Transactions of the Korean Nuclear Society Virtual Spring Meeting
July 9-10, 2020

A Numerical Study on Air Ingression phenomenon inside the Decay Tank for Research Reactor

Minkyu Jung [a*] and Ki-Jung Park [a]
[a]*Korea Atomic Energy Research Institute, Daejeon 34057, Korea*
[*]*Corresponding author: minkyujung@kaeri.re.kr*

1. Introduction

For reactor design, safety is verified by numerical analysis and experiment by assuming accident situations that may occur. For the research reactor, negative pressure may occur on the highest-positioned pipe of the PCS (primary cooling system) depending on the system design. In the highest-positioned pipe break accident, external air could be flowed in the PCS due to the pressure difference. If the incoming air does not stay in a specific area and moves to various part of the PCS, there could be problems with cooling the reactor.

A decay tank is installed to decrease the N-16 radioactivity in PCS of the research reactor. As the flow velocity is sharply decreased by large cross-section area of the decay tank, the flow of primary coolant is delayed inside the tank. In this study, numerical analysis was performed to verify that the incoming air can be collected inside the decay tank so that it cannot circulate the system.

The behavior of air in piping is mainly determined by Froude number. Froude number is defined by

$$N_{FR} = \frac{V}{\sqrt{\frac{D g_c(\rho_L - \rho_g)}{\rho_L}}}$$

where: D = pipe diameter, V = liquid velocity based on total pipe flow area, g_c = gravity, ρ= density, subscript L indicates liquid, and g indicates gas. The smaller Froude number, the more restricted the movement of the air and become stagnant. This is detailed in the NRC report entitled *Guidelines for Effective Prevention and Management of System Gas Accumulation* [1].

The design purpose of the decay tank is to secure the residence time. Although the residence time is expected to decrease somewhat due to air inflow, the time assessment was not carried out in this study because it was more important whether or not air was leaked to outlet in the air inflow accident. In addition, if a certain of air fraction is detected in the tank, the PCS pump would be stopped and the residence time should be sufficiently increased.

2. Methods and Results

This section describes the numerical techniques applied to assess the probability of collecting air from the attenuation tank. The results were mainly compared and reviewed according to the multi-phase model.

2.1 Numerical methods

In the present study, ANSYS FLUENT, a commercial computational fluid dynamics program, was utilized to simulate the air ingress phenomena into the decay tank. The geometry of the decay tank is shown in Fig. 1. The decay tank has two 2:1 elliptic heads and cylindrical body, and both the inlet and outlet are located on the lower side. Axisymmetric calculations were performed considering the geometric features and the computational cost. Water and air were utilized as materials, with densities of 998.2 kg/m^3 and 1.225 kg/ m^3 respectively. The k-w SST model were adopted for turbulence model and the second order backward Euler method was used for time advance calculation. The velocity inlet and pressure outlet boundary conditions are applied to inlet and outlet respectively, and 3 m/s velocity was set to flow into the inlet boundary. Initially, the decay tank was filled with water, and 10% of air was injected to study the flow characteristics of air inflow.

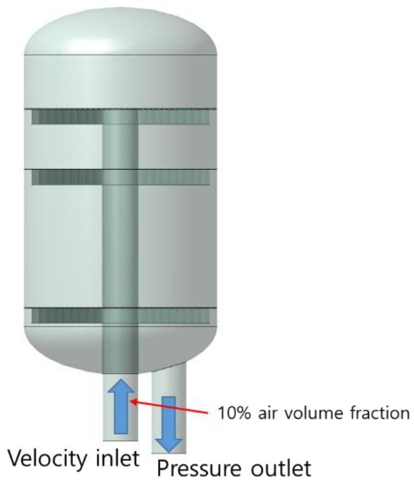

Fig. 1. Geometric configuration and boundary conditions for decay tank

2.2 Multi-phase model

The multi-phase model is very important in assessing behavior of the decay tank according to the air ingress. In this calculation, the mixture model and Eulerian model, widely known as the multi-phase flow model, were applied. The mixture model is a simplified Eulerian approach for modeling n-phase flows. The simplification assumes that the Stokes number is small, which means that particle and primary fluid velocity is nearly equal in both magnitude and direction. On the other hand, Eulerian model is known to be a powerful tool to model dispersed flows. Accuracy is determined by accuracy of interfacial terms that are usually non-linear so convergence is often difficult. For this reason, unsteady solver is used to solving the Eulerian model and should be careful in determining the particle diameter. The calculations were performed assuming 1mm of bubbles.

2.3 Results and Discussions

Figure 2 shows the snapshots of void fraction inside the decay tank by adopting the mixture model. The water and air mixture are reduced in speed at the upper head of the decay tank, resulting in stratification. As the amount of air in the decay tank accumulates, it is observed that it gradually moves downward through the perforated plates. While water and air are separated at the upper head, the flow velocity increases through the plate, which results in not being completely separated.

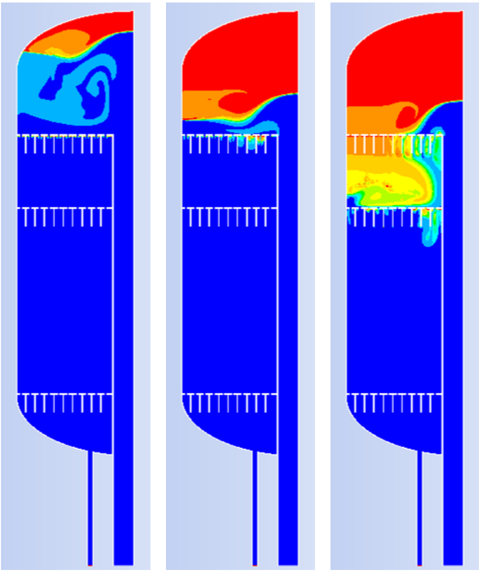

Fig. 2. Snapshots of void fraction inside the decay tank using mixture model

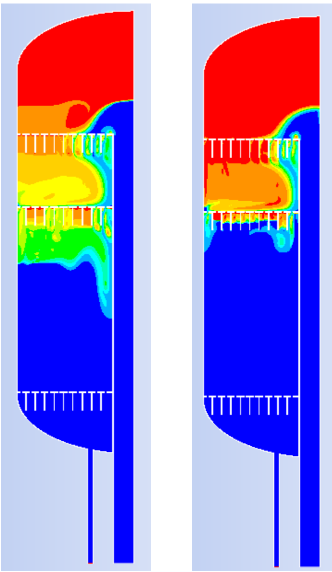

Fig. 3. Void fraction comparison inside the decay tank using mixture model (left) and Eulerian model (right)

The flow characteristics of the decay tank according to the multi-phase model are compared in Fig. 3. The overall flow features are similarly observed, stratification phenomena are well observed as water and air separation occurs well by adopting Eulerian model. As it passes through the perforated plates, air-water separation does not occur well in the mixture model because the mixture model could be applied to small Stokes number flow. In the result of the mixture model, the air moves faster to the outlet and passes through the decay tank. The void fraction of the decay tank was assessed to be 60% in the mixture model and 85% in the Eulerian model when air was escaping from the tank exit.

3. Conclusions

In this study, the characteristics of flow due to air inflow into the decay tank were verified and the comparison was carried out according to the multi-phase flow model. Stratification of air-water separation in the upper part of the tank was observed due to air inflow. Similar flow characteristics have been observed in both the Eulerian model and the mixture model, but stratification is well observed in the Eulerian model. This is due to the assumption that the mixture model is a simplified model and can only be applied to small Stokes numbers.

ACKNOWLEDMENT

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIP) (No. NRF-2020M2C1A1061014)

REFERENCES

[1] NEI 09-10 [Rev 1a-A], Guidelines for Effective Prevention and Management of System Gas Accumulation, 2013.
[2] ANSYS FLUENT theory guide, ANSYS Inc., 2019.