THERMAL AND FLOW ANALYSIS OF HEAT SINKS FOR CPU COOLING BY ANSYS

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This report is submitted
in fulfillment of the requirement for the degree of
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DECLARATION

I declare that this project report entitled “Thermal and Flow Analysis of Heat Sinks for CPU cooling by ANSYS” is the result of my own work except as cited in the references.

Signature : ....

Name : INTERAN A/L RAMAN

Date : ....

APPROVAL

I hereby declare that I have read this project report and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering with Honours.

Signature : ....

Name of Supervisor : DR. MOHD ZAID BIN AKOP

Date : ....

DEDICATION

To my beloved mother and father.

ABSTRACT

The technology development nowadays towards the revolution of industry 4.0, where the development of digital computer in advance model and it's needs are increasing day by day. When there are pros there will be cons as well, where the reliability of electronic components are getting affected extremely by the heat dissipation at which the junction operates. To work on higher processor units nowadays CPU needs a greater operating power, and as CPU design engineers there are forced to make the system smaller in the term of size because customer at this time wants everything to be in pocket size. As the size reduced the problem of transferring heat to the surrounding and controlling the temperature becomes vital. Currently the CFD simulations have become a problem solver where it's does not cost anything in the term of price and it's widely used in the studies of heat transfer. This report tells about the material that suit well to be heat sink. There are three type of material analyzed in this research, which is steel, aluminium and copper. The parameter such as heat dissipation, number of fins, fin thickness are taken from past experimental research, while the geometry of CPU chassis, CD, DVD, and HDD are taken from manufacturer data base. Besides that, in this research work the flow around the chassis has been analyzed to increase the cooling performance. The result of three different material type of heat sinks are compared in order to get the fine material that suit well to be heat sink fabrication material. Furthermore, the simulation of copper material heat sink shows a better characteristics in the simulation for heat transfer and having more inlet slots increase cooling capacity of heat sinks due to a large air flow inside the chassis.

ABSTRAK

Perkembangan teknologi sekarang ini ke arah revolusi industri 4.0, di mana perkembangan model komputer digital kian meningkat dan keperluannya semakin meningkat setiap hari. Apabila terdapat kebaikan, terdapat keburukan juga, di mana komponen elektrik dalam CPU mengalami masalah pemindahan haba yang ketara. Selain itu, untuk CPU bekerja pada prestasi penuh ianya memerlukan kuasa elektrik yang tinggi. Casis CPU juga pada masa sekarang making dikecilkan untuk mesra pengguna. Oleh disebabkan itu, reka bentuk model CPU lebih kecil dalam saiz. Lagi kecil casis CPU lagi susah untuk pemindahan haba di dalamnya. Ini disebabkan oleh ruang yang tidak cukup untuk udara sejukkan "heat sink". Pada zaman sekarang simulasi CFD telah menjadi sesuatu kaedah yang dapat menyelesaikan pelbagai masalah di mana ia tidak membebankan apa-apa dari segi harga dan ia digunakan secara meluas dalam kajian pemindahan haba. Laporan ini menceritakan tentang bahan yang sesuai untuk menjadi "heat sink". Terdapat tiga jenis bahan yang dianalisis dalam kajian ini, iaitu keluli, aluminium dan tembaga. Parameter seperti pelesapan haba, jumlah sirip, ketebalan sirip diambil dari penyelidikan eksperimen yang lalu, manakala geometri casis CPU, CD, DVD, dan HDD diambil dari jurnal masa lalu. Selain itu, dalam kajian ini, aliran angin di sekitar casis telah dianalisis untuk meningkatkan prestasi penyejukan "heat sink". Hasil daripada simulasi tiga jenis bahan tembaga menunjukkan hasil yang baik untuk menjadi "heat sink" yang bagus.

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Firstly, I wouldn't be here if not for the mercies, favor, and blessings of my Lord and personal savior. I would like to thank God for seeing me through my journey here at Universiti Teknikal Malaysia Melaka so far and for the incredible and exciting adventures he has in store for me.

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LIST OF ABBEREVATIONS

ATX	Advanced Technology Extended
CD	Compact Disc
CFD	Computational Fluid Dynamic
CPU	Computer Programming Unit
DVD	Digital Versatile Disc
HDD	Hard Disk Drive
I/O	Input / Output
PC	Personal Computer

LIST OF SYMBOL

A	=	Area
^{o}C	=	Degree Celsius
h	=	Heat Transfer Coefficient
K	=	Kelvin
k	=	Thermal Conductivity
m	=	meter
Q	=	Heat Transfer
T	=	Temperature
W	=	Watt

CHAPTER 1

INTRODUCTION

1.1 Background

21st century is keep growing beyond limitation not only in technology but every aspects and each angles. The devices in the form of electronics are replacing the human minds due to the incredible reliability in our daily routines. However, when there are pros there also will have cons. Which is our modern era wants everything to be smaller if can in the size of a pocket. The smaller the electronics devices gets the higher the heat distribution will occur. The research is on the Central Processing Unit (CPU) heat sinks plate which functioning as a cooler for the electronic devices inside CPU. The heat occur on electronics devices such as integrated circuit (IC), resistances, capacitances, diodes, graphic cards, random access memory (RAM) and other smaller chips. This heat may not release to the air if there is no heat transferring component from inside to outside. This can lead to the damage on electronics component because electronic components do have their specific temperature before over-burn (The and Publishing, 2016).

To overcome temperature rises issue there are some ways to reduce the CPU electronic devices temperature. Which are fans, thermoelectric coolers, heat sinks, plates, forced air blowing systems and also using liquids. Generally, electronics devices on CPU use forced air cooling method with the heat sink plate. This is because its high capability in the terms of larger heat transfer rate, faster cooling, light weight, price, area occupied and reliability. Plate fin and pin fin heat sink concept are using widely. This is because its own special advantages. One of the advantages of plate fin is it has small pressure drop, easy to create and also the simplest design. The pin fin having a large heat transfer rate (Desai *et al.*, 2016).

In this project the evaluation will based on the computational fluid dynamics (CFD) approach. The CFD ANSYS CFX software used to identify a cooling solution for the desktop computer. The future modern CPU will dissipate heat in the range of 100-150W. High dissipation of heat can cause the personal computer (PC) to lag and also gives a high risk to the electronic components due to the high temperature. On behalf of that, heat sink with better dimensions of fins and design will needed for the cooling process inside the CPU. Figure 1.1 shows a simple heat sink which used as heat removal source inside PC (Zhang, Long and Zhang, 2018).

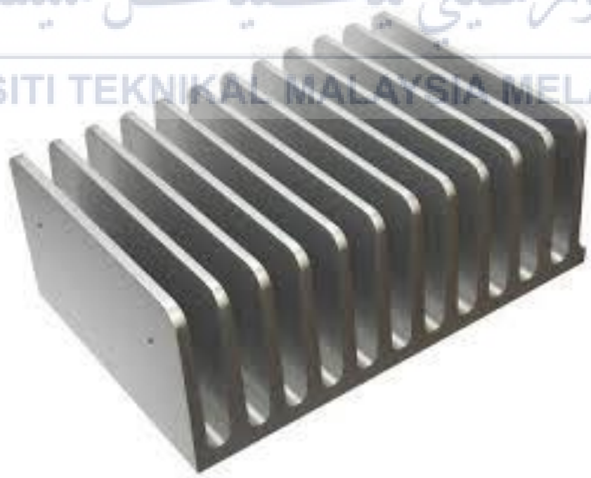

Figure 1.1: Heat Sink

(Source: wikipedia.org/wiki/Heat_sink)

1.2 PROBLEM STATEMENT

Nowadays CPU using more electric power around 100-150W. The higher the power it's uses the higher the heat dissipation rejected inside the CPU. When the heat sink materials thermal resistance is high the longer it's takes for the cooling process and this will drag the performance of CPU to the minimum or prostate characteristics mention above expected in future that will make the heat transfer rate more difficult. If a good thermal conductivity heat sinks material placed inside the CPU it will help the cooling process much more faster and also will increase the performance of CPU much greater.

1.3 OBJECTIVE

The objectives of this project are as follows:

1. To study the thermal heat distribution in CPU unit on the heat sinks caused by electronic components by analyzing experimental data using CFD simulation.
2. To compare and analyze steel, aluminium and copper, that suit perfect as heat sink production material.

1.4 SCOPE

The scope of this project are:

1. Based on the simulation approach by using ANSYS only.
2. Neglecting the heat transferring from the small electronic parts such as resistor, diode, transistor, capacitor, and the CD, DVD and also HDD is consider as lumped media.
3. The model of CPU based on the standard size only (standard ATX board is 12 x 9.6 in or 305 x 244 mm).
4. Only three types of material is considered (steel, aluminium and copper).

1.5 GENERAL METHODOLOGY

The action or steps that need to take out to achieve the objectives in this project are given below:

1. Literature review

   Journals, articles, books, internet webpages and any other resources that related to the project.

2. Dimensions gathering from journals

   The dimension of the plate-fin or heat sink is based on the standard size.

3. Simulation

   Computational fluid dynamic approach will be based on the ANSYS software.

4. Analysis and proposed solution

Analysis and data of the heat transfer rate and flows on how the heat transfer will be presented.

5. Report writing

A report regarding about the simulation will be written at the end of this project.

CHAPTER 2

LITERATURE REVIEW

2.1 Heat Sinks

Heat transfer has huge role in global, including electronic components, structures and also in industrial automation. The development to industrial 4.0 has lead the usage of electronics components increasing day by day. Besides that the components has exacerbated the heating problem. The smaller the object the larger the heat rejected by it and its absorption temperature also much smaller. So to overcome this issue the heat sinks can be use as solution. Figure 2.1 shows example of variety designed heat sinks (Strategia *et al.*, 2016).

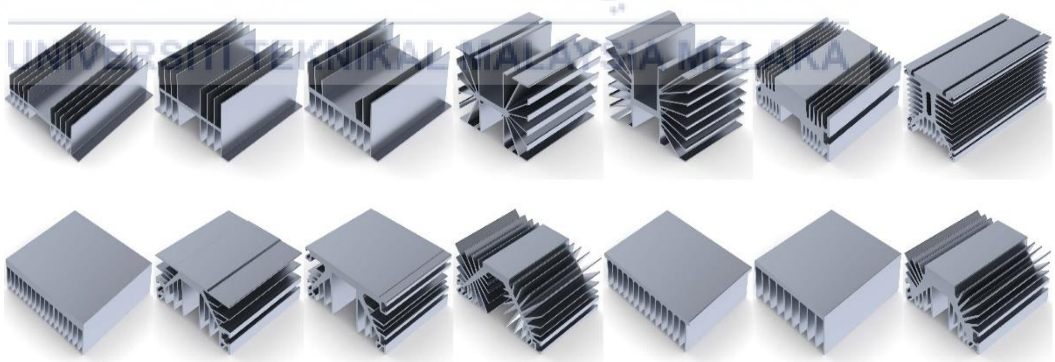

Figure 2.1: Types of Heat Sinks

(Source: vrelectronics.com)

Heat sink is an object that fabricated using custom design and aluminium alloy as material. The main objective of heat sink is to transfer the heat created by integrated chips (IC) and electronics products. Heat sink in computer programming unit (CPU) is used to cool down the graphics processor, random access memory, hard disk, and electronic components. This is because without the heat sink the electronic components might burn due to the overheat or long term operations (Haghighi, Goshayeshi and Reza, 2018).

To get a good heat sink model some characteristics should be consider such as the shape, material, angle of the heat sink placement, size, and lastly heat transfer rate for the material or thermal conductivity. Design of the heat sink is depend on the space and area that available but normally they maximize the area in order to get a larger heat transfer coefficient. The increase in surface area can lead to maximum absorption of heat and this can lead to fast cooling in CPU. However too long also not suitable. The design of giving gap in between the fins is helpful for the air to pass through the heat sink. Generally, the heat transfer of the created heat to the heat sinks happens through conduction between material and later the heat transferred to the surrounding by convection. The Eq [1] is for conduction heat transfer, while Eq [2] for convection heat transfer (Ali and Kurdi, 2018).

$$[Q = kA\,(T2-T1) \div L] \qquad [1]$$

$$[Q= hA\,(\,T2 - T1\,)] \qquad [2]$$

Aluminium is the heat sink material that widely used in CPU development. Aluminium has a greatest thermal conductivity around 229 W/m.K which is k in thermal language. Thermal conductivity is a rating which set to the material on how efficiently it can transfer the rate of heat transfer. The bigger the thermal conductivity (k) value the higher the heat transfer rate. Moreover, this can lead to instant cooling in electronic components (‘Cfd Analysis of a Notebook Computer Thermal’, 2008)

2.2 Computational Fluid Dynamics (CFD)

CFD simulation is a part of fluid mechanics study that uses numerical method analysis and data structures to perform calculation and give solutions to the problem that involves fluid flows, heat, mass transfer, chemical reactions (explosions) and related phenomena. Computer is a source that used to conduct the simulations with the surfaces defined by boundary conditions. A high capability computers can give us a better solutions and often required to solve the largest and most complex geometrics. Navier - Stokes equations, is used in CFD as foundation. Figure 2.2 below shows the flow involve in CFD. With CFD, the area of interest is subdivided into a large number of cells or control volumes. In each of these cells, the Navier - Stokes partial differential equations can be rewritten as algebraic equations that relate the velocity, temperature, pressure, and other variables, such as species concentrations, to the values in the neighboring cells. These equations are then solved numerically, yielding a complete picture of the flow down to the resolution of the grid. The resulting set of equations can then be solved iteratively, yielding a complete description of the flow throughout the domain (Uddin, 2009).

CFD is a simulation that used widely in research and mechanical engineering problems and also companies including in aerospace, aerodynamics, system design, combustion system, and also fluid flows to get solution in the term of numerical.

There are three stages in CFD which is :

1. Pre-Processing is the first step of the CFD simulation process which involving the geometry of the design. In this pre-processing process the needs to identify the fluid domain is necessary. The chosen domain later will divided into smaller grids, which called meshing. There are a lot of software in market which can be used such as Gridgen, CFD-GEOM, ANSYS, ANSYS ICEM CFD, and TGrid. This research using ANSYS to run the pre-processing process.
2. Solver Execution is a solving process after the physics problem has been identified in the pre-processing process. The flow physics model, fluid material properties, and also boundary conditions fixed to solve using a computer. Solver execution can be done by ANSYS FLUENT. ANSYS, Star CCM, CFD++, and OpenFOAM. Solver execution in this research will be ANSYS.
3. Post-Processing is a process of viewing the results in many way like contour plots, vector plot, streamlines and data curve. Each views will make the result finding more understandable and also for appropriate graphical representations report.

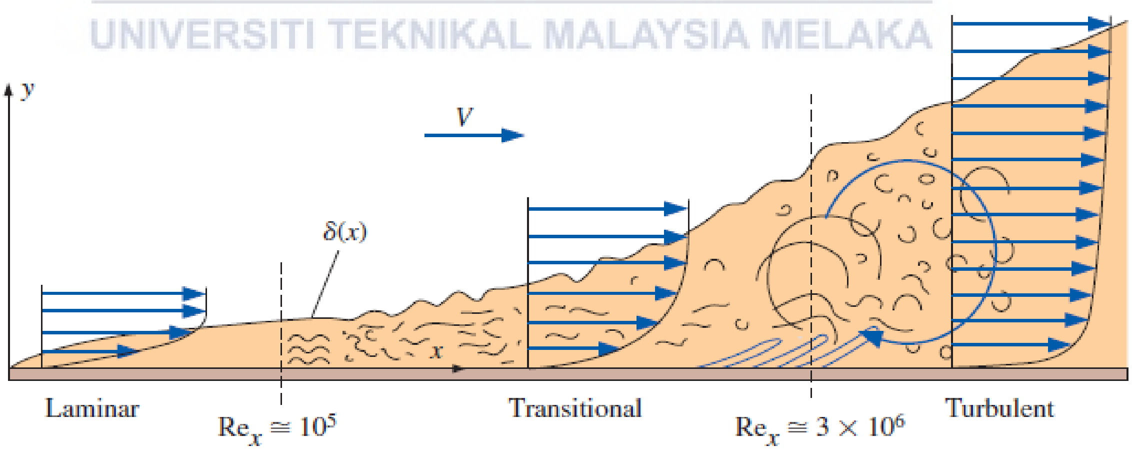

Figure 2.2: Physical characteristics of boundary layer

(Source: Burbuja.info)

In this report the software that used is ANSYS CFD version 18 similar to the ANSYS software just it's has been modified into the newer version. The software use to draw and analyze the heat distribution or heat transfer in heat sink inside CPU. Three type of material will be considered on this report which is steel, aluminium and cooper.

2.3 HEAT TRANSFER

Heat transfer is a process where heat or temperature making the temperature difference in equilibrium. Where heat transfer will stop when both temperature are same. Heat always transfer from high temperature to low temperature. Heat transfer can be classified into three which is thermal conduction, thermal convection and also thermal radiation. In CPU there are two states of heat transfer only because there are a little bit of radiation only and its negligible (Angeles, 2015).

Heat transfer by conduction can be called diffusion. Diffuse is a direct microscopic exchange of kinetic energy of material through boundary of two systems. Conduction is heat transfer between two solid phase which is in direct contact. In this case the heat transfer by conduction occur in heat sink and the base plate connected below. Figure 2.3 shows more clearly regarding about the heat transfer by conduction of a heat sink. The Eq [1] is heat transfer formula of conduction that will be used in research validation later (Bou-rabee, Sulaiman and Mazlan, 2015).

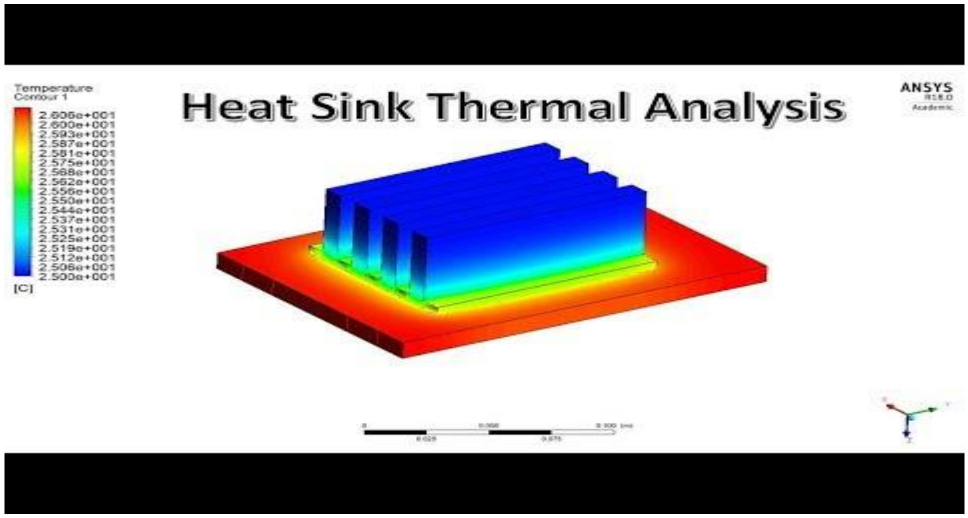

Figure 2.3: Heat Transfer by Conduction

(Source: dk-ceramics.com)

Heat transfer by convection occurs when the heat from material or object exposed to the surrounding. The heat transfer to the surrounding by the natural wind flow is called natural convection. For example a hot milo cup has put on the table for a while and after its checked back the milo get cold by the heat transfer to the surrounding naturally. There is also call forced convection. Forced convection is a heat transfer that cold by using fan or other heat removal objects. For example the heat sink inside CPU is get cooled by the forced air of the cooling fan. Figure 2.4 shows the heat transfer by convection on heat sink (Amoako, 2018).

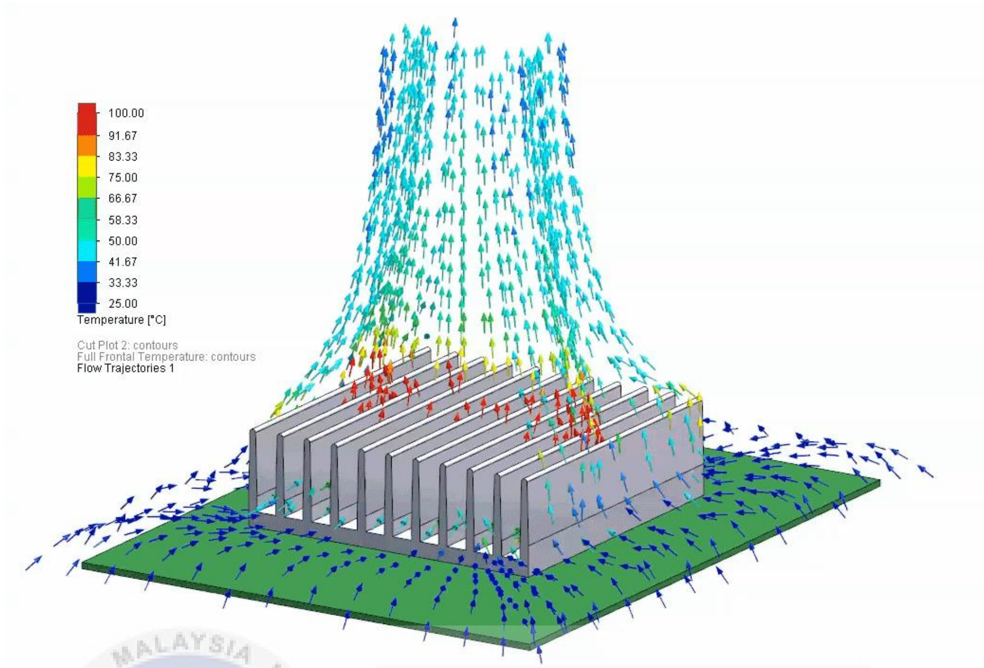

Figure 2.4: Heat Transfer by Convection on Heat sink

(Source: gifer.com/en/96XK)

Besides that, the heat transfer for DVD, CD, HDD and cooling fan are considered as lumped system analysis, where the interior temperatures of the bodies remain essentially uniform at all times during a heat transfer process. The temperature of such bodies are only a function of time, T = T (t). The heat transfer analysis based on this idealization is called lumped system analysis. Consider a body of arbitrary shape of mass (m), volume (V), surface area (A), density (ρ) and specific heat (Cp) initially at a uniform temperature (T) (Training, 2006).

2.4 HEAT SINK MATERIAL

The highest usage of heat sink material used is aluminium alloys. Why does aluminium alloy is suitable? Aluminium alloy 1050 having a higher thermal conductivity value around 229 W/m.K but due to its properties its mechanically soft (Casey, 2015).

Aluminium alloy which use as heat sinks are 6060 (low stress) and 6063 with thermal conductivity of 166 and 201 W/m.K. The aluminium material heat sinks usually fabricated by casting or extruded. Table 2.1 below shows the properties of steel, aluminium and copper, which is taken from the manufacturer database (‘www.wakefield-vette.com’, date 21/11/2018).

Table 2.1: Mechanical Properties Limits Extruded from Manufacturer

(Source: electronics-cooling.com)

MATERIAL	**ALUMINIUM**	**COPPER**	**STEEL**
Bulk Thermal Conductivity (W/mK)	180-220	397.79	50.2
Specific Thermal Conductivity (W/mK)	45	63	-
Density (g/cm^3)	8.9	2.8	-
Tensile Strength (MPa)	270	180	370

6060 aluminium is one of the most common aluminium alloys of the 6000 series. It’s has an advantages of corrosion resistance and weldability. The 6060 alloy commonly used in door frames electronic components. It is an ideal alloy for very complex cross sections and has a very good anodizing (used to increase the thickness of the natural oxide layer on the surface of metal parts) response. 6061 aluminium alloy is a heat treatable alloy with mechanical properties slightly lower than 6082. It has good corrosion resistance but like 6082 its extruded surface finish is not as good as 6060 (Ren, 2015).

Copper has the greatest thermal conductivity of all. Besides that, it's has high corrosion resistance and biofouling resistance. The thermal conductivity of copper is twice than aluminium. The applications of copper is highly in industrial facilities, power plant, solar thermal water systems, gas water heaters, forced air heating and cooling systems. One of the disadvantages of copper is its highly expensive and heavier than aluminium. Copper heat sinks are machined and skived. The one reason that highlight the most is copper is less ductile than aluminium, so it cannot be extruded into heat sinks. That's why many CPU unit using mixed aluminium as heat sink (Mohan, 2014).

As for the steel and iron is simply avoided to use in heat sink creation because its has the lowest thermal conductivity as shown in table but both of the material is widely used in the industrial production process due to the high tensile strength. When its compared to heat transferring rate it is categorized as low capacity but in this research it's still included because to see the difference between poor thermal conductivity and higher thermal conductivity, which is steel 50.2 W/m.K and copper 397.7 W/m.K (Mohan, 2014).

2.5 COMPUTER PROGRAMMABLE UNIT (CPU)

Advanced Technology Extended (ATX) is one of the motherboard design by the Intel company. It is created on 1995 to improve the old factor standards such as AT design. The dimension of the standard ATX board is 12 x 9.6 in or 305 x 244 mm. Inside of ATX consist of the mounting point, key mechanical dimensions, I/O panel, power and also connector interfaces between a computer case, a motherboard, and a power supply.

At 1995 the specification has been revised numerous times and the most recent version of it is 2.3 released on 2007. Figure 2.5 shows the example of ATX design. ATX is one of the most used motherboard design. ATX uses 12V as a power source for the running process. Table 2.2 explain detail on the components that in the motherboard.

Figure 2.5: The Intel Z77 Motherboard

(Source: Casey, 2015)

Table 2.2 : Explanation of Motherboard (Casey, 2015)

1. 12V Processor Core Voltage Connector (8 pin)	15. POST Code LED Display	29. High Definition (HD) Audio AC97 Front Panel Header
2. Voltage Regulator status LEDs	16. Front Panel Header	30. CMOS RAM Battery
3. Processor Socket (LGA1155)	17. USB 2.0 Dual-Port Header (black)	31. Rear Chassis Fan Header (4 pin)
4. Processor Fan Header (4 pin)	18. Chassis Intrusion Header	32. 5 port audio with S/PDIF
5. Memory Slots	19. BIOS Configuration Jumper	33. Intel Gigabit (10/100/1000 Mb/s) Ethernet LAN
6. Front Chassis Fan Header (4 pin)	20. Consumer IR (CIR) headers	34. IEEE 1394a port
7. Onboard Speaker	21. USB 3.0 Front Panel Connector (blue)	35. External Serial ATA (eSATA) port (3 Gb/s)
8. Main Power Connector (2x12 pin)	22. S/PDIF out Header (4 pin)	36. USB ports: 4 USB 3.0 ports (blue) 2 USB 2.0 ports (black)
9. Onboard Power Button	23. Diagnostic Status LEDs	37. Graphics ports
10. +5V Standby Power Indicator LED	24. Auxiliary chassis fan header (4 pin)	38. Back to BIOS button
11. SATA 3.0 Connector (black)	25. IEEE 1394a front panel header	39. PS/2 port
12. SATA Ports: (4 SATA 6.0 ports (blue & grey) (2 SATA 3.0 ports (black)	26. PCI Express 2.0 x1 connector	40. USB 2.0 ports (yellow) 2 high current/ fast charging ports
13. Intel z77 Express Chipset	27. Conventional PCI bus connector	41. Voltage Regulator modules with heat sinks
14. Alternate Front Panel Power LED Header	28. PCI Express 3.0 x16 connector	

Each part of the component in the chassis model will dissipate heat due to the running process. The electricity supplied to the electronic part of the computer will convert to the heat and released to the interior of the computer. This is because energy in always equal to energy out, where the losses in heat is still consider as energy out. The heat rejected by the CPU, CPU heat sink, compact disc (CD), digital versatile disc (DVD), and hard disk drive (HDD) are explained in Table 2.3.

Table 2.3 : Interior Conditions of CPU (Mohan and Govindarajan, 2011)

OBJECT NAME	MATERIAL	HEAT DISSIPATION RATE (W)
CPU	Aluminium	80
CPU Heat Sink	Aluminium	-
CD	Aluminium	15
DVD	Aluminium	15
HDD	Aluminium	20

Based on the table above the CPU heat dissipation rate stand high because the processor unit is an important component in motherboard, which run all task inside CPU. While the CPU heat sink dissipation is neglected because the aim of this research is to find it out after the CFD simulation process.

2.6 PREVIOUS RESEARCH WORKS

Mohan and Govindarajan (2011), study about the heat transfer in heat sink inside CPU chassis as shown in Figure 2.6. The objective is to identify the heat sink design that good in transferring the heat from base to the fins by conduction. The fin designed heat sink are good in heat transfer because as the theory from heat transfer subject says that long fin always has high and faster heat transfer because the area that uniform from base to up. Therefore rectangle fins show good heat transfer compare to circular and other patterns.

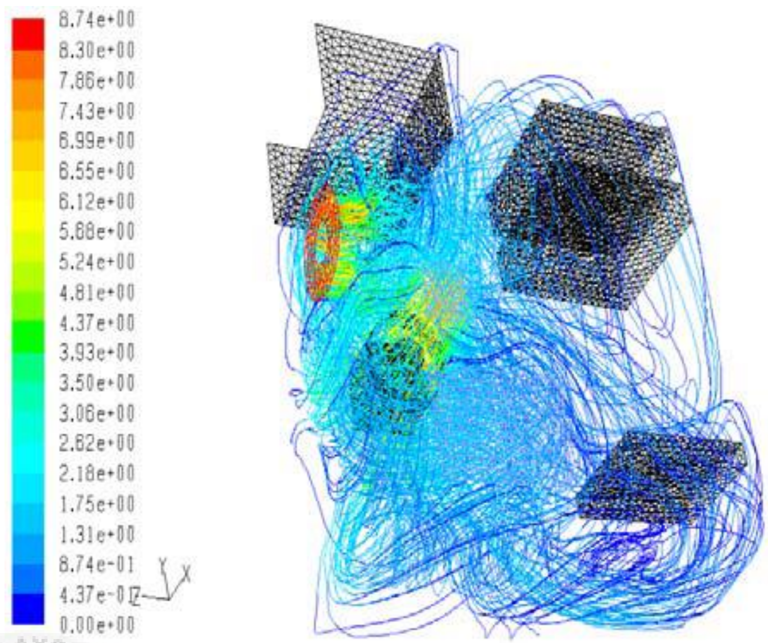

Figure 2.6: CPU Chassis Analysis

(Source: Mohan and Govindarajan, 2011)

Gupta and his team, analyze on the heat problem due to the rapid development of the digital computer power in watt (W) is increasing. The result shows that computer with higher voltage or watt required to operate releases more heat on the processor. In order to reduce the heat they focused on two type of heat sinks which is rectangular and also circular heat sink for the simulation. Data gained in CFD simulation shown in Figure 2.7 below, where rectangular plate heat sinks is more better in transferring the heat dissipation than circular. The rectangular heat sink total fin is 14, while circular is 100 in order to get the same heat dissipation temperature, which is 87 ^{o}C Gupta et.al, (2014).

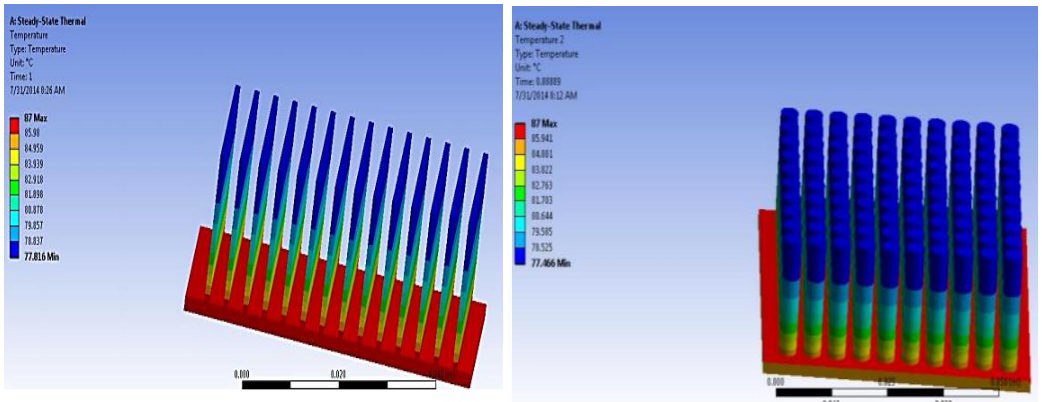

Figure 2.7: Rectangular and Circular Heat Sink

(Source: Gupta, 2014)

Mohan and Govindarajan (2011), investigated regarding about the heat sink in two approach which is experimental and CFD analysis with AL-CU in CPU. The thermal load of the selected heat sink is 20 W and heat source used was 100 ^{o}C. Heat sink performance is measured in 0 ^{o}C / W i.e. rating of 100 ^{o}C / 20 W, = 0.50 ^{o}C / W. As for cooling unit they choose heat radiating plate and an electric fan device. Copper material used as the base plate because copper is good thermal conductor which having 400 W/m.K thermal conductivity. Tapered solid fin configuration has been considered for testing by experimental and CFD analysis. Based on table 2.4 below the data of heat dissipation obtain from conducting the experimental method.

Table 2.4: Experimental Data

(Source: Mohan and Govindarajan, 2011)

Object Name	Material	Heat Dissipation Rate(w)
CPU	Silicon	80
CPU Heat Sink	Al – Cu, C-C	-
Chipset Heat Sink	Al	-
CD	Al	15
DVD	Al	15
HDD	Al	20
Power Supply	Porous	75
Miscellaneous Card	FR4	20

Liang and Hung, (2010), discussed about the importance of the heat sink in electronic device cooling process. The study investigate regarding about the effects of (Phase change material) PCM material, variation of PCM volume (50 ml to 100 ml) pin fin (circular and square), and different cavity heat sinks on thermal performance experimentally. Paraffin is used in analyze the thermal performance of the heat sink. Figure 2.8 below shows example of heat sink types which simulated in the research of experimental investigation on the thermal performance of cavity type heat sink with PCM.

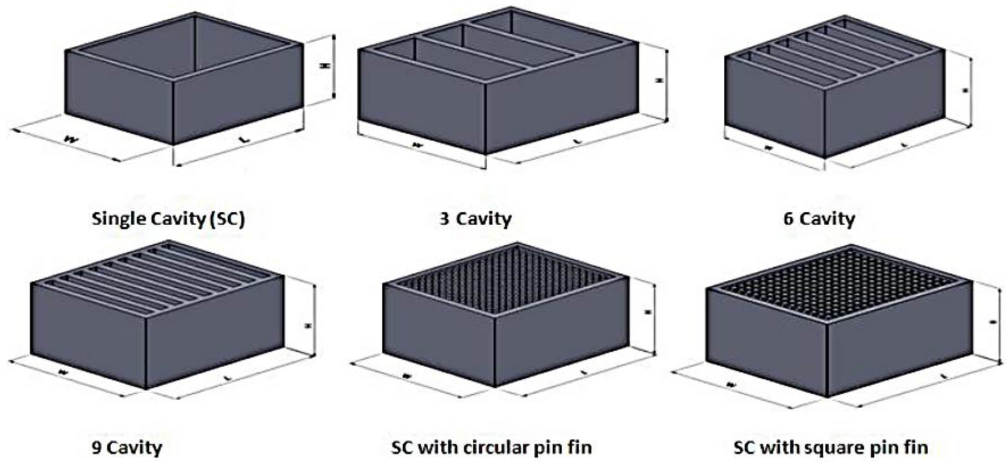

Figure 2.8: Cavity Type Heat Sink

(Source: Liang and Hung, 2010)

Amoako (2018), in this research they consider about different heatsink geometries for the electronic device cooling process. They also identify which heat sink is the best dimension by comparing the results of it. The material aluminium is selected for the study because its easy to be fabricated as heat sinks compared to copper. The research carried out by experimental and simulation. The results are shown below in Figure 2.9.

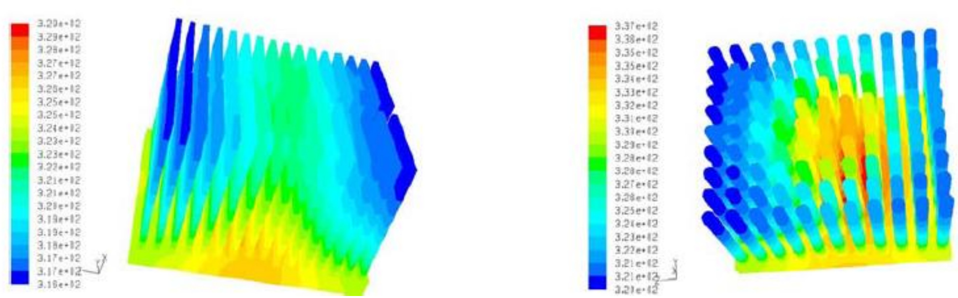

Figure 2.9: Rectangular and circular fins

(Source: Amoako, 2018)

Srivastava et.al (2012), based on the research its more focusing on the number of fins in heat sink, where the results shows too many fins on heat sink base is not a solution for dissipating the heat by the heat sink since they may prevent the passage of air coming from the fan to the hottest center parts of the heat sink. Furthermore, the heat transfer rate is strongly depends upon the placement of heat sink on heat source and the fan poisoning inside the chassis. Besides that, the researcher also focused on the space inside the CPU so it's sufficient enough for the air to circulate. The researcher also identified about the highest temperature or heat that can dissipate on the heat sink, which is shown in Figure 2.10 below. The highest temperature is 62 ^{o}C which a processor can achieve with the heat dissipation rate.

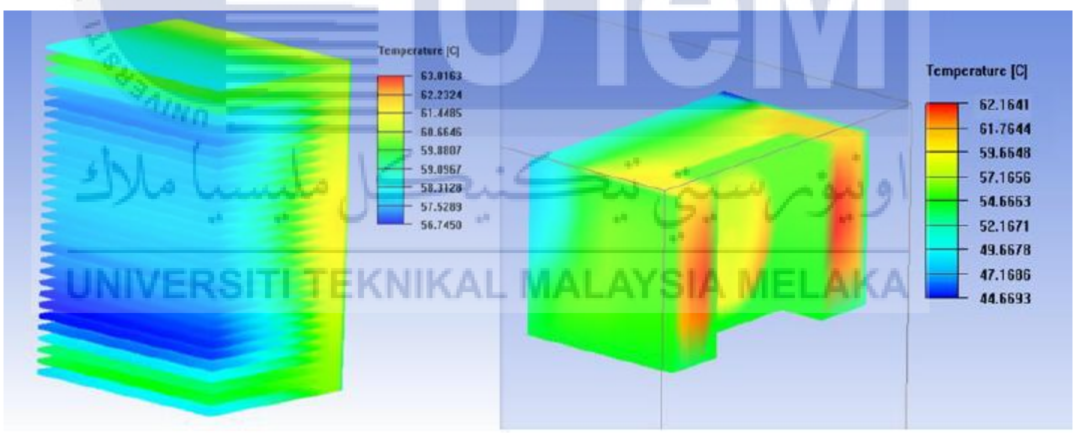

Figure 2.10`: Temperature Contour of Heat Sink

(Source: Srivastava, 2012)

Lakshmanan and Saravanan (2018), the study about the number of fins and their distribution, fin material and base plate thickness investigated and thermal enhancements for CPU cooling. The researcher also end up with a new design parameters which has better thermal transfer performance and uses less material. From the research it found out that stacking too many fins on heat sink is not a better solution for decreasing the hot spots on the base since they may prevent the air flow coming from the fan to the center of the heat sink. Compare to aluminium the copper material has low thermal resistance due to the high thermal conductivity. However choosing copper as heat sink material makes the heat sink more expensive and heavier. In this cases the footprint of the heat source is smaller than the width of the heat sink which introduces an in plane conduction resistance. Figure 2.11 below shows the copper heat distribution result of the journal.

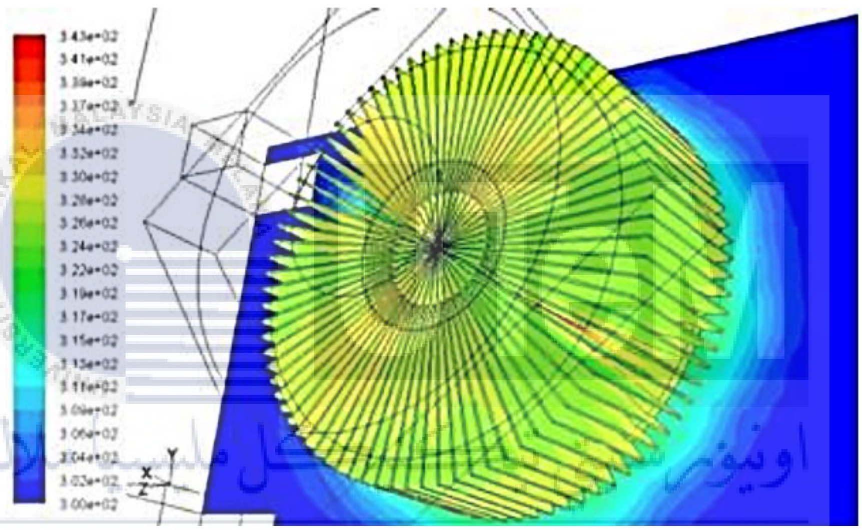

Figure 2.11: Circular Plate Fin Heat Distribution

(Source: Lakshmanan and Saravanan, 2018)

Ravikumar et.al (2017), investigated on experimental and transient thermal analysis of heat sink fin for CPU processor for better performance. Study on heat sink model with fins has to increase heat dissipation. The researcher used ANSYS on analyzing the existing materials and proposed materials and the results of steady state and transient thermal analysis are taken for comparison. From the observations of this journal CPU cooling performances of a computer chassis with rectangular and circular pin fin heat sinks were investigated using transient thermal analysis and the results were compared.

Figure 2.12 below shows the designed model used in simulation and from the result below it shows that rectangular fin highest temperature absorption is around 140 ^{o}C, where the heat transfer by conduction is efficiently dissipate.

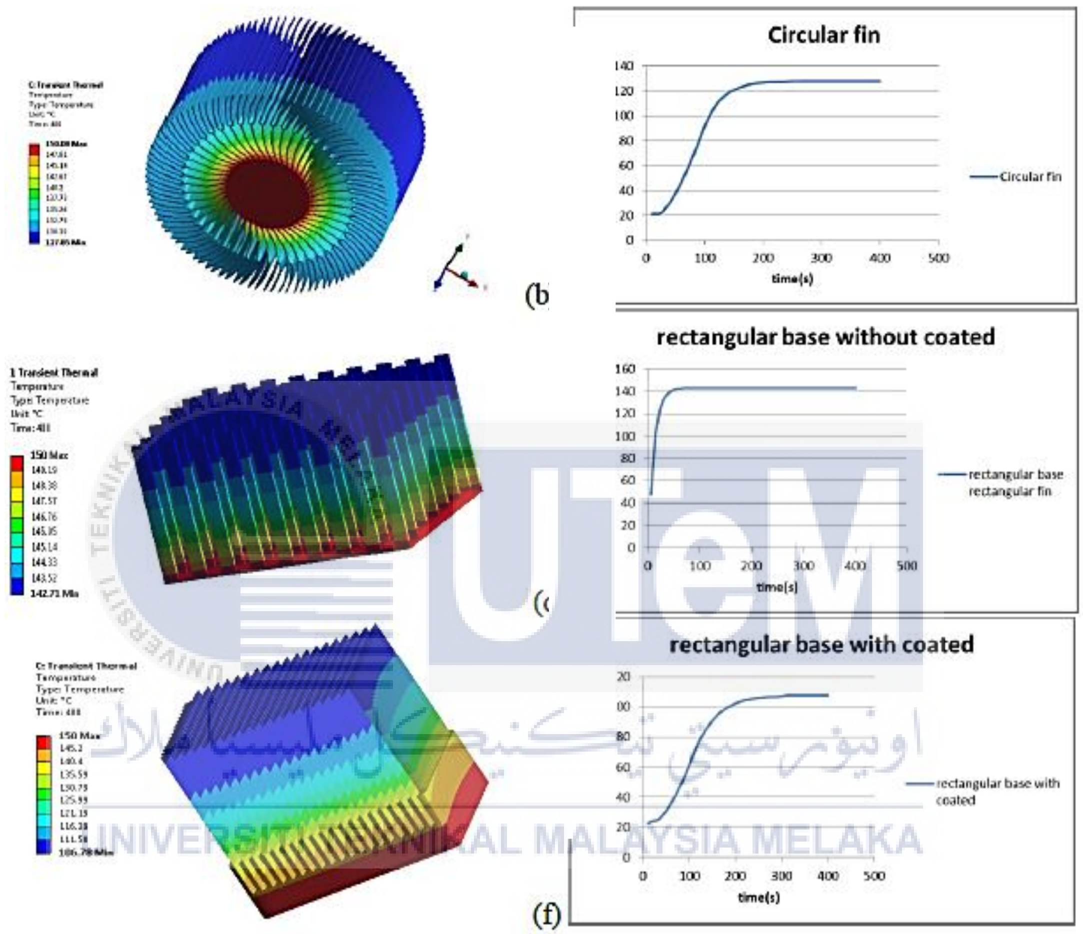

Figure 2.12: Transient Thermal Analysis Model

(Source: Ravikumar, 2017)

According to Meng et.al (2018), heat transfers of a straight fin heat sink under natural convection condition are investigated at different mounting angles. The heat sink surface temperatures are measured and used to judge its performance under constant heating power condition. The simulation results are verified by the experimental data with the maximum error less than 10.5 %. The heat sink performance is the worst at the mounting angle of 15 ^{o}, and the best performance happens at the angle of 90 ^{o}. The heat transfer stagnation zone is identified where the temperature difference is less than 2 ^{o}C. The heat transfer stagnation zone area reached the maximum when the mounting angle is 15 ^{o}, which leads to the lowest performance because the effective heat dissipation area of the heatsink is the smallest. This is verified by cutting the corner portion of the heat sink where is the heat transfer stagnation zone. The heat transfer could be enhanced by cutting appropriate corner of the heat sink, the thermal resistance reduces 2.64–3.77 % at heating power of 50 W and 6.00–10.13% at heating power of 80 W, and heat transfer coefficient increases 7.30–10.77 % at heating power of 50 W and 11.46–17.07 % at heating power of 80 W. The Figure 2.13 below shows the contour of the angled heat sinks.

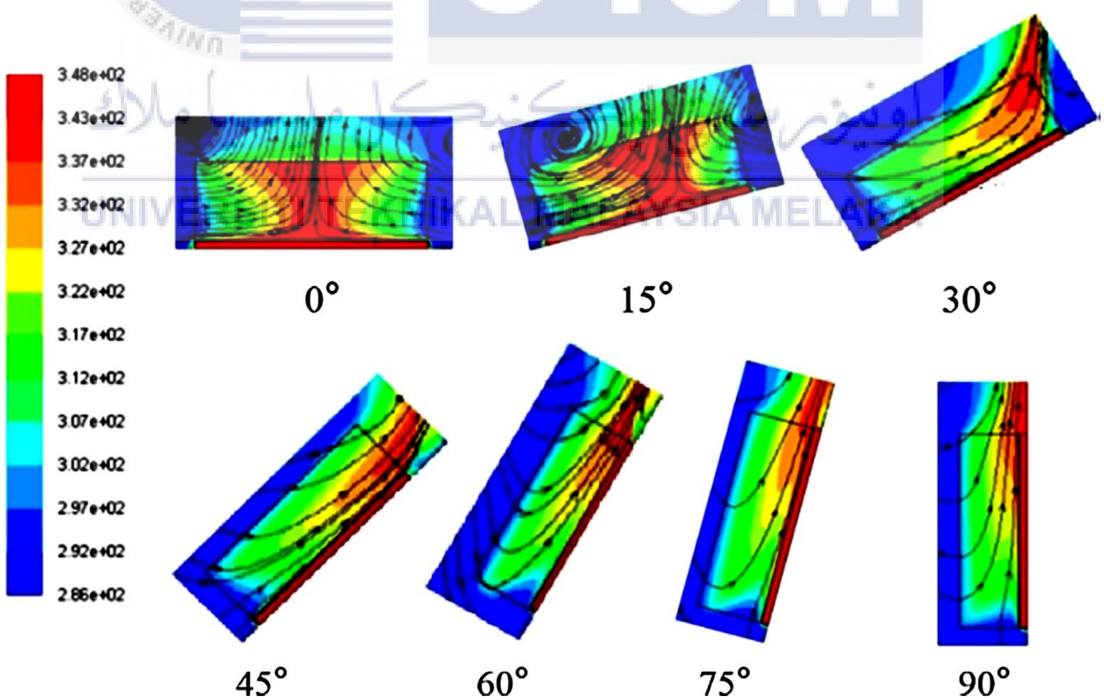

Figure 2.13: Angled Heat Sink

(Source: Meng, 2018)

Liu et.al (2012), conduct a research about the simulation and optimization of the CPU heat sink for a new type of graphite. The heat dissipation effect of graphite-metal heat sink is better than that of copper and far better than that of aluminum. Thickness and material of the basemen have an obvious influence on the heat transfer diffusion compared to the fin. Furthermore, a reasonable design can decrease temperature difference. The material and thickness of the base, height and thickness of the fin and heat transfer area of the sink considered. Compared to other common materials, the graphite dramatically decreases the conduction resistance. It consume a small amount of thickness, decrease the heat sink weight, and increase the heat dissipating area dramatically. Table 2.5 below shows graphite has the highest thermal conductivity, which as the results mention graphite is a good material to be a heat sink in this research.

Table 2.5: Thermal Properties

(Source: Liu, 2012)

Material	conductivity w/(m*K)	density /kg/m^3	specific heat J/(kg*K)
copper	398	8930	902
aluminum	236	2710	386
graphite	1500	700 ~ 2100	1400 ~ 1600
	50 ~ 60		

CHAPTER 3

METHODOLOGY

3.1 Introduction

The main purpose of this chapter is to describe the flow of the project in flow chart shown in Figure 3.1, chassis of the CPU, dimension of the heat sink and also the simulation process. The 3D model of the chassis are drawn by the Fusion 360.

3.2 Boundary Conditions

Inside the CPU unit the heat sink and fan are attached together. The chassis boundary are consist of the mainboard and other electronic components. There are also other small components that create heat in addition to CPU such small chips ic, capacitors, resistances, diods and many other. The Figure 3.2 shows the chassis 3D model.

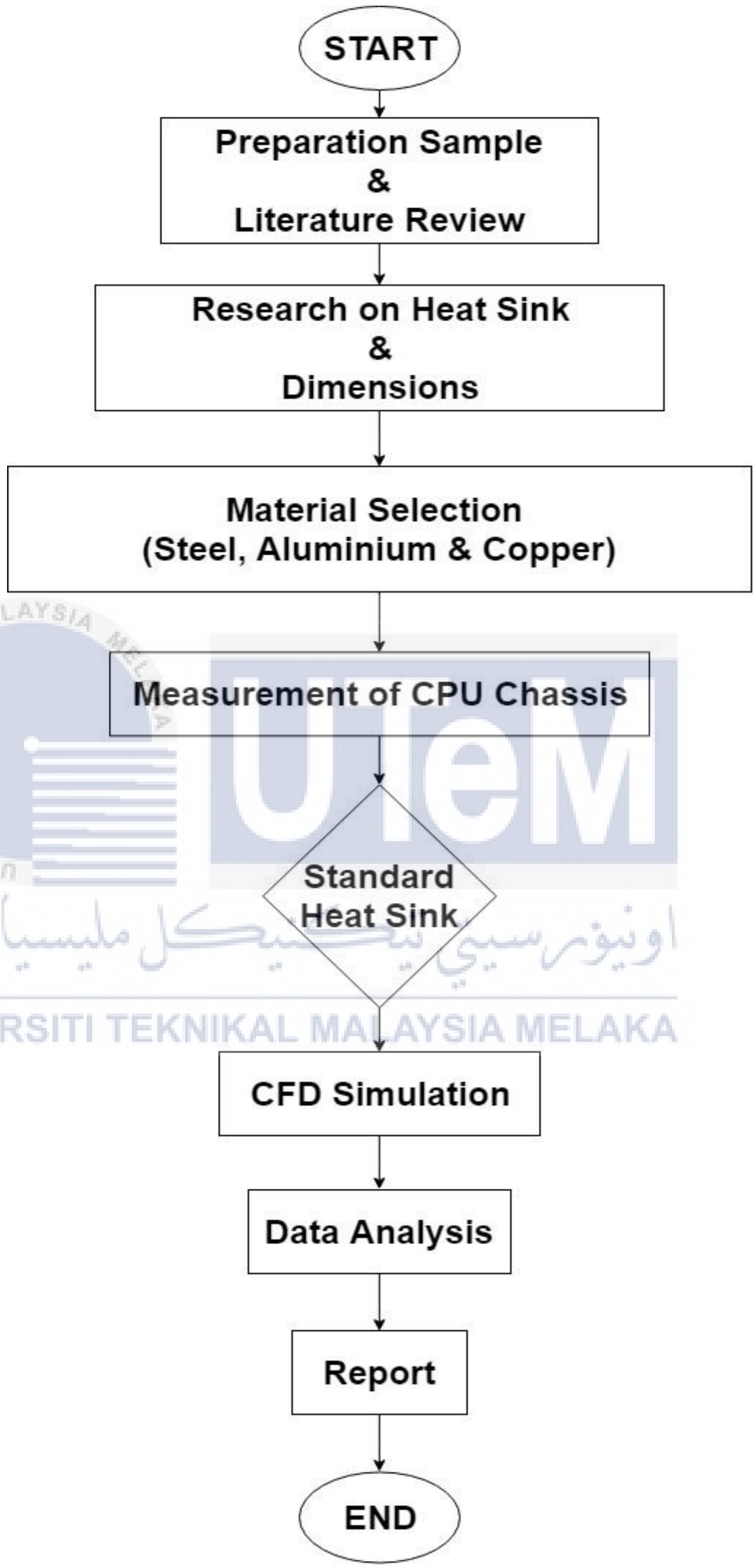

Figure 3.1: Flow Chart of Project

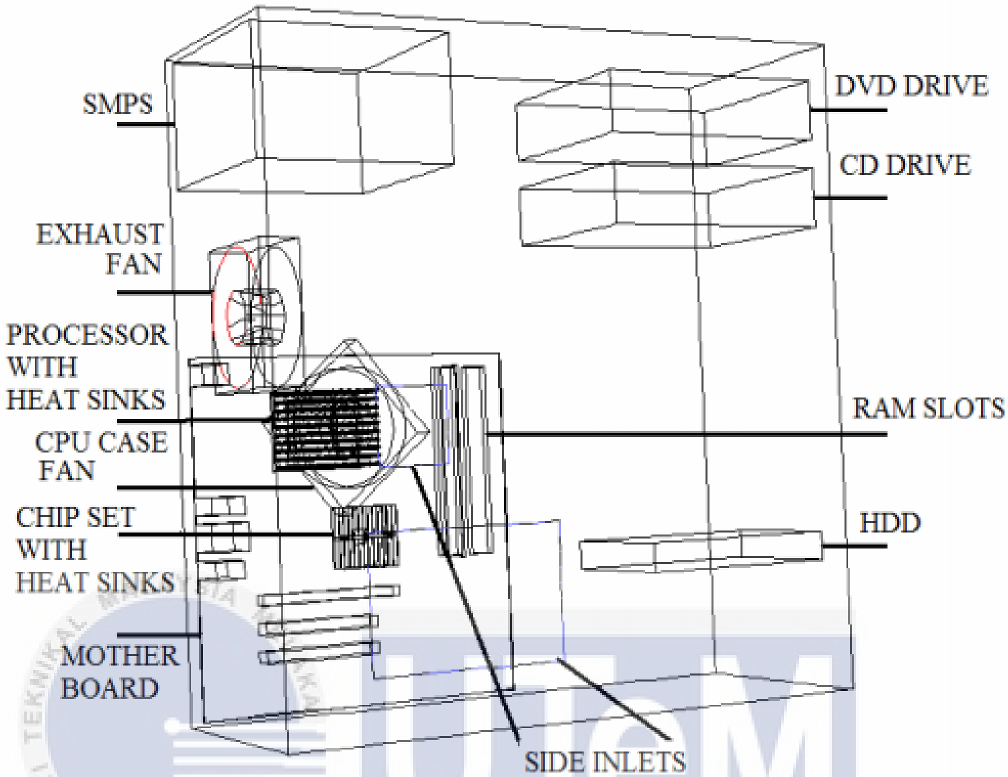

Figure 3.2 Computer chassis 3D model

(Source: Mohan and Govindarajan, 2011)

3.3 Dimensions

The standard size of the ATX is 12 inches equivalent to 30.48 with a width varying from 6.7 to 9.6 inches or 17.526 and 24.384. Cross sectional area of CPU is taken which is 25 mm x 25 mm and it is a commercially available AMD CPU 80 W is dissipates by the CPU. 53 mm x 64 mm dimensions elongated heat sink base plate size is choosen for this project. The base plate thickness is 3.5 mm which is aluminium materials (Liang and Hung, 2010).

Besides that, to improve the heat transfer rate 2.4 mm to 5.0 mm thick copper provided to spread the heat from CPU processor. For the fin the dimensions are 2.4 mm, 40 mm fin height, 55 mm x 64 mm heat sink base plate. There also 5 mm gap between power supply and the fin tips. This dimensions where choosen because it's the best optimum design of heat sinks that used in previous reasearchers. Later while in the analysis the fin height will be change randomly in order to find out the heat distribution efficiency when ever the heat sink dimension changes (Mohan and Govindarajan, 2011b).

3.4 Chassis and Components in CPU

Figure 3.3 shows the design which created by using Fusion 360 drawing software. In this design the parts and also the heat dissipate components are explained detail by drawing. The dimension of the design are according to the dimensions mention early at Figure 3.3. This drawing later will be analyze on the CFD analysis on the heat distribution inside this computer chassis.

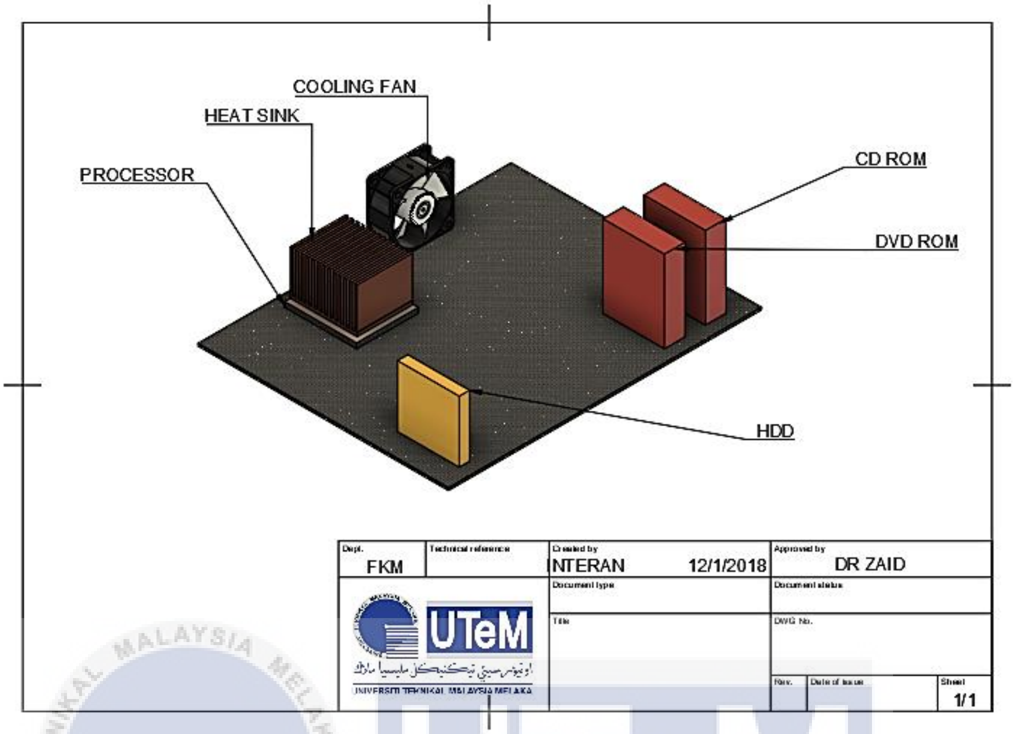

Figure 3.3 Chassis CPU Design

3.4.1 Simplified Design for CFD Pre-Processing

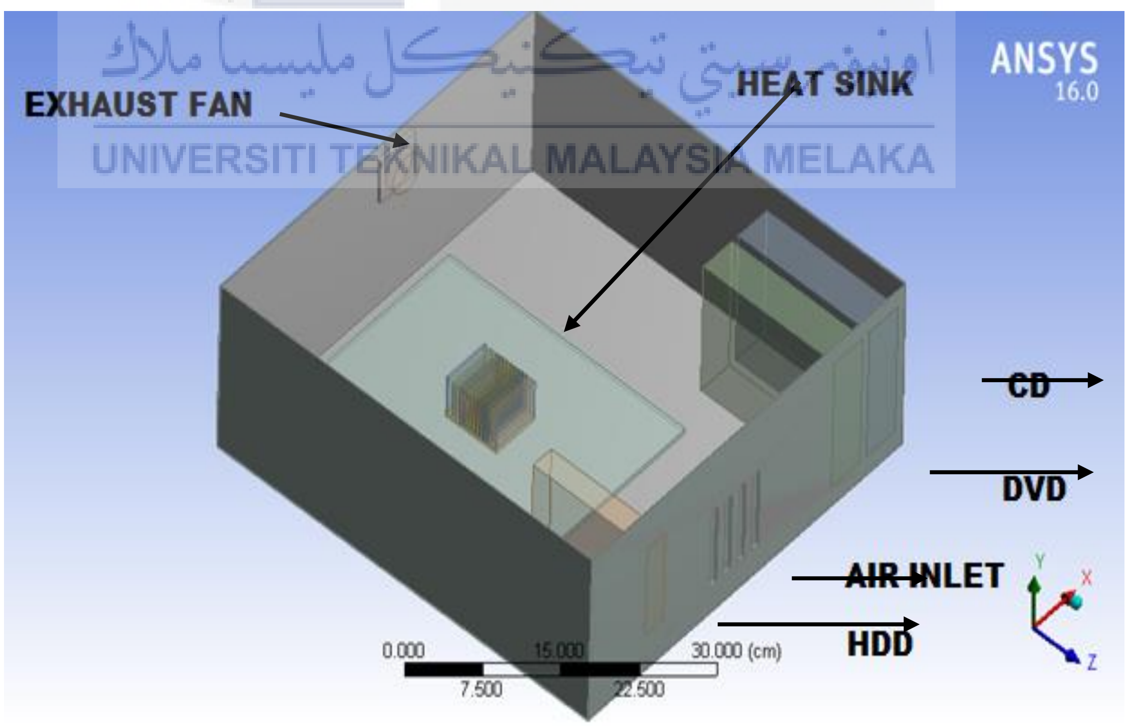

Figure: 3.4 Simplified Design of CPU Chassis for Simulation

The purposed of the design simplified is because there is an error in skewness which is above 0.95 – 1, while doing meshing. Due to this the CFD fluid fluent solver cannot solve the solution and it all give warning says “Divergence Temperature Detected”. This is because the ANSYS software fixed to be like that, where the solution can be done when the skewness is below < 0.95. In order to get a good result skewness below < 0.95 is considered as a priority in CFD fluid fluent. Besides that, from the Figure 3.4 the fan design considered as lumped system and an ideal fan, where the energy in of the fan is equal to the energy out of the fan.

CHAPTER 4

RESULTS & DISCUSSION

4.1 Introduction

A simulation is an imitation of some real thing, state of affairs, or process. The act of simulating something generally entails representing certain keys characteristics of a selected physical system. The formal modeling of systems has been by a mathematical model, which attempts to find analytical solutions to problems which enable the prediction of the behavior of the system from a set of parameters and initial conditions. Computer simulation is often used as a substitution for, modeling systems for which simple closed form analytical solutions are not possible. There are many different types of computer simulation; the common feature they all share is the attempt to generate a sample of representative scenarios for a model in which a complete enumeration of all possible states of the model would be prohibitive or impossible. Several software packages exist for running computer-based simulation modeling that makes the modeling almost effortless and simple. This chapter explain about the pre-processing, solving, and also post processing for three different types of materials and one different type of design results. Where the geometry of the CPU in chapter 3 has been proceed to the next stage in ANSYS as shown in Figure 4.1 to get the results.

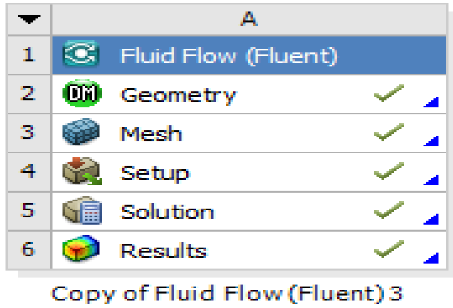

Figure 4.1: Steps to Complete the Simulation

4.2 Meshing of CPU

In this research the study of the simulation is carried out in the form of flow and temperature due to the applied heat flux in W/m^2. The process start with the meshing where the geometry has been scale to fine in order to create a good quality of meshing. The Figure 4.2 below shows the model after the meshing process.

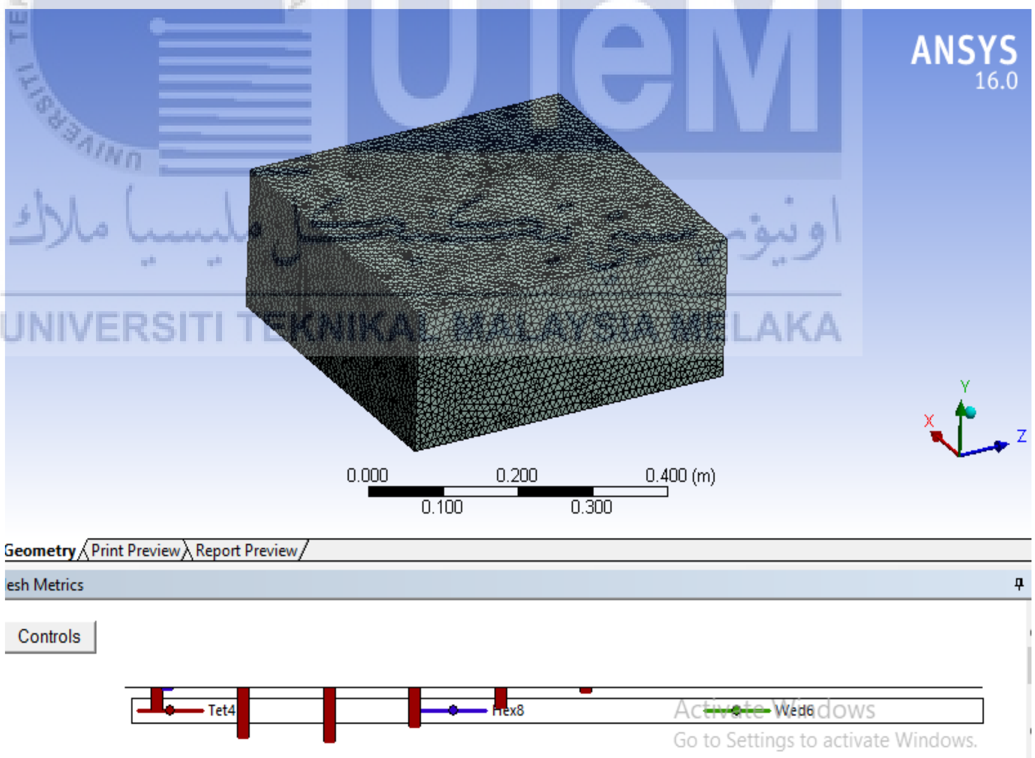

Figure 4.2: Meshing Result

Furthermore, in order to achieve a good meshing a simulator must follow the theory of CFD where it’s says a skewness generated below < 0.98 will produce a good simulation result. This is because if the skewness high enough it may cause the convergence issue, where the ANSYS solver might stop calculating the result. In this research the skewness, element and node size are shown in Table 4.1 below.

Table 4.1: Meshing Data Information

TYPE	SIZE
ELEMENTS	266148
NODES	93704
SKEWNESS	0.88598 (MAX)

4.3 Set-Up Boundary Condition

In boundary condition the information on the dependent flow variables at the domain boundaries should clearly identified. Addressing boundaries involves identifying the location of boundaries. For example inlets, outlets, wall, insulated region, heat source, and others. The data inserted in boundary setup depends upon the condition type and the physical models of the design. Poorly defined boundary conditions can have a significant impact on your solution. For example the heat generation should be from down to up but due to the wrong define it maybe be end up like up to down. In this research the boundary conditions used is a simple way by selecting the face and name it accordingly to the condition as shown in picture Figure 4.3 below.

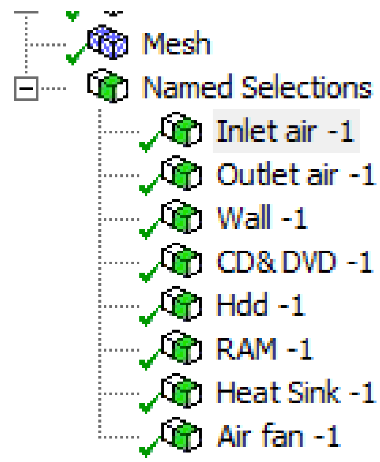

Figure 4.3: Named Selections

Where inlet is a air velocity from the fan and outlets is the heat air to be released by forced convection to the surrounding. Besides that, CD, DVD, RAM, and heat sink is solid object that release some heats. Table 4.2 below shows the value for the boundary conditions in solver (Training, 2006).

Table 4.2: Boundary Conditions Values

COMPONENTS	**VALUES**
Fan	4 .5 m/s
Heat Sink	80 W/m^2
HDD	20 W/m^2
CD	15 W/m^2
DVD	15 W/m^2
RAM	10 W/m^2
Outlet	Pressure Outlet

In addition, the solver uses Navier-Stroke equation equations are the governing equations of Computational Fluid Dynamics. It is based on the conservation law of physical properties of fluid. The principle of conservational law is the change of properties, for example mass, energy, and momentum, in an object is decided by the input and output. The equation are from Eq 3 to Eq 8 shown below (Zuo, 2012).

Continuity Equation

$$\frac{D\rho}{Dt} + \rho \frac{\partial U_i}{\partial x_i} = 0$$

[3]

Momentum Equation

$$\underbrace{\rho \frac{\partial U_j}{\partial t}}_{I} + \underbrace{\rho U_i \frac{\partial U_j}{\partial x_i}}_{II} = -\underbrace{\frac{\partial P}{\partial x_j}}_{III} - \underbrace{\frac{\partial \tau_{ij}}{\partial x_i}}_{IV} + \underbrace{\rho g_j}_{V}$$

[4]

Where,

$$\tau_{ij} = -\mu\left(\frac{\partial U_j}{\partial x_i} + \frac{\partial U_i}{\partial x_j}\right) + \frac{2}{3}\delta_{ij}\mu\frac{\partial U_k}{\partial x_k}$$

[5]

I: Local change with time

II: Momentum convection

III: Surface force

IV: Molecular-dependent momentum exchange (diffusion)

V: Mass force**Energy Equation**

$$\underbrace{\rho c_\mu \frac{\partial T}{\partial t}}_{I} + \underbrace{\rho c_\mu U_i \frac{\partial T}{\partial x_i}}_{II} = \underbrace{-P \frac{\partial U_i}{\partial x_i}}_{III} + \underbrace{\lambda \frac{\partial^2 T}{\partial x_i^2}}_{IV} - \underbrace{\tau_{ij} \frac{\partial U_j}{\partial x_i}}_{V}$$

[6]

I : Local energy change with time

II: Convective term

III: Pressure work

IV: Heat flux (diffusion)

V: Irreversible transfer of mechanical energy into heat

If the fluid id compressible, we can simplify the continuity equation and momentum equation as follows.

Continuity Equation

$$\frac{\partial U_i}{\partial x_i} = 0$$

[7]

Momentum Equation

$$\rho \frac{\partial U_j}{\partial t} + \rho U_i \frac{\partial U_j}{\partial x_i} = -\frac{\partial P}{\partial x_j} - \mu \frac{\partial^2 U_j}{\partial x_i^2} + \rho g_j$$

[8]

4.4 Results

4.4.1 Steel

In this simulation the material tested is steel, where it has a thermal conductivity of 50.2 W/m^2. Steel is the lowest thermal conductivity material simulated in this research. From Figure 4.4 below the highest temperature is 36.7 ºC, which is absorbed from the heat generated by the heat flux on the base of heat sink and transfer through conduction heat transfer. Besides that, the temperature difference of steel heat sink is around 9.7 ºC and it has the lowest temperature difference compare to the aluminium and copper. Furthermore, from the simulation can conclude that its not suitable to be the heat sink due to the lowest heat transfer rate.

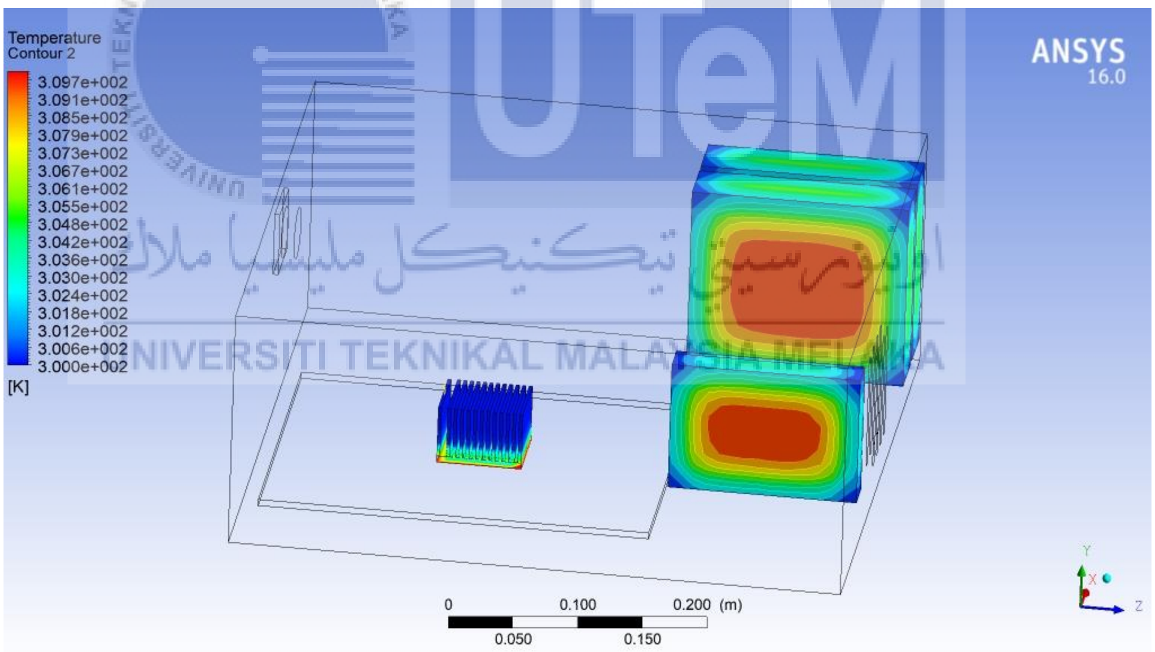

Figure 4.4: Steel Heat Sink Contour

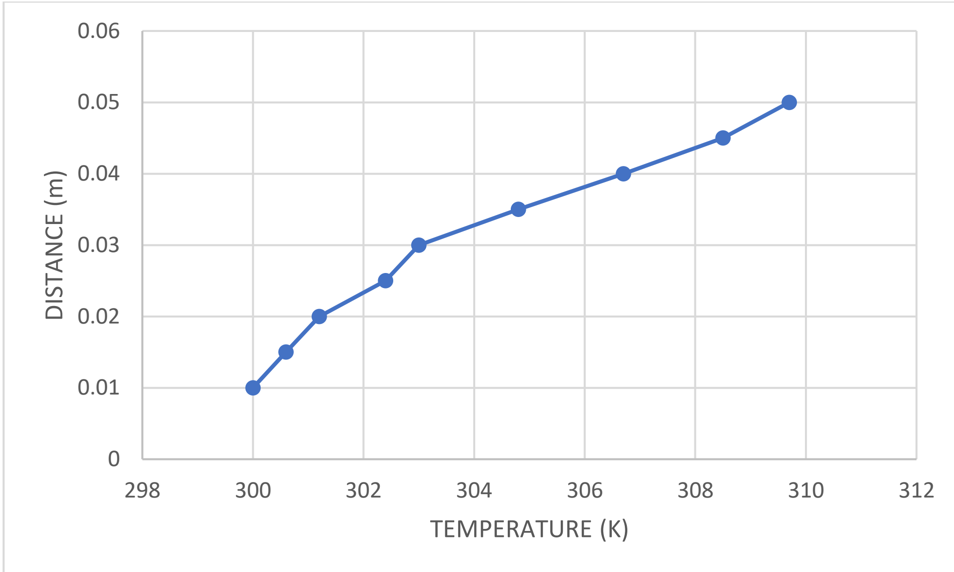

Figure 4.5: Effect of Steel

Figure 4.5 shows temperature difference over the distance of the heat sink fin from bottom to the up level.

4.4.2 Aluminium

Aluminium is the most famous material used in heat sink design and fabrication. This is because its has a medium thermal conductivity around 180 – 200 W/m^2, its much more cheaper and also it less brittle than copper. From the Figure 4.6 below can conclude that, the highest temperature of the heat sink is around 50 ^oC and the temperature different is around 23 ^oC, where its much more capable than the steel material.

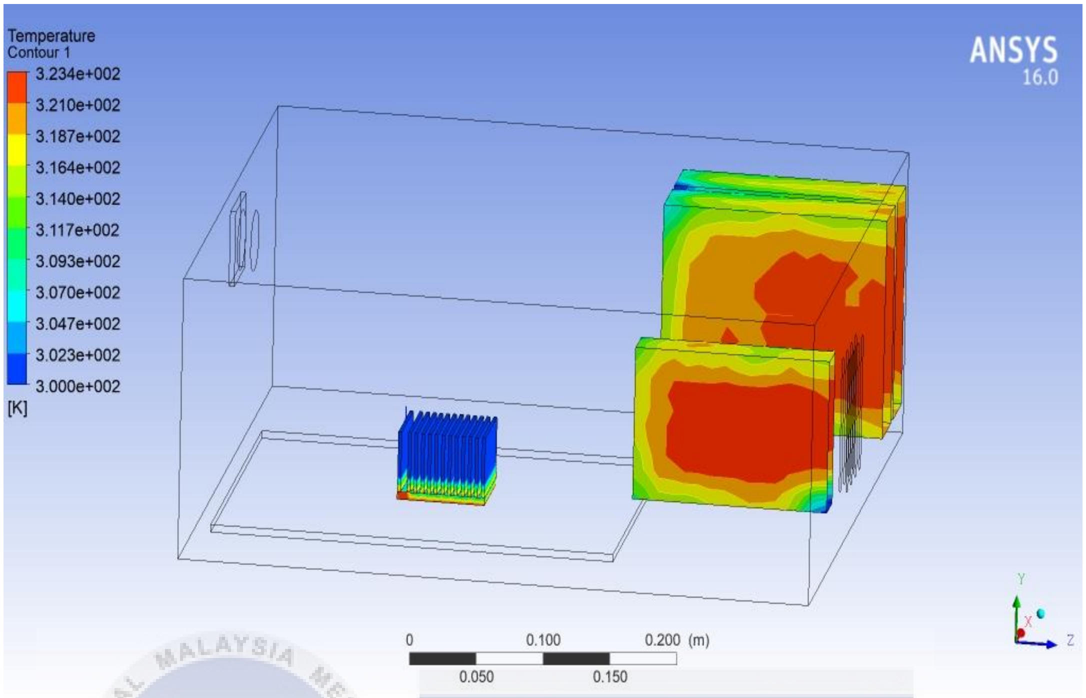

Figure 4.6: Heat Sink Contour of Aluminium

Graph in Figure 4.7 below shows the temperature rises of the aluminium heat sink over distance. Besides that, the temperature transfer due to the conduction is much higher over distance compare to the steel. This is because there is a huge gap in between the thermal conductivity of the material steel and aluminium.

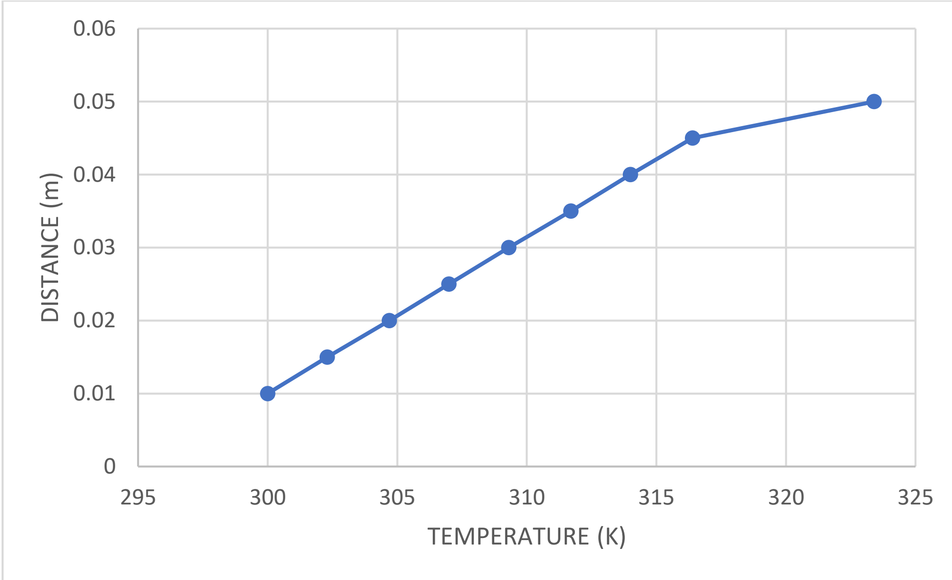

Figure 4.7: Effect of Aluminium

4.4.3 Copper

Copper is the material which having the highest thermal conductivity compare to the others. The k of copper is around 387.9 W/m^2 and it's the most suitable material for heat sink fabrication but due to the high brittleness characteristics and low quality of the milling machine in past its cannot fabricated to be a heat sink. Moreover material copper is expensive due to the good quality in heat transfer and a good current conductor. With the latest and new current technologies they can fabricate the copper heat sink in a good quality form. The Figure 4.8 shows the highest temperature absorbed by the copper heat sink, which is 60 ^{o}C and the temperature difference is 33 ^{o}C, where it has overall of 96.73 % heat transfer.

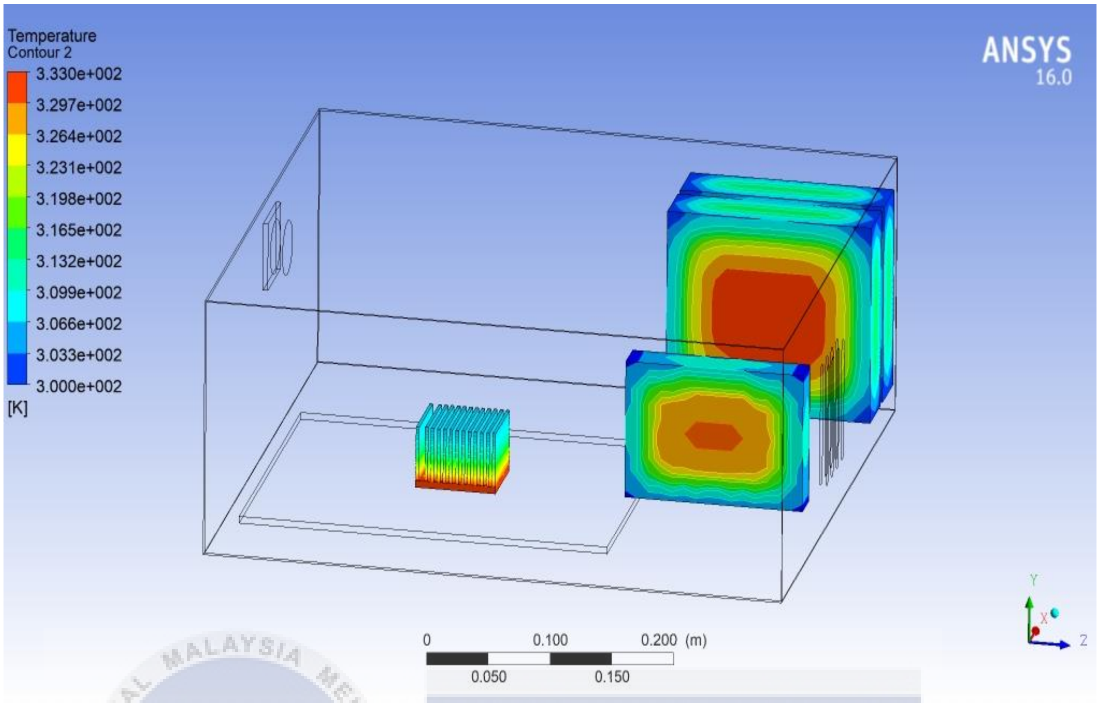

Figure 4.8: Heat Sink Contour of Copper

From the graph in Figure 4.9 below heat transfer over distance much efficient due to the high thermal conductivity of the material.

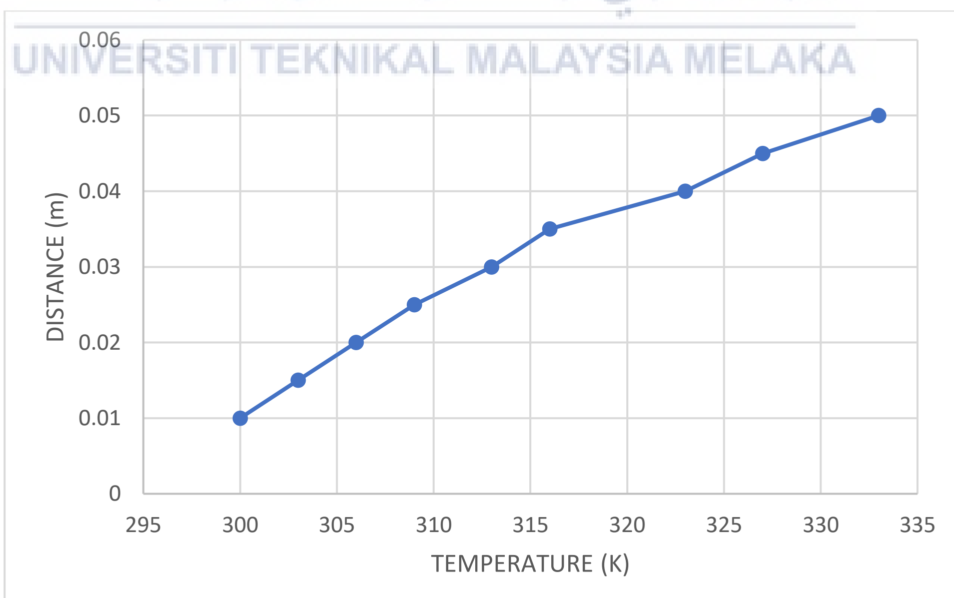

Figure 4.9: Effect of Copper

4.4.4 Flow Analysis

The flow inside the CPU chassis after simulation can be seen in Figure 4.10. The picture below shows us that the flow streamline is not uniform where it not a laminar flow. The flow identified as turbulent this because there is a fan act as forced convection and at the same time its create turbulence flow by the rotational speed and the velocity. The flow in Figure below having rotational eddies in the middle of the chassis, in between DVD&CD and also around the exhaust region. This is caused by the longer cooling process due to the unsteady flow in and out. The temperature on the base heat sink rises slowly to the upper surface. According to the thermodynamic of first law energy neither can be create or destroy but it can be transform one form to another and also includes the second law where heat always transfer from high temperature to low temperature. As in picture the heat from the base of the heat sink is slowly transferred to the upper surface.

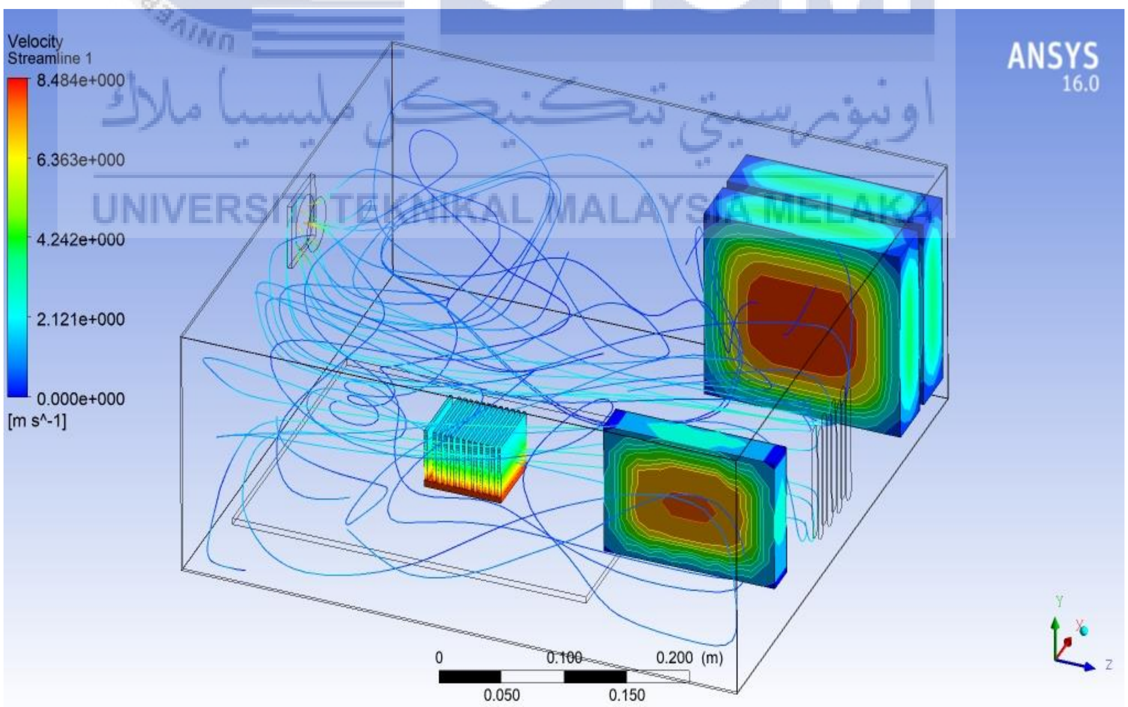

Figure 4.10: Flow Inside CPU Chassis

4.4.5 Improved Designed of Copper

Since the air flow duct is lesser, so the designed is changed to achieve a better heat transfer and heat loss in the heat sink to the surrounding. From the Figure 4.11 below the air duct in has been increased for the cooling performance of the heat sink, where the original design has 4 air inlets, while design below having 12 air inlets. The cooling rate after designed modification is around 3 ^{o}C lesser than old design, which the cooler rate is much more faster than the older chassis design.

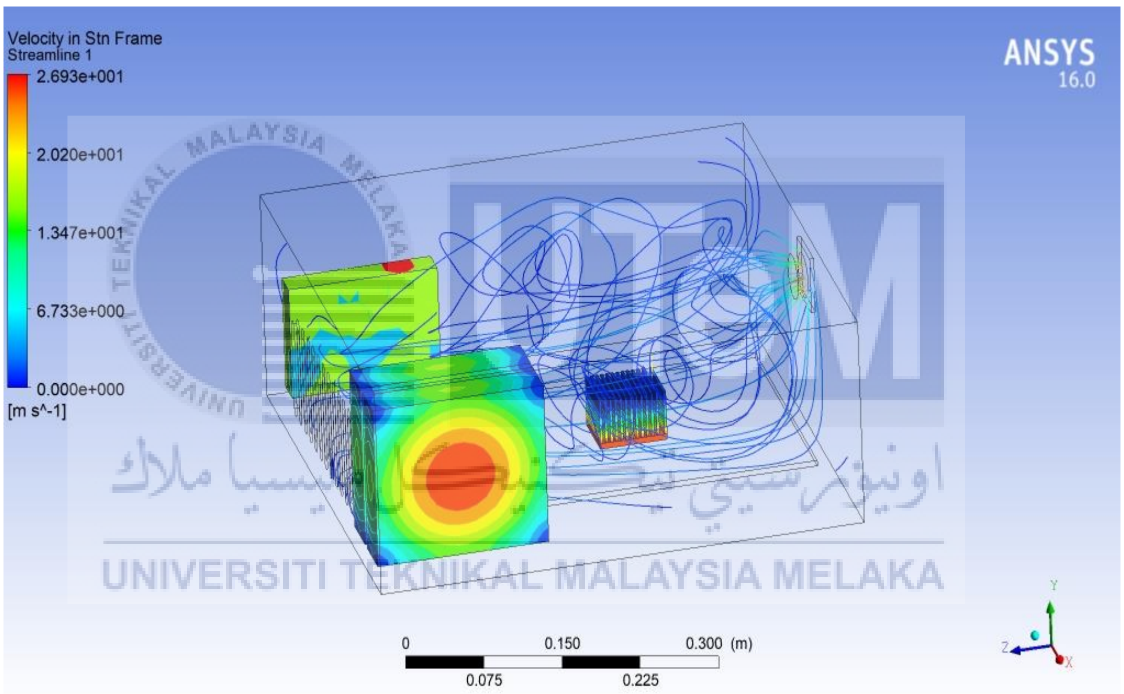

Figure 4.11: Flow inside CPU Chassis after Modification

From the Figure 4.12 below the temperature transferring over the distance is much more uniform than before this. This is because of the more air pass through the air duct.

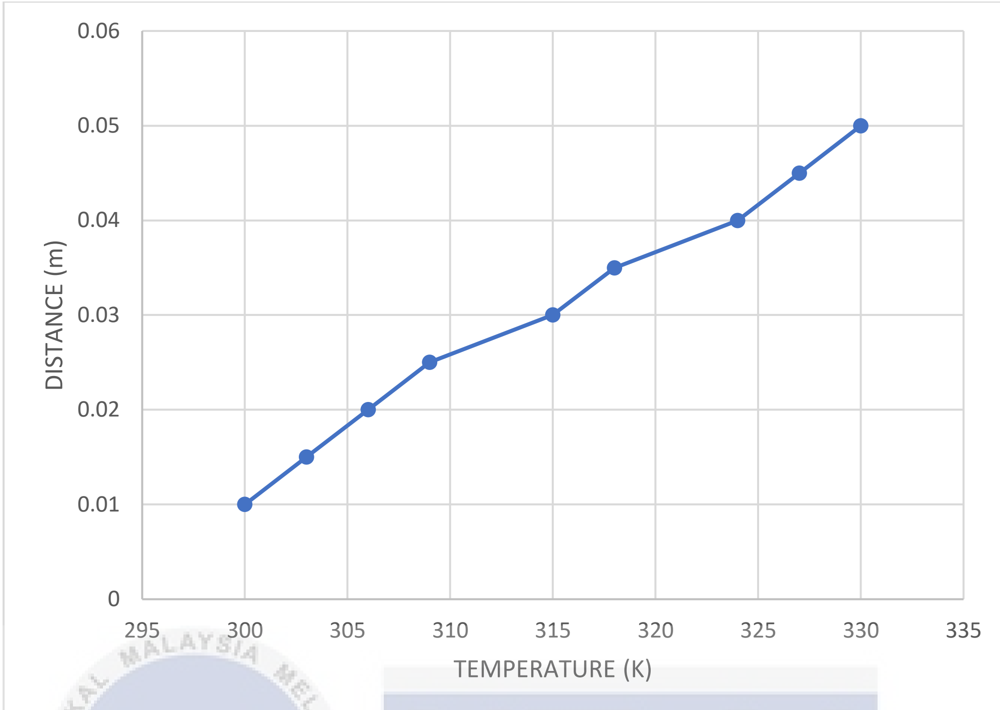

Figure 4.12: Effect of Improved Design

4.5 Discussion

This part discussed about the material comparison by using table and graph in order to show that which material is good enough to be the heat sink fabrication material and also explain about the temperature difference absorbed by the heat sink from the heat dissipation at base part of the heat sink due to the continues heat transfer through conduction by continues CPU processor operation.

4.5.1 Result Discussion

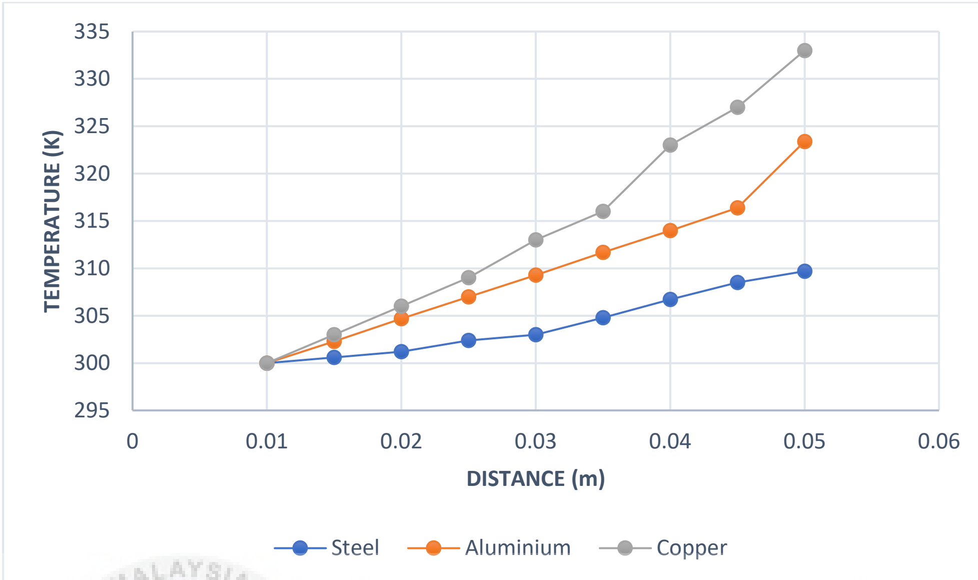

Figure 4.13: Comparison between Temperature Differences

From the Figure 4.13 above clearly shows that copper material absorbed much higher temperature than others, where the temperature is 33 °C as shown in Table 4.3. Table 4.3 is the temperature difference between the surrounding and heat sink highest temperature at the base. Besides that, the widely used heat sink material is aluminium but it's temperature different is much lower than copper, where only 23.4 °C. Furthermore, for the steel it's proven that it doesn't having the highest thermal conductivity and temperature difference to be a better heat sink.

Table 4.3: Temperature Difference between Surrounding and Heat Sink Base

MATERIAL	**TEMPERATURE DIFFERENCE**
STEEL	9.7
ALUMINIUM	23.4
COPPER	33
DESIGN CHANGED	30

4.5.2 Percentage of Heat Dissipation

Percentage of heat dissipation is the heat dissipation or electric energy that has transferred to heat energy. Figure 4.14 below clearly shows that the CPU full capacity is 2.00 GHz but the CPU working on the speed of 1.41 GHz, where after the calculation below it’s confirmed that 30 % of the energy is wasted to heat dissipation to surrounding. The cooling percentage of aluminium and copper are calculated for the heat sinks shown in below.

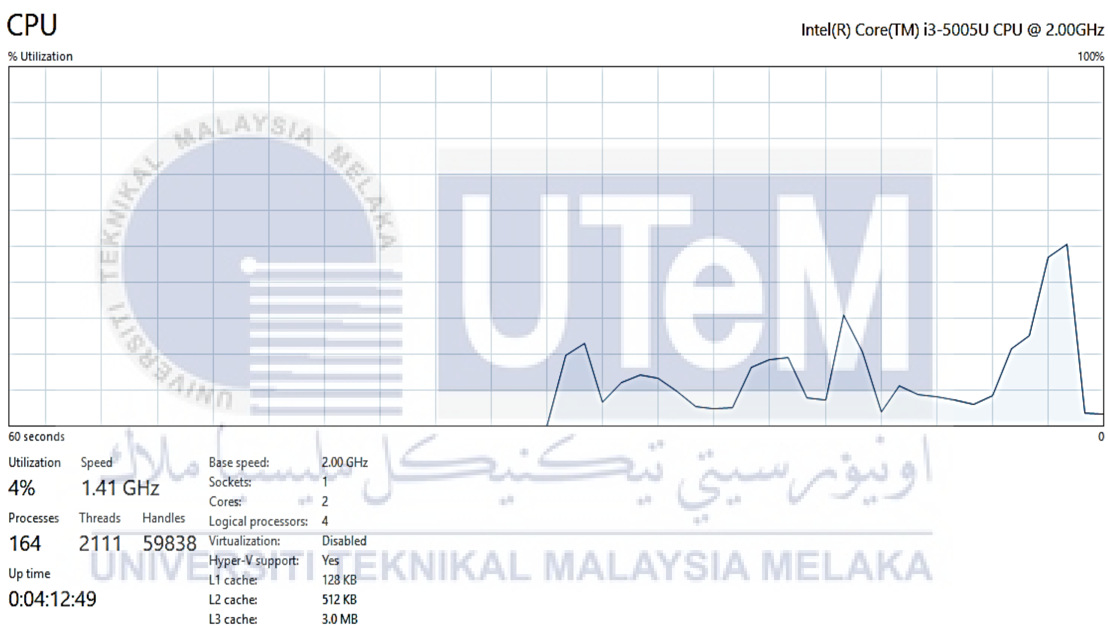

Figure 4.14: CPU Speed Performance

<u>Percentage of Heat Transferred</u>

2.00 – 1.41GHz = 0.59 GHz

(0.59/2.00) * 100 = 29.5 ~ 30%

<u>Cooling Percentage Aluminium</u>

(30/100) * 23.4 = 6.9 % heat cooling

Cooling Percentage of Copper

(30/100) * 33 = 9.9 % heat cooling

Where 9.9 % of the heat is transferred to the surrounding compare to aluminium, which is only 6.9 %.

4.5.3 Research Validation

The validation of the research is done by comparing the results obtain on CFD simulation with existing journal and also by theoretical. The design of aluminium heat sink result in temperature difference between surrounding and heat sink base has been compared in table 4.4 below, which is surrounding temperature is 300 K or 27 ^{o}C and heat sink base temperature is 323.4 K or 50.4 ^{o}C. From the table can conclude there is an error of 1.4 in CFD simulation due to the dimension of the chassis is different than the journal validation data.

Table 4.4: Aluminium Temperature Difference in CFD Simulation

VALIDATION	MATERIAL	TEMPERATURE DIFFERENCE
CFD Experimental Journal (Mohan, 2011)	Aluminium	22
CFD Simulation	Aluminium	23.4

Besides that, the validation from the Eq [9] of heat transfer for conduction below shows the temperature different is almost similar with the simulation, where from calculation below the temperature difference is 22.54 ^{o}C and from CFD simulation of this research is 23.4 ^{o}C. There is an error in the temperature difference between calculation and CFD simulation about 0.86. This due to the boundary condition that has taken count in simulation is much more deeper than in calculation such as heat loss in chassis, air flow velocity, forced convection and time is consider in simulation but neglected in equation.

<u>Heat and Mass Transfer Equation</u>

$$Q = \left(-kA\,\frac{dT}{dx}\right)^{1}$$

[9]

<u>Heat Transfer Temperature Difference</u>

80 = [-387.79 (0.00017) (26-T2/0.04)]

= 48.54°C

<u>Temperature Difference (Heat Sink & Surrounding)</u>

▲T = T2 – T1

= 48.54 – 26

= 22.54 ~ 23°C

CHAPTER 5

CONCLUSION & FUTURE RECOMMENDATION

5.1 Conclusion

In conclusion, the flow and thermal analysis on heat sink for CPU cooling with different type of material and design of chassis were investigated. Furthermore, the heat transfer in the term of temperature from base of the heat sink and to the surrounding by conduction and convection also were studied in this research. The CFD simulation process was conducted in order to achieve the objectives of this research. All the outcome results is obtained by using experimental data from previous researcher in CFD simulation process.

Besides that, the traditional rectangular plate fin heat sink widely used by thermal engineers for electronic cooling was set as the base of performance comparison since most researchers believe this model heatsink to be efficient both in performance and ease of manufacturability. The performance evaluating parameters were temperature and with different types of material. The temperature difference obtain after heat transfer simulation for steel, aluminium, copper and also designed changed were 9.7^{o}C for steel, 23.4^{o}C for aluminium, 33^{o}C for copper and 30^{o}C for designed changed respectively. Three different type of material and one designed changed models were simulated and compared to the rectangular fin heatsink. From the results obtained can conclude that, the heat sink with copper material type having the highest heat transfer rate from the CPU heat dissipation and it's consider as a good material in order to increase the performance of the CPU.

From this research, it can be concluded that numerical simulation methods / tools including such as CFD software (ANSYS) proves to be a cheaper, safer and viable way of testing heatsink performance. Also, with improved manufacturing methods like 3D / additive printing techniques nowadays, complex geometry and exotic heat sink fin models that improve cooling of electronic devices can be manufactured.

5.2 RECOMMENDATION

As a recommendation for the future works include optimizing heat sink performance by running simulations on exotic or more complex heat sink designs using knowledge not only on heat transfer but also in fluid mechanics and additive manufacturing/ 3D manufacturing capabilities. Other suggestions for future work include:

- Conduct thermal analysis on different type of heat sink such as angled heat sink fins, circular and also short rectangular fin.
- Consider the system as not a lumped system analysis on the other components inside the chassis such as CD, DVD and RAM.
- Collect the temperature and data with the most reason design because CPU geometry modification occurs rapidly.
- Determine the optimal number of fins for both plate and pin fin heat sinks geometries for maximum performance.

- Run CFD simulation with the flow in the turbulent regime and analyzed the difference in result between laminar regime.
- 3D print and conduct experimental test on heat sink models generated.
- Conduct experiment by changing the heat sink to copper in real CPU.

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