Gas Entrainment through Dual Branches in Simulated CANDU Reactor Header

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1. Introduction

Liquid and gas entrainments in PWR have been widely investigated because these phenomena have a great important on the SBLOCA analysis of PWR [1, 2]. In most of the previous experiments, the T-junction branches had three directions of top, side, and bottom. With regard to CANDU, the entrainment phenomena are also important on the safety analysis of reactor fuel channels. Reactor headers of CANDU in Korea have 95 feeder pipes i.e., T-junction branches, which have 5 different angles of 0°, 36°, 72°, 108°, and 144° downward from horizon. Recently, entrainments in arbitrary angled T-junctions have been investigated [3]. However, each feeder pipe in CANDU is not isolated, that is, the entrainment phenomena through one feeder pipe can be affected by the flow through neighboring feeder pipes. Therefore, the multiple branch effect on the entrainment phenomena should be examined in the case of CANDU.

2. Experiments

In this section, experimental apparatus and results for gas entrainment in dual T-junction branches are described.

2.1 Experimental Apparatus

Air and water are used as working fluids. The test section is designed to simulate the flow through feeder pipes of reactor headers of CANDU. It consists of (1) reservoir tank, (2) half-cylinder reactor header, and (3) dual branches with the angle of 0° and 36° downward.

The half-cylinder reactor header is attached on one side of the cubic reservoir tank. The air and water flow into the top and bottom of the reservoir tank, respectively, and discharge out through each branch. Air and water flows are stratified in the half-cylinder reactor header. The axial flow is not established in order to minimize the interfacial level fluctuation. Thus, the uncertainty on the critical entrainment height (or inception height) due to level fluctuation is effectively excluded, and the effect of multiple branches on the critical entrainment height is magnified.

The inner diameter of half-cylinder reactor header is 190mm, T-junction branches have two different inner diameters of 25mm and 35mm, which are about 1/2 of CANDU reactor headers and feeder pipes. Flow visualization is possible through transparent half-cylinder reactor header and T-junction branches. The cubic reservoir tank has a volume $1m^3$ to make the flow to each branch stable.

The present experiments can be categorized into the following two groups: single branch experiments (side branch) and dual branch experiment (side and 36° downward branches). Onset of gas entrainment through side branch and the effect of the liquid flow through 36° downward branch have been investigated.

Experiments were performed at room temperature and maximum pressure of 0.2MPa. Experiment started with pre-fixed discharge flow rate through each branch, and the water level was much higher than the top of side branch with and angle of 0°. Then the level was lowered very slowly by opening drain valve at the bottom of reservoir tank until the onset of gas entrainment through side branch happened.

The pressure loss coefficient, K, across each branch was set to equal, and pressure difference between reactor header and the outlet of each branch was same. As a result, the mass flow rate for each branch was same until the water level was low enough to the onset of gas entrainment.

2.2 Experimental Results

Figure 1 shows the sequence of gas entrainment. As the water level reaches closely to the inception height but still higher than the inception height, the surface deflection occurs and the vortex core is established.

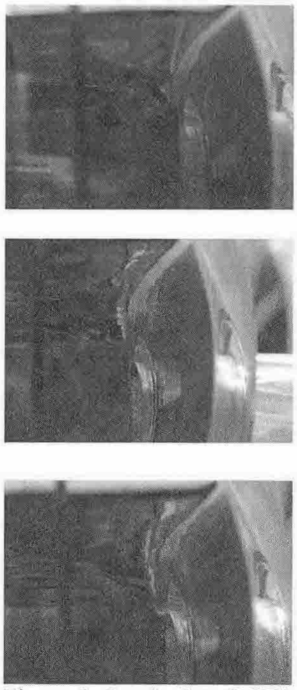

Figure 1. Just before OGE* (up left), Initiation of OGE (up right), Continuous Gas Entrainment (down left)
* OGE: Onset of Gas Entrainment

With slightly further lowering of the water level, the vortex core develops into vortex gas hose. The gas hose reaches the top of side branch and discharges the gas in a moment. Then the gas hose disappears abruptly and becomes restored to the vortex core. At this water level, the development of vortex gas hose and restoration to vortex core repeats intermittently. It is defined as the critical height for gas entrainment.

As the water level decreases further, the tail of the vortex gas hose is always connected to the upper part of the side branch, and continuous gas entrainment occurs.

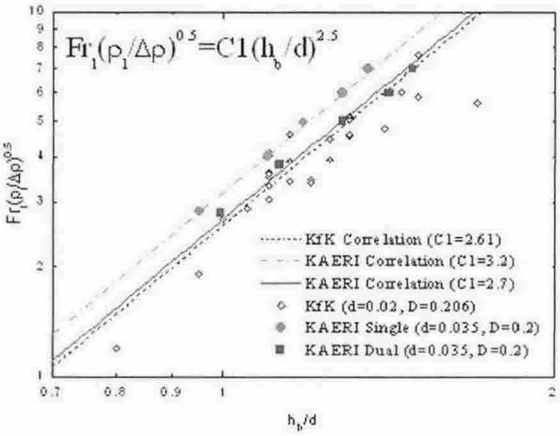

Figure 2. Critical gas entrainment height for side branch; branch inner diameter of 35mm

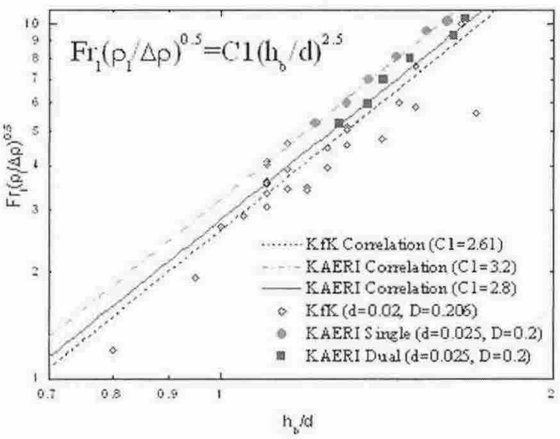

Figure 3. Critical gas entrainment height for side branch; branch inner diameter of 25mm

Figure 2 and 3 show the experimental results for gas entrainment through side branch, obtained from KfK experiments[1] and the present experiments. All the present data fall into the uncertainty boundary of KfK data. The present data are well fitted by the non-dimensional parameters of Froude number, 0.5 power of density ratio, and 2.5 power of height over diameter.

The critical heights for dual branch are constantly higher than those for single branch. This is due to the liquid flow through 36° downward branch. However, the increase in the critical height is not significant.

KfK single branch data agree better with the data obtained for the present dual branch experiments than the data for the present single branch experiments. This may be due to the fact that the axial flow is excluded and resultantly more stable free surface is established in the present experiments.

3. Conclusion

Gas entrainment through horizontal feeder pipe has been experimentally investigated with the effect of neighboring 36° angled feeder pipe. The effect of the liquid flow through 36° angled feeder pipe is not as significant as concerned. All the present data agree well with the correlation suggested by KfK[1].

The effect of the flow through neighboring feeder pipe is expected to be more definitive in the case that the water level is between side branch and 36° angled branch. Liquid entrainment through side branch and gas entrainment through 36° angled branch will compete, and one of them will be dominant depending on the closeness of the free surface to each branch. Experiments for this phenomenon are being carried out.

REFERENCES

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