Evaluation of impaction characteristic of particle leaked by steam generator tube rupture using lab-scale experimental system

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1. Introduction

Steam generator (SG) tubing is subject to a variety of degradation processes that can lead to cracks, thinning and, potentially, rupture. Despite improvements in SG design, manufacturing and modes of operation, SG tube rupture (SGTR) events occasionally occur during PWR operation worldwide which underline the need to pay particular attention to SGTR sequences. A particular safety challenge arises from an SGTR in combination with other failures such that a core melt occurs, in which case there may be a direct path by which radioactive fission products can be transported to the environment. To trap the aerosols effectively during a severe accidents, the characteristics of particle impaction have to be evaluated. In this study, particle impaction behavior in the SGTR events was evaluated using lab-scale experimental system.

2. Methods and Results

2.1 Test particle

TiO_2 particle was used to evaluate particle characteristics because TiO_2 particle can simulate the radioactive fission products that generated by agglomeration. Compressed air was used as a carrier gas after using a clean-air supply to remove oil droplets, moisture, and contamination particles. This supply consisted of an oil trap, a diffusion dryer, and a HEPA filter. TiO_2 particle particles were generated from an atomizer (9302, TSI, USA). The airflow rate to the atomizer was maintained at 2.0 L/min. Then TiO_2 particles pass through a diffusion dryer to remove the residual moisture and then enters a soft X-ray type aerosol neutralizer (4530, HCT, Korea) to eliminate charges induced during the aerosolization process. The neutralizer neutralizes aerosol particles using soft X-ray photoionization. Additionally, particle size selector was used to remove nano-particles generated from atomizer in the aerosolization process. The generated TiO_2 particle size distribution was measured by SMPS (Scanning Mobility Particle Sizer), APS (Aerodynamic Particle Sizer).

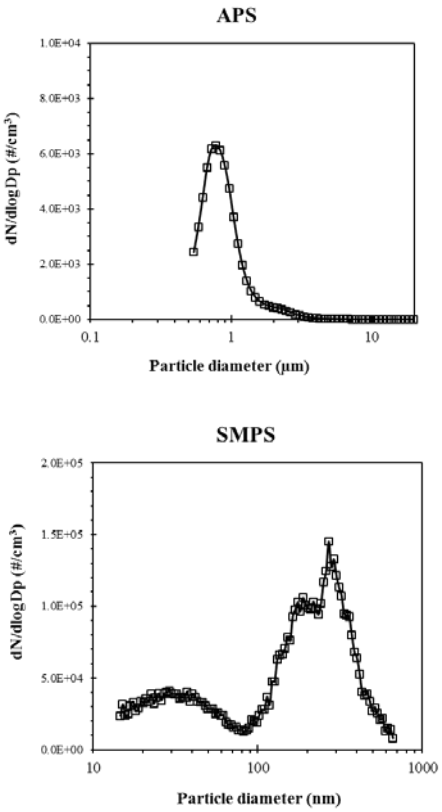

Fig. 1. TiO_2 particle size distribution measured by APS and SMPS.

2.2 Particle impaction characteristic

Single stage impactor and sampling chamber was developed for evaluation of particle impaction. The single stage impactor and the sampling chamber were used in combination to investigate the break-up and bounce of the TiO_2 agglomerates. The generated TiO2 agglomerates were first size-classified using the Particle Size Selector to produce monodisperse particles and then introduced into the single stage impactor for impaction onto the impaction plate. The bounced particles were sampled in the sampling chamber, which is designed for low-pressure sampling. The bounced particles were then analyzed by the SMPS and APS. The intact particles were characterized by carrying out the same analysis and sampling procedure without the impaction plate. The differential pressure of the impactor was -7.67 kPa and the jet velocity of the nozzle at this condition was 50 m / s. The impaction characteristics were evaluated by comparing the particle

size distributions of before and after the impaction.

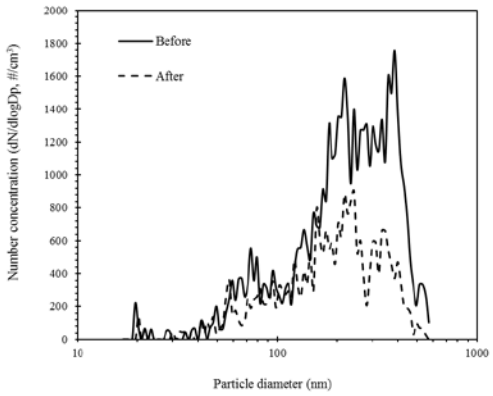

Fig. 2. TiO_2 particle size distribution before and after impaction.

It was confirmed that the particle number concentration after impaction was totally decreased. However, it is thought that the particle break-up by impaction does not appear. This is because the jet velocity was not so fast enough to cause break-up.

3. Conclusions

Particle impaction behavior in the SGTR events was evaluated using lab-scale experimental system. A single-stage impactor and a low-pressure sampling chamber were used to study the break-up and bounce of TiO_2 agglomerates by impaction. After impaction, particle number concentration was decreased overall. However, particle break-up by impaction was not observed. It is thought that the impaction velocity was low. In the near future, the impaction characteristics at the higher velocity will be evaluated.

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