Applied Thermal Engineering 42 (2012) 34–40

Contents lists available at SciVerse ScienceDirect

Applied Thermal Engineering

journal homepage: www.elsevier.com/locate/apthermeng

Experimental investigation of loop heat pipe with flat evaporator using biporous wick

B.B. Chen, W. Liu*, Z.C. Liu*, H. Li, J.G. Yang

School of Energy and Power Engineering, Huazhong University of Science and Technology, 415 Power Building, 1037 Luoyu Road, Hongshan District, Wuhan 430074, China

ARTICLE INFO

Article history:
Received 9 December 2011
Accepted 6 March 2012
Available online 13 March 2012

Keywords:
Loop heat pipe
Flat evaporator
Biporous wick
Evaporator temperature
Heat flux
Electronic cooling

ABSTRACT

In order to solve heat dissipation of electronic equipment, an experimental investigation was carried out on the thermal performance of a miniature stainless-steel-ammonia loop heat pipe (LHP) with a flat disk-shaped evaporator. A biporous wick made from nickel powder was used for developing the capillary force. Tests demonstrated that the device could start up at heat load as low as 2.5 W. Meantime, the maximum heat load the LHP could transfer reaches 130 W (heat flux 12.8 W/cm^2) at the allowable evaporator temperature of below 60 °C. The LHP showed a very fast response to variable heat load and operated stably without obvious temperature oscillation. The evaporator surface has very high isothermality while the monitored temperature difference between the maximum and minimum value on the evaporator surface does not exceed 3 °C for heat load below 130 W. The operation modes of variable conductance and constant conductance are found in the whole tested heat load range. The total thermal resistance varies between 1.42 and 0.33 °C/W at heat load ranging from 10 to 130 W.

1. Introduction

In recent decades, some two-phase devices have been developed for solving the thermal control of electronic devices with high heat flux and limited space. Loop heat pipe (LHP) is an efficient two-phase device which is based on the evaporation and condensation of working fluid to transfer heat. The working fluid is circulated by capillary force developed in the fine porous wick. LHP offers many advantages over traditional heat pipes, including high heat transfer capability, flexible transport lines and heat transfer over long distances.

Since LHP is first proposed in the early 1980's [1], many researchers have studied the operating principle of the LHP experimentally and theoretically [2–4]. The main components of LHP include evaporator, compensation chamber (CC), condenser, vapor and liquid lines. Among all the existing LHP designs, the evaporators are designed into cylinder or plate shapes. As most heat sources have flat thermo-contact surfaces, the cylindrical evaporator needs a saddle to locate at the evaporator surface. This configuration has disadvantages of increasing the thermal resistance and the mass of the body. The flat evaporator does not have these problems mentioned above. As the electronic devices are miniaturized, LHP with flat evaporator is more adapted to electronic cooling applications [5]. Meantime, due to the liquid evaporating uniformly on the flat surface, the LHP with flat evaporator has very high isothermality among the two-phase cooling systems.

Several different flat evaporator configurations in LHP have been investigated. Maidanik et al. [6] tested a LHP with a flat disc-shaped evaporator at horizontal and vertical orientations. The thermal resistance varied in the range from 1.05 to 0.42 °C/W at heat load from 40 to 80 W. Tu et al. [7] developed an overall two-dimensional numerical model to address the heat and mass transfer characteristics in the evaporator and investigated the start-up characteristics of a LHP with flat evaporator experimentally. A flat-oval evaporator with a finned radiator equipped on the CC was designed by Becker et al. [8] to reduce the LHP operating temperature. The minimum thermal resistance of the LHP was 0.2 °C/W for a heat load of 100 W. The thermal performance of the LHP is related to the working fluid, fluid inventory, elevation and heat sink temperature. Liu et al. [9] investigated the effects of different working fluids, methanol and acetone, on the operating characteristic of LHP with flat evaporator. Joung et al. [10,11] developed a LHP with a thin planar bifacial evaporator to examine its operating characteristics at different fluid inventories, elevations and heat sink temperatures. The maximum heat flux at allowable evaporator temperature is very important for the electronic cooling. A miniature copper-water LHP with flat disk-shaped evaporator designed by Singh et al. [12] was able to transfer the maximum heat load of 70 W with the evaporator temperature

* Corresponding authors. Tel.: +86 27 87542618; fax: +86 27 87540724.
E-mail addresses: w_liu@hust.edu.cn (W. Liu), zcliu@hust.edu.cn (Z.C. Liu).

1359-4311/$ – see front matter © 2012 Elsevier Ltd. All rights reserved.
doi:10.1016/j.applthermaleng.2012.03.006