World Academy of Science, Engineering and Technology
International Journal of Chemical and Molecular Engineering
Vol:13, No:09, 2019

Open Science Index, Chemical and Molecular Engineering Vol:13, No:09, 2019 publications.waset.org/abstracts/109334.pdf

Study on Aerosol Behavior in Piping Assembly under Varying Flow Conditions

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Abstract : In a nuclear reactor accident scenario, a large number of fission products may release to the piping system of the primary heat transport. The released fission products, mostly in the form of the aerosol, get deposited on the inner surface of the piping system mainly due to gravitational settling and thermophoretic deposition. The removal processes in the complex piping system are controlled to a large extent by the thermal-hydraulic conditions like temperature, pressure, and flow rates. These parameters generally vary with time and therefore must be carefully monitored to predict the aerosol behavior in the piping system. The removal process of aerosol depends on the size of particles that determines how many particles get deposit or travel across the bends and reach to the other end of the piping system. The released aerosol gets deposited onto the inner surface of the piping system by various mechanisms like gravitational settling, Brownian diffusion, thermophoretic deposition, and by other deposition mechanisms. To quantify the correct estimate of deposition, the identification and understanding of the aforementioned deposition mechanisms are of great importance. These mechanisms are significantly affected by different flow and thermodynamic conditions. Thermophoresis also plays a significant role in particle deposition. In the present study, a series of experiments were performed in the piping system of the National Aerosol Test Facility (NATF), BARC using metal aerosols (zinc) in dry environments to study the spatial distribution of particles mass and number concentration, and their depletion due to various removal mechanisms in the piping system. The experiments were performed at two different carrier gas flow rates. The commercial CFD software FLUENT is used to determine the distribution of temperature, velocity, pressure, and turbulence quantities in the piping system. In addition to the in-built models for turbulence, heat transfer and flow in the commercial CFD code (FLUENT), a new sub-model PBM (population balance model) is used to describe the coagulation process and to compute the number concentration along with the size distribution at different sections of the piping. In the sub-model coagulation kernels are incorporated through user-defined function (UDF). The experimental results are compared with the CFD modeled results. It is found that most of the Zn particles (more than 35 %) deposit near the inlet of the plenum chamber and a low deposition is obtained in piping sections. The MMAD decreases along the length of the test assembly, which shows that large particles get deposited or removed in the course of flow, and only fine particles travel to the end of the piping system. The effect of a bend is also observed, and it is found that the relative loss in mass concentration at bends is more in case of a high flow rate. The simulation results show that the thermophoresis and depositional effects are more dominating for the small and larger sizes as compared to the intermediate particles size. Both SEM and XRD analysis of the collected samples show the samples are highly agglomerated non-spherical and composed mainly of ZnO. The coupled model framed in this work could be used as an important tool for predicting size distribution and concentration of some other aerosol released during a reactor accident scenario.

Keywords : aerosol, CFD, deposition, coagulation
Conference Title : ICAST 2019 : International Conference on Aerosol Science and Technology
Conference Location : Prague, Czechia
Conference Dates : September 05-06, 2019