Thermal Field of Moderator Circulation in CANDU-6 Reactor

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1. Introduction

When a loss of coolant accident occurs, the contact between PT (pressure tube) and CT (calandria tube) threatens the fuel channel's safety. The coolability of heavy water moderator in a CANDU reactor has an effect on the prevention of PT/CT contact. Prediction of high temperature region in moderator gives insight to the design of nuclear reactors. Therefore, we measure the temperature of flow patterns such as the Momentum flow, the Mixed flow and the Buoyancy flow in 1/8 scaled calandria tank like SPEL and STERN equipment of Canada [2,3].

2. 1/8 scaled Moderator cooling system

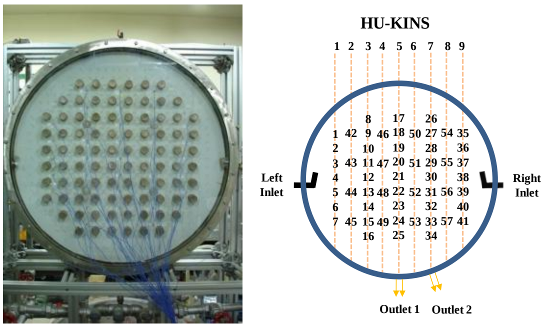
Lee et al (2006) [1] produced the scaling laws for circulation flow in calandira tank. In the scaling law, the linear scaling based on the power density and local dimensionless numbers for the buoyancy and inertial force balance were used. As shown in Fig. 1, 1/8 scaled Moderator cooling system is depicted.

Fig. 1. HU-KINS experimental equipment

HUKINS experimental facility has devices such as a power controller, a heater controller and the calandria tank. There are 88 heaters in calandria tank. After electric heaters are produced, they have different resistances. It causes the internal thermal inequality and makes it difficult to generate accurate demonstration experiments. We made each heater to have a resistance value of equality with variable resistor.

3. Experimental Method

As shown in Fig. 2, monitoring positions are indicated. The numbers of fifty-seven thermocouples are inserted into the calandria tank. Input and output portions are also inserted with four thermocouples each part. The experimental method is as follows, inlet nozzle velocities divide 0.183 L/s, 0.117 L/s, 0.067 L/s at each flow patterns in order to measure of the Momentum flow, the Mixed flow, and the Buoyancy flow. In the case of the mixed flow, we conducted two experiments in different conditions with the outlet of 0° and 16.4° to predict the effects of the exit. Power consumption is approximately 10kW and output power is 7.7kW. The inlet nozzle temperature is 36.2℃ (the Momentum flow), 36.4℃, 35.9℃ (the Mixed flow), and 34.2℃ (the buoyancy flow) in the steady state and the temperature of surrounding is 22℃. Thermocouple is the K-type and the Agilent is data acquisition equipment. The Measured time is 2480 second and the acquisition rate is 25Hz.



(a) (b)

Fig. 2. (a) Thermocouples inserted into the HUKINS, (b) monitoring positions

4. Results

In Fig 3, the temperature data is shown in the vertical direction as X-axis. Y-axis is Celsius temperature. Figures of Fig 3 are expressed monitoring positions of HUKINS by the vertical direction. Buoyancy driven flow has totally higher temperature than the Mixed, momentum flow. The momentum driven flow has the lowest temperature distribution.

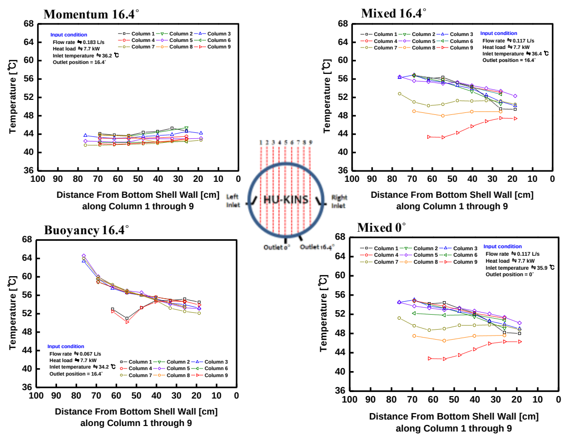


Fig. 3. Analysis of the vertical direction (Column 9)

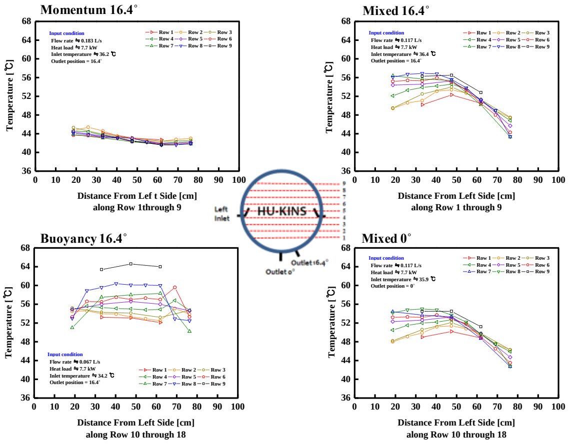


Fig. 4. Analysis of the horizontal direction (Row 9)

In the case of buoyancy, its flow has high temperature region at the top of calandria, and low temperature region at the bottom. It is made by low jet flow of inlet nozzle. At a certain height, the jet cannot penetrate the stratified line due to the temperature difference. So buoyancy driven flow has hot spot at the top of the tank. The mixed flow has an asymmetric circulation. We can see the distribution of the wider temperature at left than the one at right. It is formed by balancing of both Jet force and buoyancy force subtly. In momentum, driven flow has almost no temperature variation. It is caused by stronger jet force than buoyancy force. So the circulation hits the top of the tank.

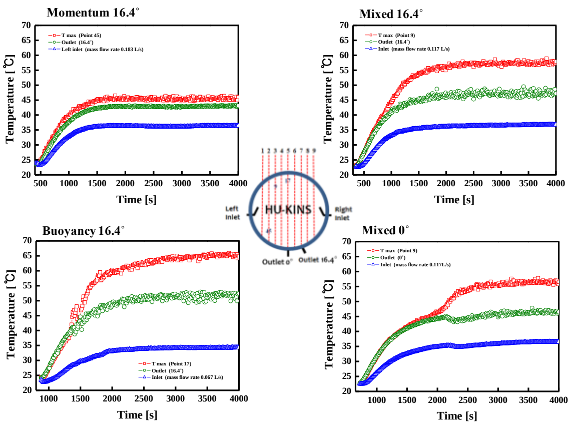


Fig. 5. Temperature pattern of outlet part and maximum temperature point in the passage of time

Figure 4 shows the data in the horizontal direction as a result of the newly arranged with the position of the exit. Effects of the exit in each flow pattern can easily find insight of the temperature distribution. The Momentum flow with a little variance of temperature doesn't complete symmetry but it is slightly moved to the right. Analysis of horizontal direction describes the asymmetric flow characteristic better than analysis in the Mixed flow. The buoyancy flow pattern is also reflected hot region in top of tank. The time for each pattern about outlet and the peak temperature are shown in the Fig 5. The singularity of the mixed-flow is that the exit temperature is lower previous step and maximum temperature point is increasing phenomenon. The mixed flow changes flow pattern more rapidly in the outlet 0° than in the outlet 16.4° in the transient state.

5. Conclusions

We obtain three patterns of temperature fields; the Momentum flow, the mixed flow, the buoyancy flow in tank, we monitored sixty-one monitoring points inside HUKINS tank. The result shows that the momentum flow has almost no variation in the temperature field. The temperature of the Mixed flow is evenly distributed and its pattern is asymmetry. The buoyancy flow shows the temperature curve with the hot region in the top and the cold region in the bottom of tank. We think these results are expected to be utilized further data for CFD code and set up the safety regulation index.

Acknowledgment

The present work is supported partially by Korea Institute of Nuclear Safety and National Agenda project in Korea.

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