Dissertation

Enhancement of the critical heat flux in pool boiling by honeycomb porous plate and nanofluid

（ハニカム多孔質体とナノ流体によるプール沸騰限界熱流束の向上）

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Abstract

The subject of critical heat flux (CHF) has received particular attention by many scholars due to its direct implication to safety caused by a rapid rise in wall temperature, and the sudden decreased of heat transfer coefficient that possibly jeopardizes the system. CHF enhancement is vital to increase the safety margin, for example, the in-vessel retention (IVR) method to cool down the reactor vessel during severe accidents at the nuclear power plant which requires a very high heat flux removable. This study proposes a new method of combining a few surface modification techniques to enhance the CHF further in comparison to CHF of the plain surface under saturated and atmospheric conditions. A simple method of attaching a honeycomb porous plate on a ϕ30 mm heated surface enhanced CHF about 2.5 times compared to non-modified heated surface in a saturated pool boiling of water. A significant CHF enhancement using nanofluid either as a nanoparticle deposited surface or as the working fluid have been reported by many because of improvement of surface wettability and capillary wicking performances due to surface roughness changes on the heated surface. Combination both of the methods, honeycomb porous plate, and nanoparticle deposited surface in saturated pool boiling of water show a significant CHF enhancement in all heater sizes used in the present study, 10 mm, 30 mm and 50 mm in diameter. Further enhancement of CHF with honeycomb porous plate attachment on ϕ30 mm heated surface is achieved in a high concentration of nanofluid (0.1 vol.%) boiling. The CHF was three times of that plain surface in water boiling, and surprisingly, nanoparticle deposition on the honeycomb porous plate did not affect the liquid supply by the porous part. However, with the increased size of the heated surface, ϕ 50 mm, the same amount of enhancement (three times) could not be achieved with the combination of honeycomb porous plate attachment in the nanofluid. The idea of increasing the vapor jets by a square-shaped metal structure is adopted. Several dimensions of the metal structure were fabricated, and the best performance of it used to further the investigation. Experiment results show that a high heat flux about 3.1 MW/m^2 is removable with the combination of honeycomb porous plate and square-shaped metal structure in the nanofluid. ϕ 50 mm of the heated surface can be considered as an infinite heater surface because the dimensionless heater size of ϕ 50 mm has a value of 20. These experimental results indicate that the possibility of improving the CHF of a large heated surface by this method. Heater orientation is another primary concern in the real application because CHF tends to decrease with the increase of heater orientation approaching downward-facing surface. Experiments were conducted under saturated, and atmospheric conditions using water as a working fluid from upward-facing (0°) to the downward-facing (180°) heated surface. A small heated surface of the ceramic heater, 12 mm × 12 mm is used, and the heated surface is modified with nanoparticle deposited surface, honeycomb porous plate attachment and its combination. The experimental results show that the CHF is significantly increasing by the combination of the honeycomb porous plate attachment on the nanoparticle deposited surface, even under downward-facing heater conditions. Additionally, the CHF enhancement increases as the orientation of the heated surface approach downward-facing.