Application of Siphon Breaker Simulation Program for small scale siphon breaker

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1. Introduction

In a research reactor, a siphon phenomenon happens through the pipe when the main pipe of the primary cooling system is ruptured. If all coolant is removed from reactor pool, the reactor core would be damaged and it could lead to a severe accident. The principle of a siphon breaker is to block the flow of water in the U-tube by air inflow. This equipment can be applied to research reactors which have the characteristics of core downward flow to prevent a loss of coolant accident (LOCA).

Until now, there have been several researches about siphon breakers. First, in 1993, Neill and Stephen[1] carried out an experiment with a 4-inch main pipe. They defined the zero, partial, and full sweep-out modes in accordance with the forms of air sweep-out. In 2011 and 2013, Kang et al.[2][3] experimented on a real-scale research reactor with a 16-inch main pipe and checked the effects of major variables such as size and type of siphon breaker, size and position of ruptured pipe. Lee and Kim[4][5], in 2016, developed a siphon breaker simulation program to analyze the siphon breaking phenomena with complex two-phase flow. They defined C factor reflecting the characteristics of air and water movement, and suggested some formula for B factor used in Chisholm model.

The siphon breaker simulation program was developed using the Kang et al.'s experimental data obtained on a 16-inch main pipe with various LOCA sizes from 16-inch to 8-inch. This study considers small scale siphon breaker covering the C factor range from 8.42×10^4 to 4.2×10^4 to verify that the program can be applied on a variety of scales. We have examined the expected data on small scale siphon breakers using the simulation program, and designed new siphon breaker test facility.

2. Analysis using simulation program

Fig. 1 shows a schematic diagram of the experimental facility. This facility consists of the main pipe, SBL, upper tank, and lower tank. The important factors to be considered for scale down are C factor, Chisholm coefficient B and undershooting height. Equations (1)~(3) show the definitions and formula for them.

$$B = 1.4618\times10^{-10}\times C^2 - 2.7856\times10^{-5}\times C + 1.831678 \quad (1)$$

$$C\ factor = \frac{Mass\ flow / Area}{\sqrt{Area_{siphon\ pipe}}\times\sqrt{1/K_{02}}} \quad (2)$$

$$undershooting\ \ height = waterlevel - Z_0 \quad (3)$$

Chisholm coefficient B and C factor are variables to be tested using the siphon breaker simulation program. K_{02} of C factor is a pressure loss coefficient of siphon breaker line (SBL). The undershooting height is a difference in height from point 0 in Fig. 1 to water level in the upper tank during siphon breaking. High undershooting height means that the core is exposed to air. Therefore, this is an important factor to be considered in this experiment.

The sizes of main pipe, SBL, upper tank, LOCA, and the position of LOCA affect to the previous important factors.

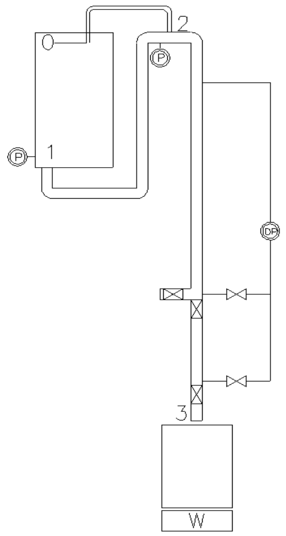

Fig 1. Schematic diagram of experimental facility

Table I and II show the experimental variables for small scale siphon breaker test. They are selected considering the expected ranges of C factor, Chisholm coefficient B, and undershooting height to have similar values from the experimental data by Kang et al [2]. At first, we test with SBL in Table I, and then experiment with LOCA size and LOCA height in Table II.

Table I: Experimental variables about SBL

Main pipe size (inch)	Upper tank area (m^2)	SBL size (inch)
2	0.09	3/16
		4/16
		6/16
		8/16
		10/16

Table II: Experimental variables about LOCA

LOCA size (inch)	LOCA position (m)
2	1.6
	1
1.5	1.6
	1
1	1.6
	1

Fig. 2 and 3 show the expected C factor & Chisholm coefficient B and the expected undershooting height in small scale experiment. We think the range of expected C factor & Chisholm coefficient B are proper to check the applicability of the siphon breaker simulation on a variety of scales. Also, the expected undershooting height should be considered to decide the depth of upper tank.

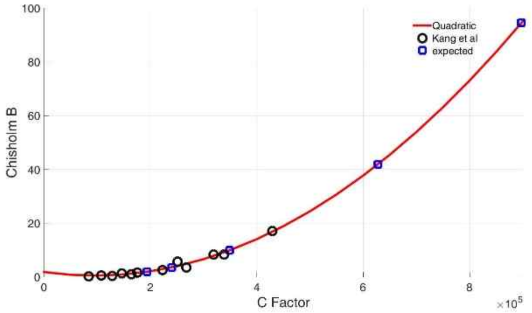

Fig 2. Range of expected C factor & Chisholm coefficient B

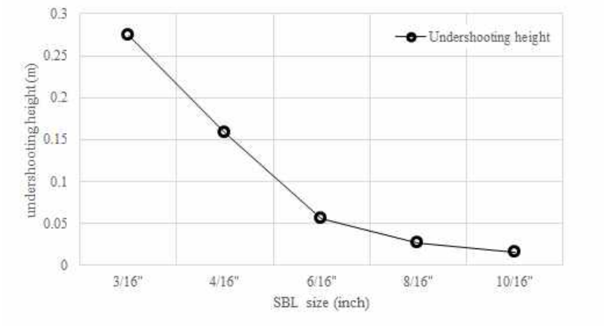

Fig 3. Undershooting height according to SBLs

3. Design of Experimental facility

The upper tank has an area of 0.09 m^2 with the depth of 650 mm. Siphon breaking starts when the SBL, located at 600mm height from the bottom of upper tank, is exposed to air. On the interior surface of the upper tank, a ruler is installed to see the real-time water level and undershooting height. There are two absolute pressure transmitters, which have a 2 bar pressure range and ±0.25% accuracy, at the point 1 and 2 in Fig. 1. The pressure transmitter at point 1 can also check the change of water level in the upper tank. And the pressure transmitter at point 2 can measure the negative pressure following Bernoulli's law at the apex of main pipe. We assumed many possible situations in real accidents by setting the ruptured pipe position and size as variables. LOCA position is located at 1.6 m or 1 m from the SBL and water is discharged through this point. A differential pressure transmitter installed between points 2 and 3 in Fig. 1 can measure the differential pressure up to 0.2-bar with ±0.3% accuracy. The under tank has an area of 0.09 m^2 with 500 mm in height and there is a balance to record the water weight change of lower tank in real time. The balance uses 2 gram as the minimum unit and helps to know water flux as kg/s unit.

The new experiment facility is almost manufactured. After commissioning test, we will perform the tests for small scale siphon breaker and verify the applicability of the simulation program. In addition, the reliability of the experiment results will be enhanced by carrying out every experiment twice and analyzing the data.

4. Conclusion

This study is carried out to verify the applicability of the newly developed siphon breaker simulation program on various scales. We have designed new small scale siphon breaker test facility by miniaturizing the existing experimental facility on a real scale in the proper proportion using the simulation program. We are going to experiment with C factor and Chisholm coefficient B on a wide range including the scope of existing experiment. The newly designed experimental facility is almost completed. We will perform siphon breaking test using this facility with various variables such as the size of SBL, and the position and size of LOCA.

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