Effects of the Upside Inflow Area on Pool Boiling Heat Transfer in a Vertical Annulus with Closed Bottoms

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1. Introduction

The mechanism of pool boiling heat transfer has been studied extensively for the several decades [1]. Although many workers have in the past two generations investigated effects of heater geometries on boiling heat transfer, knowledge on the confined spaces on pool boiling heat transfer is still very limited. Studies on the crevices can be divided into two categories. One of them is about annuli [2-5] and the other one is about plates [6-8]. In addition to the geometric conditions, flow to the crevices can be limited. Some geometry has a closed bottom [2,5,6].

It is well known from the literature that the confined boiling is an effective technique to enhance heat transfer. It can result in heat transfer improvements up to 300%-800% at low heat fluxes, as compared with unconfined boiling [2,6]. However, a deterioration of heat transfer appears at high heat fluxes for confined than for unrestricted boiling [6,8]. The major cause of the deterioration in an annulus was suggested as active bubble coalescence at the upper regions of the annulus [4]. Recently, Kang [5] published effective results of removing the deterioration point to a higher heat flux and preventing the creation of the critical heat flux. Kang [5] controlled the length of the outer tube of the annulus. Kang [9] identifies that the bottom inflow area changes heat transfer coefficients much and moves the deterioration point of heat transfer coefficients to the higher heat fluxes.

Summarizing the previous works about the pool boiling heat transfer in an annulus with closed bottoms, the amount of the heat transfer coefficient is highly dependent on the geometry and confinement condition. One of the interesting and important geometric parameters is the inflow area at the upside region of the annulus with closed bottoms. Up to the author's knowledge, no previous results concerning to this parameter have been published yet.

2. Experiments and Results

A schematic view of the present experimental apparatus and a test section is shown in Fig. 1. Four auxiliary heaters were installed at the space between the inside and outside tank bottoms. The heat exchanging tube is a resistance heater (Fig. 1(B)) made of a very smooth stainless steel tube (L =0.5 m and D =25.4 mm). Electric power of 220 V AC was supplied through the bottom side of the tube. The tube outside was instrumented with five T-type sheathed thermocouples (diameter is 1.5 mm). To measure and/or control the supplied voltage and current, two power supply systems were used. The capacity of each channel is 10 kW.

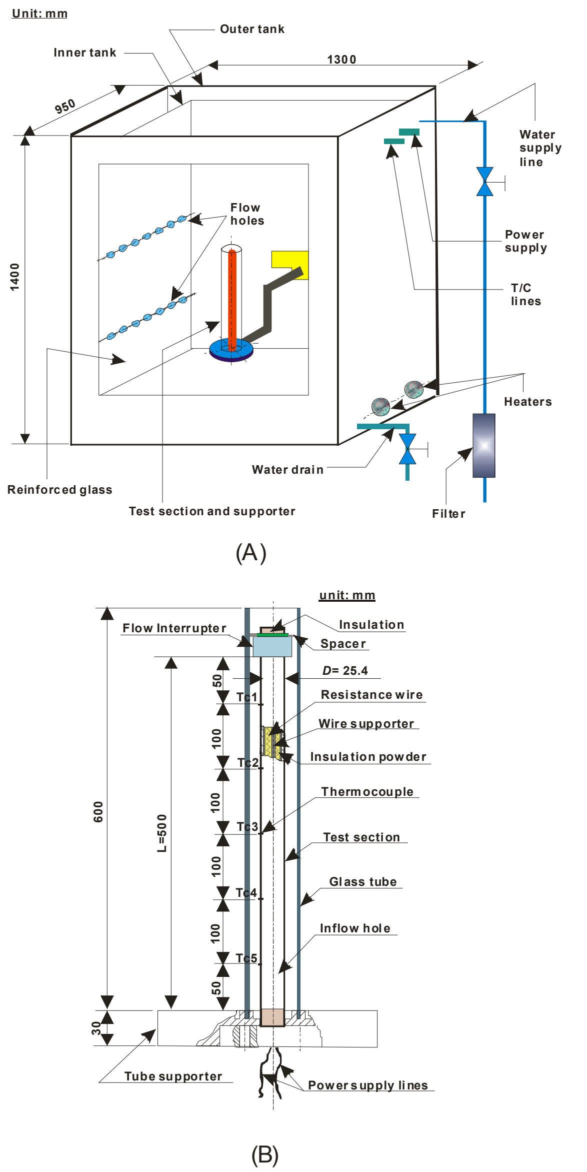

Fig. 1. Schematics of the experimental apparatus.

To make the annular condition, a glass tube (gap size, s =15 mm) of 55.4 mm inner diameter and 600 mm length were situated around the heated tube. To maintain the gap size between the heated tube and the glass tube a spacer has been installed at the upper region of the test section. Because of the flow interrupter the gap size around the interrupter (s_d) is different from the gap size of the annulus. Thereafter the ratio of the gaps ($s_r = s_d / s$) varies from 0.18 to 1 as shown in Table I. s_r =1 is the case of without the flow interrupter. The temperatures of the tube surfaces (T_W) are measured when they are at steady state while controlling the heat flux on the tube surface with input power. The uncertainty of the heat flux and the measured temperature are estimated to be ± 1.0% and ±0.15 °C, respectively.

Table I: Test matrix and q'' versus ΔT_{sat} data

d , mm	s , mm	s_d ,mm	s_r	Remark
-	-	-	-	Single
-	15.0	15.0	1.00	Annulus
40	15.0	7.7	0.51	Annulus
45	15.0	5.2	0.35	Annulus
50	15.0	2.7	0.18	Annulus

Figure 2 shows variations in heat transfer as the diameter (d) of the flow interrupter changes. The characteristic of heat transfer can be divided into two categories according to the heat flux. For the heat fluxes less than 60kW/m² heat transfer coefficients for the annuli are much larger than the single tube and approaches to the curve of the annulus without the flow interrupter. As the heat flux increases more than 60kW/m² curves for s_r =0.35 and 0.18 converges toward the curves of the single tube. The heat transfer coefficient for s_r =0.18 is 25.3% greater than the single tube at q'' =40kW/m². As the heat flux increases to 120kW/m² and s_r =0.18 only 4.8% increase in heat transfer coefficient is observed comparing to the result of the single tube. If a vertical annulus has closed bottoms the incoming liquid into the annular space should flow along the upside region where the bubble slugs flowing outward. Because of the countercurrent flow between the bubble and the liquid, a fluid friction generates at the interface. This friction, then, disturbs the outward bubble flow and creates bigger bubbles in the annular space. If the upside area is not enough like the s_r =0.35 and 0.18, much faster flow is generated and, as a result, greater fluid friction is created between the bubble slugs and the incoming liquid. Since the bubble slugs have glowed to a bigger size, the retard of the outward flow prevents the incoming liquid to the space. Therefore sudden decrease in heat transfer is observed at the heat fluxes larger than 60kW/m² as the value of s_r =0.35 or 0.18.

3. Conclusions

To investigate effects of the upside inflow area on pool boiling heat transfer in a vertical annulus with closed bottoms, the gap size at the upper region of the annulus has been regulated by a flow interrupter. The flow interrupter changes the gap size around the interrupter from 2.7 to 15 mm. Variation of the upside inflow area changes the tendency of heat transfer. As the gap ratio is less than 7.7 much change in heat transfer is observed comparing to the annulus without the flow interrupter.

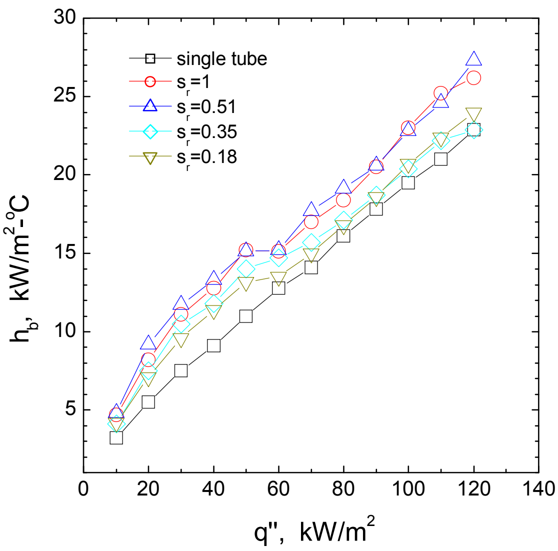

Fig. 2. Curves of the experimental data.

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