CALIFORNIA STATE SCIENCE FAIR
2007 PROJECT SUMMARY

Name(s)

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Project Number

S1618

Project Title

On Propulsive Leidenfrost Phenomena: Exploring Theory, Experiment, and Applications

Abstract

Objectives/Goals

The Leidenfrost phenomenon occurs when a liquid in contact with a sufficiently hot mass produces an insulating vapor layer which supports the liquid itself. However the presence of asymmetrical surface geometries has been recently shown to influence the vapor flow, resulting in a net force being exerted on the liquid. A series of theoretical developments and experiments were formulated to characterize and explain this novel behavior, in addition to investigating its heat transfer characteristics.

Methods/Materials

To geometrically characterize the vapor flow domain a DSLR camera with a self-constructed Fourier optics system was used to obtain images of the Leidenfrost droplets. The Fourier optics system consisted of a He-Ne laser adjunct to a 100X objective lens and spatial filter, allowing the uniform expansion of light for projection. These images were mathematically analyzed using MATLAB to approximate the height of the vapor layer. A similar approach was used to determine the pressure gradient based on extrapolations from local droplet curvatures.These values were then meshed with a self-derived parallel-plate slip flow model.

A mathematical model describing heat flux within the substrate and vapor layer was developed based on the solution to a specific case of the 3-D heat equation. It was found that temperature could be effectively simplified to vary as the modulus of its 3-D position with respect to the droplet. In conjunction, fine-wire thermocouples and computer-assisted data collection were used to experimentally corroborate theoretical temperature distributions.

Results

It was found the heat transfer coefficient of the Leidenfrost droplets was a significant 611 W/m2 K. In addition the mathematical modifications analyzing flow in the slip regime, which takes into account rarefaction had much less deviation from experimentally observed value than those that neglected rarefaction.

Conclusions/Discussion

The adaptation of the Navier-Stokes equations to account for micro-scale rarefaction effects led to better agreement between experimental and theoretical predictions of heat transfer. In addition, some of the unexpected results such as the high heat transfer coefficient can be explained by the micro-scale phenomena. Leidenfrost systems offer a natural manifestation of #micro-channels# which may lead to their usage in novel, self-actuated, heat-dissipators requiring no sensors, moving parts or pumps.

Summary Statement

My project aims to investigate the mechanisms and applications of relatively unexplored propulsive Leidenfrost phenomena

Help Received

Mr. Garabedian and Dr.Vandernoorda provided equipment; Dr. Kriehn and Dr. Nunna allowed computer usage