Study of Homogeneous Bubble Nucleation during Jet Impingement Quenching

Project Director: Dr. Md. Ashraful Islam
Professor, Department of Mechanical Engineering
BUET

Project Duration: Aril 2007 to April 2008

Awarded by: Committee for Advanced Studies and Research (CASR), BUET

Summary

An analytical investigation has been performed to explicate the phenomenon that happens during a brief contact of a water/ ethanol jet impinging on a hot surface. A simple semi-infinite conduction heat transfer model is used to find the temperature distribution within the liquid. The heat transfer analysis has been carried out for three heating cases of the impinging liquid, namely with (i) prescribed surface temperature (PST) case, (ii) prescribed surface heat flux (PHF) case and (iii) time-dependent surface temperature (TST) case. For each of the three cases, explicit equations of temperature distribution within liquid, average liquid temperature and average internal energy have been derived as a function of liquid depth equal to the critical diameter of vapor embryo and contact time. An algorithm is developed to solve these equations numerically and the fallouts have been presented graphically to get a better view of the observable facts. Variation of average liquid temperature, equilibrium radius of vapor embryo, average internal energy with time and variation of liquid instantaneous temperature with liquid depth have been illustrated for different cases. Besides, the effects of different parameters such as boundary conditions, liquid initial temperature, contact time, working fluid and block material have been studied. It is seen that, although the time and temperature to initiate homogeneous bubble nucleation for water and ethanol varies considerably, their nature of jet impingement cooling is almost identical. It has been also observed that, keeping other parameters constant, a smaller contact time (0.1-1 μs) is needed to trigger homogeneous bubble nucleation for PST case than for PHF and TST cases (10-40 μs) and this is true for both water and ethanol. The minimum energy required to initiate homogeneous bubble nucleation has also been calculated for different cases. Interestingly enough, in all cases the internal energy of the liquid exceeds this minimum energy at some period of contact. This indicates a strong possibility of homogeneous bubble nucleation during jet impingement quenching phenomenon.