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A Preliminary Experimental Study of Filmwise and Dropwise Condensation on SUS316 Surface

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1. Introduction

The passive safety features against station blackout (SBO) and containment safety became important issue after Fukushima accident. As a result, passive containment cooling system (PCCS) is selected as candidate option for the advanced light water reactors to guarantee integrity of containment. To design efficient heat exchanger of PCCS inside of concrete containment, a number of attempts were studied to compensate the low heat transfer coefficient of condensation in non-condensable gas circumstance.

The study in this paper focused on the dropwise condensation to enhance the cooling performance of PCCS heat exchanger. Plenty of studies by Tanner (1965), Griffith(1967), Graham(1969), Mikic(1969), Tanaka (1973), Rose(1975), Hannemann(1976), Hatamiya(1986) were reported. Griffith[1] and Hannemann[2] conducted experiment with gold coated SUS surface. However, for the application to nuclear system, surface treatment or surface coating were not preferred. For bare surface, Watanabe[3] reported about the dropwise condensation on SUS316.

This paper studied about the cooling characteristic of SUS316 surface as a PCCS heat exchanger. Specifically, filmwise and dropwise condensations on SUS316 surface were compared.

2. Experiment Method

2.1 Experimental Apparatus

Overall structure of experimental apparatus used in the study was shown in figure 1. Apparatus was composed of three main parts: Steam generator, cooling system and test section. Test section had cooling surface on its fore-end and coolant path was covered by insulator to suppress unnecessary condensation. Cooling surface had its diameter of 13mm with 6mm thickness.

In the test section tank, pressure gauge and thermocouples were installed to measure the pressure and temperature of saturated steam, respectively. Four thermocouples were installed in the cooling surface from the backside. Those thermocouples were buried in SUS316 with different depths (2, 3, 4, 5 mm each).

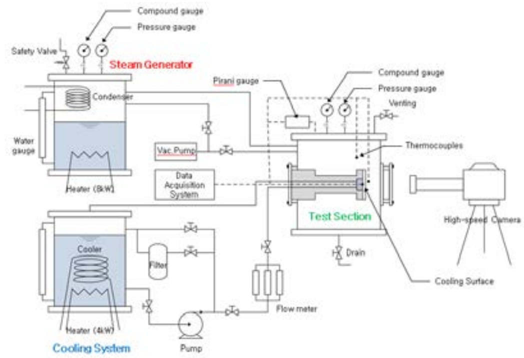

Fig. 1. General view of experimental apparatus

2.2 Experiment Method

Overall experiment condition was shown in table I. Ni-P coated and bare surface of SUS316 were used to observe both condensation phase. Almost stagnated steam was flowed with each concentration of air described in the table. Four buried thermocouples were utilized to extrapolate the surface temperature.

All experiments were conducted in atmospheric pressure condition. Air concentration was estimated by the partial pressure ratio of steam and air. Subcooled temperature, which is the difference between steam saturated temperature and surface temperature, was tested with 1 to 30 degree Celsius. High-speed camera visualize the condensate on the cooling surface with several magnification and frame speed. All measurement were measured after the whole system reached to equilibrium state and sustain it 30 minutes. Each data was recorded for 60 seconds and time averaged its measurement.

Table I: Experiment Condition

Parameter	Condition	
Condensation Phase	Filmwise (FWC)	Dropwise (DWC)
Cooling Surface	SUS316 (Ni-P)	SUS316 (bare)
Thermal Conductivity	16.7kW/mK	
Working fluid	Pure water	
Steam flow speed	Stagnated (<2cm/sec)	
System pressure	1atm	
Non-condensable gas	Air	
Air concentration	0%, 10%, 20%, 30%, 40%	
Subcooled temperature	1~30 ℃	

3. Results and discussions

Figure 2 shows the filmwise and dropwise condensation phase on two SUS316 surface, respectively. Bare SUS316 surface represented stable dropwise condensation phase over 12 hours of experiment for all experiment condition shown in Table I.

Figure 3 shows the previous studies conducted by other researcher with our result. Subcooled temperature versus heat transfer coefficient (HTC) of DWC on various cooling surface with coatings were compared.

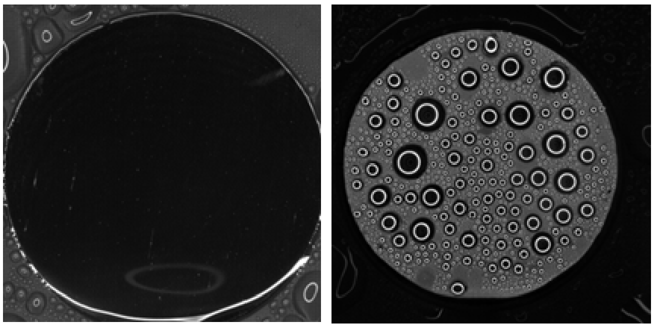

Fig. 2. Condensation surface of filmwise and dropwise condensation

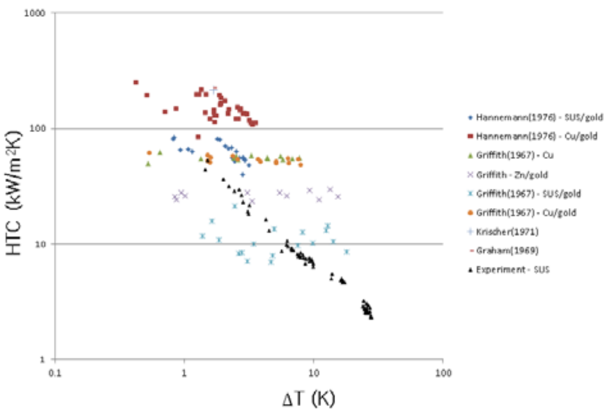

Fig. 3. Subcooled temperature versus HTC of DWC on various cooling surfaces

Figure 4 and 5 shows the condensation HTC of DWC and FWC with different non-condensable gas fractions. The result of DWC with pure steam was well proportional to the power of subcooled temperature. Otherwise, the result with non-condensable gas shows HTC in low subcooled temperature under 5℃ seems to be decreased, but the result was shaded by the high uncertainty. The result of FWC also proportional to power of subcooled temperature regardless of air concentration and well separated by air concentration condition. Figure 6 represents the cooling enhancement of DWC was neglected around 21.49℃. Within the low air concentration (0~10%), the degraded cooling effect was more remarkable for DWC compared to FWC.

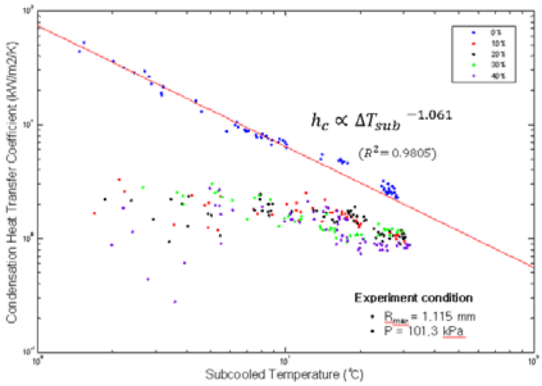

Fig. 4. Condensation heat transfer coefficient of DWC

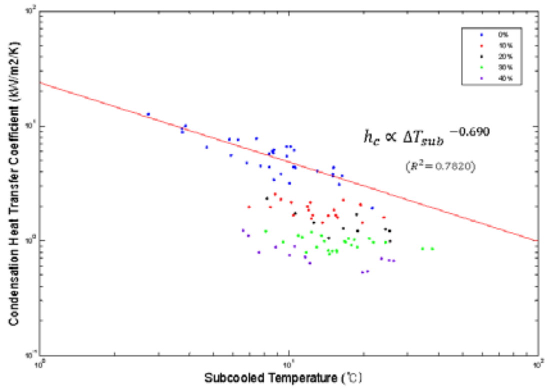

Fig. 5. Condensation heat transfer coefficient of FWC

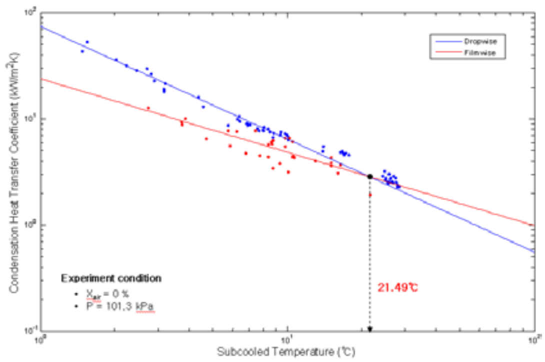

Fig. 6. Comparison of Condensation heat transfer coefficient between DWC and FWC at pure steam condition

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[1] Griffith, P., & Lee, M. S. (1967). The effect of surface thermal properties-, International Journal of Heat and Mass Transfer, 10(5), 697-707.

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