

# Computational Analysis of Fluid Flow and Heat Transfer in Wire-Sandwiched Microheat Pipes

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The microheat pipe is a promising option in the thermal management of high-heat flux electronic components and packages. A computational analysis of wire-sandwiched (wire-bonded) microheat pipes, a relatively new design in microheat pipes, is presented in this paper. A transient one-dimensional model has been used in the analysis, which incorporates the longitudinal variation in the flow cross-sectional areas within the heat-pipe channel, frictional effects, and phase change during the process. The governing equations have been solved using a fully implicit finite difference scheme to obtain the velocity, pressure, and temperature distributions. These results are used to calculate and characterize the effective thermal conductivity of the heat pipe. The predicted results for the wire-sandwiched design are compared with those for the triangular cross section microheat pipe channel and discussed extensively.

## Nomenclature

$A$	=	area of cross section, $m^2$
$C$	=	specific heat, $J/kg\ K$
$D_H$	=	hydraulic diameter of the channel, $m$
$E$	=	total energy per unit volume, $J/m^3$
$f$	=	friction factor
$h_{lv}$	=	latent heat of vaporization, $J/kg$
$h_o$	=	heat transfer coefficient, $W/m^2\ K$
$k$	=	thermal conductivity, $W/m\ K$
$L$	=	length of the heat pipe, $m$
$P$	=	perimeter, $m$
$P_w$	=	pitch of the wires (center-to-center distance of the wire), $m$
$p$	=	pressure, $Pa$
$Q$	=	heat, $W$
$q$	=	heat flow rate, $W/m^2$
$R$	=	universal gas constant, $J/kg\ K$
$Re$	=	Reynolds number
$R_{min}$	=	minimum meniscus radius, $m$
$R_w$	=	radius of the wire, $m$
$r$	=	radius of the meniscus, $m$
$T$	=	temperature, $K$
$t$	=	time, $s$
$u$	=	axial velocity, $m/s$
$v$	=	velocity, $m/s$
$x$	=	axial coordinate
$\alpha$	=	contact angle, $deg$
$\Delta T$	=	temperature difference, $T - T_{amb}$ , $K$
$\mu$	=	dynamic viscosity, $kg/m\ s$
$\rho$	=	density, $kg/m^3$
$\sigma$	=	surface tension, $N/m$

## Subscripts

$a$	=	adiabatic section
$amb$	=	ambient
$c$	=	condenser section

$e$	=	evaporator section
$eff$	=	effective
$h$	=	hydraulic
$i$	=	interface
$l$	=	liquid
$li$	=	liquid interface
$lw$	=	liquid wall
$sat$	=	saturation
$v$	=	vapor
$vi$	=	vapor interface
$vw$	=	vapor wall

## Introduction

THE heat pipe is a passive heat transport device of highly effective thermal conductance that depends on the phase change of a working fluid and capillary action in a wick structure for its operation [1]. The construction and operation of the microheat pipe is more or less similar to the conventional heat pipe, except that it does not require a wick, but uses the sharp corners of its passage for the capillary circulation of the working fluid [2,3]. The concept of using microheat pipes for heat dissipation from semiconductor devices was first introduced by Cotter [2]. In general, passages with polygonal cross sections, which can provide sufficient capillary pressure difference for the flow of the liquid phase adjacent to their corners, can function as microheat pipes. The cross sections studied extensively in the literature are trapezoidal, rectangular, and triangular. On top of the applications in electronics cooling, microheat pipes also find a large number of other applications in various fields. They can be used for heat dissipation from laser diodes and other small localized heat generating devices and from photovoltaic cells. They are suitable for heat dissipation in association with microfabrication processes. Microheat pipes can be effective options for localized cooling of aircraft structures. In the biomedical field, they are recommended for heat removal and heat spreading associated with the treatment of carcinoma and control of epileptic seizures. Microheat pipes of various designs also have a significant role in space radiator recovery systems [3]. The wire-sandwiched (wire-bonded) microheat pipe is a relatively new design in microheat pipes [4], which uses a simple method to produce the flow passages, as will be described later.

The first steady-state model of the microheat pipe was developed by Cotter [2]. Based on this, Babin et al. [5] developed a steady-state model for trapezoidal microheat pipes to predict the maximum heat transport capacity, with conventional techniques outlined by Chi [6]. Khrustalev and Faghri [7] presented a detailed mathematical model

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