

## Spatial distribution of droplets during dropwise condensation

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### MOTS CLES

Spatial distribution, Poisson process, dropwise condensation

### INTRODUCTION

The aim of this study is to simulate water droplets spatial distribution on a flat glassy surface under atmospheric pressure. This process has a great importance in analyzing and manufacturing of condensers, heat exchangers and other steam operating devices. In the dropwise condensation there are two main mechanisms for droplet growth. When the droplets are smaller than the half of the mean distance between two drops, they grow by absorbing water molecules from the gas phase, and for droplets bigger than this amount the mechanism is the droplets coalescence [1] which means joining of the neighboring drops to form a new bigger drop. In the current study, the process of dropwise condensation was modeled using a computer program considering both absorption and coalescence. Then the results of this model were compared to experimental results using Ripley function method.

#### Computer simulation

We used an algorithm starting with 90 random points with size of 1 $\mu$ m, containing an irritating process in which, droplets grow in each time step according to equation 1.

$$r_{\text{new}} = [(r_{\text{old}})^2 + G]^{1/2}, \quad G = 4.15 \frac{K \Delta T}{H \rho} \quad (1)$$

where K is water thermal conductivity,  $\Delta T$  is temperature difference between substrate and water, H is heat of condensation and  $\rho$  is water density. In each step the probability of coalescence was checked by calculating the distance between each two points and if the distance was less than sum of two drops radiuses, these two drops coalesced and formed a bigger drop. The radius of droplet resulted by coalescence was calculated based on it's volume and it's centroid was in the center of mass of the two coalescing drops.

Figure 1 shows the initial and final distribution of droplets in this program. Comparing these two figures will reveal that by coalescing both size and number of droplets change in each time step. Small drops grow because of water absorption from air and then when they touch each other they can coalesce and form a bigger drop. The big drops will slide on the vertical surface and form more vacancy for nucleation of smaller drops.

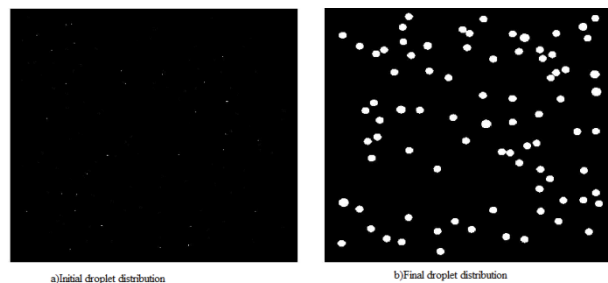


Figure 1: Initial and final droplets distribution.

#### Data validation

This part was done by comparing the results of the model with experimental data. For this reason real pictures were taken from dropwise condensation before the first sliding on a plaque of Polycarbonate

by resolution of 2.2 Megapixels (2028x1088) grayscale 8-bit, and a magnification allowing to have 0.87 microns / pixel.

The method that was used for comparison is Ripley function that counts the number of drops in specified distances from center by drawing circles with specified radiuses. So it can be expected that for a completely random process the graph of number of events according to the circle radius must be a straight line. In the case of clustering or dispersion the graph will deviate from this line.

Ripley function  $\hat{K}(x)$  can be calculated according to equation below.

$$\hat{K}(x) = \hat{\lambda}^{-1} \sum_i \sum_{j \neq i} w(l_i, l_j)^{-1} \frac{I(d_{ij} < x)}{N} \quad \text{equation. 13}$$

Where  $d_{ij}$  is the distance between the  $i$ th and  $j$ th points, and  $I(x)$  is the indicator function with the value of 1 if  $x$  is true and 0 otherwise. However, since the boundaries of the study area are usually arbitrary, Edge effects arise because points outside the boundary are not counted in the numerator, even if they are within distance  $t$  of a point in the study area. The weight function,  $w(l_i, l_j)$ , provides the edge correction. It has the value of 1 when the circle centered at  $l_i$  and passing through the point  $l_j$  (i.e. with a radius of  $d_{ij}$ ) is completely inside the study area. If part of the circle falls outside the study area (i.e. if  $d_{ij}$  is larger than the distance from  $l_i$  to at least one boundary), then  $w(l_i, l_j)$  is the proportion of the circumference of that circle that falls in the study area.

Figure 2 shows the Ripley function of results of model and experimental data. The straight orange line indicates Poisson point process. As it can be seen in these two graphs there is a gap around 10  $\mu\text{m}$  between each two drops center. This means that each two droplets cannot become very close to each other without coalescing. The rest of graphs are asymptotic to Poisson line. This shows that Poisson process can predict properly the experimental results except at the first part, before the first sliding.

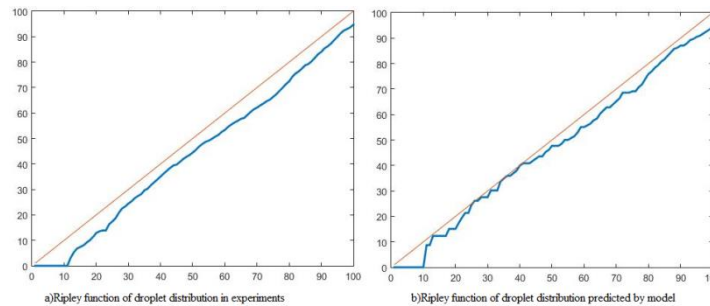


Figure 2: Ripley function of results of model and experimental data.

## CONCLUSION

In this study a model based on Poisson point process was used to describe droplet spatial distribution in a dropwise condensation. The comparison of results that was predicted by model and experimental data shows that there is a good agreement between droplet spatial distribution and Poisson point process before sliding of big droplets, except at the first part. Taking in to account the minimum radiuses will reveal that maybe it is better to use hard-core model for describing the spatial distribution of droplets during dropwise condensation.

## Références

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