OPTIMAL HEAT SINK BASED ON HEAT TRANSFER MODEL AND PARTICLE SWARM OPTIMIZATION METHOD

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ABSTRACT

The advancement of electronic technology has led to increase in heat dissipation especially in Central Processing Unit (CPU). This problem occurs when CPUsare scaled down to reduce size, to raise power density and performance of device. High heat dissipation can increase device temperature that will reduceproducts lifespan. Currently, conventional air cooling technologies such as fan and heat sink have been used to minimize device temperature. However, heat sink is a preferable choice where it is easy to handle and cost effective. Thus, to reduce the temperature of CPU electronic package, the process of heat transfer is also needed to be enhanced and in this case it must consider a high performance heat sink component. Therefore, in this study thermal resistance network is used to develop a model of radial plate fin heat sink. Heat sink dimension has been optimized using Particle Swarm Optimization (PSO) technique. The main objective is to maximize heat dissipation rate and to minimize the size of heat sink. Simulations for single and multi objectives PSO are explored for searching the optimal dimensions of radial plate fin heat sink design. The optimal design could maximize heat dissipation and minimize the size of heat sink. The results show that heat dissipation can be increased by 16% while the size of heat sink has been reduced by 31.2%.

ABSTRAK

Kemajuan dalam bidang teknologi elektronik telah menyebabkan kenaikan pelesapan haba terutamanya di Unit Pemprosesan Pusat (CPU). Masalah ini berlaku apabila komponen CPU ini dikecilkan untuk mengurangkan saiz dan meningkatkan ketumpatan kuasa dan prestasi peranti. Pelesapan haba yang tinggi ini boleh meningkatkan suhu peranti, di mana ia akan mengurangkan jangka hayat produk. Pada masa kini, teknologi penyejukan udara konvensional seperti kipas dan penyerap haba telah diguna untuk mengurangkan suhu. Walaubagaimanapun, penyerap haba menjadi pilihan yang lebih baik di mana ia adalah mudah untuk dikendalikan dan berkesan kos. Oleh itu, untuk mengurangkan suhu pakej elektronik, proses pemindahan haba juga perlu ditingkatkan, di mana di dalam kes ini perlu mengambil kira prestasi tinggi komponen penyerap haba. Oleh itu, dalam kajian ini rangkaian rintangan haba telah diguna untuk membangunkan satu model plat jejarian penyerap haba sirip. Dimensi penyerap haba telah dioptimumkan menggunakan teknik Pengoptimuman Kerumunan Zarah (PSO). Objektif utama adalah untuk memaksimumkan kadar pelesapan haba dan mengurangkan saiz penyerap haba. Simulasi-simulasi untuk objektif tunggal dan objektif berbilang menggunakan PSO diterokai untuk mencari dimensi optimum plat reka bentuk jejari penyerap haba sirip. Reka bentuk yang optimum boleh memaksimumkan pelesapan haba dan mengurangkan saiz penyerap haba. Keputusan menunjukkan bahawa pelesapan haba boleh meningkat sebanyak 16% manakala pengurangan saiz penyerap haba dapat dikurangkan sebanyak 31.2%.

TABLE OF CONTENTS

LISTS OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AI	-	Artificial Intelligent
CPU	-	Central Processing Unit
GA	-	Genetic Algorithm
IC	-	Integrated circuit
IT	-	Information Technology
LED	-	Light emitting diode
P	-	Pareto Solution Set
PIs	-	Performance Indices
PC	-	Personal Computer
PCB	-	Printed Circuit Board
PSO	-	Particle Swarm Optimization
S	-	Solution Set
SP	-	Spacing
SPAD	-	Seven Point Average Difference
TIM	-	Thermal Interface Material

LIST OF SYMBOLS

%	-	Percentage
Cu	-	Copper
Al	-	Aluminum
Sn	-	Tin
Zn	-	Zinc
°C	-	Degrees Celsius
J	-	Joule
kg	-	Kilogram
q	-	Heat transfer rate, W(Watt)
h	-	Convection heat transfer coefficient
K	-	Thermal conductivity, *(W/m·K)*
x_1	-	length of area 1, m
x_2	-	length of area 2, m
t	-	thickness of fin, m
Q	-	Heat dissipation
ΔT	-	Temperature difference between heat source and ambient
$\theta_{sa} = R_{\text{sink}}$	-	Total thermal resistance
q_{cod}	-	Heat dissipation for conduction
q_{cov}	-	Heat dissipation for convection
A_{cod}	-	Area for conduction material
A_{cov}	-	Area for convection material
dT	-	temperature difference

ΔX	-	distance of conduction material
T_{ave}	-	temperature average
T_{amb}	-	temperature ambient
L_p	-	length of plate fin heat sink
t_b	-	thickness of plate fin heat sink base
w	-	width of plate fin heat sink
b	-	difference between 2 fins
L	-	Height of heat sink
r	-	radius of cylindrical shape
R_{cd}	-	conduction of resistance
π	-	3.242
L_1	-	height of cylindrical shape
$\|\|$	-	Parallel
n	-	numbers of fin
R_{fin}	-	thermal resistance for fins
R_o	-	thermal resistance for open space in cylindrical shape
R_{cd}	-	thermal resistance for conduction in cylindrical shape
$R_{fin\,1}$	-	thermal resistance for fin of area 1
$R_{fin\,2}$	-	thermal resistance for fin of area 2
w	-	inertia (weight)
c_1 and c_2	-	acceleration parameters (constant acceleration)
r_1 and r_2	-	random value (0-1)
X	-	position value
V	-	velocity value
p_{best}	-	local best position
g_{best}	-	global best position
V_i	-	velocity of i-th particle

pbest_i	-	particle best position for i-th particle
i	-	numbe of iteration
X_i	-	position of i-th particle
V_i	-	velocity of i-th particle
S	-	number of pareto optimal solution
$\bar{d}$	-	average of d_i
M	-	number of objective
f	-	fitness function value
R	-	reference set

LIST OF APPENDIX

CHAPTER 1

INTRODUCTION

1.1 Background

Heat generated by the electronics component on Central Processing Unit (CPU) is increasing day by day due to high performance. With reduction of size and increment of power density have led to improve the performance of CPU.

The high power density of CPU has led to higher heat dissipation, which increases the temperature of the component and reduces the lifespan of the device. Thus, many works have been done to find the solution in managing thermal problem for electronic devices.

Mohan and Rovindarajan (2010) described that the failure rate of electronic components grows as an exponential function with their rising temperature as today's rapid Information Technologies (IT) development like internet Personal Computer (PC) capable of processing more data at a tremendous speed. It shows that the electronic components failures are mostly influenced by temperature compare to other causes.

Generally there are two known approaches introduced to reduce the heat generated by CPU, these are heat sink usage and optimization of Printed Circuit Board (PCB). Firstly, by introducing cooling technique application into electronic packages. There are many cooling techniques adopted and applied such as heat pipes, cold water, semiconductor and even liquid nitrogen that have been used.

But due to cost consumption and constraint, a conventional air cooling technology with a fan and heat sink combination is widely used to cool a desktop computer. Heat sink applications form is the most common and cost effective way.

The second approach is the placement of electronic components on Printed Circuit Board (PCB). In practice, the position of electronic component placement on PCB has an influence on its junction temperature and overall PCB thermal distribution in practice. This means if the components are wellpositioned on PCB, the thermal distribution can be well minimized and distributed (Ismail and Yusuf, 2012). If the placement of the component arrangement is not properly arranged, it may produce a hot spot, which can shorten the lifetime and even cause damage to the system device (Masana, 2001).

Various types of design have evolved to meet the rising of heat dissipation demands. Patel and Modi (2012) presented the thermal management of high heat flux in microelectric devices using microchannel as one of the heat removal. Microchannel can directly integrate into heat generating substrates which makes them particular attractive. Among these, heat transfer by cooling to single phase and boiling liquids flowing in microchannels is one of the promising directions (Hetsroni and Masyak, 2002). However one weakness of a microchannel heat sink is that the high temperature rises relatively along the microchannels compared to the traditional heat sink design.

Khan and Culham (2005) studied the thermodynamic losses caused by heat transfer and pressure drop in cylindrical pin fin heat sinks. It was used for application that exhibited severe space and acoustic restrictions for application that poses amount of heat. However the study did not specifically apply for CPU package board. Thus, because of the current trend involving increasing heat dissipation along with shrinking of package size, optimization and multidisciplinary design is the key in launching a competitive new product (Suwa and Hadim, 2007).

1.2 Problem Statement

This study will focus on processor component of Central Processing Unit (CPU) that has very high capability in processing more data at higher speed. With the demand of high speed processing system, the temperatures of the package has increased compared to normal condition. Thus to reduce the temperature of this electronic package, the process of heat transfer is also needed to be increased, which in this case must consider the possible high performance heat sink component (Mohan and Govindarajan, 2010).

Many researchers have generally focused on the parametric optimization design by experimental or numerical analysis for a given application environment for heat sink design (Rodgers and Eveloy, 2004). However, until now there is no well established design that can guarantee optimal power dissipation within certain manufacturing constraint.

The main reason is that most study only apply optimization approach using none manufacturing heat sink design such as basic plate fin, basic pin fin and to name a few. Kasza and Malinowski (2013) proposed an optimization of staggered pin fin heat sink made of a thermally conductive polymer using neural network approach without considering realistic manufacturing constraint. Baodong and Lifeng (2010) proposed of multi objective optimization design of micro-channel heat sink using adaptive genetic algorithm which focus only on basic plate heat sink design.

This research will improve the current dimension of heat sink placed into Intel PCB board. Basic plate heat sink will be used as a reference to obtain mathematical model for the selected heat sink. Radial plate fin heat sink was selected as it is used in current Intel manufacturing board. Therefore, this study will introduce an optimization method using radial plate fins heat sink model and Particle Swarm Optimization (PSO) as an Artificial Intelligence (AI) technique. The main objective is to reduce the total power dissipation of electronics component and finally can maximize the system performance.

1.3 Objective of the Study

i. To develop heat transfer model using thermal resistance network for radial plate fins heat sink.
ii. To optimize the dimension of radial plate fin heat sink dimension in order to reduce the size with high heat dissipation using Particle Swarm Optimization.
iii. Evaluate the proposed method of designing and optimization by doing analysis and comparison study.

1.4 Scope of the Study

i. Develop thermal resistance network model for heat transfer process
ii. Study the current development and trend of heat sink design, which focus on thermal performance with multiple output problems.
iii. Study on radial plate fin heat sink type for CPU electronic component.
iv. Develop an optimization method using AI approach, specifically using Particle Swarm Optimization for heat sink design within a parameter of manufacturing constraint.

1.5 Hypothesis of the Study

This research was conducted with several proposed hypothesis that will be proved by doing analysis and conclusion at the end of the study.

i. Heat transfer model using thermal resistance network can be used to describe the behaviour of radial plate fins heat sink.
ii. High performance heat sink with high heat transfer rate can be produced if the optimal dimension and design are proposed.
iii. Optimal heat sink with optimal dimension could increase the heat dissipation.

1.6 Thesis Outline

The thesis is presented into five chapters. Chapter 1 introduces the background for this research, describing recent thermal problem in CPU, the problem statement, objectives of study, scopes of study and hypothesis of study.

Chapter 2 discusses the literature review of related work to this research. The review includes thermal background, CPU management, the performance of heat sink, material selection, heat transfer model, optimization approach with AI method.

Chapter 3 illustrates the methodology approach which contain the used of radial plate fins heat sink design, mathematical model using thermal resistance network and single and multi optimization approach procedures.

Chapter 4 discusses the finding of the research which includes heat sink behaviour study, single and multi-optimization approach and analysis and comparative result between current dimension and proposal dimension described in detail.

Lastly, Chapter 5 concludes the study and suggestions for the future directions of the project.

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