UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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DESIGN AND ANALYSIS OF FINS UNDER UNCERTAINTY HEAT CAPACITY

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering (Manufacturing Design) (Hons.)

by

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APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering (Manufacturing Design) (Hons.). The member of the supervisory committee is as follow:

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ABSTRAK

Project ini terutamanya memberi pertumpuan atas reka bentuk sirip dan analisis untuk sirip di bawah kapasitas haba yang tidak menentu. Tiga sink haba yang bersirip dengan mempunyai geometri yang berbeza tetapi mempunyai volume yang sama telah dipilih. Beberapa parameter yang berkaitan dengan reka bentuk sirip telah dikenal pasti dan dipertimbangkan dengan dimensi geometri meraka. Kekangan system seperti suhu operasi yang tertinggi pada unit pusat pemprosesan dan suhu udara yang menyelilingi sinki haba juga telah dikenalkan sebelum simulasi dijalankan. Aloi Aluminium 6063 yang mempunyai keberaliran haba yang dikira cukup tinggi telah digunakan sebagai bahan untuk sinki haba yang bersirip. Lakaran bagi model-model sirip telah dibuat untuk menjadikan reka bentuk tertentu sebagai konsep pada peringkat awal project ini. SolidWorks 2010 yang merupakan salah sebuah perisian CAD yang digunakan untuk menghasilkan model-model 3D bagi reka bentuk sirip. Analisis unsur terhingga telah dijalankan dengan menggunakan perisian ANSYS. Pada peringkat awalnya, tiga model sirip 3D, contohnya sink haba yang bersirip plat, jalur dan splayed dianalisis di bawah keadaan yang mantap bertujuan untuk mengaji taburan suhu dan jumlah fluks haba. Manakala, analisis struktur static dilakukan juga untuk mendapatkan factor keselamatan bagi ketiga-tiga sink haba bersirip. Model pemarkahan wajaran dihasilkan dengan merujuk kepada criteria yang berkaitan. Kemudian, haba tenggelam bersirip splayed telah dipilih sebagai reka bentuk sirip yang terbaik dan reka bentuk sirip yang lebih baik dicadangkan berdasarkan penemuan daripada analisis keadaan mantap. Analisis fana haba sink bersirip telah terpilih dan haba tengelam bersirip dengan tebukan telah dijalankan masing-masing. Hasilnya, haba tenggelam bersirip berlubang telah dipilih sebagai reka bentuk yang paling unggul dalam erti prestasi terma.

ABSTRACT

This project primarily focuses on the design and analysis of fins under uncertainty heat capacity. Three finned heat sinks with different geometry are selected at a fixed volume. The design parameters of fins are identified and considered with geometrical dimensions through reviewed literature. System constraints such as maximum operating temperature of central processing unit and air temperature surrounding the heat sink are also defined before simulation. Aluminium alloy 6063 which has considerably high thermal conductivity is used as the material of finned heat sink. CAD software which is SolidWorks 2010 is used to conduct 3D modeling of the fin designs. Finite element analysis is performed by using ANSYS software. At first, the 3D fin models which including heat sinks with plate fins, strip fins, and splayed are analyzed under steady state condition in order to investigate their temperature distribution and total heat flux. However, static structural analysis is performed also to obtain the factor of safety for each fin design. Weighted scoring model is generated by referring to the relevant criteria. In addition, the splayed finned heat sink is chosen as the best fin design and an improved design is proposed based on the findings from the steady state analysis. Transient thermal analysis of the selected finned heat sink and proposed finned heat sink with perforations is conducted respectively. As a result, the perforated finned heat sink is selected as the most superior design in sense of thermal performance.

DEDICATION

To my beloved parents, siblings and friends due to their love and support.

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I would like to express my deep gratitude to Dr. Taufik, my supervisor for his patient guidance, useful advice, and assistance along the progress of this project. I am grateful for his professionalism and his tolerance to guide me.

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2D	Two dimensional
3D	Three dimensional
A	Fin surface area
A_b	Cross-sectional area of fin at the base
A_c	Cross-sectional area of fin
A_{fin}	Total surface area of all the fins on that surface
$A_{no\ fin}$	Area of surface when there are no fins
A_{unfin}	Area of the unfinned surface portion
A_s	Heat transfer surface area
AA	Aluminium Association
Al	Aluminium
ANSYS	Analysis System
β	Coefficient of volume expansion
CAD	Computer-Aided Design
CFD	computational fluid dynamics
CPU	central processing unit
et al	Et alia
etc	Et cetera
D	Diameter of cylindrical pin fin
FEA	Finite Element Analysis
FYP	Final Year Project
g	Gravitational acceleration
G	Interrupted length
Gr_L	Groshof number
h	Convection heat transfer coefficient
h	Base thickness
H	Fin height
IGES	Initial Graphics Exchange Specification

k	Thermal conductivity
K	Kelvin
L	Base length
L_c	Corrected length
$L_{c.l}$	Characteristic length of the geometry
m	Parameter in theoretical fin efficiency
m	meter
mm	millimeter
n	Number of fins
Nu	Nusselt number
$\dot{q}$	Heat flux
$\dot{Q}$	Heat flux rate
$\dot{Q}_{conv}$	Rate of heat transfer by convection
$\dot{Q}_{fin}$	Actual heat transfer rate from the fin
$\dot{Q}_{fin,max}$	Ideal heat transfer rate from the fin if the entire fin were at base temperature
$\dot{Q}_{no\ fin}$	Rate of heat transfer if no fin is attached to the surface
$\dot{Q}_{rad}$	Rate of heat transfer by radiation
$\dot{Q}_{total,fin}$	Total rate of heat transfer from a finned surface
$\dot{Q}_{total,no\ fin}$	Total rate of heat transfer from unfinned surface
Ra_L	Rayleigh number
Pr	Prandtl number
s	Fin spacing
t	Fin thickness
T_b	Base temperature
T_f	Film temperature
T_s	Surface Temperature
T_∞	Ambient temperature
ΔT	temperature difference across the medium
v	Kinematic viscosity of the fluid
w	Fin length
W	Sink width

W	Watt
θ	Splayed angle
η_{fin}	Fin efficiency
$\eta_{adiabatic\ fin}$	Fin efficiency in adiabatic temperature
ε	Emissivity of the surface
ε_{fin}	Fin effectiveness
σ	Stefan-Boltzmann constant
°C	Degree Celsius

CHAPTER 1

INTRODUCTION

This chapter introduces the general idea of this project and provides the problem statement, objectives, and project scope. This chapter also provides a report organization to briefly introduce about the purpose of all the generated chapters.

1.1 Background

Nowadays, the new wave of computer technology makes a crucial impact on modern world. Desktop computer is widely employed in state-of-the-art industry and more data are capable to be processed with a tremendous speed due to rapid development of IT. This capability not only leads to higher density of heat and increases heat dissipation of personal computer, but also causes the temperature of central processing unit (CPU) rises (Mohan & Govindarajan, 2010). Based on Figure 1.1, the density of thermal flow is highly needed to concern, no matter what is the manufactured CPU (Mihai, 2007). The high temperature of CPU seriously increases its failure mode and also shortens its own life (Mohan & Govindarajan, 2010).

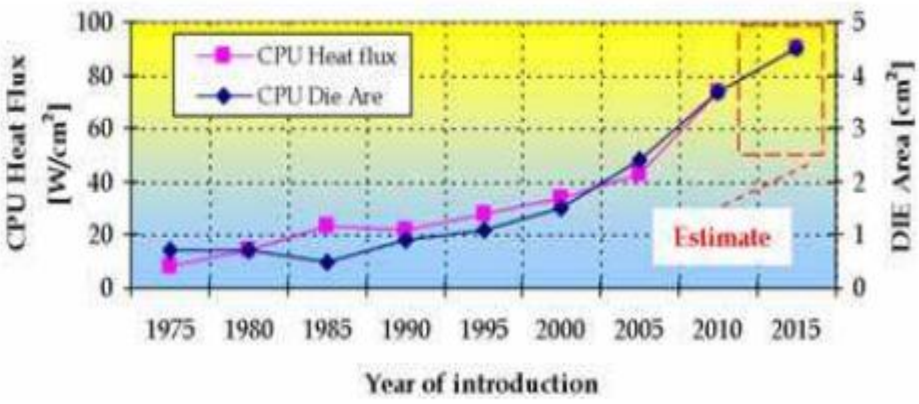

Figure 1.1: Thermal Flow Variation and CPU die size depending the production year (Mihai, 2007)

In order to ensure the device operates within safe temperature condition, heat sink –a structural device used removes heat from a functional electronic package to the surrounding– is required (Ekpu et al., 2011). Various heat sink design options have been developed to offer efficient and economical solutions over the years (Eppes et al., 2012). According to Huang & Chang (2012), there are a vast researchers has been seen that a heat sink with excellent geometrical design will provide higher efficiency and better cooling performance. A good design of heat sink should comply with the related standards, and has good reliability and durability, manufacturability, reasonable cost and etc., so that to meet the desired temperatures under the worst working condition (Liu et al., 2012).

For the production of heat sinks, thermal management materials such as aluminium are commonly used because they exhibit high thermal conductivity and reasonably low coefficient of thermal expansion properties. Lower density thermal management materials are preferred due to miniaturization of electronic devices at present (Ekpu et al., 2011). Aluminium air-cooled heat sink has becomes one of the most commonly used devices to cool CPUs because it leads to the advantageous of simple maintenance process, more reliability, lower manufacturing cost, and no environmental concerns. According to Das (2006), recycling aluminium alloys are provided major economic benefits. Therefore, the aluminium alloy is definitely an appropriate material for heat sink in considering the perspective of sustainable development.

This paper focuses on three types of fin designs such as plate finned heat sink, in-line strip finned heat sink, and splayed pin finned heat sink, which are the common types used in the computer for CPU cooling. 3D SolidWorks models for the three fin designs are presented and temperature distribution and total heat flux are predicted for the heat sinks in a range of temperature using finite element analysis which is implemented using ANSYS software. This project is proposed an improved design of finned heat sink and it is compared to the other finned heat sink. Therefore, a fin design which has the most excellent in thermal performance is obtained at the end of this project. The aluminium alloy 6063 is used as material of fins, but the addition of other metals in the amounts commonly used in aluminium alloys does not appreciably change the density (EAA, 1994).

1.2 Problem Statement

Computers continue to get faster via smaller and more intricate circuitry, which generates mass amounts of heat. Heat given off by processors must be dissipated to prevent the electrical equipments operate slowly or malfunction. According to Gurrum et al. (2004), heat dissipation rates for computer CPUs may increase as high as 180 W for the next few years and as high as 288 W by the year 2016.

The finned heat sinks work under uncertainty conditions with fluctuated temperature and heat capacity. Electrical equipments will failure in operation as the heat transfer rate of finned heat sinks is much lower compared to the total heat released from CPU. This had become the main problem which arises in designing fins with a desired material. Therefore, thermal analysis on the fin designs are required to test the thermal performance of fins under certain range of ambient temperature, as well as the factor of safety and fin efficiency are analyzed under steady state and transient condition respectively.

In addition to the present world, sustainable development of the environment has become the pivotal political and social issue to solve the problems of destruction the environment and natural resources. The selection of recyclable material for fin could be a critical part, but the integration of appropriate material with the fin designs and analyzed under uncertainty heat capacity has becomes more challenging. Therefore, a high thermal conductivity material is required so the fins can resist under any temperature.

1.3 Objectives

The objectives of this project are

a) To investigate the design parameters of fins.
b) To analyze the uncertainty heat capacity for fins using engineering analysis software.
c) To design of fins under uncertainty heat capacity.

1.4 Scope of Project

This project focuses the design of finned heat sink used in the cooling of central processing unit (CPU) for computer. There are many different designs of finned heat sink commercially available in the market, but only three existing designs which are the heat sinks with plate fins, in-line strip fins, and splayed pin fins are investigated under natural convection. Aluminium alloy 6063-O is used as the only and desirable material for the three fin designs for further simulation and analysis.

The performance of a heat sink is affected by various parameters such as fin shapes, fin arrangement or alignment; base length (L), fin height (H), fin thickness (t), sink width (W), fin spacing (s), base thickness (h), fin length (w) and number of fins (n) which all are measured in unit of millimeter (mm). These parameters can considered as the performance improvement paths for the selected heat sinks. Many design constraints such as heat transfer surface area (A), heat transfer coefficient (h), ambient temperature (T_∞), surface temperature of fin (T_S), and thermal conductivity (k) are also explored and attention is focused on the selection of fin designs under uncertainty heat capacity.

Three dimensional (3D) fin design models are generated using SolidWorks 2010 software and the simulations are conducted with the aids of ANSYS software. Thermal analysis is conducted respectively under steady state condition and transient condition that involves conduction and convection phenomena.

Thermal analysis of the three fin models was first conducted under steady state condition at different ambient temperature to analyze the temperature distribution, total heat flux, and factor of safety of finned heat sink. The results from the simulations are analyzed and discussed; therefore, the best among the three fin models can be selected by weighted scoring method. Besides, an improved design of finned heat sink is proposed based on the comparison of the candidate fin models.

The selected fin design and proposed fin design are then analyzed under transient condition. This analysis is required to predict the temperature distribution and total heat flux of the heat sink body which are vary with time. The results of simulation for both fin models are analyzed and compared so that a fin design with the best thermal performance is selected at the end of this project.

1.5 Project Organization

This report is divided into five different chapters which are completed within the duration of one year. These chapters are briefly introduced and described at below:

(a) Chapter 1 - Introduction

Chapter 1 proposes an overview for the entire project and shows the systematic plan to conduct this project. This chapter involves the project background, problem statements, objectives, scope of project, project organization. The Gantt chart illustrates the activity planning of FYP I and FYP II is attached at Appendix A.

(b) Chapter 2 - Literature Review

Chapter 2 provides the explanations of fins used in the cooling of CPU in computer, fin designs, design principles, heat capacity and the material used, aluminium alloy 6063 is used for the fin designs. This chapter provides also the reviews of the software, including SolidWorks 2010 and ANSYS software. The information regarding to each element which includes introduction, properties, and some applications are obtained from the past studies, journals, books and articles to help in understanding more about the elements that involved in this project and as the guidance for the project flow. Relevant methods used by other researchers are reviewed and compared in order to act as guideline to solve the problems and to achieve the objectives.

(c) Chapter 3 - Research Methodology

Chapter 3 is described the methodology used to solve the problems and to achieve the objectives. A flow chart is generated with its descriptions to show the process flow and methodology that used as a guideline for this project. In this chapter, the relevant variables and elements are defined in detail together with the engineering sketching of three different fin designs.

(d) Chapter 4 - Result and Discussion

Chapter 4 describes the implementation of the methodology which had proposed in Chapter 3 to obtain three detail designs of fin and their accurate data through the uses of design and analysis software. The results are then to be explained and compared between each other using the relevant variables. The weighted scoring method is implemented for the selection of design. Lastly, the best fin design is selected based on the analysis and it is investigated and compared with proposed design through simulation. Finally, only one with best performance is chosen.

(e) Chapter 5 - Conclusion

Chapter 5 is the last chapter which conclude the overall findings of the entire project and the most excellent design of fins is obtained. This chapter provides also the recommendation for future research.