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Random and geometric model of droplets nucleation on textured surfaces

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Introduction

The aim of this study is to simulate dropwise condensation in order to control the rate of droplets nucleation and growth. The process of dropwise condensation attracted lots of attention since about 80 years ago, when Schmidt et al. [1] proved that its heat transfer coefficient is significantly higher than filmwise condensation. Dropwise condensation is preferred when higher rate of heat transfer is needed [2]. The problem that we are dealing with is the formation of liquid droplets in car light shield which will cause the light reflection, in such cases it is preferred to achieve the filmwise regime. In this research we are going to develop a computer algorithm to simulate spatial distribution as well as growth rate of droplets at each time step. The results of the presented algorithm are validated by comparing with the experimental data and spatial distribution in Poisson point process.

Experimental Apparatus

In order to study dropwise condensation, at first a set of gray scale images of droplets nucleation and growth was taken by CCD camera during laboratory experiments. Then these images were binarized and used to drive the information of number and size of droplets at each step. These data is used to validate the results of computer simulation.

Experimental setup consists of a chamber containing hot air and cold substrate and a compressor to adjust the relative humidity at about 40%. Temperature of hot air and substrate are set to 86° f and 62°f respectively. Nucleation and growth of droplets are recorded at each second by a high resolution CCD camera installed outside the chamber.

Simulation algorithm

The present model is based on physical description of dropwise condensation. At first a specified amount of random points with nucleation site density of $4.6 \times 10^6 \text{ ft}^{-2}$ (the same as experiments) are distributed completely randomly according to Poisson point process. Then each droplet grows through a main loop which consists of three main parts.

- Adsorption: which means droplet growth by adsorbing water molecules from humid air. The rate of adsorption can be calculated by the heat balance around a sole droplet according to equation 1.

$$r_k = r_{k-1} + G, \quad G = \frac{dr}{dt} = \frac{C_1(1 - \frac{r_{min}}{r})}{C_2 + C_3 r}, \quad C_1 = \frac{(T_{sat} - T_{sub})}{\rho H_{fg}}, \quad C_2 = \frac{1}{h_i}, \quad C_3 = \frac{1}{K_w}, \quad \text{eq (1)}$$

In this equation r is the droplets radius, k is the counter of droplets generation, G is the growth rate due to adsorption, r_{min} the minimum size of droplets, T_{sat} air saturation temperature, T_{sub} substrate temperature, ρ water density, H_{fg} water latent heat, h_i convection coefficient and K_w water thermal conductivity.

- Coalescence: refers to the merging of two or more droplets in order to form a bigger one. This happens when the distance between the droplets is less than the summation of their radiuses.

- Nucleation of new droplets: refers to the formation of small droplets that are ready to grow. Nucleation occurs at the beginning as well as during the process.

Results and discussion

Figure 1 shows acceptable accordance between droplets size and nucleation site density for both simulation and experimental data. According to this figure at first due to adsorption droplets grow very rapidly, also coalescence and nucleation of new droplets accelerate the rate of growth which leads to a fast reduction in the number of droplets in earlier stages. After a while due to formation of vacant area between droplets and the friction factor between big droplets and substrate the rate of coalescence reduces. Steady state situation in these graphs comes from the contrary between coalescence and nucleation of new small droplets. Coalescence increases the size of droplets rapidly and reduces nucleation site density, While nucleation of new droplets lower the average droplets size and increase nucleation site densities.

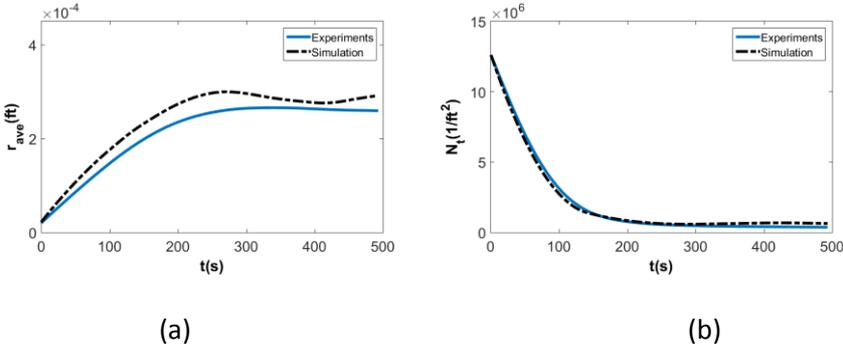


Figure1 Changes in (a)droplet size and (b) Nucleation site density for simulation and experiments

Figure 2 compares the Ripley function of both simulation and experimental data with Poisson point process. The main idea of Ripley function is to draw circles at different distances from center of substrate and count the number of events in each circle [3]. It can be seen that there is visible similarity between Ripley function of simulation results and experimental data at steady state. The blue straight line represents Ripley function of Poisson point process dealing with completely randomly distributed points. Any positive and negative deviation from this line indicates dispersion and coalescence respectively. In the Ripley function of both experimental and simulation results, there is a minimum distance of around 8 microns between droplets. This indicates that there is no pair of droplets that can get closer than 8 microns unless they coalesce. The accordance between the graphs of experimental and simulation results indicates that the program could predict spatial distribution of droplets at steady state very well.

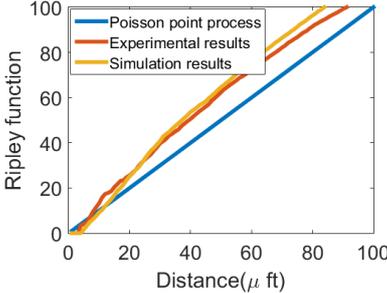


Figure2 Ripley function of progress at steady state

Conclusion

A physical-based model was used to simulate spatial distribution of droplets in dropwise condensation. The predictions of model for evolution droplets size and nucleation site densities were in good agreement with experimental results. Also the spatial distribution estimated by model was the same as real droplets according to Ripley’s function at steady state stages.

References

[1] E. Schmidt, W. Schurig, W. Sellschopp. Technische Mechanik und Thermodynamik, 1(1930):53–63.
 [2] J. R. Lara, M. Holtzapfle. Desalination, 280(2011):363–369, 2011.
 [3] Philip M Dixon. Ripley’s k function. Encyclopedia of environmetrics, 2002.

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