Seminar

Institute for Plasma Research

Title : Moist Air Condensation in Drop Mode

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Venue : Online - Join the talk:
https://meet.ipr.res.in/Dr.VishakhaBaghel_PDFtalk

Abstract :

Moist air is a mixture of water vapor and dry air, incorporating various non-condensable inert gases. The ambient air contains 1.29×10^{13} m^3 of freshwater in the form of water vapor. Once extracted efficiently this amount of water is ample to accomplish all the basic requirements of life on Earth. In this context, research was carried out to develop a holistic mathematical model for droplet condensation of moist air. To investigate the effect of various operating parameters on the heat transfer and condensation rates associated with moist air condensation. Simultaneously, an experimental study for moist air condensation on the hydrophobic surface was carried out to validate the developed model. Further, these experiments and simulation results were used for realizing an atmospheric water harvesting device. In this work, prior to the development of a mathematical model, a numerical study was performed to examine thermo-fluid transport through a liquid droplet, in presence of pure vapor, considering the effect of all possible thermal resistance acting on a liquid droplet growing via direct condensation. This numerical study also illustrates in detail the effect of thermocapillary Marangoni convection on a droplet, which was otherwise excluded in the prior state-of-the-art single drop models.

In this work, the comprehensive model for moist air condensation in drop mode was developed for vertical and horizontal surfaces. Here, the existing pure vapor condensation model was updated to cater to the effect of the non-condensable present in moist air. Wherein, majorly the expression for minimum droplet radius at nucleation and drop growth rate via direct condensation were modified, however, the model for drop coalesces and instability sub-processes were adopted as given for pure vapor condensation, as per the findings of pure vapor and moist air comparison experimental study performed in this work.

Jointly, an experimental study of moist air condensation over the homogenously hydrophobic surface was performed for validation of the developed model. In the experimental study, the condensation was performed on Al and Cu surfaces fabricated hydrophobic and superhydrophobic by combination of physical and chemical texturing methods.

Post-validation, simulations were performed over a range of operational parameters from the viewpoint of amplifying the condensation rates. The results of the study demonstrate, enhancement in the rate of condensation with an increase in the relative humidity, subcooling, and moist air temperature. In addition, a vertical surface with a low wettability increases the drainage of a water droplet from the surface. Hence, leads to increase in the water yield of the surface. Also, interfacial resistance increases substantially in the presence of a non-condensable medium. Therefore, the degree of subcooling

required for producing water in the presence of atmospheric moist air is higher than that of pure water vapor.

The results of the experimental and simulation studies were further utilized towards designing and fabricating atmospheric water harvesting devices used for providing potable water in humid, arid, hot, and drought-affected regions worldwide. Four devices with different designs, shape and sizes of the condenser unit were developed in this work. Qualitative and quantitative estimation of the water productivity was performed. Cost and energy estimations were carried out to design and develop an economically viable device for producing water from moist ambient air.