Post-CHF Heat Transfer characteristics in one rod bundle geometry

Kwi Lim Lee and Soon Heung Chang
Dept. of Nuclear & Quantum Engineering, KAIST, Daejeon, Republic of Korea
Tel: +82-42-869-3856, Fax: +82-42-869-3810, E-mail: kantavia@kaist.ac.kr

1. Introduction

In the present paper, experimental study of forced convection boiling were performed to investigate the post-CHF characteristics of a vertical annular channel with one heated rod and four spacer grids for new refrigerant R-134a. The experiments were conducted under outlet pressure of 11.6, 13, 16 and 20 bar, mass fluxes of 100-600 kg/m^{2}s, and inlet temperatures of 25-51 ^{o}C. The parametric trend of the post-CHF data was well consistent with previous studies.

The two phase flow regime in tube flow occurring downstream of the CHF has been called post-CHF, dispersed flow, liquid-deficient flow, mist flow and film boiling. This regime is characterized by a continuous vapor phase with discrete liquid drops and a non-wetted heated surface. This regime has a considerable importance in the areas of light water reactor(LWR) accident analysis and other film boiling applications. The post-CHF region occurs by design in heat exchangers operating in the once-through mode where subcooled liquid enters the exchanger and superheated vapor exits. This region can also occur at off-normal operating conditions in nuclear reactor cores. In this case, knowledge of heat transfer in the region is important to safety analysis and assessments.

Although extensive studies of the heat transfer characteristics for this flow situation have been carried out by numerous researchers, there have been very few systematic investigations of the hydrodynamics of annular flow in case of Freon.

Experiments have been carried out in the R-134a forced convection boiling CHF loop at Korea Advanced Institute of Science and Technology (KAIST). It is schematically shown in Fig. 1. The experimental loop consists of a test section, a non-seal canned pump, a Coriolis-type mass flow meter, a preheater for inlet subcooling control, a pressurizer of an accumulator connected to high pressure N_2 gas bottle and venting system for pressure control, a chiller or chilling system consisting of a heat exchanger of R-134a flow chilled with circulation system of water-propylene glycol cooled by R-22 refrigeration system, a condenser cooled by tap water. The mass flow rate is controlled by adjustments of the pump rotation speed, bypass valve and two throttling valves. The throttling valves are located at the upstream of the test section inlet to prevent flow fluctuation..

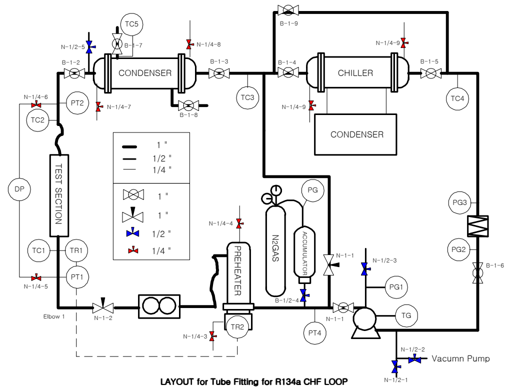

Figure 1: Schematic diagram of experimental test loop

2. Experimental results

The test section consists of a body of an inner rectangular flow channel (D_e=10.97 mm, D_h=38.90 mm) of 19x19 mm^2 , single heater rod with outer diameter of 9.5 mm in the center of flow channel and visualization windows of two sides. The heater rod consists of sheath or cladding made of Inconel 600 of 1 mm thickness, an electrical insulation layer of MgO which fill between the sheath layer and heating element and spiral-strip heating element which is filled by Al_2O_3. The rod is heated indirectly by 22 kW AC(alternating current) power supply for 1830 mm length. Power shape of the heater rod is uniform throughout the heated section. Four I-types of spacer grids have been used for providing a uniform annular gap for rod and for preventing rod vibration and contact between the rod and the shroud. Three of them are located in the 298, 798, and 1443 mm from the bottom of heated rod. The other one is installed in inlet part.

To measure the heated wall surface temperature, six K-type thermocouples, whose sheath diameter is 0.5 mm, are embedded in the cladding of the heater rod. The length from the bottom end of heated section to each thermocouple is 920, 1320, 1520, 1720, 1800, 1820 mm, respectively. For the measurement of fluid temperature, four T-type thermocouples and four pressure taps are installed axially in the annular channel.

In the present study the experiment on critical heat flux of R-134a was performed for the refrigerant mass flux varying from 100 to 600 kg/m^{2}s, the pressure of 11.6, 13, 16, and 20 bar and the subcooling temperature from

23 to 51°C. Table 1 shows the test condition. The uncertainties of the measurement parameters are analyzed by the error propagation method. The uncertainties of the applied heat flux and mass flux were less than ±2.5% and ± 2.0 %, repectively. The heat balance tests are conducted to estimate heat loss resulting in negligible loss. Uncertainties for the pressure and fluid temperature measurements are ±9 kPa and ± 0.5 °C.

Test conditions	
Geometry type	Annulus
Mass flow rate	0.02 ~ 0.05 kgs-1
Working fluid	R-134a
Inlet temperature	27 °C
Heat flux	200-222 kWm-2
Pressure	1~2 MPa
Mass flux	2 and 3 mgm-2s-1

Table 2: Test conditions for the experiment

Post-CHF heat transfer coefficients obtained are compared with Dougall-Rohsenow, Condie-Bengston and Groeneveld 5.9 post-CHF heat transfer correlations even if this correlations is mainly developed by using a tube database. Figure 2 shows while the Condie-Bengston correlation underestimates the heat transfer coefficients, Dougall-Rohsenow correlation shows good predictions for the measured heat transfer coefficients.

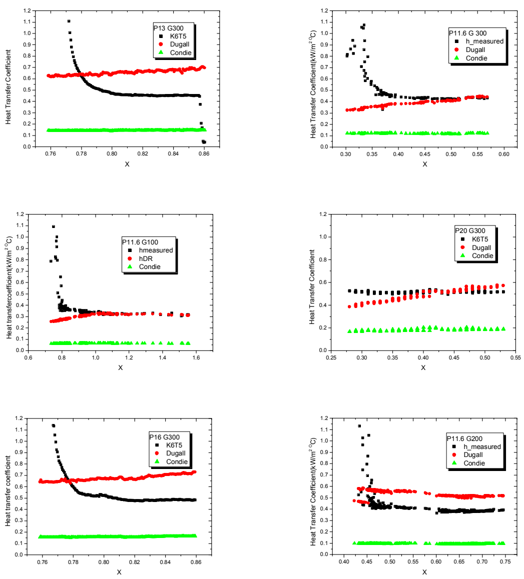

Fig 2. The effects of mass flux on the Post-CHF in pressure of 11.6 and 13 bar

Following figure 3 shows that the heat transfer coefficient decreases with an increasing equilibrium quality and the post-CHF heat transfer coefficients slightly increase with the increasing mass flux.

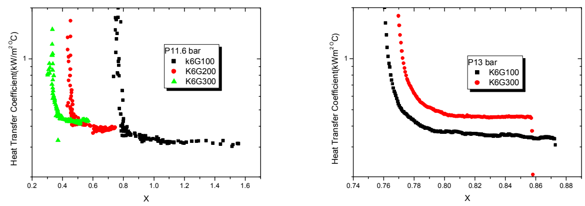

Fig. 3. The effects of mass flux on the Post-CHF in pressure of 11.6 and 13 bar

3. Conclusion

An experimental study of the post-CHF using R-134a in uniformly heated vertical tube was performed in case of annular channel. Experimental data on the temperature of R-134a flow in an annulus channel have been obtained. The experimental results show a general agreement with previous studies. The results contained the impact of the obstacle effect by a strong enhancement of heat transfer at location downstream of the obstacle. Therefore, the good knowledge of the heat transfer in post-CHF regime requires the more experimental investigation.

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