Effects of Magnetic Fields on the Flow Boiling CHF of Magnetic Nanofluids

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1. Introduction

The improvement of CHF characteristics is related to the safety margins and economics for thermal hydraulic devices we concern. Therefore, many engineers have tackled this topic. Many attempts have been tried to improve the CHF characteristics, and the use of nanofluids as the working fluids is regarded as a one promising candidate. Main reason of CHF enhancement would be the incensement in wettability of heater surfaces due to the deposition of nanoparticles on heater surfaces.

In this paper, magnetite-water nanofluids are used as a working fluid. Since the magnetic nanofluids have higher thermal conductivity with respect to pure water and the existence of external strong magnetic field which helps the deposition of magnetite particles on heater surface, more improvement would be expected in the CHF characteristics. To prove these hypotheses, series of flow boiling CHF experiments are conducted.

2. Experiments, Results and Discussion

2.1 Experiments

A schematic of experimental loop used in this study is shown in Fig. 1. Experimental loop consists of centrifugal pump, needle valve, electromagnetic flow meter, condenser and pre-heater. In this study, 1/2 inch SS316 tube is used as the test section. A brief description of test section is tabulated in Table I.

Table I. Test Section

Uniformly Heated Tube (SS316)	
Outer Diameter	12.70 mm
Inner Diameter	10.92 mm
Entrance Length	550.00 mm (L/D = 50.0)
Heated Length	250.00 mm (L/D = 22.9)
Electric Resistance	5.61 m-ohm

Vertically installed test section is heated uniformly by means of direct current Joule heating with 100 kW (25V 4000A) capacity DC rectifier. Electric heating power and corresponding heat flux are estimated by measuring the electric current and potential difference values between two electrodes. Also, K-type thermocouples are attached onto the outer surface of tube test section to measure the tube wall temperature and to detect the onset of CHF.

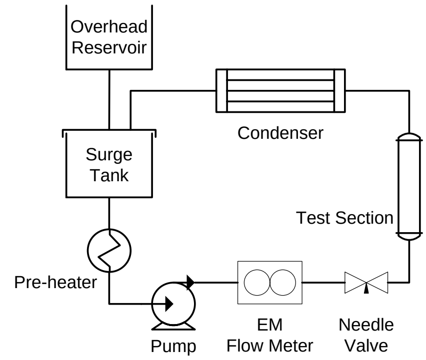

Fig. 1. Schematic of flow boiling CHF test loop

Inside the tube test section, there are no electricity-induced magnetic fields. Therefore, the effect of working fluid itself and the effect of magnetic field on the CHF characteristics can be de-coupled and investigated respectively. To make a strong magnetic field inside the tube test section, permanent Neodymium magnets are used. Installation position of these permanent Neodymium magnets is just below the upper electrode, at which CHF would occur.

2.2 Effects of Magnetic Nanofluids

By using the magnetic nanofluids as a working fluid, the flow boiling CHF characteristics is improved drastically. The degree of flow boiling CHF enhancement is higher when the magnetic nanofluids of higher concentration are used as a working fluid.

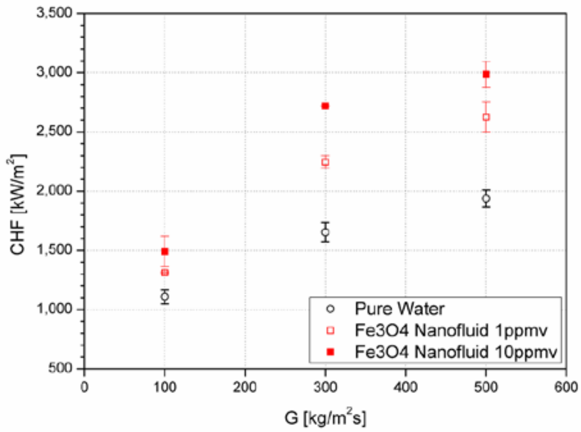

Fig. 2. Effects of magnetic nanofluids itself on the flow boiling CHF characteristics

The reasons of improvement in the flow boiling CHF characteristics for the magnetic nanofluids are summarized as followed: 1) when nucleate boiling occurs on the heater surface, magnetite nanoparticles in the magnetic nanofluids are deposited on the heater surface. And the deposition of magnetite nanoparticles results in the improvement of wettability and rewetting characteristics of heater surface. As a consequence, the flow boiling CHF characteristics is improved by using the magnetic nanofluids as a working fluid. It seems that the amount of deposited magnetite nanoparticles on the heater surface depends not only on the concentration of magnetic nanofluids but also on the amount of magnetic nanofluids evaporation on the heater surface. Therefore, the history of heater power should be controlled for the impartial comparison. 2) Compared with the pure water, magnetic nanofluids has better wettability and rewetting characteristics for the heater surface – which are made of SS316. Contact angle measurement result supports this statement.

In summary, the use of magnetic nanofluids itself improves the flow boiling CHF characteristics drastically, and this promising result comes from the improvement in the wettability and rewetting characteristics of both a working fluid and the heater surface. As a further work, we should explain the reason of flow boiling CHF enhancement in detail, by considering the mechanism of LFD-type CHF occurrence.

2.3 Comparison to the Alumina-Water Nanofluids

The flow boiling CHF values of magnetic nanofluids are slightly higher than those of alumina-water nanofluids. Therefore, we can conclude that a magnetic nanofluid is better than alumina-water nanofluids, in terms of boiling heat transfer capability on the heater surface.

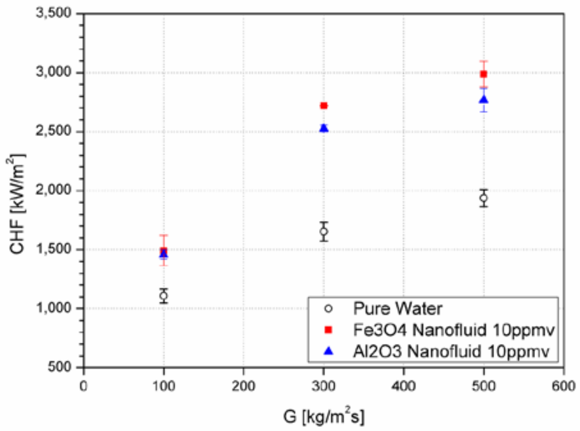

Fig. 3. Comparison of the flow boiling CHF characteristics: magnetite-water nanofluids vs. alumina-water nanofluids with concentration of 10ppmv

2.4 Effects of Matnetic Fields

For magnetic nanofluids, the effects of magnetic fields are negative in terms of flow boiling CHF characteristics. This pessimistic result comes from the suppression of bubble mobility in very near heater surface region, where the concentration of magnetic nanofluids is very high due to the existence of the very strong external magnetic fields of 300G. Compared with the pure water case, however, the flow boiling CHF characteristics for magnetic nanofluids are improved drastically, whether the very strong external magnetic fields exists or not.

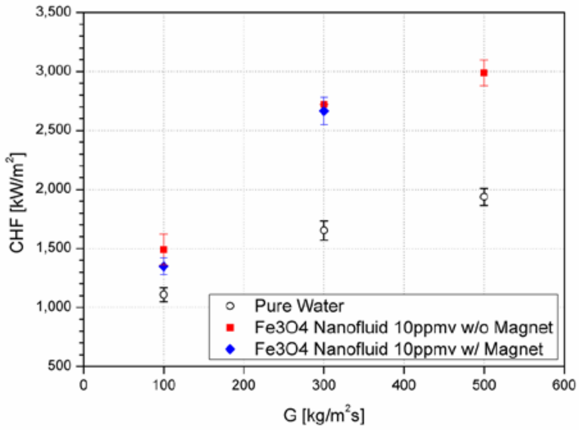

Fig. 4. Effects of magnetic fields on the flow boiling CHF characteristics for magnetic nanofluids with concentration of 10ppmv

3. Conclusions

Flow boiling CHF experiments were performed for magnetic nanofluids of various concentrations with and without the strong external magnetic fields. The enhancement in the flow boiling CHF values exists for magnetic nanofluids with respect to that of pure water cases, whether the strong external magnetic fields exist or not. As the further work, kinetics of flow boiling CHF characteristics should be examined, with and without the external magnetic fields.

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