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Grid effects on the post-CHF heat transfer in one rod bundle geometry

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1. Introduction

An experimental studies were performed in the post-CHF condition using R-134a in uniformly heated vertical tube to investigate the effects of girds and hybrid mixing vanes in case of the one rod annular geometry. The experiments were conducted under outlet pressure of 11, 13, 16 and 20 bar and mass fluxes of 100-400 kg/m^{2}s. About 500 of post-CHF data are obtained in the annular geometry. The grid test results show the negative effect by the break-up of the liquid film in high quality condition. The hybrid mixing vane tests are also performed, but that did not show the improved effects compared with the bare condition. The experimental data are compared with typical of the equilibrium correlations of Dougall-Rohsenow, Groeneveld 5.9, and Condie-Bengston. Douall-Rosenow correlation shows the reasonable predictions for the measured R-134a heat transfer coefficients.

Although extensive studies of the heat transfer characteristics for post-CHF 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.

The spacer or mixing vane generally increase the heat transfer, however, they do not affect or even decrease the heat transfer under some flow conditions. The major mechanisms would be directing entrained liquid droplets to the heated wall (positive effect) and break-up of the liquid film in annular flow (negative effect)

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..

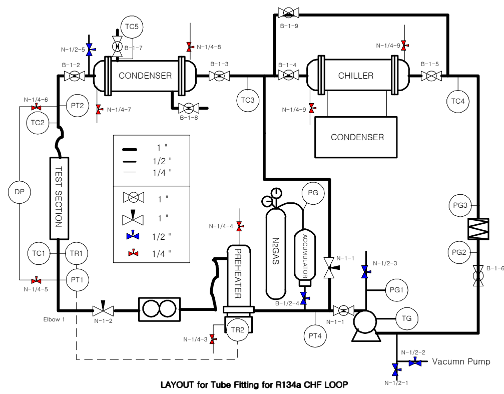

Figure 1: Schematic diagram of experimental test loop

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 the post-CHF of R-134a was performed for the refrigerant mass flux varying from 100 to 400 kg/m^{2}s and the pressure of 11, 13, 16, and 20 bar. Table 1 shows the test condition.

The post-dryout tests were performed until the maximum wall temperature is less than about 550^{O}C in order to protect the physical melting.

Test conditions	
Geometry type	Annulus
Working fluid	R-134a
Inlet subcooling	27 kJ/kg
Heat flux	200-222 kWm-2
Pressure	1~2 MPa
Mass flux	1 and 4 kgm-2s-1

Table 1. Test conditions for the experiment

In the post-CHF regime, the wall superheat is very large and the heat transfer coefficient is very small. Figure 2 shows the measured wall temperature in the mass flux 200 and 300 kgm-2s-1 in the pressure of 11 and 13 bar. The hybrid mixing vane test results show that wall temperatures are lower than that of the grid tests, but did not show the improved effects compared with the bare condition.

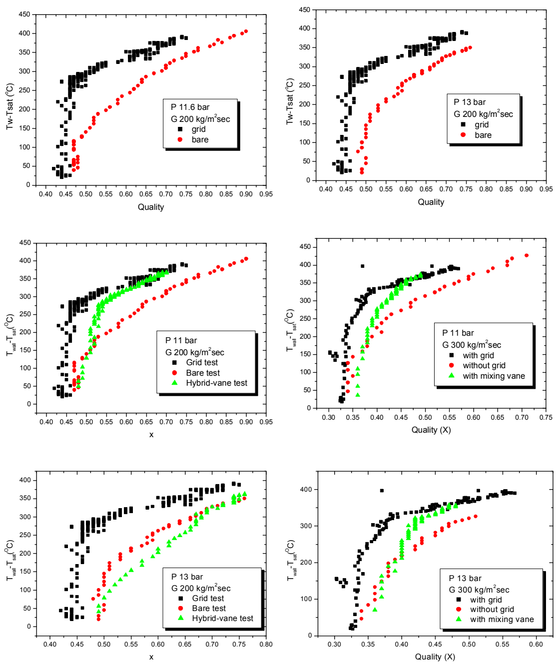

Fig. 2. The effects of grids and mixing vanes on the wall temperature in post-CHF condition

Following figure 3 shows that the heat transfer coefficient decreases with an increasing equilibrium quality in the mass flux 200 and 300 kgm-2s-1 in the pressure of 16 bar.

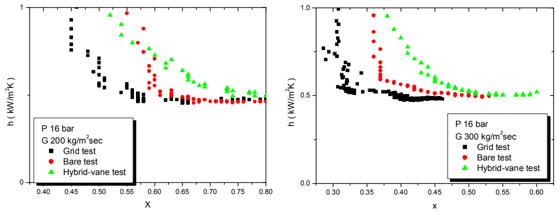

Fig. 3. The effects of grids and mixing vanes on the heat transfer in post-CHF condition

3. Conclusion

An experimental studies were performed in the post-CHF condition using R-134a in uniformly heated vertical tube to investigate the effects of girds and hybrid mixing vanes in case of the one rod annular geometry. Experimental results show that the gird and mixing vane tests don't have the improved effects compared with the bare tests in present experimental ranges. But, hybrid mixing vane results show the more improved heat transfer coefficients than that of grid tests.

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