A design of DAVINCI.

Fig. 1 shows a design of DAVINCI facility (Debris Bed Research Apparatus for Validation of the Bubble-Induced Natural Convection Effect Issue) in POSTECH [3]. Simulant particles fall down from the funnel into the water pool made by acrylic. At the bottom of the pool, there are 32 grid sections for air injection locally controlled by respective rotameters. Those simulate the steam generated by decay heat. Using 3D scanner, air flow rate is determined by the volume of particle bed on each section. Since controlling the air flow rate is discontinuously carried out at a distance of time, it is not a real-time value related to debris mass deposited on each section. Also, DAVINCI isn't able to simulate the steam generated by sensible heat.

2.2 PDS-P (KTH)

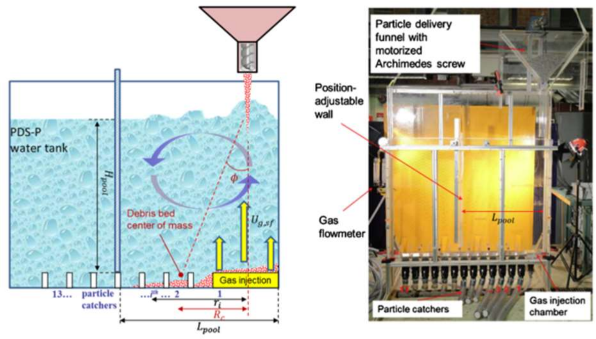

Fig. 2. A design of PDS-P.

Fig. 2 shows a design of PDS-P (Particulate Debris Spreading in the Pool) facility in KTH [4]. Simulant particles are delivered by the Archimedes screw from the funnel into the pool having a fixed narrow width. The position adjustable wall enables to change the pool length. Air is injected vertically upward to the funnel from the bottom of the pool. Particle catchers, small funnels collecting the particles, are installed along with the length of the pool and separated by the partition wall. It collects the particles to find spreading angles by air injection. PDS-P is the facility for investigating particles spreading in a pool under two-phase flow condition. Since there is no gas generation from the surroundings of each falling particle, it is necessary to validate the spreading effect about it.

2.3 PDS-C & PDS-1 & PDS-2 (KTH)

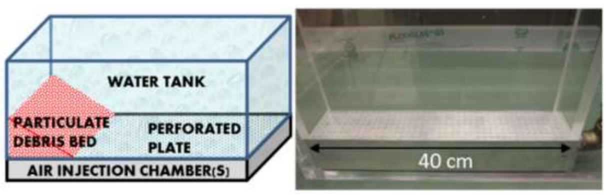

Fig. 3. A design of PDS-C.

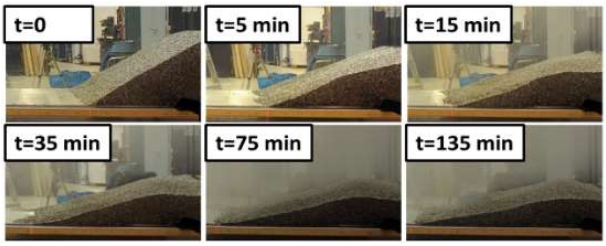

Fig. 4. Experiment images in PDS-2.

Fig. 3 shows a design of PDS-C (Particulate Debris Spreading Closures) facility in KTH [5]. PDS-1 and PDS-2 have similar design with PDS-C except a number of air injection chamber and size. As shown in Fig. 4, these facilities are for studying self-leveling phenomenon of particulate debris bed having pre-determined shape. Injected air from the bottom perforated plate simulates the steam generated by decay heat. Thus, it is needed providing the debris bed shape at early stage by simulating the steam generation by sensible heat.

3. DEFCON Facility

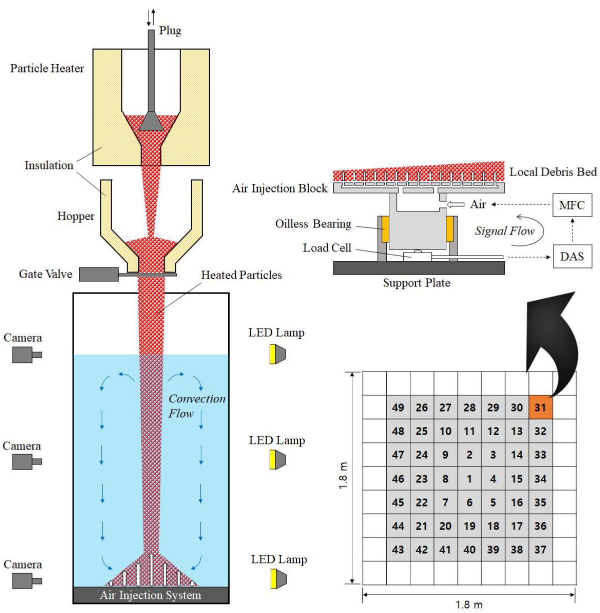

Fig. 5. A design of DEFCON.

Fig. 5 shows a design of DEFCON (DEbris bed Formation and COolability experimeNt) facility in KAERI. It is composed of heating system for particles, particle delivery system, water tank, air injection system, and visualization system. It was constructed for experiments using maximum 1000 kg simulant particles. The cuboid water tank has the size of 2 m × 2 m × 4 m. In order to withstand hydraulic pressure, stainless-steel frame was used. It has several polycarbonate windows to visualize experiment process by using cameras and LED lamps. The hopper is the space in which the particles from the heating system are held for a short time so as to drop the particles packed into the hopper nozzle. Since the nozzle where the gate valve is installed is assembly with the hopper, it is possible that a falling distance and a release area for particles are controlled by replacing the nozzle. Above all things, the systems that could simulate steam generation by sensible heat and decay heat were constructed. Those are heating system for particles, and air injection system as follows.

3.1 Heating system for particles

The heating system for particles is possible to heat particles up to about 1,000 °C to simulate the sensible heat of fragmented debris. Kanthal electric heaters are installed at the outer wall of the crucible and heat is transferred by conduction. The insulation minimizes the heat loss. The plug being pulled upward, the heated particles are shattered and delivered to the hopper without clogging.

3.2 Air injection system

The air injection system is for simulating the steam generation by decay heat. There are 49 sections at the bottom of the water tank. A load cell and a MFC (Mass Flow Controller) are respectively installed at each section with the size of 200 mm × 200 mm. This design enables to control the real-time local air flow rate in proportion to the quantity of sedimentation. In order to accurately measure the arbitrary distributed load by local debris bed on an air injection block even underwater, an oilless bearing is used.

4. Conclusion

DEFCON facility was constructed to provide the empirical shape of fragmented ex-vessel debris bed in a pre-flooded reactor cavity. It is assumed that released ex-vessel corium becomes solidified particles because of a deep water pool. Since the shape of debris bed is related to its coolability, it is necessary to study it. The driving factor affecting the debris bed shape is the steam generation by sensible heat and decay heat. Therefore, the facility simulating both of the two phenomena synthetically is needed. DEFCON facility constructed in KAERI is possible to simulate the steam generation by both heats. It is expected that DEFCON builds a database of the debris bed shape by performing experiments under various conditions and contributes to the development and validation of the model about it.

ACKNOWLEDGMENTS

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