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Flow Residence Time Analysis for Decay Tank by the Design Parameters

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1. Introduction

This paper describes the numerical simulations of a decay tank, which will be utilized in KIJANG Research Reactor (KJRR) project. In the research reactor, the heat generated in the core is removed by primary cooling system (PCS), thus primary coolants contain many kinds of radioactive nuclides. N-16 comprises a majority of radiation level for PCS due to the generation of high strength γ-rays. Since the half-life of N-16 is 7.13 seconds, the radiation level could be decreased by installing the decay tank at the core outlet pipe of PCS. The N-16 activity is decreased by the sufficient flow residence time in the decay tank [1-3].

In the present study, the flow characteristics and residence times are compared according to a variety of design variables. A commercial flow simulation program, ANSYS-CFX is utilized for the calculation.

2. Methods and Results

In order to provide the sufficient residence time, the tank has very large volume and perforated plates. The perforated plates make the flow evenly distributed inside tank. Therefore to design a tank, there are both external design parameters, tank length, diameter, head type, etc., and internal design parameters, a configuration of perforated plate and the distance between plates. In the present study, the flow characteristics and residence times are studied for the external design parameters.

Tetrahedral meshes are introduced to represent the complex geometric shapes of perforated plates. For a turbulence model, Shear Stress Transport (SST) model is employed to simulate the flow separation by the adverse pressure gradient region. One-eighth model of full configuration is employed for this simulation owing to the symmetry of the tank. The mass flow inlet and pressure outlet boundary conditions are used at both ends and symmetry boundary condition is also adopted at sides.

2.1 Tank Length

The first design parameter is the tank length. Although the increase of the tank length makes longer residence time, installation space and construction costs may be escalated in some cases. In this case, designated tank length and enlarged length are calculated and compared. The streamlines generated from inlet are shown for two cases in Fig. 1. Inlet flow impinges on the first plate and spreads to radial direction. After the flow passes the first and second plates, the flow velocity is decreased by sudden expansion of downstream area. The flow characteristics between two length cases are almost similar thus it can be inferred that only increased length effects on the residence time. The increased residence time from enlarged length can be estimated around 6.5 seconds by using the mass flow rate and cross-section area.

The residence time distribution at outlet boundary is shown at Fig. 2. The increased time is about 6.0 seconds from the time distribution, so N-16 activity is reduced about 45%. This result is consistent with the preliminary calculation.

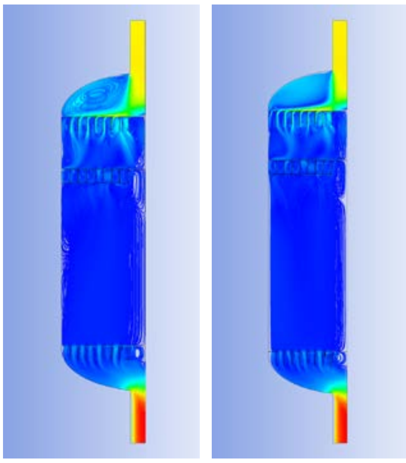

Fig. 1. Streamlines colored by velocity magnitude for decay tank with designated (left) and enlarged (right) length.

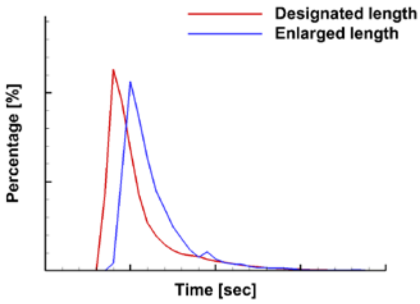

Fig. 2. Residence time distribution at outlet boundary for designated (red) and enlarged (blue) length.

2.2 Tank Diameter

As the tank diameter increases, the flow velocity decreases along the increase of cross-sectional area. Thus, the increased diameter could provide longer residence time in view of fluid dynamics. However in the view of structural mechanics, the structural stability is vulnerable by increase of self-weight for the perforated plate. In this case, the time distribution is compared for two cases with an initially designed diameter and a decreased one.

The residence time distribution for two different diameter cases is shown at Fig. 3. The averaged residence time is reduced about 5.5 seconds, while time decrease of 7.9 seconds is preliminarily calculated using the mass flow rate and cross-sectional area. This little difference can be discerned from the effect of turbulence fluctuation by decreasing the hole diameter.

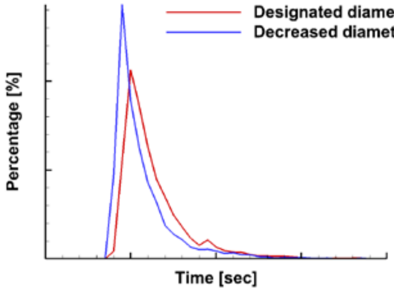

Fig. 3. Residence time distribution at outlet boundary for designated (red) and enlarged (blue) length.

2.3 Tank Head Type

2:1 semi-elliptical and dished head types are considered for the tank head. 2:1 semi-elliptical tank head is a commonly used tank head shape. On the other hand, the dished tank head can increase the tank length by reducing the head length. As previously explained at the section *2.1*, the tank length is very important design parameter. Figure 4 compares the flow lines for two head type cases. For the case of the dished head type, it is shown that the flow at the 1st plate end is reduced and flow separation region is also represented around the 3rd plate end. As the flow region is reduced by occurrence of flow separation, the flow velocity could be increased inside tank.

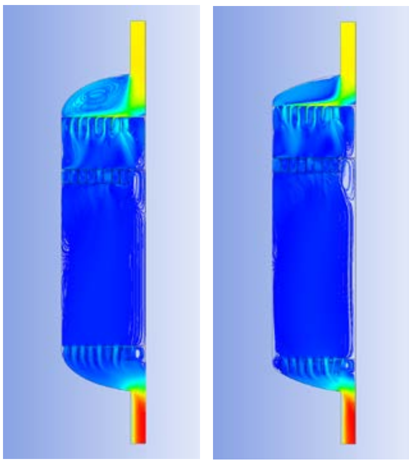

Fig. 4. Streamlines colored by velocity magnitude for decay tank with 2:1 semi-elliptical (left) and dished (right) tank head.

The residence time distribution is shown at Fig. 5 for two types of tank heads. The residence time for the dished head is decreased owing to distorted inlet flow at 1st plate and occurrence of flow separation. The difference of averaged residence time is about 1.8 seconds.

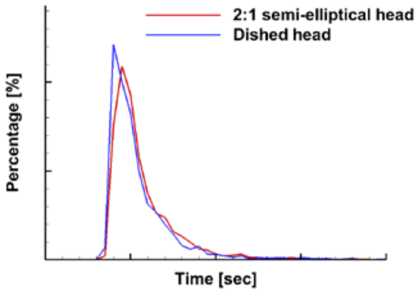

Fig. 5. Residence time distribution at outlet boundary for 2:1 semi-elliptical (red) and dished (blue) tank head.

3. Conclusions

This paper describes the flow characteristics and residence time analysis in accordance with the external design parameters, such as tank length, diameter, and head type. The numerical simulations were conducted with a commercial program, ANSYS-CFX. More accurate and elaborate flow simulation will be performed with hexahedral meshes to enhance the resolution of unsteady flow phenomena. Furthermore, Fluid Structure Interaction (FSI) simulation will be also conducted to assess the structural safety analysis on decay tank. All these numerical results will be utilized to design the decay tank in KJRR project.

ACKNOWLEDMENT

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