Research on solidifying liquid droplets

Smirnov Alexey

The purpose of the investigation

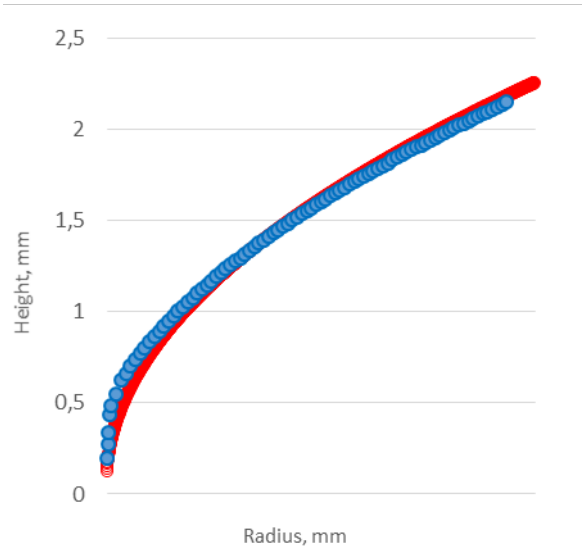
An understanding of solidification dynamics is crucial to predict the behavior of freezing liquid. This research is aimed to discover the proper way to model the appearing singularities (or ice pikes' at top of liquid droplet during freezing) in different liquids, in various conditions, e.g. small liquid droplets (with radius less than 1 mm), greater droplets and surfaces, covered by liquid. The final shapes of liquid systems can be found from the liquid-solid-vapor trajectories in time, thus giving us the generatrixes of frozen droplets.

Method of the investigation

The cooled metal (aluminum) surface was used to freeze liquid droplets and the digital camera to get the images of eventual frozen shapes. Solidification was observed at -15, -24, -78 and -196 degrees Celsius. Lower temperatures made process go faster: solidification continued up to several milliseconds, that's why video filming wasn't possible. The theoretical model was developed and numerically calculated using the MATLAB. The results of the experiments were compared to the model and verified. The noticed effects were explained.

Results of the experiment

On the graph below you can notice similarities in theoretically predicted generatrix of small frozen droplet (red curve) and approximated generatrix derived by digital photo analysis (blue dots over the line), axis have equal scale.



When defining the shapes of small solidified droplets, precision is quite good, but the larger droplets we take, the larger the mismatch becomes. Consequently, the simplified geometrical model stops working for large area surfaces, covered by solidifying liquid. It was found out that, sharp ice pikes form only in solidifying liquids, which have their solid/liquid density ratio from 0.75 up to 1, not including 1.

Conclusion

Summing up, results of this research are quite surprising. Empirical results prove that the shape of frozen liquid doesn't depend on temperature of cooled surface. Experiments also prove the existence of inflexion point near the top or ice pike; which relates to gravity, which we neglected in small droplets investigation. Solidifying liquid puddles can't have several points of singularity, where pikes form, they behave like axis-symmetrical droplets near the singularity point, where the pike appears.