Passive Pumping in Pool and Open Channel Configurations via Meso-Scale Asymmetric Surface Patterning

By Logan Strid
Candidate for Master of Science in Mechanical Engineering

Abstract

An innovative means to passively pump fluid during boiling using meso-scale asymmetric patterning of the surface is presented. Such a passive phase-change mechanism has great potential for thermal management in spacecraft and in zero-gravity environments.

Fluid pumping is demonstrated in two configurations—one in which the patterned surface is immersed in a pool of liquid, and a second in which two patterned surfaces form the vertical walls of an open channel. The surface pattern consists of 60-30 degree mm-scale ratchets. In the pool configuration, ratchets have a cavity on the 30 degree slope of the ratchets for preferential nucleation.

In the pool configuration, the asymmetric geometry causes bubbles to preferentially grow normal to the surface rather than in a vertical direction. A semi-empirical model predicting resultant liquid velocities is validated with particle tracking velocimetry. A single bubble was found to have an area of influence on the surrounding liquid equal to the average projected area of the bubbles during its growth cycle and was capable of imparting average fluid velocities of 75 mm/s at an angle 32.7° from vertical.

In the open channel configuration, high speed videos document the dramatic preferential motion of vapor slugs with velocities ranging from 12.8 mm/s to 94.6 mm/s under both diabatic and flash boiling conditions. Four regimes of channel flow are identified and bubble kinematics is presented. A thin liquid film is observed to exist in between the ratchet wall and the vapor slug. A model to determine slug velocities based on a balance of the net Young-Laplace pressure gradient in the thin liquid film and the viscous drag of the channel walls is put forth.

Wednesday, September 25, 2013
10:00 AM, Rogers 226

School of Mechanical, Industrial, and Manufacturing Engineering