Experimental Study of Subcooled Flow Boiling CHF enhancement on modified zirconium alloy tube with micro structure

Soon Ho Kang[a], Ho Seon Ahn[a], Hang Jin Jo [a], Seol Ha Kim [a], Gunyeop Park [a], Ji Min Kim [a], Moo Hwan Kim[b*]
[a]*Mechanical Engineering Department, POSTECH, Pohang, 790-784, Republic of Korea*
[a]*Division of Advanced Nuclear Engineering, POSTECH, Pohang, 790-784, Republic of Korea*
[*]*Corresponding author: mhkim@postech.ac.kr*

1. Introduction

In the heat transfer system which uses the boiling phenomena, the CHF(critical heat flux) acts as the limitation of the system performance. The nucleate boiling heat transfer shows the enormous high efficiency compared with other method. However, when the system faces the CHF situation, the temperature of the heat transfer surface suddenly increases in so much that fail. By this reason, all boiling system has been operated with safety margin which could reduce the system efficiency.

Since 1950s, many researchers have investigated to enhance the CHF with various methods such as surface etching, coating and etc. Some of researchers focused on the nanofluid as a working fluid to enhance CHF and they revealed that the dramatic increase of the CHF was coming from the nanoparticle deposition and change of surface characteristic. [1] Now a day, POSTECH [2] tried to imitate the micro/nano structure surface which had been shown on the nanoparticle deposited surface. Various ZnO structures were made on silicon base and CHF experiment was conducted. Investigation on surface characteristic also carried out and micro/nano structured surface showed higher CHF enhancement than the limitation of wettability effect. In addition, POSTECH [3] conducted the CHF enhancement experiment using zirconium alloy by anodic oxidation method and it shows the about 90% enhanced CHF. It also showed the significant increase of CHF and analysis by liquid spreadability was carried out. [4]

The experiment of flow boiling is very important in the aspect of application to industry. Thus experimental scope was expanded from pool boiling experiment to flow boiling experiment about the CHF enhancement on the modified zirconium surface.

2. Experiment

In this section, the experimental facility and result are described. The upward vertical flow boiling experiment was conducted. 20 ℃ sub-cooled inlet condition at the atmospheric pressure was used and CHF experiment was conducted.

2.1 Experimental apparatus

The experimental apparatus is designed for a flow boiling experiment under atmospheric pressure. It

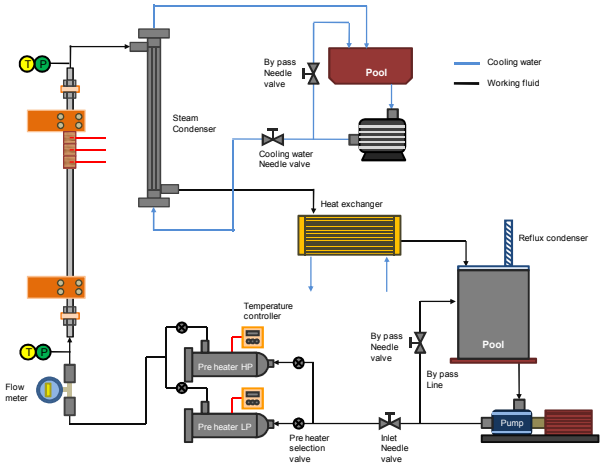


Fig. 1. The schematic images of test loop and test section

consists of a test section, pump, pre-heater, steam condenser and surge tank. The test sample is the zirconium tube which has the 3/8" of outer diameter and 430mm of heating length. The test sample connected by copper bus bar and joule heating method was used to add heat by DC power supply (150kW).

2.2 Experimental Results

Fig.2 shows the CHF value of bare and modified surface with various mass fluxes. The experimental range of mass flux was from 300 kg/m^{2}s to 1500 kg/m^{2}s and high mass flux case showed the high CHF value. CHF values on the modified zirconium alloy tube

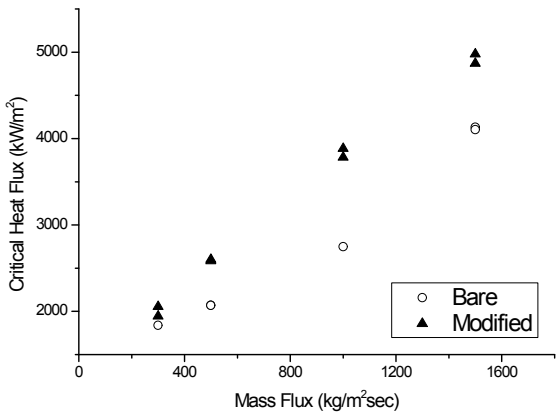


Fig. 2. CHF values on bare surface and modified surface with various mass fluxes

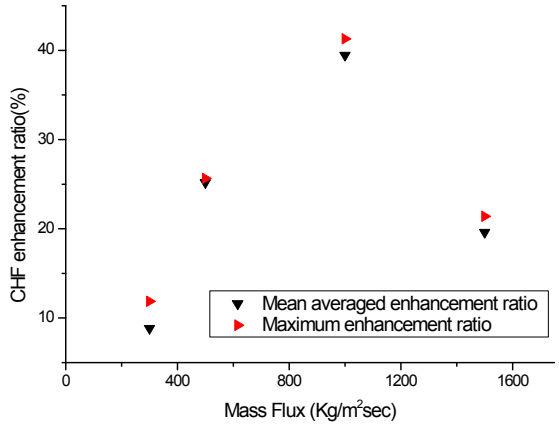
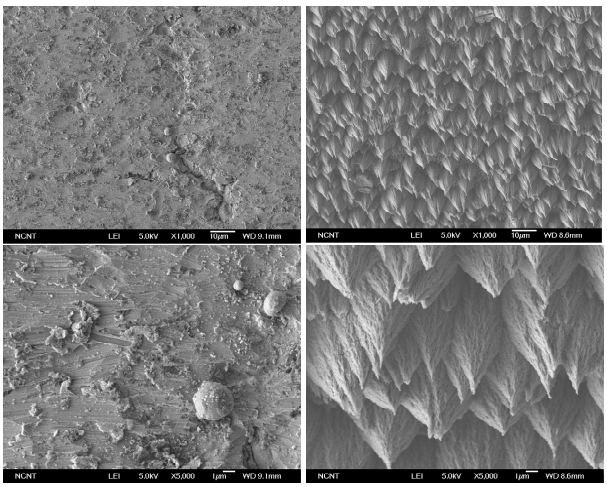


Fig. 3. CHF enhancement ratio on the modified zirconium alloy tube ($CHF_{enhance}/CHF_{bare}$)

enhanced in all mass flux cases. It could be explained by investigation of surface characteristics, such as wettability and liquid spreadability. Fig. 3 shows the CHF enhancement ratio of the modified surface compared to the bare surface. From 300 kg/m^{2}s to 1000 kg/m^{2}s, enhancement ratio was continuously increased, 10% to 40%, but 1500 kg/m^{2}s shows reduced enhancement ratio. These experiments are still on-going and additional experiments will be conducted to obtain more data.

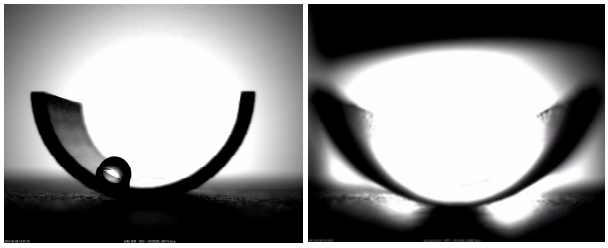
2.3 Surface characteristics

Fig. 4 shows the SEM images of bare and modified zirconium tube surface. The modified zirconium surface has the micro scale structures like a mountain and a valley. The structures are also very similar with plate zirconium case. [3] Fig. 5 shows the contact angle image of the bare and modified zirconium tube surface. On the bare surface, CA was 88° but on the modified



(a) (b)

Fig. 4. SEM image of (a) bare and (b) modified zirconium tube surface



(a) (b)

Fig. 5 Contact angle image of (a) bare and (b) modified zirconium tube surface

zirconium tube, it was complete-wetting because of the super-hydrophilic surface characteristic. So, the liquid spreadability on the modified zirconium tube surface should be also investigated like a pool boiling result on modified plate surface[4].

3. Conclusions

Flow boiling CHF experiment for modified zirconium alloy tube surface was investigated under subcooled and atmospheric conditions. Surface of zirconium alloy tube was treated by anodic oxidation to create the micro/nanostructures. CHF enhancement was observed in all mass flux cases but enhancement ratio couldn't show the clear trend. Surface investigation of bare and modified zirconium tube surface were also carried out. Like a plate type specimen, the modified zirconium tube surface also showed the micro scale structured surface and has the complete-wetting surface characteristic. However, additional investigation on surface characteristic and quantification method of wettability to apply on circular tube should be needed in the future.

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