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Theoretical Prediction on the Lifetime of Sessile Evaporating Droplet in Blade Cooling

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Abstract : The effective blade cooling is of great significance for improving the performance of turbine. The mist cooling emerges as the promising way compared with the transitional single-phase cooling. In the mist cooling, the injected droplet will evaporate rapidly, and cool down the blade surface due to the absorbed latent heat, hence the lifetime for evaporating droplet becomes critical for design of cooling passages for the blade. So far there have been extensive studies on the droplet evaporation, but usually the isothermal model is applied for most of the studies. Actually the surface cooling effect can affect the droplet evaporation greatly, it can prolong the droplet evaporation lifetime significantly. In our study, a new theoretical model for sessile droplet evaporation with surface cooling effect is built up in toroidal coordinate. Three evaporation modes are analyzed during the evaporation lifetime, include “Constant Contact Radius”(CCR) mode，“Constant Contact Angle”(CCA) mode and “stick-slip”(SS) mode. The dimensionless number E0 is introduced to indicate the strength of the evaporative cooling, it is defined based on the thermal properties of the liquid and the atmosphere. Our model can predict accurately the lifetime of evaporation by validating with available experimental data. Then the temporal variation of droplet volume, contact angle and contact radius are presented under CCR, CCA and SS mode, the following conclusions are obtained. 1) The larger the dimensionless number E0, the longer the lifetime of three evaporation cases is; 2) The droplet volume over time still follows “2/3 power law” in the CCA mode, as in the isothermal model without the cooling effect; 3) In the “SS” mode, the large transition contact angle can reduce the evaporation time in CCR mode, and increase the time in CCA mode, the overall lifetime will be increased; 4) The correction factor for predicting instantaneous volume of the droplet is derived to predict the droplet life time accurately. These findings may be of great significance to explore the dynamics and heat transfer of sessile droplet evaporation.

Keywords : blade cooling, droplet evaporation, lifetime, theoretical analysis
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