Flow boiling characteristics of binary mixtures

Daniel F. Sempértegui-Tapia* and Tassos G. Karayiannis

* corresponding author
College of Engineering, Design and Physical Science, Brunel University London, Kingston Lane, Uxbridge, London UB8 3PH, UK, Daniel.SemperteguiTapia@brunel.ac.uk, Tassos.Karayiannis@brunel.ac.uk

Keywords: convective boiling, two-phase flow, binary mixtures

ABSTRACT

Pool and convective boiling of binary mixtures are used in many applications such as in petrochemical engineering, chemical engineering, process industries and refrigeration systems. Due to their importance in industry, a number of studies were performed on flow boiling of mixtures in macro-scale channels in the last decades. However, several fundamental aspects are still unclear due to the fact that most of the studies provide different experimental behaviour and were performed under a wide range of experimental conditions. These studies also generated proposals of heat transfer coefficient predictive methods for flow boiling in conventional channels for binary mixtures. Most of them consider nucleate and convective contributions, see Kandlikar (1998) for an extensive review of these predictive methods. However, as pointed out by Thome (1996), most of the predictive methods available in the literature were based on restricted experimental databases and the authors usually included empirical factors that were either mixture specific, did not include a heat flux effect or have not been tested against independent experimental databases.

In the last few years, flow boiling in micro channel heat exchangers has been extensively researched and these heat sinks are proposed as a possible solution for cooling high and ultra-high heat flux devices such as electronics cooling, turbine blades, fusion reactor blankets, power electronics in avionics and hybrid vehicles, Mudawar (2011), and Fayyadh et al. (2017). More recently, in an effort to improve heat transfer rates even further flow boiling reports on mixtures in micro-scale channels have emerged in the literature, although it is worth mentioning that the number of papers for microchannels is still restricted. Peng et al. (1996), for example, performed flow boiling experiments for water/methanol mixtures and reported and optimum concentration at which the heat transfer coefficient reached a maximum value. Surface tension and its dependence on temperature and mixture composition is a crucial factor, leading to interfacial stress and Marangoni effects, which can stabilize/destabilize interfaces or liquid films and incite convective flow. According to Fujita and Bai (1997), the Marangoni effects may induce an additional liquid restoring force to the three-phase contact line. Lin et al. (2011), Fu et al. (2012a) and Fu et al. (2012b) studied flow patterns, heat transfer coefficient and critical heat flux for binary mixtures flowing through a diverging microchannel. This research group performed experiments for ethanol/water and methanol/water mixtures and proposed new correlations for the heat transfer coefficient and critical heat flux including Marangoni effects.

A critical review on fundamental issues, physical mechanisms, and predictive methods on flow boiling characteristics of binary mixtures will be presented. The analysis and review will start with studies and predictive methods for pool and convective boiling for conventional channels for binary mixtures. In the second part, emphasis will be placed on the recent developments and studies on flow boiling of mixtures in micro-scale channels. Available correlations predicting flow boiling characteristics in these small to micro scale passages will also be presented.

References

1. Fayyadh, E.M., Mahmoud, M.M., Sefiane, K., Karayiannis, T.G., 2017. Flow boiling heat transfer of R134a in multi microchannels. Int. J. Heat Mass Transf. 110, 422–436.
2. Fu, B.R., Lin, P.H., Tsou, M.S., Pan, C., 2012a. Flow pattern maps and transition criteria for flow boiling of binary mixtures in a diverging microchannel. Int. J. Heat Mass Transf. 55, 1754–1763.
3. Fu, B.R., Tsou, M.S., Pan, C., 2012b. Boiling heat transfer and critical heat flux of ethanol – water mixtures flowing through a diverging microchannel with artificial cavities. Int. J. Heat Mass Transf. 55, 1807–1814.
4. Fujita, Y., Bai, Q., 1997. Critical heat flux of binary mixtures in pool boiling and its correlation in terms of Marangoni number. Int. J. Refrig. 20, 616–622.
5. Kandlikar, S.G., 1998. Boiling heat transfer with binary mixtures - Part II - Flow boiling in plain tubes.pdf. J. Heat Transfer 120, 388–394.
6. Lin, P.H., Fu, B.R., Pan, C., 2011. International Journal of Heat and Mass Transfer Critical heat flux on flow boiling of methanol – water mixtures in a diverging microchannel with artificial cavities 54, 3156–3166. doi:10.1016/j.ijheatmasstransfer.2011.04.016
7. Mudawar, I., 2011. Two-Phase Microchannel Heat Sinks : Theory , Applications , and Limitations. J. Electron. Packag. 133, 1–31. doi:10.1115/1.4005300
8. Peng, X.F., Peterson, G.P., Wang, B.X., 1996. Flow boiling of binary mixtures in microchanneled plates. Int. J. Heat Mass Transf. 39, 1257–12264.
9. Thome, J.R., 1996. Boiling of new refrigerants : a state-of-the-art review. Int. J. Refrig. 19, 435–457.