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Experimental study on the loop heat pipe with a planar bifacial wick structure

Wukchul Joung [a], Taeu Yu [b], Jinho Lee [a,*]

[a] School of Mechanical Engineering, Yonsei University, 134 Shinchon-dong, Seodaemoon-gu, Seoul 120-749, Republic of Korea
[b] Industrial Facility Team, KITECH, 35-3, Hongchon-ri, Ibjang-myun, Chonan 330-825, Republic of Korea

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Abstract

Due to their high heat transfer efficiency, LHPs have been developing with cylindrical as well as flat evaporators for diverse applications. Nevertheless, they have limitations in applying to the closely packed heat sources such as fuel cells due to their unsuitable evaporator shape. In order to resolve this problem, a thin planar bifacial evaporator with a bifacial wick structure was devised. With the LHP developed, we examined the operating characteristics in a horizontal position for different fluid inventories. Steady state and transient state responses were studied in detail, and the relationship between fluid inventories and operational characteristics is discussed.

Keywords: Loop heat pipe; Flat evaporator; Planar bifacial wick; PEMFC thermal control; Fluid inventory

1. Introduction

Loop heat pipes (LHPs) are highly promising two-phase heat transfer devices utilizing latent heat of working fluid in transferring heat and are regarded as very efficient heat transfer devices with considerable potential for applications in various areas [1–5]. Although fundamental physical principles of the operation of LHPs are very similar to those of conventional heat pipes (HPs) and capillary pumped loops (CPLs), LHPs supplement them with new possibilities in such a way as to make it possible to manage high heat transfer capacity, create miniature or large, flexible and ramified, well-regulated and adapted designs of different shapes, and operate efficiently in any positions in a gravitational or micro-gravitational environment [6].

Since the early development of these devices, LHPs have found their applications in the thermal control of spacecraft equipment and have achieved satisfactory results [1–11]. Besides this, the development of miniature LHPs for the thermal control of highly integrated electronics is a recent trend in LHP researches [1,6,12–15]. For the applications in this area, the miniaturized LHPs with the evaporator diameter of no more than 6 mm were developed and tested. However, the development of such miniaturized LHPs has an intrinsic problem, specifically, an increased parasitic heat leak to the compensation chamber through the thin wick, which might yield the increase of the operating temperature and the minimum start-up heat load [13].

In another branch of LHP researches, there has been continuous efforts to create flat evaporator LHPs (FEL-HPs) to fit the flat thermo-contact surfaces without the use of any conventional intermediaries that cause additional thermal resistance (Fig. 1). In this way, some reported results showed that the flat evaporator LHPs, mainly of flat disc-shaped evaporator with a single evaporating surface, had operated satisfactorily and also showed possibility of a bifacial flat evaporator LHP [1,6,16–18]. However, the employment of the relatively large flat evaporator surface for such purpose may result in an intolerable internal pressure increase and higher parasitic heat leak to the compensation chamber. In particular, increased heat

* Corresponding author. Tel.: +82 2 2123 2816; fax: +82 2 312 2159.
E-mail address: jinholee@yonsei.ac.kr (J. Lee).

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Nomenclature

B	coefficient
k	thermal conductivity
P	pressure
Q	heat load
r	radius of curvature of a meniscus
T	temperature

Greek symbols

ε	porosity
σ	surface tension

Subscripts

cap	capillary
eff	effective
ext	external
heat sink	heat sink
heat source	heat source
l	liquid phase
max	maximum
s	solid phase
sat	saturation
t	thermal
tot	total

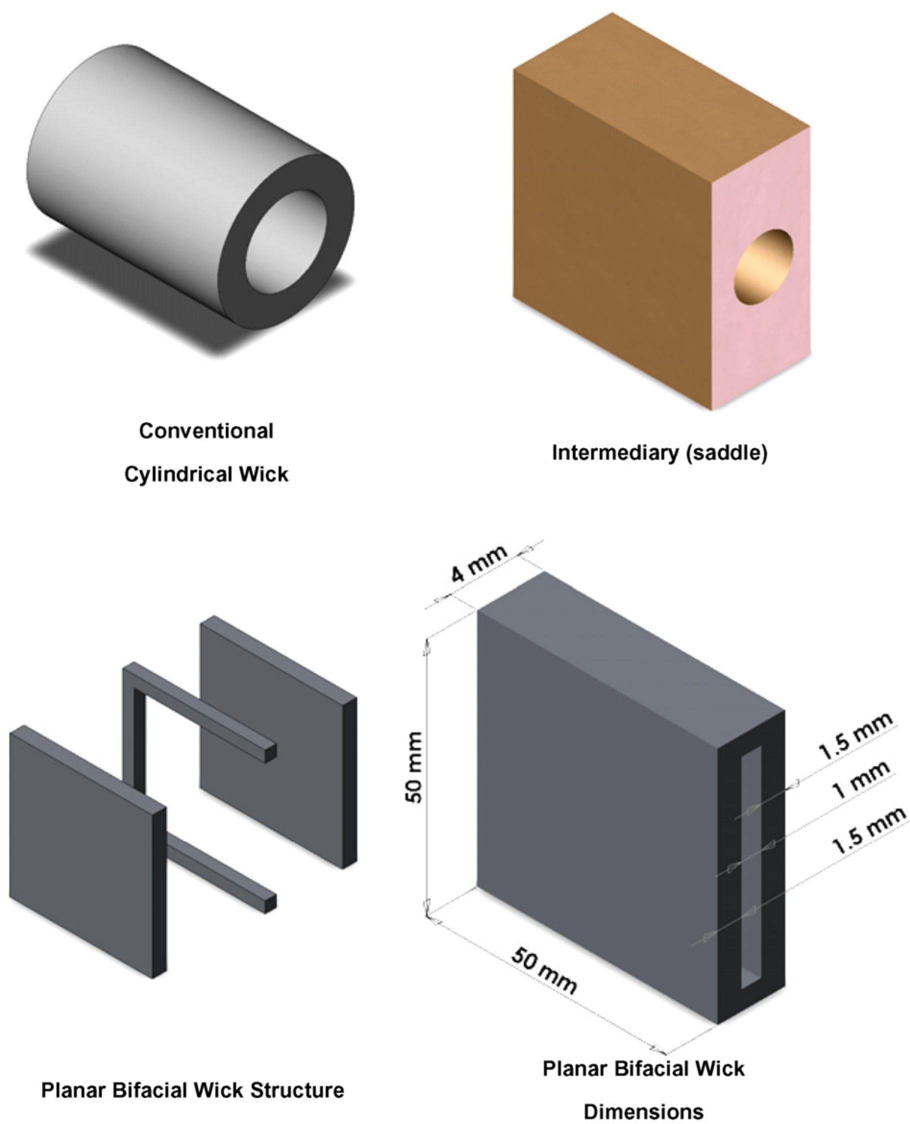

Fig. 1. Schematic of the conventional cylindrical wick structure, intermediary and the present planar bifacial wick (Stainless steel (316) porous plate of 2 μm mean pose size).