Abstract

The phase change heat transfer processes are widely implemented for heat extraction as they utilise both sensible and latent heat (Rohsenow and Griffith, 1955). The capability to remove the higher magnitude of heat at low wall superheats, and the lack of moving parts makes pool boiling appealing (Memmott and Manera, 2011). Pool boiling is economical, simple, and prevalent among all available cooling schemes. The utilization of the aforementioned technique is widely implemented for thermal management in nuclear industries and in microelectronic devices. Conventional air cooling systems cannot handle these devices cooling requirements which may be due to their low heat transfer performance. In such instances, pool boiling, and droplet evaporation techniques can be implemented. Nowadays, the nuclear industries, renewable energy sectors, and power plants are implementing compact heat exchangers as preheaters, regenerators, and intermediate heat exchangers (Pattanayak et al., 2022) (Pattanayak and Kothadia, 2020). These compact heat exchangers are basically of tubular or plate-type. Therefore it gives the urge to study the heat transfer characteristics of those heat exchangers and analyse the methodologies that can enhance the heat transfer from the surface of tubes and plates (Pattanayak et al., 2022).

The lack of qualitative theories, quantitative data, and explanations in the area of critical heat flux (CHF) in tube and plate makes it an interesting domain of research. There is limited research explaining the effect of high, substrate and liquid temperatures, on droplet evaporation. There is a scarcity of research in analysing the heat transfer coefficient during the evaporation process (Pattanayak et al., 2021) (Pattanayak and Kothadia, 2022). The research highlights the critical heat flux (CHF) studies on mini-channels, micro-channels, and plates during pool boiling under uniform heat flux conditions. Identification of the tube and plate length and diameter beyond which CHF becomes independent of the dimensions is discussed. The effect of tube and plate orientations and pool subcooling on CHF has been analysed. Different regimes of pool boing under uniform heat flux conditions are discussed based on bubble behavior. The instantaneous heat transfer coefficient during droplet evaporation is analysed. The CHF data are used to derive an empirical correlation that includes the impact of subcooling, orientation, and dimensions (Pattanayak et al., 2023).

In the case of the analysis of compact heat exchangers, SS 304 tubes and plates are used. The orientation is changed from 0^{o} to 90^{o} for tubes and 0^{o} to 180^{o} for plates. The length and diameter of tube is varied from 50 mm to 1000 mm and 1.2 mm to 9 mm, respectively. The water pool is kept at 30°C, 50°C, 75°C, and saturation temperature. The length of the plate is varied from 50 mm to 300 mm. The width of the plate ranges from 10 mm to 20 mm. The pool is maintained at 25℃ and saturation temperature corresponding to ambient pressure. It has been noted that the severity of CHF lessens as pool temperature rises. For a particular pool temperature, the shortest length has a higher magnitude of CHF. As tube diameter and width expand, CHF values decrease. In the case of tubes, the CHF value is larger for horizontal orientation than vertical orientation.

The study demonstrates that for horizontally oriented tubes, CHF fluctuation is negligible beyond a length of 500mm, regardless of diameter. According to the study performed for vertical channels, CHF fluctuation is negligible for tubes with a diameter more than 2.5 mm beyond a length of 200 mm. The vertical orientation of the plates results in a higher CHF

magnitude as compared to the horizontal upward and downward orientations respectively (Pattanayak and Kothadia, 2020), (Pattanayak et al., 2021), (Pattanayak et al., 2023). The hydrophobic surface of copper electrodeposited tubes exhibits a lesser CHF magnitude than the uncoated surface and is efficient for phase change heat transfer applications in lower heat flux regimes. Furthermore, the analysis of heat transfer during droplet evaporation is conducted to study the effect of surface and liquid temperature on the instantaneous heat transfer coefficient. It is observed that the evaporation rate is higher for copper than aluminum. The instantaneous heat transfer coefficient increases with the temperature of droplet evaporating on a given substrate and is higher for copper. When substrate temperature increases for a given droplet temperature, the instantaneous heat transfer coefficient increases (Pattanayak and Kothadia, 2021) (Pattanayak et al., 2022). The regimes from natural convection to CHF limit in a subcooled pool of water maintained under uniform heat flux conditions are studied for SS 304 upward-facing plates of different dimensions (Clifton and Chapman, 1969) (Pattanayak et al., 2022). During the heat transfer process, the temperature distribution along the plate is examined. The Nusselt number is seen to be independent of aspect ratio (Pattanayak et al., 2022) (Pattanayak and Kothadia, 2022). The Nusselt number rises when the plate length and width are independently increased. The study is also carried out in saline water of solutions with varying salinity from 0%, 0.2%, 0.5%, and 2%, and is observed that beyond salinity 0.2%, the heat transfer coefficient decreases (Pattanayak et al., 2022).

...