論 文 の 内 容 の 要 旨

論文題目　A study on the effect of surface oxidation on critical heat flux in downward-face boiling
（表面酸化による下向き沸騰の限界熱流束に関する研究）

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To successfully execute in-vessel retention external reactor vessel cooling (IVR-EVRC), critical heat flux (CHF) plays a key issue in securing the thermal and structural integrity of the reactor pressure vessel (RPV). In real-world applications, the RPV outer surface is exposed and oxidized. So it is very important to study the oxidation effects on boiling and CHF. In this study, we performed experiments as well as numerical simulations to study the oxidation effect. For the experiments, several experiments were done. First, downward-face flow boiling CHF enhancement by copper oxidation in the air was investigated under atmospheric conditions, it was found that after oxidation, copper CHF increased and fewer bubbles were found to generate on the surface. The CHF enhancement is related to the decrease in contact angle and nucleate site density (NSD). Then, an experiment concerned with the downward pool boiling CHF using a carbon steel block was performed and the results were analyzed through a comparison with the CHF of a copper block, it was found that the carbon steel block CHF under both 5° and 10° inclination angles were much lower than that of the copper block. As seen from the surface images, the carbon steel block generates more bubbles than the copper block,

which leads to more dry patches. This may result in lower CHF. At last, a downward-face pool and flow boiling experiment conducted using a carbon steel plate and compared the results with those of previous experiments. Enhancements were found both in pool boiling and flow boiling and fewer bubbles generated on the surface after oxidation. The CHF increase is due to iron oxidation on the heater surface. The combined effect of the increase in wettability and decrease in NSD is likely to be the reason that the CHF increases. The gradual oxidation process of carbon steel could be beneficial to real-world applications of IVR-ERVC. From the results of the experiments, it was believed that CHF enhancement was related to the decrease of NSD. Based on this observations, a new model for the downward-face pool boiling and flow boiling CHF based on the bubble interaction theory was proposed. The relationship between NSD and CHF was revealed, and several experiments and numerical simulation were applied to validate the model. The relationship between CHF and NSD agreed well with the experimental data for both the flow boiling and pool boiling. And it was also validated through Monte Carlo methods. A numerical simulation study was done to study the effect of NSD. The numerical results also showed the same tendency with the model proposed. This model can be a candidate in explaining the oxidation effect on CHF.