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Flow Visualization of Calandria Tank of CANDU nuclear reactor

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1. Introduction

In order to have the market opportunity in the nuclear industry in both terms of competitive environment of demand and chances for supply in other word export, the study and development of CANDU reactor are of quite importance. Series of studies have been made for enhancing the safety and performance of CANDU reactor. Among them, we have been developed an experimental method to identify the flow patterns of moderator circulation in the Calandria Tank of the CANDU reactor. As reported we have developed a scaling method based on the jet force and buoyancy force in the medium and finally developed 1/8 scale facility.

2. 1/8 scaled experimental facility

Lee et al (2006) 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, the 1/8 scale calandria tank and support systems for power and instrumentation were constructed.

Fig.1 HUKINS-1/8 scale Moderator cooling system [1]

3. Flow regime map and analysis

In the present study, we utilized CFX, the three dimensional computational fluid dynamics code, to find the flow structure in the calandria tank. We developed mesh structure to realize the turbulent dissipation near the wall and nuclear fuel channels. With the variation of power and inlet flow rate, we can produce two-dimensional flow pattern map based on the Reynolds number and Archimedes number. Once we have the reliability of the code estimation, we can easily extend the present work to the real case of CANDU-6 and we can set up the safety regulation index, archimedes number for calandiria cooling system.

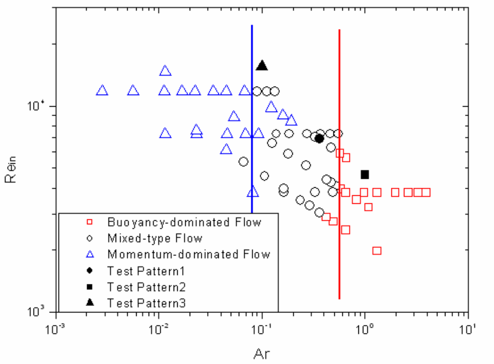
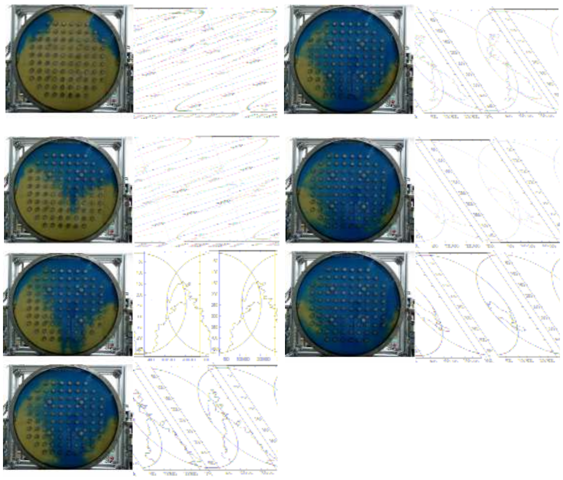


Fig.2 Flow pattern map [2]

As shown in Fig.2, there are three distinguished flow patterns: the momentum driven flow regime, the mixed flow regime, and the buoyancy flow regime. It is very easy to see the danger of the buoyancy flow regime because the hot moderator in the upper part makes the lower heat transfer capability. Therefore, we need to set the circulation mode at least in the mixed flow regime.

4. Flow visualization of the HUKINS

In order to visualization of the circulation mode of the moderator in the calandria, we adopted chemical method. At first, we dissolve BTB into the moderator which changes into blue color when it mixes with NaOH solution. Therefore, we equipped a NaOH injector near the jet nozzles. As shown in Fig.3, the typical flow patterns of the momentum driven flow are depicted. As expected, the jet from the injection nozzles hit the top of the calandria and flow down to the bottom outlet. The total sweeping time was short as the velocity indicated



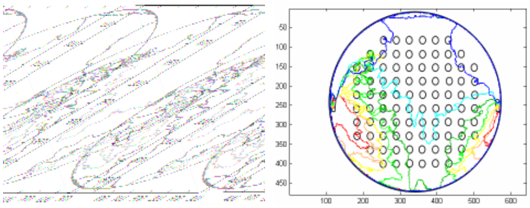


Fig.3 The flow visualization of the momentum driven flow regime

The buoyancy driven flow are depicted in Fig. 4. As noted it takes long time to cover up the whole tank with the chemical. The flow pattern showed that the injected jet flow down immediately near the nozzle and makes a circulation near the bottom of the tank and finally make the rising flow to the upper part. However, at a certain height, the jet cannot penetrate the stratified line due to the temperature difference.

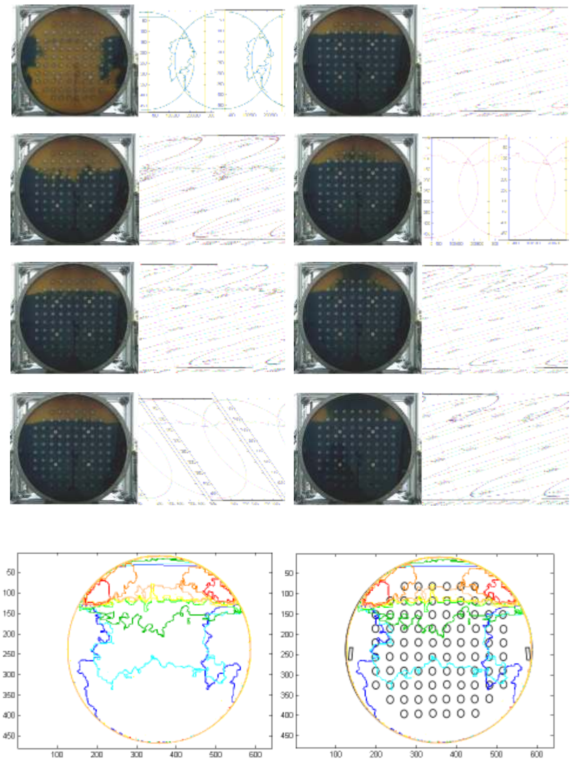
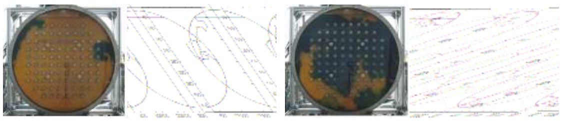
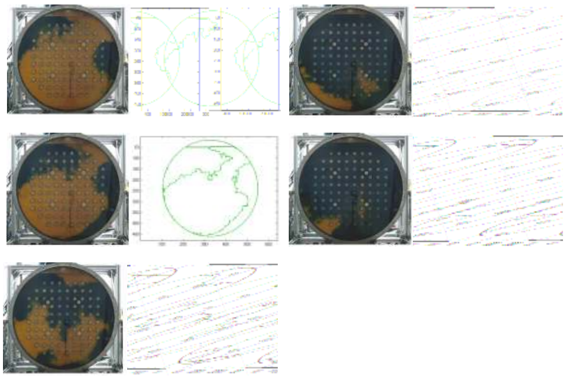


Fig.4 The flow visualization of the buoyancy driven flow

Finally, we take the flow circulation in the mixed mode which represents the circulation and buoyancy but the circulation hit the top of the tank so there is no stratified horizon in the tank. Therefore, there is no risk of hot spot in the tank. As shown in Fig. 5, we can see asymmetric circulations of flow.





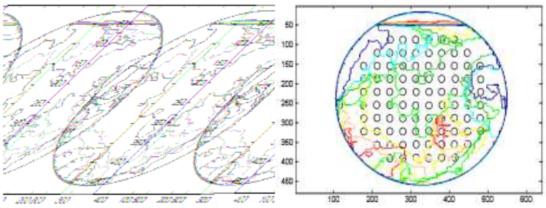


Fig.5 The flow of mixed flow regime

5. Conclusions

The 1/8 scaled facility for Calandria, HUKINS, is used to visualize the circulation of moderator. The visualization is made by the characteristics of color change when BTB solution and NaOH are missed. We successfully observed three distinguished flow patterns including the momentum driven, mixed, and buoyancy driven flow. When we compare the present visualization results with the CFD analysis, we found that the global parameters are well matched each other but needs to refine many factors to realize the experimental results with the computer codes. The present study showed that the experimental works with HUKINS can be used to evaluate the computational analysis and safety index for the moderator cooling system.

Acknowledgment

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