Modeling oscillating heat pipes

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Abstract

I will present background on oscillating heat pipes (OHPs), published results on an ODE model, and give a progress report on a new PDE model. In short, an OHP is a serpentine closed tube (toroidal geometry) partially filled with a liquid. When part of the boundary is heated and part is cooled, it is possible that the liquid separates into a two-phase flow consisting of vapor plugs separating fluid slugs that is set into oscillatory motion and serves as a device to efficiently transfer heat from the hot to the cold zone with no moving mechanical parts except for the fluid motion within the tube. At one level of modeling (usually with ODEs) fluid slugs are tracked and artificial means are used (if at all) to model nucleation and merging of fluid cells. A more sophisticated approach, and the main focus of the talk, seeks to model the two-phase flow as a phenomenon that arises naturally from the underlying physics and eliminates the need to track slugs. This latter approach, called phase field modeling, is based on the ideas of Allen, Cahn, and Hilliard that lead to the Allen–Cahn and the Cahn–Hilliard equations, which form the basis of all such models. Roughly speaking, the dependent variable in these equations is a so-called order parameter, which is akin to a smoothed indicator function evolving in space and time, which gives the locations of the two phases of the flow. The underlying physics is thermodynamics; in particular, the minimization of Gibbs energy at equilibrium. An overview of this methodology, which has far reaching applications, will be discussed. Its application to OHPs is the motivation for a proposed PDE model whose predictive power has not yet been fully explored. Most of the content of the talk is joint work with Frank Feng, Steve Lombardo, and Dave Retzloff all colleagues in the College of Engineering.