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Investigation on siphon breaking phenomenon with two-phase downward co-current flow regime transition

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1. Introduction

A rupture in the primary piping of a cooling system in a research reactor could lead to a loss-of-coolant accident (LOCA). Therefore, the water level of the reactor pool should be sustained and a reactor scram follows. The remained quantity of the water in reactor pool could be connected to the time for handling the crisis. However, the existence of siphon breaker as passive safety device affect to the decrease of working fluid flow rate, so the optimal design of siphon breaker is needed.

Siphon breaking phenomenon is complicated due to the transient, turbulent, two-phase flow, so suitable models or correlations that describe this phenomenon do not exist, and no general analysis been developed. In previous study, Neill and Stephens conducted siphon breaker experimentally [1]. They suggest the concept of air sweep-out to separate the mode of siphon breaking. Kang et al. conducted experiment using the real scale facility which mimics the research reactor. [2] They set the size of siphon breaker, size and position of pipe rupture and existence of core pressure drop as the experimental parameter.

In this study, the siphon breaking phenomenon was investigated with comparing of flow regime during the siphon breaking. The experimental data from Neill and Stephens [1] and Kang et al. [2] was used to analyze.

2. Analysis

2.1 Air sweep-out mode and flow regime transition

From the Neill and Stephens [1], siphon breaking phenomenon could be divided to three group with the concept of air sweep-out. They suggested the change of slope of differential pressure through the two-phase co-current downward flow as the characteristics of each mode. From the zero sweep-out mode to partial and full sweep-out mode, the portion of the air swept out due to the flow of water was increased and the slope of differential pressure was decreased.

The purpose of the siphon breaker is cut-off of water flow by induced air. However, if induced air flowed out with water, the time to siphon breaking could be expanded and the more coolant in reactor would be lost.

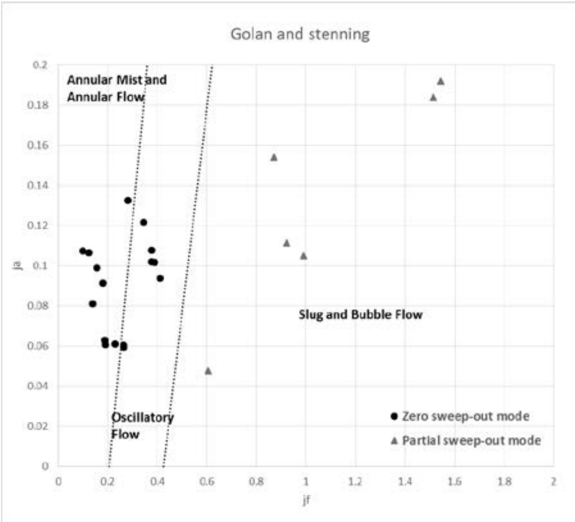

Fig. 1. Flow regime [3] at the start timing (Neill and Stephens cases[1])

The siphon breaking phenomenon is started when the air is flowed in and water-air two phase flow is developed. Figure 1 showed the relation between the separation of air sweep-out mode and flow regime map. The vertical downward two-phase flow map suggested

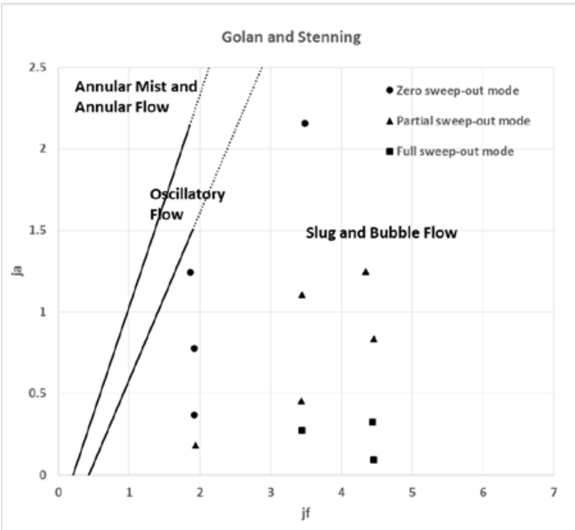

Fig. 2. Flow regime [3] at the start timing (Kang et al. cases[2])

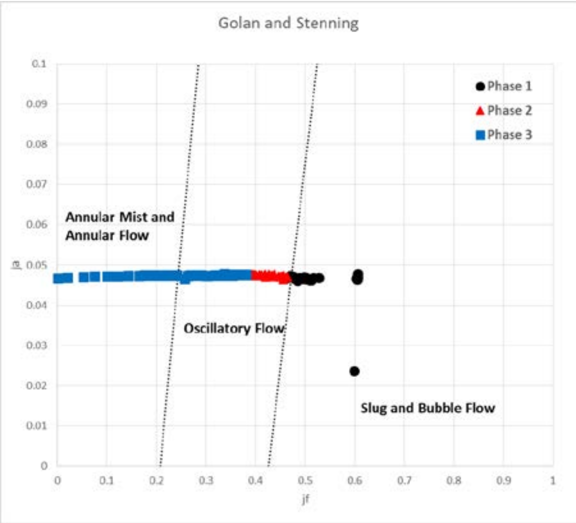

Fig. 3. Flow regime transition during the siphon breaking (WF31003 case from Neill and Stephens [1])

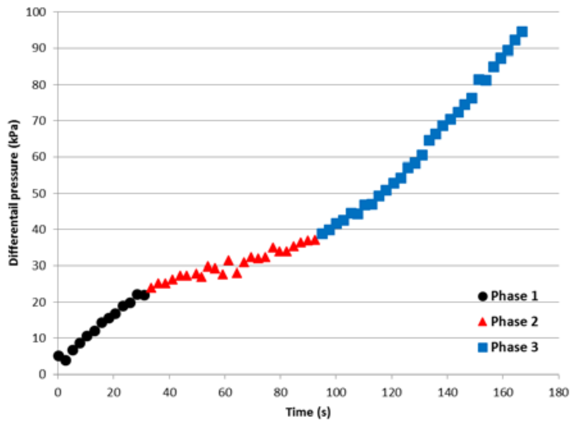

Fig. 4. Change of differential pressure during the siphon breaking (WF31003 case from Neill and Stephens [1])

by Golan and Stenning [3] was used. The cases at the partial sweep-out mode were started in the slug and bubble flow regime, however the cases at the zero sweep-out mode were started in the oscillatory or annular mist and annular flow regime. The oscillatory flow and annular mist and annular flow regime could be treated as separated flow regime and slug and bubble flow could be defined as homogeneous flow. Therefore, the air sweep-out could be occurred when the water-air two phase flow experience the homogeneous flow.

However, at the cases of Kang et al. (Fig. 2), all of cases were started at the slug and bubble flow without the consideration of air sweep-out mode. The flow regime map by Golan and Stenning[3] was investigated with 1.5 inch size of pipe and Neill and Stephens conducted experiments with 4 inch size of pipe. However, the experiments of Kang et al. [2] were conducted with 16 inch size of pipe. The transition of flow regime was affected by the dimension of pipe, so the cases on Kang et al. could be analyzed well with flow regime map in large pipe size.

2.2 Differential pressure trend and flow regime transition

Neill and Stephens [1] suggested the concept of air sweep-out using the slope of differential pressure. When the transient differential pressure data was separated as 3 phases based on the slope of data, figure 3 and 4 could be got. Transition between phases was almost well matched with transition between flow regimes. At the Kang et al. cases [2], similar trend has been shown however, the criteria was not well match as shown in fig 2.

As mentioned before, the flow regime map could be classified to homogeneous and separated flow. From fig. 3, the phase 3 could be treated as the zero sweep-out mode and it exists on the separated flow regime. Therefore, it is needed that the transition to separated flow for finalization of siphon breaking.

The criteria between slug and bubble flow and oscillatory flow is influenced by the bubble rise velocity. Therefore the new criteria considering the pipe dimension could be got from calculation of bubble rise velocity.

3. Conclusions

In this study, the experimental data from the previous studies [1, 2] was analyzed with vertical downward co-current two-phase flow regime map.

1. When the flow regime at the start of siphon breaking was slug and bubble flow, it showed the characteristics of partial sweep-out mode.
2. When the transient data cross the criteria between slug and bubble flow and oscillatory flow, the slope of differential pressure was differed.
3. The different characteristics between homogeneous flow and separated flow might be used to explain the air sweep-out and final of siphon breaking.

REFERENCES

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