12-20-2017

The Analysis of Asymmetric Micro Droplets

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Semester Report Benjamin Gaffney
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Abstract: The primary object of the research activities in this semester is to investigate how to adapte the Popov's evaporation model to droplets with asymmetric geometries. Besides, extensive work with Surface Evolver were performed to analyze the equilibrium geometries of droplets on different solid substrate. Progress has been significant in the development of skills in Surface Evolver, specifically in investigating droplets at the point of bursting. Progress has been less significant in the adaptation of Popov's Model as there are many aspects of this that require in-depth analysis, but the progress made has been promising. Outcomes of this semester include a much more substantial understanding of Surface Evolver as well as Popov's model. Significant progress were made towards making Popov's Model being applicable to asymmetric droplets.

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Introduction: This semester began with thorough analysis of Popov's evaporation Model. The model describes the evaporation of symmetric droplets. The ability to easily analyze the rate of evaporation of a droplet is vital in the research of the lab. The Popov's model provides a simplified correlation that allows for prediction of evaporation rate with fast and easy calculations without having to run a full lengthy simulation for every individual droplet shape.

The focus of the research in the laboratory is to develop a cooling system for technology that is liquid based. The dissipation of the excessive heat is realized through the evaporation of micro droplets. Through the investigation of other lab members, it has been found that there is a higher heat flux for asymmetric droplets over symmetric droplets. This means that an easy way to analyze the evaporation of asymmetric droplets must be developed in order to reduce the required number of simulations performed.

The need to analyze asymmetric droplets motivated the adaptation of Popov's Model. The model takes into consideration the shape of the droplet in the form of a curvature equation. The model uses polar coordinates to describe the droplet (r,ϕ,z). In the current model the curvature is only reliant upon r and z because of the symmetry. The challenge for this semester was including the angle phi into the equations. In order to do this the droplet shape has to be analyzed by a computer program to produce a curvature formula. Currently, there is no explicit mathematical equation for describing the local curvature of a droplet with arbitrary angles. Instead, the local curvature distribution can only be found for one specific meniscus shape with numerical methods. This motivated the development of a further understanding of Surface Evolver as well as the learning of Comsol (the software used for calculating the local curvature of an asymmetric droplet numerically).

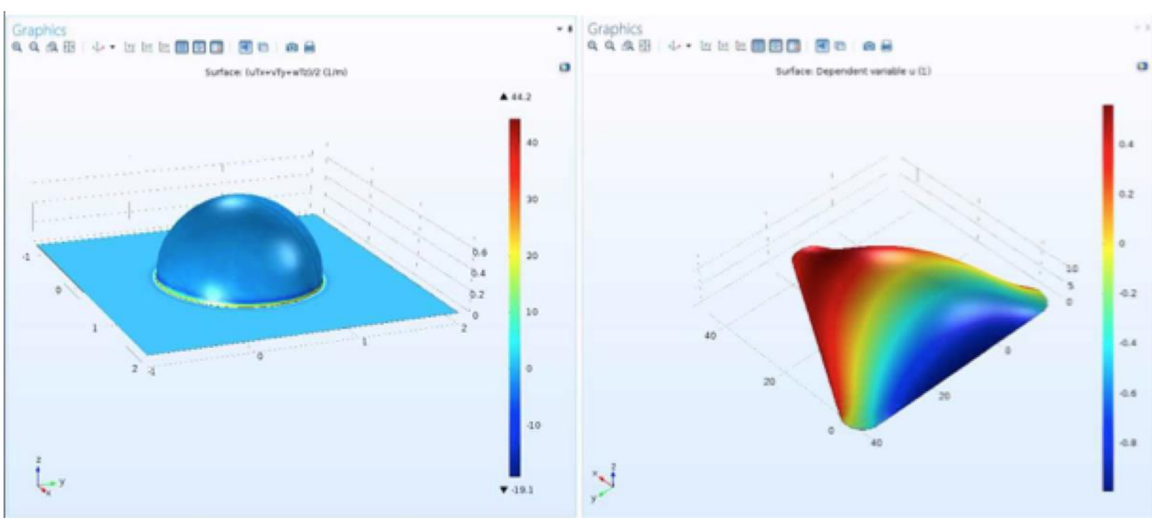

Figure 1.1 displays the output graphic of Comsol. Seen on the left is the mound shape and pictured on the right is a droplet with a triangular base and it is asymmetric.

The procedure for calculating curvature in Comsol involves first importing an .stl file of the geometry developed by Surface Evolver, and then running a computation on the geometry with a weak form of partial differential equation. The simulation results in a graphic demonstration of local curvature distribution as seen above, as well as an excel file containing the curvature at every meshed point on the surface of the geometry. This data provides vital information about the curvature of the droplet. The next step involves forming an equation out of this data.

The final mark of progress was the semester was ended with a presentation to the entire lab about analyzing droplets through the use of Comsol. A slide show was created that doubles as a tutorial that can be referenced at later dates in order to easily analyze droplets.

Materials and Methods: The primary tool investigated for this semester of research was Surface Evolver. Surface Evolver proved to be useful in the formation of the droplet shape. Surface Evolver is a program that finds the minimum energy state of a given mass with various properties such as contact angle and surrounding geometries. Through the use of Surface Evolver the droplet shape can be found which can be then taken to analysis.

Comsol was employed to analyze the droplet shapes produced by Surface Evolver. This program allows the user to define a mesh around the shape and run a simple computation, which results in the curvature of the shape at every point on the surface.

Results: Not every goal was met this semester, but great progress was made towards a final model, and much knowledge was gained along the way.

Throughout the semester comprehension of evaporation of droplets and computer analysis of droplets was greatly improved. Understanding of evaporation was achieved through reading papers on evaporation as well as physically working with and trying to manipulate an evaporation model. Along with this many skills were developed through the use of Surface Evolver and Comsol. The use of these two programs has allowed for great progress to be made towards finally achieving an adapted version of Popov's model.

Future Directions: Adaptation of Popov's model will be further explored in order to make the model applicable to more than the evaporation of a simple symmetric droplet. This will be done by taking the data obtained through Comsol and developing an empirical mathematical formulation for parametrizing the local curvature as a function of location (i.e., coordinates). This can then be used as the curvature equation that is required to expand Popov's model.

Having a model that can analyze the evaporation of asymmetric droplets will greatly assist in the research of the NEIT lab. Current research has shown that asymmetric droplets are more promising in the use of cooling, but a model must be created in order to easily investigate various droplet shapes.