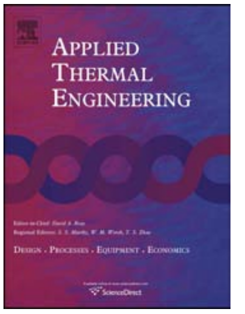

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Abstract

In the previous models of oscillating heat pipe (OHP), only the evaporation and condensation in the liquid-vapor interfaces were considered as phase changes. Thus, only a simple sinusoidal oscillating motion of liquid slugs and vapor plugs was produced due to the small driving force. From our visualization results, the motions of liquid slugs and vapor plugs are very random and very different from the previous models. We observe that the bubble generation and growth phenomena are one of the reasons of the random motion of liquid slugs and vapor plugs. This means that those bubble generation and growth phenomena provide the large driving force. The velocity of liquid-vapor interfaces are accelerated suddenly when the TS (tube-size) bubbles, bubbles with the diameter equals to inner diameter of tube, are generated. The visualization results show that the TS bubbles will generate if the velocity of liquid slug is lower equal 0.2 m/s. The small bubble generation, before TS bubbles are generated, is ignored because they do not provide the large driving force. The model of TS bubble generation and growth is made by considering those visualization results to describe those phenomena.

Keywords: Oscillating heat pipe, Pulsating heat pipe, Visualization, Bubble generation and growth

1. Introduction

Oscillating heat pipes (OHPs) are very promising heat transport devices because of their simple structure and high performance [1]. OHPs are made from a serpentine channel with sufficient small inner diameters to establish a liquid slugs-vapor plugs flow, as shown in Fig. 1. The liquid slugs and vapor plugs move circulatory and/or oscillatory with large amplitude (seems like random motions). Heat is transferred from the heating section to the cooling section both with phase changes and by motions of liquid slugs and vapor plugs. The high heat transfer rate occurs when OHPs are charged at the optimum filling ratios (about 50−60 vol%), which are higher than those of conventional heat pipes.

To study the behaviors of liquid slugs and vapor plugs and also the heat transfer characteristic in an OHP theoretically, many researchers did OHP simulations [2–12]. In the previous models of OHP, only the evaporation and condensation in the liquid-vapor interfaces are considered as phase changes, then the researchers could reproduce the simple sinusoidal oscillating motion of liquid slugs and vapor plugs. Tong et al. [2] performed a simulation of liquid slugs and vapor plugs motions in an OHP by giving a sudden pressure disturbance in one end of tube. They obtained an oscillating motion of the neighboring vapor plugs but it was gradually damped because the pressure difference between those vapor plugs went to zero. At the same time, Dobson and Harms [3] presented the simulations of closed and open OHPs. The results showed the simple sinusoidal oscillating motions of liquid-vapor interfaces and the heat transfer rates change oscillatory.

Shafii et al. [4] presented one-dimensional model for both looped and unlooped OHPs by ignoring the effects of liquid films and surface tension. They obtained the simple sinusoidal oscillating motions of liquid-vapor interfaces and heat was transferred mainly by sensible heat due to the motions of liquid slugs and vapor plugs. Later, Shafii et al. [5] and Zhang and Faghri [6,7] presented one-dimensional model for both looped and unlooped OHPs by considering the effects of liquid films and surface tension. In their model, the evaporation and condensation occurred only at the meniscus and liquid films. By considering those effects, they could reproduce the similar simple sinusoidal oscillating motions with the previous simulations. Holley and Faghri [8] presented an OHP simulation with capillary wick and varying channel diameter. They could obtain the simple sinusoidal oscillating motions followed by the circulating motions due to the liquid slugs break off and flow toward a neighboring tube. The recent OHP simulation studied the effects of parameters such as the initial conditions, gravity accelerations and OHP orientations [9]. However, the results were almost the same with the previous ones.