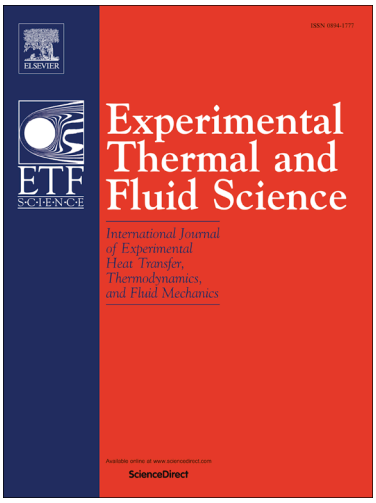

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Experimental investigation and statistical analysis of icing nucleation characteristics of sessile water droplets

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Abstract: Nucleation and freezing of water droplet are very common in aerospace, power, meteorology and refrigeration. This study experimentally investigates the nucleation temperatures of sessile water droplets with volumes of 1, 5 and 10 μL on a cold horizontal aluminum plate which greatly influence the droplet freezing process. Analyses are made on the droplet nucleation sequence and nucleation temperature series as well as their correlations to estimate the systematic errors in the nucleation data, and the results support that such errors are negligibly small. The nucleation temperatures are further analyzed statistically to obtain their average value, standard deviation, frequency distribution and cumulative distribution. The nucleation results for different droplet volumes indicate that a smaller droplet has a lower average nucleation temperature and a larger standard deviation (wider frequency distribution). The nucleation rates are fitted using the classical nucleation theory. The results show that the nucleation rate increases as the temperature decreases and the droplet volume increases. The nucleation time, which involves transient nucleation and is often used to evaluate the surface anti-icing/frosting characteristics, is measured experimentally at a constant plate temperature. The nucleation rate for transient nucleation is found to increase with time. A higher temperature yields larger minimum, average, and maximum nucleation times but a lower nucleation rate. These results provide guidance for predicting ice/frost accretion on surfaces and for designing anti-icing/frosting surfaces.

Key words: Water droplet; Nucleation; Icing; Statistical analysis

Nomenclature

a_T, a_t	fitting parameters
b_T, b_t	fitting parameters
f_{ice}	frozen droplet fraction, °C
$f(\theta_{SL})$	geometric factor
$\Delta G^*(T)$	free energy excess of a critical nucleus, J
J_0	prefactor, s^{-1}
k	Boltzmann's constant
m_i	number of water droplet whose nucleation time is within $[t_i - \Delta t_i/2,\ t_i + \Delta t_i/2]$
n_i	number of water droplet whose nucleation temperature is within $[T_i - \Delta T_i/2,\ T_i + \Delta T_i/2]$
q	latent heat of fusion, J kg^{-1}
$R(T_i)$	nucleation rate at T_i, s^{-1}
r_C	cooling rate, °C/min