A Preliminary Computational Investigation for Flow Distribution in Impregnated Active Carbon Adsorber

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1. Introduction

The air conditioning unit of the nuclear power plant is an engineered safety feature which is devised to not only reduce the release of the radioactive material to the environment, but also assure that operators can have access to the main control room in the case of a postulated accident. The air conditioning unit is typically composed of a moisture separator, an electrical heater, a pre-filter, a pre-HEPA filter, an impregnated active carbon adsorber and a post-HEPA filter. Once the operation of the air conditioning unit is initiated, the moisture contained in the atmosphere is removed by the moisture separator or dried by the heater. The relatively large dust and impurities are captured by the pre-filter and the pre-HEPA filter removes small particles with a several micrometer size. As toxic chemicals including methyl iodide, nitrogen oxides, and sulfur oxides contained in the atmosphere are accumulated on the surface of the impregnated active carbon adsorbent, the surface of the carbon adsorbent becomes oxidated and active sites for chemisorption decrease, leading to the aging of the impregnated active carbon adsorbent.

Many researches have been conducted to investigate the aging of the impregnated active carbon adsorbent [1,2,3,4,5], however, a general mechanism for the aging has been still unknown since the aging is accompanied by complicated chemical processes. In addition, the type and concentration of the toxic chemicals differ according to the sites of the nuclear power plants.

This work has been motivated to investigate the aging of the impregnated active carbon adsorbent with poisoning effects. To accomplish this objective, experimental facilities for verification tests and several small-scale laboratory apparatus for poisoning effects have been under design. This paper, as a preliminary study, will present results of CFD analyses, in particular, focusing on flow distribution in an experimental facility for verification tests.

2. CFD Modelling and Results

2.1 Experimental facility for verification test

A schematic for the experimental facility is illustrated in Fig. 1. The experimental facility for verification tests is made by a rectangular duct with about 6 m in length. The cross sectional area of the duct entrance is 0.3721 m^2 (0.61 m × 0.61 m) and is expanded up to 0.931 m^2 (0.965 m × 0.965 m) through the diffuser with 1.447 m in length. Inside the duct, there are several components including a flow straightner, a moisture separator, an electrical heater, a pre-filter, a HEPA filter, an impregnated active carbon adsorber equipped with the total 12 canisters and 4 beds containing the impregnated active carbon adsorbent. Here, the 6 canisters are installed in the upstream side and the remaining 6 canisters are attached on the downstream side of the adsorber. The distance between the upstream and downstream sides of the adsorber is 0.318 m. The 4 beds are installed inside the adsorber with same distance between the beds. Each canister has 0.05468 m in diameter and 0.1016 m in height. Similarly, the width and height of the carbon beds are 0.1016 m and 0.9652 m, respectively.

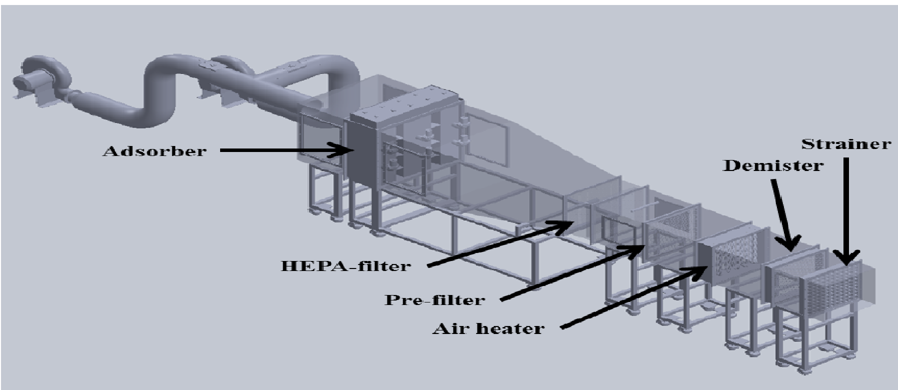

Figure 1. Schematic of experimental facility for verification tests

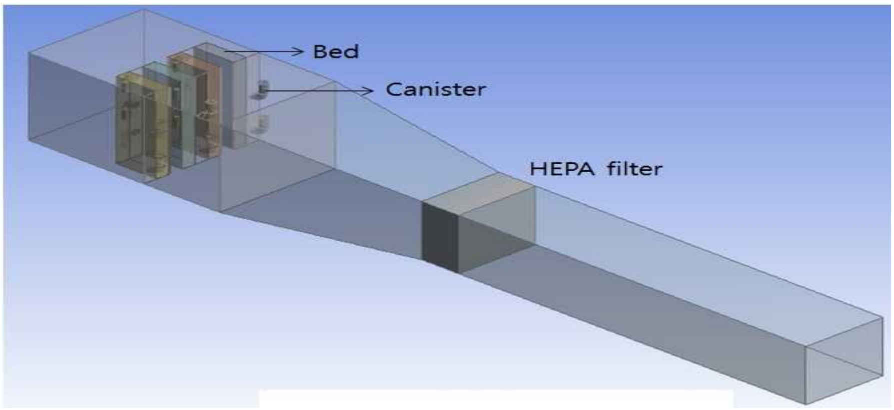

Figure 2. Configuration used for CFD simulations

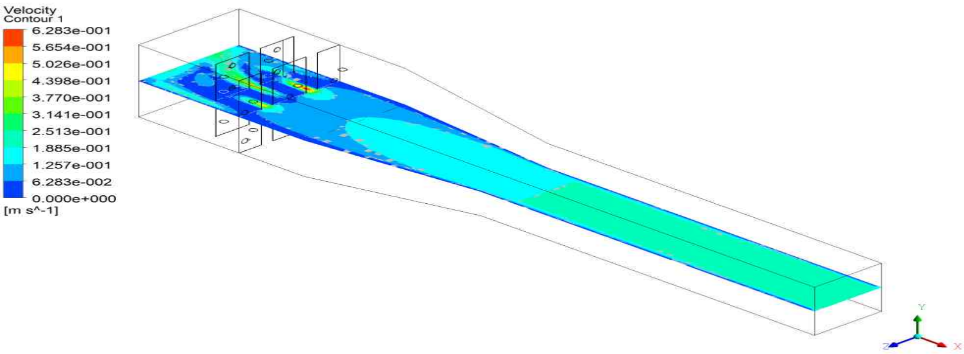

Figure 3. Velocity contour inside the experimental facility for verification tests

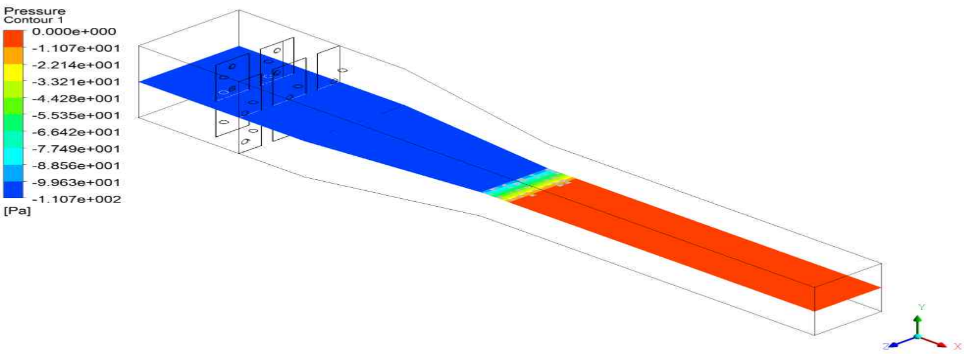

Figure 4. Pressure contour the experimental facility for verification tests

2.2 CFD modelling

Figure 2 shows the configuration used for CFD simulations. The geometry includes the HEPA filter and carbon adsorber assembly, but the flow straightner, moisture separator, heater and pre-filter are not considered. The operating fluid is assumed to be only air and its reference temperature is 25ºC. The pressure boundary and the condition of the mass flow rate with 152.35 cfm are applied to the inlet and outlet faces, respectively. The canisters and beds are treated as porous media. The turbulence is modelled using k-ε model with 5 % intensity. The CFD simulations are performed using the transient mode and calculations are proceeded until stationary conditions are reached.

2.3 Results

In Fig. 3, it is observed that the air flowing through the HEPA filter is distributed to each canister and bed. The HEPA filter acts as a flow resistance, thus a pressure drop occurs across the HEPA filter as shown in Fig. 4. The pressure drops for each canister and bed are almost identical with an order of 10 Pa. Consequently, the velocities through the canisters and beds are also comparable as given in Fig. 5.

Based on the simulation results, it is expected that air flow would be uniformly distributed to each canister and bed in the current experimental configuration. This means that the face velocity and residence time through the canister can be representative of those in beds.

Finally, the sizes of the canisters and beds are confirmed by considering the CFD result that the pressure drops across each canister and bed are identical and with consideration of the real open area of the beds.

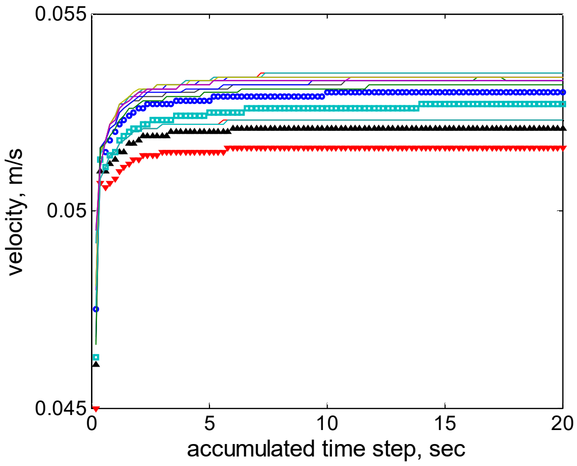

Figure 5. Velocities in each canister and bed (lines : canisters, symbols : beds)

3. Conclusions

In this work, CFD simulations were conducted to analyze flow distribution in an impregnated active carbon adsorber of the experimental facility designed to investigate the aging of the carbon absorbent in the air conditioning unit of the nuclear power plant. From the CFD calculations, it was observed that the pressure drops for each carbon canister and bed with the same characteristic lengths are almost identical and the face velocities are also comparable. Based on these results, it can be concluded that air flow into the impregnated active carbon canisters and beds would be uniform and the design requirements such as the face velocity and residence time would be met.

REFERENCES

[1] M. Nakayama et al., Effects of weathering on impregnated charcoal removal efficiency for radioactive methyl iodide, 28th ISNATT, 2004.

[2] H. Deuber et al., Investigations on the aging of activated carbons in the exhaust air of a pressurized water reactor, IAEA-TEDOC-52, 1989.

[3] D. Broadbent, The aging and poisoning of charcoal used in NPP air cleaning system, IAEA-TEDOC-52, 1985.

[4] B. H. M. Billinge and D. Broadbent, The effects of temperature and humidity on the aging of TEDA impregnated charcoals, IAEA-TECDOC-52, 1985.

[5] V. R. Deitz, Effects of weathering on impregnated charcoal performance, NUREG/CR-2112, 1981.