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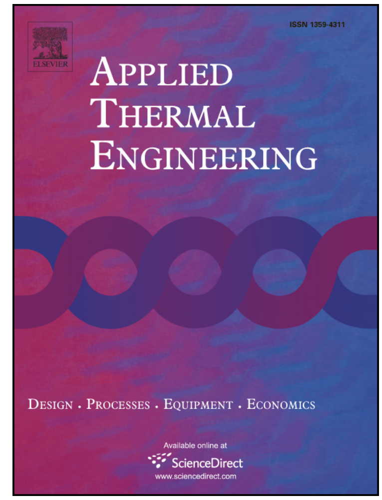

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Optimized distribution of a large number of power electronics components cooled by conjugate turbulent natural convection

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Abstract

Natural convection allows for passive cooling which is used in many engineering applications. Placing dissipating components on a common vertical heatsink can be optimized to give the best possible cooling capacity. In this study, a numerical model for three-dimensional conjugated convective and conductive heat transfer was used to evaluate the distribution of up to 36 flush-mounted rectangular heaters. The temperature profiles and the heat fluxes were compared with experimental data for validation. The dissipated power was set as an input parameter and the optimal distribution was selected as the one with the lowest temperature elevation. Two different heuristics—a geometric parameter and an artificial neural network—were proposed and evaluated as alternatives to heavy CFD calculations.

Keywords: Optimization, discrete heating, conjugate natural convection, artificial neural network, Computational Fluid Dynamic

Nomenclature

α	Thermal diffusivity	m^2/s
β	Volumetric thermal expansion coefficient	$1/K$
ρ	Density	kg/m^3
λ_{fluid}	Fluid thermal conductivity	W/mK
λ_{plate}	Plate thermal conductivity	W/mK
λ_1, λ_2	Geometric parameter	-
λ_3	Geometric parameter	m^{1-b}
ν	Kinematic viscosity	m^2/s
μ	Viscosity	kg/ms
μ_T	Turbulent viscosity	kg/ms
ϕ_{ij}	Angle between sources number	rad
θ	Dimensionless temperature $\Delta T/(T_{max} - T_\infty)$	-
C_p	Heat capacity	J/kgK
d_{ij}	Distance between sources	m
e	Plate thickness	m
$\mathbf{F}$	Sum of external forces	N/m^3
g	Gravitational constant	m/s^2
h	Convective heat transfer coefficient	W/m^2K
$\mathbf{I}$	Identity matrix	-
k	Turbulence kinetic energy	m^2/s^2
L	Heat source width	m
p	Pressure	N/m^2
q"	Heat flux density	W/m^2
Q	Volume heat source	W/m^3
H	Heat source height	m
N	Number of heat sources	-
Nu	Nusselt number $\partial\theta/\partial Y^*$	-
Pr	Prandtl number	-
Ra	Rayleigh number	-
T	Temperature	K
$\mathbf{u}$	Velocity	m/s
Y^*	Dimensionless distance to the wall	-
z	Vertical coordinate	m
Z^*	Dimensionless vertical coordinate $(= z/H)$	-
ΔZ	Vertical spacing	m
ΔT	Temperature elevation $T - T_\infty$	K
ANN	Artificial Neural Network	
BL	Boundary Layer	
CFD	Computational Fluid Dynamic	

1. Introduction

Natural convection occurs spontaneously every time a temperature gradient appears in a fluid. As such, it is a very reliable cooling technique. In addition to reliability, passive convective cooling is also quiet and cheap. A better understanding of this phenomena is crucial in many engineering applications and it has been extensively studied [1].

Passive cooling, which is enabled by free convection, is well suited for electronic packages. But this technique offers limited cooling capacity in air and has primarily been limited to low power applications [2]. However, because of its high level of reliability natural convection cooling is also interesting in power generation, some example of which are solar photovoltaic panels [3] and power electronics for marine energy for which liquid cooling is easily available

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