Title: Pore-scale approach to developing high-performance capillary evaporator in loop heat pipe

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Abstracts

Two-phase state in the porous media of loop heat pipe (LHP) evaporator, which is induced by nucleate boiling, is key to enhance the evaporator performance but complicated. To investigate the liquid-vapor phase behavior and the relationship with the evaporator heat-transfer coefficient, this work visualizes the liquid-vapor phase distribution at the contact surface between the evaporator casing and wick and simulates the two-phase thermal hydraulics in the evaporator by pore network model. The visualization study shows evolution of the liquid-vapor phase distribution with changing the heat load and the relationship between the length of the three-phase contact line (TPCL) within the casing, liquid and vapor phase and the heat-transfer coefficient. The simulation work shows effect of pore size distribution of the wick on the heat-transfer coefficient which will be presented in the paper.

A sapphire tube having the thermal conductivity comparable to metal was used for the cylindrical evaporator casing that has a wick inside. A transparent conductive film of indium tin oxide to the same length as the groove was formed on the surface of the evaporator, and the heat flux was applied by electric heating. This makes it possible to perform visualization experiments. Since the constructed LHP visualizes with practical thermal materials, the observed vapor-liquid interface behavior can be closer to the actual behavior. The images of the vapor-liquid phase interface at the contact surface between the wick and casing were taken with a single-lens reflex camera, and the captured images were distinguished between the vapor and liquid phase region by binarization.

Figure 1 shows the temperature history of the visualized LHP obtained in the experiment. At a heat load of 10 to 15 W, the evaporator temperature does not stabilize and continues to rise. Nucleate boiling was observed at a heat load of 15 W. It was observed that the wick surface instantaneously dried out due to nucleate boiling in the evaporator, and then the liquid permeated. After nucleate boiling, the evaporator temperature decreases and reaches a steady state.

Figure 2 shows the evaporator heat-transfer coefficient and the TPCL length of region of interest. Some binarized images are shown in Fig. 3. The heat-transfer coefficient reached the maximum at a heat load of 20 to 25 W. The TPCL length also shows the maximum at a heat load of 20 W, and then decreases. The scattered vapor phase region increases the TPCL length where high-efficient evaporation takes place, resulting in high heat-transfer coefficient.

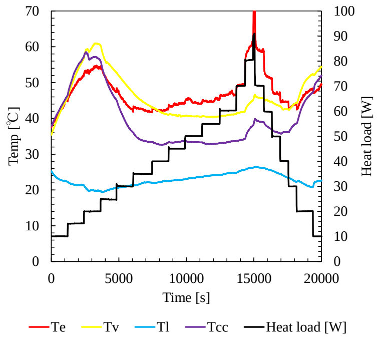

Figure 1. Temperature history of visualized LHP.

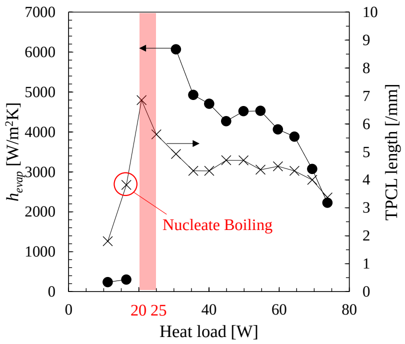

Figure 2. Evaporator heat-transfer coefficient and TPCL length.

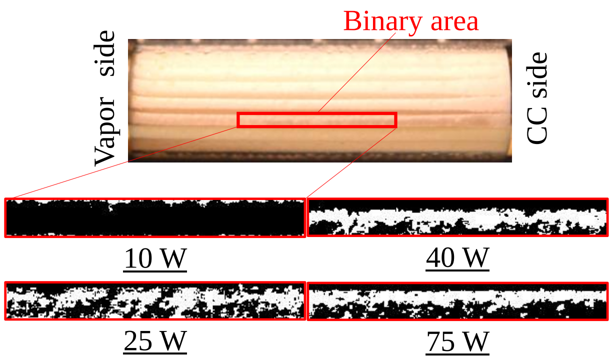

Figure 3. Binarized images at typical heat loads. White is vapor phase, black is liquid phase.

What is unique about the work:

Visualization experiments and pore network simulation to understand liquid-vapor two-phase behavior in the wick at pore scale

A status of the state of the work: Development

Session Descriptions: Active Thermal/Fluids/Life Support