Preliminary Experiments on Critical Heat Flux in a Vertical Narrow Rectangular Channel with Bottom Blockage

Dongwook Jang[a*], Huiyung Kim[a], Jonghark Park[a]
[a]*Korea Atomic Energy Research Institute, 989-111 Daedeok Daero, Yuseong Gu, Daejeon, 305-353, KOREA*
[*]*Corresponding author: dwjang@kaeri.re.kr*

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1. Introduction

The critical heat flux(CHF) phenomenon under low flow and low pressure conditions is important in various accident scenarios of research reactors. In a research reactor that is normally cooled by downward forced convection, the flow direction is reversed and the velocity is temporarily reduced when it switches to natural convection in an accident situation. In addition, it is also possible to consider a situation in which the fuel cooling channel is blocked by foreign matter, so that the velocity in the channel decreases sharply.

As the velocity decreases, the heat transfer efficiency decreases sharply, and CHF can occur even when the decay heat is very low. Therefore, in this study, a research reactor using plate-type fuel was set as the target reactor, and preliminary experiments on CHF under low pressure and low flow conditions were performed.

2. Methods and Results

2.1 Estimation of CHF

The Critical Heat Flux (CHF) for narrow rectangular channels can be predicted through the Sudo-Kaminaga correlation developed by Sudo et al[1-4]. The correlation for the low flow rate region among these was proposed by Mishima[5], as shown in Equation (1). The key factors in the correlation are density, latent heat, and channel shape. In Equation (1), A_F , A_H and W are flow area of channel, heated area of channel and width of channel, respectively.

$$.q_{CHF} = 0.7\frac{A_F}{A_H}\frac{\sqrt{W/\lambda}}{[1+\left(\rho_g/\rho_l\right)^{\frac{1}{4}}]^2} \qquad (1)$$

The research reactor selected for this study to investigate the CHF characteristics is the Kijang Research Reactor. The main specifications of the fuel cooling channel used in the reactor are presented in Table 1. The CHF value calculated using the main specifications presented in the table and the Mishima correlation is about 50 kW/m^2.

Table 1: Fuel Cooling Channel Design Parameter

Parameter	Value
Heated Length	600 mm
Channel width	66.6 mm
Channel Gap	2.35 mm

2.2 Experimental Apparatus

The test section used in the experiment was manufactured to the same size as the cooling channel of the research reactor fuel, as shown in Fig. 1. The heater was constructed from STS, with a design that accommodates heating from both sides. Insulation was achieved for the shell using Bakelite.

Fig. 1. Installed Test Section

The schematic of the experimental apparatus is shown in Fig. 2. The experimental procedure is as follows:

First, degassing is performed and upward flow is maintained. Then, the preheater and pressurizer are used to adjust the initial conditions, and power is supplied to the heater of the test section. Finally, the valve at the bottom of the test section is closed to create a condition where the flow stops.

In the experiment, the inlet and outlet coolant temperatures, the test section wall temperature, and the power of the heater were measured. In the result graph, a higher temperature sensor number indicates that the temperature sensor is located on the upper side of the test section.

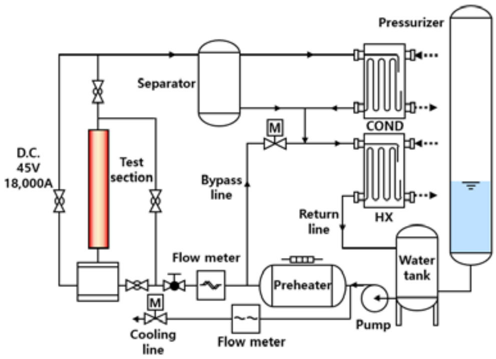

Fig. 2. Schematic of Test Loop

3. Results and Discussion

The experiment was conducted for two cases. The first case was a stepwise power increase experiment starting from subcooled condition, and the second case was an experiment starting from saturated condition with the same method of power increase.

The heat flux and temperature of each part of the experiment in the first subcooled case are shown in Fig. 3 and 4 respectively. As seen in the figures, it was confirmed that the wall temperature sharply increased around 70 kW/m^2, which is estimated to be the point of CHF occurrence. This value is about 50% higher than the predicted value of 50 kW/m^2 by Mishima correlation, which did not consider the inlet subcooling effect. The correlation was later improved by Sudo et al. by adding the inlet subcooling effect. The modified Mishima correlation are shown in Equation (2) and (3).

$$q_{CHF} = 0.7\frac{A_F}{A_H}\frac{\sqrt{\frac{W}{\lambda}}}{\left[1+\left(\rho_g/\rho_l\right)^{\frac{1}{4}}\right]^2}\left(1+3\Delta T^*_{inlet,sub}\right) \quad (2)$$

$$\Delta T^*_{inlet,sub} = C_p \Delta T_{inlet,sub}/h_{fg} \quad (3)$$

The results of measurements of heat flux and temperature in the saturated condition for the second case are presented in Fig. 5 and 6. As shown in the figures, CHF occurred at around 50 kW/m^2 in the saturated condition, which is consistent with the Mishima correlation without considering subcooling effect.

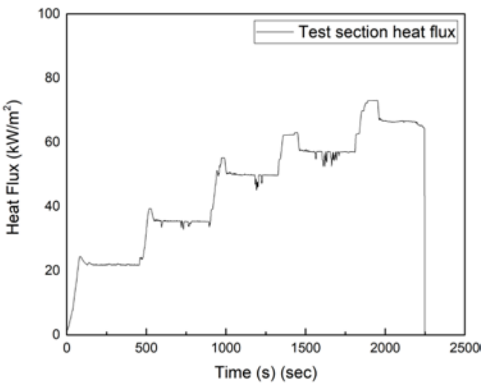

Fig. 3. Heat Flux Curve of Case 1

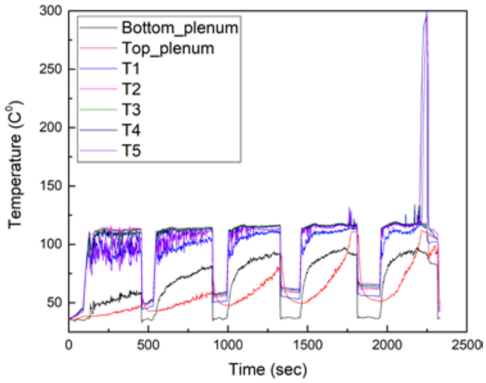

Fig. 4. Temperature Curve of Case 1

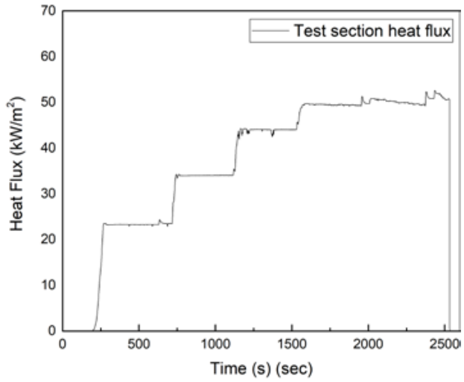

Fig. 5. Heat Flux Curve of Case 2

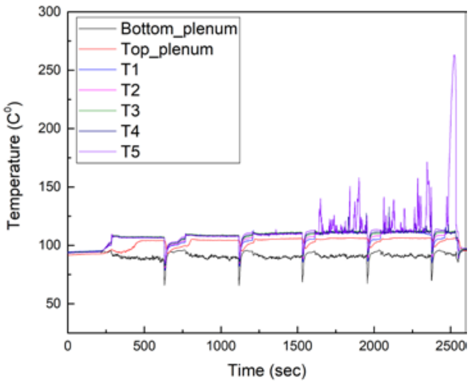

Fig. 6. Temperature Curve of Case 2

3. Conclusion

In the low-pressure, low-flow condition, CHF can occur even at low heat flux, making it an important phenomenon in research reactors. To investigate the CHF characteristics under these conditions, we utilized the Mishima correlation to predict CHF and conducted preliminary experiments to validate it. The experimental results confirmed that the Mishima correlation accurately predicted the observed phenomena under saturated conditions.

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