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Theoretical analysis of the lifetime of sessile evaporating droplet with surface cooling effect

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Abstract - Liquid droplets are ubiquitous in daily life and industries, therefore the insight of the evolution of droplet evaporation can be of great significance on practical applications. So far the majority of studies on the evaporation of sessile drops are based on the isothermal quasi-steady cases, in which the temperature distribution is assumed uniform along the droplet interface. However, in the actual process, due to the influence of uneven evaporation flux along the air-liquid interface, there is significant variation of temperature along the air-liquid interface, leading to longer lifetime of evaporation. In this paper, by taking account into the interfacial cooling on the basis of isothermal model, the new theoretical model for sessile droplet evaporation with surface cooling effect is built up in toroidal coordinate, three evaporation modes are analysed during the evaporation lifetime, including "Constant Contact Radius"(CCR) mode、"Constant Contact Angle"(CCA) mode and "Stick-Slip"(SS) mode. The dimensionless number E_0 is introduced to indicate the strength of the evaporative cooling, and it is defined based on the thermal properties of the liquid and the atmosphere. It is found that the larger the dimensionless number E_0 is, the longer the lifetime of three evaporation modes is; The variation of droplet volume over time still follows "2/3 power law" in the CCA mode, as in the isothermal model without the cooling effect; In addition, the correction factor for predicting instantaneous volume of the droplet is also derived, which illustrate the difference between the isothermal model and non-isothermal models. These findings may be of great significance to explore the dynamics and heat transfer of sessile droplet evaporation.

***Keywords*:** Droplet evaporation; Interfacial cooling; Theoretical analysis; Lifetime.