論 文 の 内 容 の 要 旨

論文題目

Critical Heat Flux Enhancement in Downward-facing Pool Boiling with Honeycomb and Irradiation Effect

（ハニカムと照射による下向きプール沸騰における限界熱流束の改善）

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In nuclear power plants (NPPs), one of safety strategy responding to severe accident is to activate ex-vessel cooling system. With regard to the strategy, critical heat flux (CHF) in lower head of reactor vessel is a key standard to assess such kind of cooling ability. Thus far, especially after Fukushima accident safety analysis has been proven in present NPPs. However, for the new type of NPPs present evaluating criterion is not available. This is because the new ones are usually coming with a higher thermal power, which needs a higher cooling ability correspondingly. Thus the requirements for CHF enhancement has been back to the center by lots of researchers.

Recently, many researcher used different methods for CHF enhancement study, such as

nano-particle, micro-fin, porous layer and so on. Regarding with these methods, it was found CHF can be enhanced. However, there is a need for further study. Thus, in this study, honeycomb and irradiation methods are selected for CHF enhancement study. Meanwhile, the bare surface was carried on as controlled experiment for future comparison. In this study, many factors are taken into consideration. These are inclination, honeycomb pore size, honeycomb structure, dose amount, dose source and some combination of several factors. Through experiment, CHF results can be obtained. Based on honeycomb and irradiation experiment, the findings are list as follows:

- In bare surface case, CHF increases as inclination, which means the higher inclination it is the larger CHF value it shows;
- In honeycomb surface cases, a) solid honeycomb surface can enhance CHF compared with bare surface case. Moreover, porous honeycomb surface cam further enhance CHF performance; b) present pore size has no effect on CHF value; c) CHF also increases as inclination going up; d) CHF value increases as hole-area ratio;
- In irradiation cases, a) irradiation reduces contact angle, increasing surface hydrophilicity. Also, at same dose amount extent of angle decreasing is similar which means source type has no effect; b) in 5° bare surface case, CHF can be largely enhanced by high dose irradiation. Besides, source type has similar effect on CHF performance; c) in 10° and 20° bare surface case, CHF cannot be enhanced; d) in all honeycomb surface case, irradiation cannot affect CHF performance;

Combined with present CHF results, the theoretic explanation is given.

- Inclination can affect BFDF, one factor that can determine the speed of bubble removal and decide the surface wettability in the end. More specifically, at high inclination, bubble removal speed is rapid so that BFDF is larger. So it can provide heating surface with more room for water refluxing, leading to an increasing CHF. And it is true in both bare surface and porous honeycomb surface case. In a word, wettability can affect CHF performance.

- The boiling area can affect CHF performance. Through the comparison between solid and porous honeycomb surface cases, the values of porous case is higher. This is because, the heating surface covered by porous honeycomb plate is another boiling area (water can be absorbed by porous surface). It means the extended boiling area can enhance CHF value.
- CHF value is a balance of water refluxing and bubble removal mass flow rate, which means the lower value can determine the final CHF performance. In this study, based on model water refluxing mass flow rate decreases as hole-area ratio while bubble removal mass flow rate increases as hole-area ratio. So CHF can reaches the maximum when both mass flow rate are equal. Besides, this crossing point of both water refluxing and bubble removal mass flow rate curve is at the hole-area ratio 0.41.
- Irradiation can increase nucleation site area. If the nucleation site area is big, the level of water replenishment toward heating surface is larger, causing an improved heat transfer condition. That is the reason for CHF enhancement.

In a word, in this study CHF enhancement is determined by these factors: 1) extended boiling area; 2) surface wettability; 3) balance of water refluxing and bubble removal mass flow rate; and 4) nucleation site area.

Keywords: critical heat flux enhancement; pool boiling; heat transfer; honeycomb; irradiation; inclination;