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Flow Boiling CHF Enhancement using Porous Surface Coatings

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1. Introduction

Porous coatings (either metallic or ceramic) have been a heat transfer enhancement technique of great interest to many researchers in the world. Various geometric parameters have been considered to produce higher enhancements, out of which particle size, particle shape, coating thickness and porosity were the primary variables. Use of the porous coated surfaces as a boiling enhancement method is to increase the number of small scale cavities on a surface. This enhancement is due to the lateral capillary assist to the liquid flow towards the phase-change interface. It reduces the liquid vapor counter flow resistance and hinders the development of localized dryout conditions. Capillary pumping in porous media generates the required liquid draw, and establishes the fluid flow artery

However, the effect of microporous coating on critical heat flux for flow boiling has not yet sufficiently investigated. Particularly, critical heat flux hardly studied at low mass flow rate and at low pressure flow boiling loop with microporous coatings. Most of the research has been done with pool boiling and effect of microporous surface coatings during flow boiling still needs to be explored. S.M. You et al, used Alumina (Al_2O_3) particles (0.3-3 μm) as the coating material and tested in FC-72 [1]. The deposited particles adhered to the surface due to Van der Walls molecular attraction forces. O'Connor and S.M. You developed a boiling enhancement paint with silver flakes (3-10 μm). They showed an 80% reduction in nucleate boiling superheat and a 109% increase in CHF over the non-painted surfaces as shown in Figure 1.

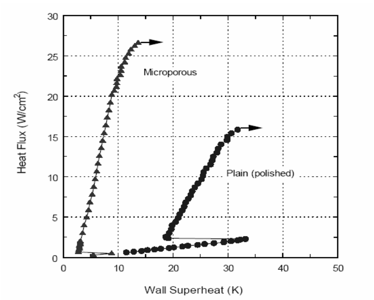

Figure 1: Comparative analysis of microporous coated and plain surfaces [1]

By manufacturing optimum cavity sizes on a heat surface, both the boiling site density and the nucleate boiling heat transfer can be efficiently increased.

2. Experimental Apparatus and Procedure

To produce porous coating inside a circular tube, we have used the same manufacturing technique mentioned by S. M. You et al in the U.S. Patent 1998 (PCT/US95/03607). Alumina and Titania powder with Omega bond thermal epoxy, paint was prepared for coating. Compositions of ingredients are:

- Powder = 1.5g
- Omega bond Thermal Epoxy = 0.4ml
- Isopropyl Alcohol = 10ml

It was stirred and heated to make uniform slurry and the adhesion strength improved with heat treatment curing at 204 ^{o}C for 2 hour. Three different sized particle powders were used: Al_2O_3 (<10 μm), TiO_2 (<5 μm) and Al_2O_3 (Nanopowder). The porous structure of SEM image of microporous Al_2O_3 TiO_2 are shown in Figure 2.

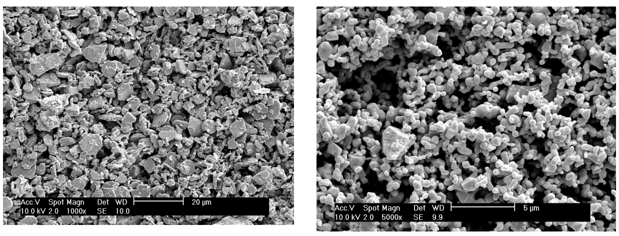

Figure 2: SEM image of microporous Al_2O_3 and TiO_2

Boiling heat transfer under planning performed at a high heat flux up to CHF at Korea Advanced Institute of Science and Technology. The experimental facilities consists of a closed water flow boiling loop, a test section, which is heated directly using an electrical DC power supply unit (maximum capacity of 64 kW). The schematic diagram of tubular test section is shown in Figure 3. The experiments will be carried out at atmospheric pressure by venting to ambient. The main test loop consists of a condenser, surge tank (with overhead water reservoir), a centrifugal pump, turbine flow meter, a pre-heater (to control the inlet water temperature), needle valve (to provide throttling) and a test section.

The water will flow in the upward direction in the test section tube, which is coated from inner side. The dimensions of the cylindrical tube and vertical upward flow parameters are mentioned in Table 1.

Table 1: Test conditions for the flow boiling experiment

Scope of Experiment	
Test Section	Uniformly heated tube
Outer Diameter	12.7 mm
Inner Diameter	10.92 mm
Length	230 mm
Inlet Temp	25 & 50 ºC
Mass Flux	100 ~ 300 kg/m² –sec
Pressure	Atmospheric

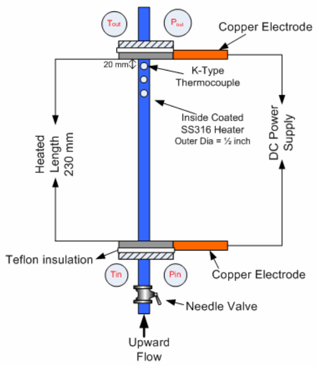

Figure 3: Schematic diagram of experimental test section

3. Results and Discussion

Experiment was performed at two different inlet subcooling levels and at mass fluxes 100~300 kg/m^2 sec. The significant increase in CHF for the microporous tube is shown in Figure 4. Wettability test was performed to get the better water entrapment capabilities of all three applied coatings as shown in Table 2, which shows the better wettability index for the Al_2O_3 microporous coatings.

Table 2: Wettability comparison of coatings

Coating material	Al_2O_3 (<10µm)	TiO_2 (<5µm)	Al_2O_3 (Nanopowder)
Bare weight of coated tube W1 (g)	139.38	139.25	139.01
Wet weight of coated tube W2 (g)	140.06	139.81	139.42
Wettability (W2-W1)	0.68	0.56	0.41

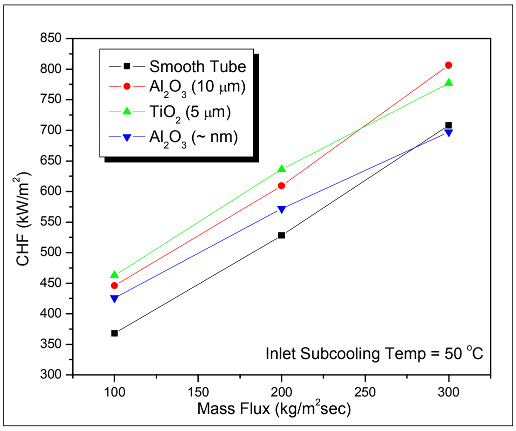

Figure 4: Variation of CHF with various coatings

4. Conclusions

The present research is an experimental study of a novel technique of flow boiling CHF using microporous surfaces. The porous alumina and titanium oxide coatings inside SS tube are performed. Significant increase (~ 25%) in critical heat flux is observed at different mass flux and different subcooling levels at atmospheric pressure. Microporous coatings proved better for flow boiling CHF enhancement as compared to nanoporous coatings. The Wettability index also showed that microporous structure (larger particle size < 10µm) give better water entrapment and nice porous structure, which resulted in better CHF enhancement capabilities. It seems that the high thermal conductivity of Al_2O_3 is not the major reason of improvement in heat transfer enhancement because CHF enhancement in nano aluminum oxide (k=25 W/m-K) is not better than that of micro titanium oxide (k=6.7 W/m-K).

REFERENCES

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