

CHF Enhancement in Flow Boiling using Al₂O₃ Nano-Fluid and Al₂O₃ Nano-Particle Deposited Tube

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Introduction

Nano-fluids are considered to have strong ability to enhance CHF. Most CHF experiments using nano-fluids were conducted in pool boiling conditions. However there are very few CHF experiments with nano-fluids in flow boiling condition. In the present study, flow boiling CHF experiments using bare round tube with Al₂O₃ nano-fluid and Al₂O₃ nano-particle deposited tube with DI water were conducted under atmospheric pressure. CHFs were enhanced up to ~80% with Al₂O₃ nano-fluid and CHFs with Al₂O₃ nano-particle deposited tube were also enhanced up to ~ 80%. Inner surface of test section tube were observed by SEM and AFM after CHF experiments.

CHF Experiments with Al₂O₃ Nano-fluid and Nano-Particle Deposited Tube

The schematic diagram of CHF test apparatus of KAIST is shown in Fig. 1. Two kind of test section tube were used for flow boiling CHF experiments. Bare round tube was used with Al₂O₃ nano-fluid and DI water, and Al₂O₃ nano-particle deposited tube was used with DI water.

Al₂O₃ nano-particle deposited tube was prepared as follows. First, flow boiling CHF experiments using bare round tube with Al₂O₃ nano-fluid were conducted at each condition in the test matrix (Table 1). Second, same experiments were repeated at each condition but power was shut down just before CHF. Then, we obtained Al₂O₃ nano-particle deposited tubes at each experimental condition.

The experimental procedure is as follows. The experimental loop is filled with DI water or Al₂O₃ Nano-fluid. And then, working fluid is circulated by centrifugal pump and heated by pre-heaters to remove non-condensable gas. After degassing process the heating power in the test section tube is increased by increasing voltage gradually. The increment of heat flux near the CHF is ~20kW/m². The CHF condition is defined as a dramatic increase in the temperature in the test section tube. Heat flux in the test section tube is calculated as

$$q'' = VI/\pi D_i L$$

where V and I are the measured voltage and current, and D_i and L are the test section inner diameter and heated length, respectively.

CHF experiments were conducted at two inlet temperatures (75 °C and 90 °C) and three mass flux levels (500, 1000 and 1500 kg/m²s) under atmospheric pressure.

After CHF experiments, test section tube is replaced by new one.

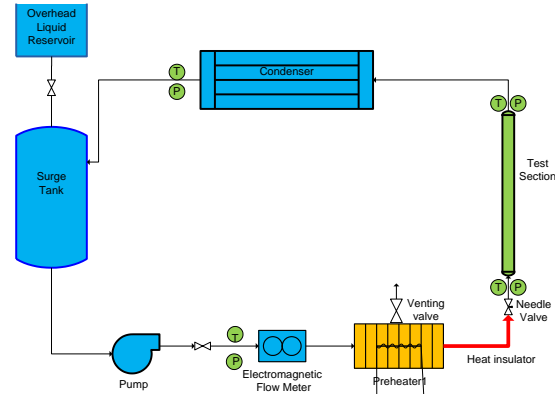


Figure 1. Schematic diagram of experimental loop

Table 1. Test matrix of CHF experiments

Test Matrix		
Bare round tube		
Outer diameter		9.525 (mm)
Inner diameter		7.745 (mm)
L/D ratio		51.65
Heated length		400 (mm)
Vertically upward flow		
Pressure		101.3 (kPa)
Mass flux		500, 1000, 1500 (kg/m ² s)
Inlet temperature		75, 90 (°C)
Working fluid		
Total fluid in the loop		50 (l)
DI water		
Concentration of nano-fluid		10 ⁻⁵ ~10 ⁻³ (vol %)
Nano-particle	Al ₂ O ₃ - γ	99.97 (%), 20~30 (nm)

Results and Discussion

The CHF of Al_2O_3 nano-fluids and Al_2O_3 nano-particle deposited tube were enhanced up to ~80%. There is no big difference in CHF enhancement between nano particle deposited tube with DI water and bare tube with nano-fluids. These results indicate that the main reason of CHF enhancement in flow boiling using Al_2O_3 nano-fluid is deposition of nano-particles on heater surface. SEM observation showed that the morphology of inner surface of test section tube were almost same for both condition and also AFM observation showed that roughness of test section tube were similar for both condition. The flow regimes of all experimental conditions were annular flow. In the annular flow CHF may occur by some local dryout [1]. Deposition of Al_2O_3 nano-particles can help to rewet the heater surfaces when the CHF occurs.

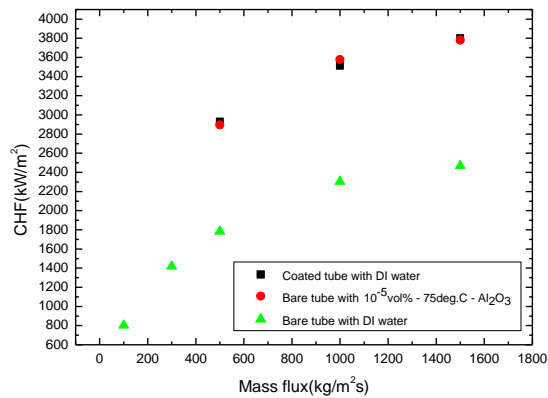


Figure 2. CHF experimental data at 75 °C of inlet temp.

REFERENCES

1. T.I. Kim et al, "An experimental study on CHF enhancement in flow boiling using Al_2O_3 nano-fluid" Int. J. Heat Mass Transfer, 53 (2010) 1015–1022.