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Experimental Investigations on Performance Analysis of a Wickless Thermosiphon Heat Pipe With Two Heat Sources and Multiple Branches

In an electronic circuit of laptops, supercomputers with multiple central processing units, spacecraft etc., it is required to arrange the cooling system for multiple heat loads in the smallest possible space in view of power-saving opportunities. In the present study, the experimental investigations are carried out on a wickless multi-branch heat pipe in gravity-assisted mode with two evaporators and one condenser on each of the individual branches. The start-up and dynamic characteristics were studied with different filling ratios (range, 40–70%), with equal heat loads (range, 0–200 W) and unequal heat loads (range, 0–100 W) on evaporators. The results are analyzed in terms of temperature variation in axial direction, thermal resistance, and heat transfer coefficient for a multi-branch thermosiphon heat pipe (MBTHP). It was found that the optimal filling ratio depends on the applied heat load under tested conditions. In a thermosiphon mode, the heat pipe was capable of transporting a maximum heat load of 210 W and maximum heat flux of 20.31 W/cm^2 with the maximum evaporator temperature lower than 100 °C. The minimum wickless thermal resistance of heat pipe was found to be 0.21 °C/W at 50% filling ratio and 160 W and maximum total heat transfer coefficient was found as 6.33 k W/m^2 °C. [DOI: 10.1115/1.4054163]

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1 Introduction

In the past few years, miniaturization in electronics and space thermal control systems caused a significant reduction in the size of electronics devices and circuits, which subsequently increases the thermal duty on cooling devices [1]. Heat pipes have been proven to be effective, efficient, and simple thermal cooling devices for electronics and spacecraft cooling applications [2]. A heat pipe is a device in which heat transfer occurs between a heat source and a heat sink by the phase change process. In recent years, the technology associated with heat pipes has shown significant and rapid advancements as far as size, shape, types, and heat transport capability are concerned [3–6]. Conventional heat pipes work on single source and single sink methodology. One source is in contact with an evaporator of the heat pipe, which absorbs heat, and this heat is carried away to the condenser using the working substance and rejected to the heat sink.

In the single source-single sink method, it is a common practice to consider heat flux as uniformly distributed throughout the length [7]. However, in many practical situations, it is required to remove heat from multiple heat sources like in a single cluster with multiple central processing units (CPUs) or multiple electronics chips on a single circuit board. Wang et al. [8] investigated the potential of multiple heat pipes in CPU cooling and found 66.2% fan power-saving with multiple heat pipes in comparison to the conventional heat sink. Although, whenever available, space constrains may not allow the user to accommodate a multiple number of heat pipes as in the case of electronics and spacecraft applications for individual sources, it becomes necessary to rethink and redesign the thermal management system. The continuous evolution of miniaturization pushes heat pipe technology toward more and more challenging heat transport duties. A few investigators have started working on the multiple heat source thermal management problems in the last few years.

Tang et al. [9] investigated a cylindrical heat pipe with multiple heat sources and double end cooling for the application of the spacecraft. The investigation was carried out on the performance of grooved heat pipe by placing two heat sinks at both ends of heat pipe and multi-heat sources in the middle by considering the effects of different water flowrates (1.5–3.5 l/min), heat inputs (5–60 W), and power distributions. It was concluded that under variable heat load, the temperature of each section becomes steady without much variation in temperatures and it becomes operational in a short period with higher heat transport capability compared to the conventional heat pipe. Desai et al. [10] investigated the effect of geometrical parameters on the performance of ammonia-based grooved heat pipes for space application.

Boo et al. [11] investigated a copper heat pipe with wire screen mesh as a wick structure with distilled water as a working substance with 100% and 120% fluid charge ratios based on wick void volume. The heat pipe was kept at 45-deg inclination with gravity-assisted mode. Multiple and varying heat loads were applied using five heat sources placed along the length of the heat pipe. The heat pipe performance was optimized for the parameters like fluid ratio, uniform heat load, and thermal resistance.

Han et al. [12] developed a novel flat plate heat pipe with multiple sources capable to transport high heat flux with a minimum thermal resistance of 0.103 °C/W for three heat loads and 4.5 m/s cooling air velocity and 90-deg inclination. The heat pipe was capable of transporting a maximum of 400 W heat with 65 °C maximum temperature. However, due to a number of condensing zones and a large number of fins, the size of the heat pipe sink was significantly

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