Modeling and simulation of ellipsoidal droplets growing on patterned substrates during dropwise condensation

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Modeling and simulation of ellipsoidal droplets growing on patterned substrates during dropwise condensation

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Introduction

- Aim: presenting a mathematical model for simulating growth of ellipsoidal droplets on patterned substrates.
- Application: studying how to control the size of water droplets formed on the vitreous substrates like glasses, optical lens and car light shields.

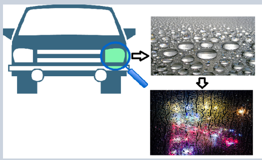


Figure: Formation of water droplets (because of dropwise condensation) on car light shields reduces light reflection in foggy days.

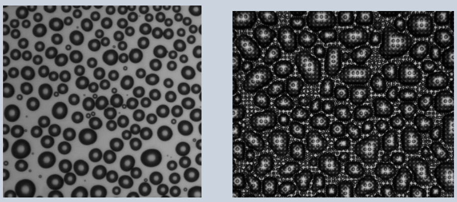
Dropwise condensation

The process of dropwise condensation consists of five main steps:

- nucleation of initial droplets
- growth rate due to adsorption
- growth rate due to coalescence
- nucleation of new small droplets
- sliding very big droplets from the surface.

Flat *v.s* textured substrates

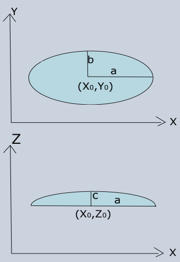
The most important difference between droplets on flat and textured substrates is their geometry:



(a) (b)

Figure: (a) Spherical droplets on the flat, (b) elliptical droplets on the sinusoidal substrates.

Mathematical modeling



$$\frac{1}{a^2}(X-X_0)^2+\frac{1}{b^2}(Y-Y_0)^2+\frac{1}{c^2}(Z-Z_0)^2=1$$

Figure: Hemi-ellipsoidal droplets in two planes (X-Y) and (X-Z) and their corresponding equation.

Coalescence of ellipsoidal droplets

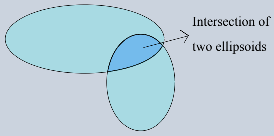


Figure: Checking for coalescence is done by verifying the existence of real intersection between two ellipses

For calculating the intersection between two ellipses in two dimension, one has to solve the system of equations of two ellipses, considering the point of (0,0) in the center of first ellipse. So the equation of the first ellipse will reduce to equation (1).

$$\begin{cases} A_1X^2+Y^2=R_1, & (1)\\ A_2(X-X_0)^2+(Y-Y_0)^2=R_2, & (2)\end{cases}$$

$$A_1=\frac{b_1^2}{a_1^2},\ R_1=b_1^2,\ A_2=\frac{b_2^2}{a_2^2},\ R_2=b_2^2.$$

Mean errors of the model

Table: Mean errors of the model in calculating density and radius of the droplets on 6 different textured surfaces.

configuration of pillars	Mean error of density (%)	Mean error of radius (%)
configuration 1	21.28	-0.62
configuration 2	3.55	9.26
configuration 3	3.01	-2.01
configuration 4	13.14	0.18
configuration 5	11.33	1.80
configuration 6	7.7	5.04
Mean	10.00 ± 0.68	2.28 ± 0.42

Conclusions

- we presented a mathematical model for simulating coalescence of ellipsoidal droplets on textured substrates
- The presented model is applied to 6 different pillared surfaces and its mean error is calculated on all the surfaces of about **10%** for droplets density and **2%** for droplets size.
- The main source of error is recognized as the similarity between the droplets appearance and pillars that makes it difficult to identify the exact number of droplets.

Acknowledgements

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