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Decay Tank Design in KiJang Research Reactor

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1. Introduction

This paper describes the detailed design and numerical analysis results of a decay tank, which will be utilized in KJRR (KiJang Research Reactor) project. The primary coolant passed through the reactor core contains various radionuclides, N-16 comprises a majority of radiation level at the reactor outlet of the PCS due to the generation of high strength ɣ-rays. Since the half-life of N-16 is very short, 7.13 seconds, a decay tank is installed in the core outlet pipe to reduce the N-16 radioactivity in the compartments installed such as PCS pumps and heat exchangers.

On the other hand, negative pressure could be occurred on the highest-positioned pipe of the PCS including a core downward cooling flow. The pipe breakage leads to the air inflow, which affects the structural integrity of the main fluid equipment of the PCS. The behavior of air in piping is mainly determined by Froude number. Due to the low velocity in the decay tank, the Froude number is defined as very low, and the air introduced into the decay tank may become stagnant.

In this study, the decay tank shape according to the design requirements and its main flow characteristics were confirmed. The design requirements applied to the decay tank are as follows.

1. Secure required residence time considering the shielding of equipment room
2. Air-water vertical stratification and measurement signal generation to cope with air ingress accidents.

2. Methods and Results

2.1 Initial Model

Initially, the decay tank shape was designed to secure the residence time, and this research team performed the design by reducing the flow velocity in the tank using a perforated plate [1]. Figure 1 shows the initial decay tank shape and streamline distribution. In design a decay tank using a perforated plate, the number and arrangement of the plates directly affect the residence time. In this study, three perforated plates were arranged. The first perforated plate serves to change the coolant flowing in the vertical direction into a radial flow, and the second plate serves to reconvert the radial flow into a vertical flow. And, the third perforated plate serves to minimize the interference of the outlet boundary in order to continue the vertical flow. Therefore, an important shape factor for securing residence time is the length between the second and third perforated plates that maintain a low flow velocity in the vertical direction. In the relevant section, it should be designed so that a dead zone due to separation does not occur as much as possible.

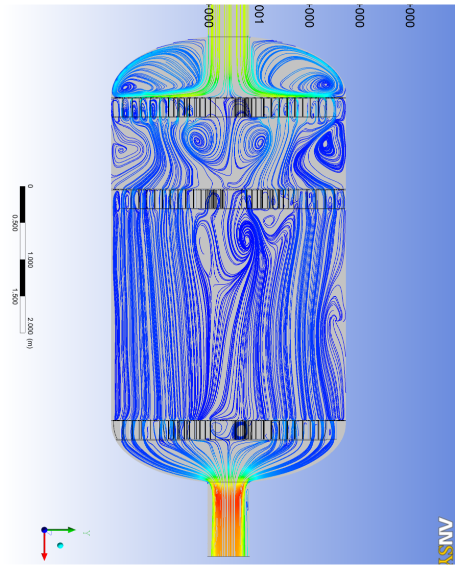

Fig. 1. Initial design shape and streamline by velocity contour for decay tank.

2.2 Intermediate Model

After the initial design of the decay tank, there were concerns about the structural integrity of the fluid equipment due to an air ingress accident, and a design change of the decay tank was required to relieve the accident. Air-water vertical stratification should be occurred in order to maintain the state in which the air is captured in the decay tank. Air is collected at the top of the decay tank by air-water stratification phenomena. In the initial model of decay tank, the inlet pipe was located at the top of the tank, and the outlet pipe was located at the bottom of the tank. It was judged that the inlet pipe located at the upper part would adversely affect the air-water vertical stratification, so the position of the inlet pipe was changed to the lower part of the tank.

The changed decay tank shape and void fraction according to the air ingress was compared with initial model as shown in Fig. 2 [2]. As the inlet pipe moved to the center of the lower elliptical head, the outlet pipe was placed on the side. The position of first perforated plate was significantly lowered to capture as much air as possible. Accordingly, a relatively higher air void fraction than initial model is shown in the upper part of the tank, and it is evaluated that air is located in the upper part of the tank. However, as described above, as the distance between the second and third plates became shorter, the residence time was greatly reduced by about 20%.

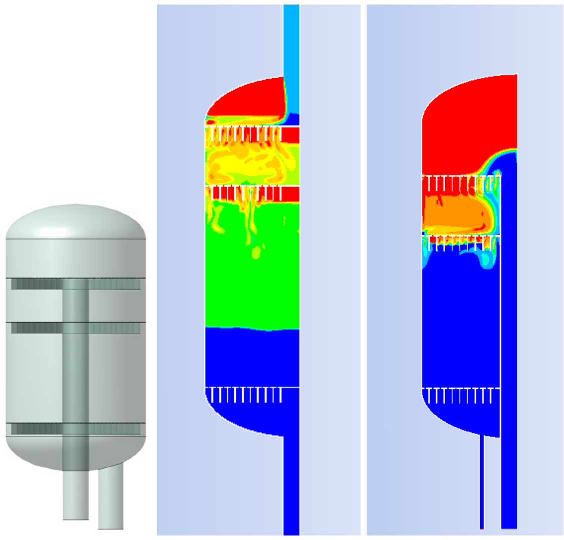

Fig. 2. Intermediate design shape and streamline by velocity contour for decay tank.

2.3 Present Model

If the residence time in the decay tank is greatly reduced, the shielding of the PCS pump and heat exchanger room is directly affected. In addition, although air capture in the decay tank is very important in an air ingress accidence, it is more important to safely shutdown the reactor by generating an appropriate trip signal. Also as one outlet pipe is installed as shown in Fig. 2, flow imbalance occurs in the decay tank, which affects the structural integrity due to the fatigue load in the long term. Therefore, the same distance between second and third plates was maintained as the initial design shape by moving the plates to the upper part, and two outlet pipes located in the lower elliptical head were installed. In the air ingress accident, air capture was efficiently applied according to the arrangement of bottom inlet piping, and a tank top/outlet differential pressure gauge was applied for the trip signal.

The present model and velocity contour are shown in Fig. 3. It is almost similar to the flow characteristics of the initial model, except that the flow from the bottom head impinges the upper head and creates a rotational flow. In the present model, it can be seen that the axial flow is maintained after the second perforated plate.

Figure 4 shows the distribution of residence time evaluated using the present model compared to the initial model. It can be seen that the distribution of the residence time is almost same except that the residence time of present model is slightly shortened. Quantitatively, a residence time reduction of less than about 5% was confirmed.

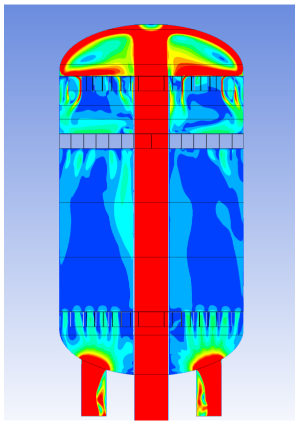

Fig. 3. Present design shape and velocity contour for decay tank

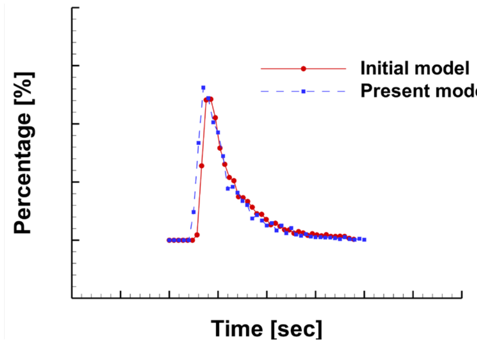

Fig. 4. Residence time distribution for initial and present models of decay tank

3. Conclusions

In this study, the decay tank shape according to the design requirements and its main flow characteristics were confirmed. The present model is designed to satisfy the two design requirements applied to the decay tank. It was confirmed whether the required residence time was satisfied through the residence time distribution, and the air-water vertical stratification phenomenon was confirmed through the air ingress flow simulation.

ACKNOWLEDGEMENT

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