論 文 の 内 容 の 要 旨

論文題目　Study on Saturated Flow Boiling CHF using Porous Honeycomb Plate and Irradiation Effect
（ハニカム多孔質体と照射効果を用いた飽和流動沸騰における限界熱流束の研究）

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In-vessel retention (IVR) of molten corium through external cooling the reactor vessel is one of the key severe accidents management strategies in advanced nuclear reactors. During the cooling process, the heat removal is limited by the occurrence of critical heat flux (CHF) at the outer surface of the reactor vessel. As the nuclear plant power increase, the critical heat flux should be increased to give enough safety margin. Therefore, methods to increase the CHF should be considered. Many methods involving nanofluids, surface modifications, have been investigated to enhance the CHF values, but most of the previous works focus on pool boiling and upward-facing conditions.

The first objective of this study is to investigate the CHF enhancement effect of a metal porous honeycomb plate in downward-facing saturated flow boiling conditions. Honeycomb plates with different parameters were used to find the enhancement effect under different water flow rates conditions, investigate the enhancement mechanism and then find out a honeycomb parameter which can obtain a maximum enhancement effect for downward-facing flow boiling conditions. The second objective is to investigate the irradiation effect on flow boiling CHF of bare surface and honeycomb plate surface.

For honeycomb experiment, it is found that porous honeycomb plates can all enhance the CHF in saturated downward-facing flow boiling under four flow rates, but the CHF enhancement effect decreases as the flow rate increases. CHF enhancement of porous honeycomb plate is due to honeycomb structure as well as the additional water supply through the porous media. At high flow rates, water supply through the porous media is very weak due to bubbles constantly covering the honeycomb plate. Among different honeycomb plates, the porous honeycomb plate with a 1.7mm hole diameter, 2.5mm hole pitch (100μm raw particle size) can obtain a maximum enhancement effect due to a high boiling area ratio and a suitable hole diameter.

For irradiation experiment, it is found that flow boiling CHF values do not increase after the boiling surface being irradiated by Gamma-ray even though the surface wettability increased significantly due to RISA effect due to water supply is enough for flow boiling condition. Surface wettability increased significantly after the surface being irradiated by electron beam due to RISA effect. However, this study found that in saturated, downward-facing flow boiling, the CHF values decrease when the copper boiling surface is irradiated by an electron beam, whereas heat removal almost remains the same even though the surface wettability increases after irradiation. The CHF values decrease more in the low irradiation dose range (30 – 300 kGy) than in the high irradiation dose range (1000 – 3000 kGy). This is mainly because low dose electron beam irradiation can generate considerably more nucleation sites on the boiling surface, which increases the bubble surface coverage area and decreases the bubble removal ability. In this case, water supply to the boiling surface becomes difficult and the CHF occurs at a low heat flux. This observation is contrary to the traditional opinion that a high nucleation density increases nucleate boiling heat transfer and enhances the CHF.