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An investigation into the effective thermal conductivity of vapour chamber heat spreaders

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Abstract

Vapour chambers are a promising solution to thermal spreading issues associated with high heat flux devices. This paper presents a numerical investigation into vapour chamber heat spreaders using the concept of effective thermal conductivity. A 2D axisymmetric model was built and thermal performance was analysed through variation in effective thermal conductivity. The vapour chamber had more even temperature distributions and lower spreading resistances than an equivalent copper spreader. At a larger radius the superiority over copper was less distinct as only a 7% reduction in spreading resistance was observed compared to 20% reduction at a smaller radius. The effective thermal conductivity was identified as the limiting factor for this case and thus further advances are required to improve the spreading performance of vapour chambers.

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Keywords: vapour chamber; heat spreader; high heat flux; effective thermal conductivity

1. Introduction

Two phase heat transfer devices have been used in the past to cope with demand for more effective heat transfer from high flux heat sources. Such devices include heat pipes and more recently vapour chambers (also referred to as a flat plate heat pipe). The vapour chamber acts as a transformer which spreads heat to a larger sink area. It does this

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more efficiently than an equivalent copper spreader thus has been the focus of much research recently.

Nomenclature

h	heat transfer coefficient, W/m^2.K
H	thickness of spreader, cm
k	thermal conductivity, W/m.K
k_{eff}	effective thermal conductivity, W/m.K
q''	heat flux, W/cm^2
Q	heat, W
r	radial direction
R	outer radius of spreader, cm
R_{sp}	spreading thermal resistance, °C/W
T	temperature, °C
z	height direction

The operating principle of phase change heat transfer devices is shown schematically for a vapour chamber in Fig. 1. Heat is absorbed in the evaporator which causes the working fluid to vaporise and travel to the condenser where it condenses into a liquid, releasing the absorbed heat. The working fluid is commonly returned to the evaporator via a wick structure. The main difference between a heat pipe and vapour chamber is that for a heat pipe, heat is transferred axially from the evaporator, whereas for a vapour chamber, heat is transferred mostly radially from the evaporator as seen in Fig. 1. This is owing to the design of the vapour chamber, which is often two parallel plates with a heat source located centrally on one plate. Hence they are often used for heat spreading.

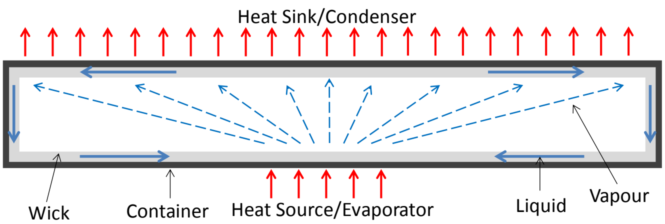

Fig. 1. Working principle of vapour chamber. A high heat flux input can be spread to a lower heat flux output with vapour chambers.

Vapour chambers have recently been subject to much research, with particular focus on experimental work [1-3]. They have also been investigated numerically through computational fluid dynamics (CFD) models [4-6]. Such CFD models have taken into account fluid modelling of the internal processes of the vapour chamber. An alternative approach is one where an effective thermal conductivity of the vapour chamber is used.

Chen et al. explored this is their work [7]. The effective thermal conductivity was based on previous experimental work and analytical relations developed therein [8, 9]. They suggested the effective thermal conductivity of a vapour chamber was at least 435.6 W/m.K when an isotropic approach was considered and this was strongly dependent on heat source size. An effective thermal conductivity of 557.9 W/m.K was reported when a larger heat source was used. The authors claimed an orthotropic method was better which resulted in effective radial thermal conductivity at least 23.5 times greater than effective axial thermal conductivity.

Wang & Wang [10] proposed an empirical formula to determine the effective thermal conductivity. Buckingham Π theorem was used to correlate variables and experimental data to determine constants. The authors suggested that the effective axial thermal conductivity was much smaller than in the radial direction. An isotropic value as high as 910 W/m.K was reported. This was again dependent on the size of the vapour chamber.

Other work has aimed at determining the effective thermal conductivity of the vapour space inside the vapour