UNIVERSITI TEKNIKAL MALAYSIA MELAKA

STUDY FOR THE EFFECT OF BLOWING DIRECTION ON HEAT TRANSFER OF COOLING TUBE BY CFD SIMULATION AND EXPERIMENTAL PROCESS

This report is submitted in accordance with the requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor of Mechanical Engineering Technology (Refrigeration and Air-Conditioning Systems) with Honours.

by

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DECLARATION

I hereby declare that the result of this project titled "Study for the Effect of Blowing Direction on Heat Transfer of Cooling Tube and Heat Optimization by CFD Simulation and Experimental Process" is based on my research except for the sentences as cited in references.

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Date	:	13 December 2017

APPROVAL

This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfilment of the requirements for the degree of Bachelor of Mechanical Engineering Technology (Refrigeration & Air-Conditioning Systems) with Honours. The member of the supervisory is as follow:

Dr. Mohamad Haidir Bin Maslan

(Project Supervisor)

ABSTRAK

Tiub penyejukan ialah komponen yang digunakan secara meluas dalam aplikasi mekanisma pemindahan haba. Komponen ini mempunyai kebolehan yang baik untuk memindahkan tenaga haba daripada cecair yang mengalir di sekelilingnya dan mengalihkan tenaga tersebut ke dalam cecair yang mengalir di dalamnya. Bagi sistem pendingin hawa, terdapat dua peranti pemindahan haba boleh didapati untuk mengawal keperluan beban penyejukan dalam ruang tertentu. Dalam kajian ini, peranti penyejukan di ambil kira untuk melakukan aktiviti-aktiviti penyelidikan yang selanjutnya. Salah satu faktor yang dikenalpasti boleh mempengaruhi kadar pemindahan haba di dalam peranti ini adalah sudut kedudukan tiub penyejukan terhadap arah aliran udara. Oleh itu, kajian ini dijalankan bagi menyiasat sudut kedudukan tiub penyejukan apa yang mempunyai kadar pemindahan haba yang tertinggi antara cecair-cecair yang terlibat dalam sistem tersebut. Tiub penyejukan yang dipilih ialah tiub tembaga. Satu model prototaip yang ringkas dibina mengandungi laluan pada kedua-dua belah dinding prototaip bagi mengawal sudut kedudukan tiub tembaga. Tiga sudut kedudukan tiub tembaga yang berlainan yang dipilih ialah sudut 90°, 45° dan 0°. Dua nilai parameter yang di ambil untuk setiap sudut adalah suhu udara keluar dan air sejuk keluar. Suhu udara masuk dan air sejuk masuk ditetapkan pada nilai yang sekata. Terdapat dua jenis kajian yang dibuat iaitu kajian eksperimen dan kajian simulasi bagi membandingkan hasil kedua-duanya. Perisian pengiraan dinamik bendalir digunakan dalam kajian simulasi. Kedudukan tiub tembaga pada sudut 90° mempunyai nilai kadar pemindahan haba yang tertinggi dalam kajian eksperimen manakala dalam kajian simulasi: kedudukan tiub tembaga pada 45° mempunyai nilai kadar pemindahan haba yang tertinggi. Berdasarkan konsep situasi sebenar dalam kehidupan, data dalam kajian eksperimen telah diputuskan untuk dipilih sebagai data yang sewajarnya. Secara konklusinya, kajian ini telah mengenalpasti dan membuktikan sudut kedudukan tiub tembaga apa yang paling cekap dalam peranti penyejukan.

ABSTRACT

Cooling tube is a component that has been widely used in the application of heat transfer mechanism. This component has a good capability to transfer heat energy from a fluid flowing outside them and impart the energy into the fluid flow inside them. In air conditioning system, there will be two heat transfer devices available to regulate the cooling load inside the space. In this study, a cooling device is being taken into account for doing further research activities. One of the factors that has been identified can affect the heat transfer rate in this device is the angle of cooling tube position towards blowing direction of air. Hence, this study was carried out to investigate which angle of cooling tube position has the greatest rate of heat transfer between the fluids involved in the system. Cooling tube chosen surely is a copper tube. A simple modelling of prototype had been built includes a pathway at the both side wall of the prototype for regulating the angle of copper tube position. Three different angle of copper tube position chosen are 90°, 45° and 0° angle. Two parameter values were being taken for each angle which was outlet air and outlet water temperature. Inlet air and inlet water temperature were being kept at a fixed value. There were two types of study have been practiced which were experimental and simulation study in order to compare both results. Computational fluid dynamics (CFD) software was being used for the simulation study. The 90° angle of copper tube position had the highest value of heat transfer rate in experimental study while in the simulation study; 45° angle of copper tube position had the highest value of heat transfer rate. Based on the concept of real life situation, the results in experimental study have been decided to take into consideration as the appropriate results. In conclusion, this study had determined and verified which angle of copper tube position is the most efficient in the cooling devices.

DEDICATION

This final year project specially dedicated to my beloved parents, Mr Johari Bin Sargi and Mrs Sariffah Rodiah Binti Ariffin. Their endless love motivates me to complete my project successfully. Not to forget to my family who always cherish me up and supported me.

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I felt very grateful to have completed my final year project for bachelor degree in Universiti Teknikal Malaysia Melaka (UTeM). Thank you to my supervisor, Dr. Mohamad Haidir Bin Maslan for always keeps giving me guidance through the progress of this project and shared much knowledge to help me doing my tasks in a proper way. I could transform my basic idea into this project successfully with his assistance and encouragement.

Next, thank you too to other lecturers whose being very cooperative in teaching me about the techniques to use Computational Fluid Dynamics (CFD) software and also advise me in the construction of prototype model. Thanks to lab assistants whose always giving me opportunity for using the lab equipment and also supervise me during the experimental process.

Special thanks to my beloved family who supported me to build my passion for completing this project successfully. Their concerns boost my confidence level whenever I feel down.

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LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

CFD	-	Computational Fluid Dynamics
$\dot{Q}$	-	Heat transfer rate
W	-	Watt
k	-	thermal conductivity
A	-	area
h	-	convection heat transfer coefficient
T	-	temperature
α	-	absorptivity value
σ	-	Stefan-Boltzmann constant
$\dot{m}$	-	mass flow rate
ρ	-	density
$\dot{V}$	-	volume flow rate
V	-	velocity
c_p	-	specific heat value
atm	-	atmospheric pressure
MPa	-	megapascal
g/cm^3	-	gram per cubic centimetre
W/m.K	-	watts per meter-kelvin
L/h	-	litre per hour
m/s	-	meter per second
psi	-	pounds per square inch
kg/s	-	kilogram per second
C	-	Heat capacity rate
ε	-	emissivity value / heat transfer effectiveness
K	-	kelvin
kW/k	-	kilowatt per kelvin

CHAPTER 1

INTRODUCTION

This chapter describes about five subtitles which are background, problem statement, project objective, work scope and limitation. Project objective has been divided into two types which are general objective and specific objective.

1.1 Background

Heat transfer played the important roles in many aspects of life. This natural phenomenon gives many advantages to the life of living things and with the application of heat transfer, people can build a machine or a devices that will makes us live in a comfortable condition and doing the daily activities more easily. One of the applications is the heating, ventilating and air conditioning system. In general, this system will control the temperature and humidity for the occupant by its counteracting to the environment condition and weather. People can achieve their thermal comfort using this system.

There are three basic mechanisms of heat transfer named conduction, convection and radiation. Conduction is the energy transfer between the particles and this mode can occur through solids, liquids and gases. Convection is the energy transfer between gases or liquid that is in motion with the solid surface. Radiation is the energy send out by a body in the form of electromagnetic waves. All this three modes of heat transfer require temperature difference in order for them to happen and the transfer of energy was always from the higher temperature to the lower one.

Basically, heat transfer of cooling tube occurred by the two modes which are conduction and convection. Firstly, convection heat transfer takes place on the interior surface of cooling tube between the fluid and solid surface. Fluid inside the tube will transfer its heat energy to the solid surface. Then, heat energy imparted to the solid surface will experienced conduction heat transfer between the particles through the wall of cooling tube. Lastly, convection heat transfer further takes place on the exterior surface of cooling tube between the solid surface and surrounding fluid. Heat energy from the solid surface transferred to the surrounding fluid. In the cooling device application, fluid flows inside the tube will be chilled water while fluid flows through the tube were surrounding air. Both fluids forced by the mechanical devices such as water pump and blower. In conclusion, heat energy from the chilled water transferred to the air makes the forced air leaving the cooling tube in a cold temperature.

This project is about a study on the rate of heat transfer for different angle of copper tube position towards the blowing direction of air. There will be several angle have been chosen for this case study which are 90°, 45° and 0° of copper tube position. Student need to do the experimental and simulation on this study. For the experimental, a prototype will be build up from the parts included such as copper pipe, usb aqua pump, usb fan and vinyl tubing. Then, a simulation will be doing by Computational Fluid Dynamics (CFD) software. Many parameters from the simulation of this study can be obtained through this software such as heat dissipation amount and heat transfer coefficient.

1.2 Problem statement

Different direction of fans blowing towards the cooling tube gives different effect on heat transfer occurred throughout the cooling tube. It is important to justify which one of the direction for air flow will gives the higher rate of heat transfer. For this project study, there are three angle of cooling tube position towards blowing air direction have been chose which are in 0°, 45° and 90° angle. A better choice for the angle that contributes to higher efficiency of heat transfer will makes an air conditioning system works more efficient. This is because the cooling effect by the medium of heat transportation involved can be maximized without the need of high energy consumption compared to another angles of air flow towards the tube. Rate of heat transfer for the fluids involve at each configuration can be determined to analyse the effect of heat transfer on the different angle of cooling tube position.

1.3 Project objective

1.3.1 General objective

1. This project aims to study heat transfer on cooling tube with different angle of cooling tube position towards air blowing direction

1.2.2 Specific objective

1. To find out the rate of heat transfer of different angle of cooling tube position by determining the temperature difference
2. To establish an experimental study and propose a simulation which uses Computational Fluid Dynamics (CFD)
3. To compare and analyze the data between the experimental and simulation study
4. To validate Computational Fluid Dynamics (CFD) simulation model with experiment

1.4 Work scope

Main parameter to be investigating is the different angle of cooling tube position towards air blowing direction. There are three angle chosen for these projects which are 0°, 45° and 90° angle of cooling tube position. Another parameter that is important in analysing the result is the rate of heat transfer. Rate of heat transfer will be calculated using specified formula by taking the air and chilled water temperature. Both the discharge air temperature and the chilled water outlet temperature will be inserted into the specific formula for analysing the heat transfer rate. Temperature of water before and after entering the system also will be taken and the temperature gain for blowing direction will be determine and further being analyse.

1.5 Limitation

The limitation for this project study is the temperature of water in water tank maybe varies as the temperature of the environment affects the water temperature. This limitation needs to be managed by manually control the inlet water temperature in a proper way. Second limitation is the temperature of air inside the box may be varies when the experiment was being kept running as the time consuming increased. This variation in temperature will affect the temperature of air inside the box. Hence, the data of inlet and outlet tube also being affected because of the existing process of heat transfer occurred before.

CHAPTER 2

LITERATURE REVIEW

For the introduction in this chapter, commonly it will describe on the literature review related to the title which is heat transfer. There are many points and sub points that will discuss in this chapter. The points will be cooling tube, heat transfer, heat transfer of cooling tube and the effect of cooling tube orientation. Heat transfer will be converging into three sub points which are conduction, convection and radiation. Then, heat transfer of cooling tube has two sub points named modifications and the equation.

2.1 Cooling tube

Cooling tube is one of the main components in heating, ventilating and air conditioning (HVAC) systems. It contributes to the important role in the systems which is air flow being forced over the tube into the space to be conditioned for transferring the cooling load from the air loop to the chilled water loop (Wang et al., 2004). Basically, cooling tube was located in the heat exchanger devices for the purpose of transferring heat. There are many models for cooling tube currently available in markets. Many considerations on the properties of the cooling tube must be taken to get the optimize performance for the cooling tube to play its role. Usually, the heat transfer properties of the tube determine their performance and affect the performance of HVAC systems. In addition, there were some other properties that a cooling tube must have which are resistant to corrosion, high level of heat transfer, machinability and consumption of less refrigerant.

2.2 Heat transfer

Heat transfer is the science that deals with the determination of the rates of such energy transfers (Cengel & Afshin J. Ghafar, 2015). This transfer of heat energy was always from the higher temperature to the lower temperature medium and it stops transfer when the two mediums have achieved the same temperature. From the statement above, we can conclude that the transfer of energy will be triggered when there is a difference in temperature between systems. Heat transfer can be defining as something flows from hot objects to cold ones and it is called flow of heat (Iv & Lienhard, 1986).

Heat transfer was commonly happened around us without our control and conscious. It is very important to take a detailed study as its concept and science were related to our life. As an example of heat transfer process, we can notice that cooling tube always being warm by getting the heat from the air flows that being forced by a fan. Actually, heat flows constantly from the sucked air into the surface of cooling tube. Although there is no presence of fan to the room, some small buoyancy-driven motion of the air will continue because of the density difference between the hot and cold air (Iv & Lienhard, 1986). This process occurred on all living things and in the air around us. It is naturally happens and we cannot prevent the transfer of heat but this process can be control with the application of the heat transfer study. That"s why we need to learn about the science of heat transfer and not just concern with the thermodynamic analysis alone.

As we know, thermodynamics study is about the amount of heat transfer as one system goes from one equilibrium state to another. Meanwhile, the science of heat transfer deals with the question of how fast a change is accomplished (Vlachopoulos & Strutt, 2002). In simple words, the study of heat transfer can gives the indication on how long the process of heating or cooling will consume. For example, amount of heat transferred from a heater lunch box can be determine as the food inside the box cools from 50°C to 40°C using a thermodynamics analysis but user and the designer of the heater lunch box must be considered about how much the times taken for the hot food inside the box cools to 40°C. This problem will be solving by the science of heat transfer. From the statement above, we can see there is a relationship between the subject of thermodynamics and heat transfer. This relationship was being proved from the fact that the laws of thermodynamics lay the framework for the science of heat transfer (Cengel & Afshin J. Ghafar, 2015).

The first law states that the rate of energy transfer into a system is equal to the rate of energy increase of that system. The second law states that the heat will be transferred from the higher temperature to the lower one (Figure 2.1). For example, this phenomenon can be seen through the mechanism of heat exchanger in air conditioning system. When cool water or refrigerant flows inside a cooling tube, apparently heat from the surface of the cooling tube will be transfer to the medium as a result of temperature difference. Heat will be transferred to the medium and the medium becomes hot. It is same with the nature of life that all the things from the higher place will move to the lower one as a result of gravity force. As stated before, heat transfer process needs a difference in temperature in order for them to occur. If there is no difference in temperature, there will be no net heat transfer between the systems. As a conclusion, temperature difference is the driving force for heat transfer. The magnitude of the temperature gradient (the temperature difference per unit length or the rate of change in temperature) affects the rate of heat transfer in a certain direction (Cengel & Afshin J. Ghafar, 2015). Higher rate of heat transfer corresponds to the larger temperature gradient.

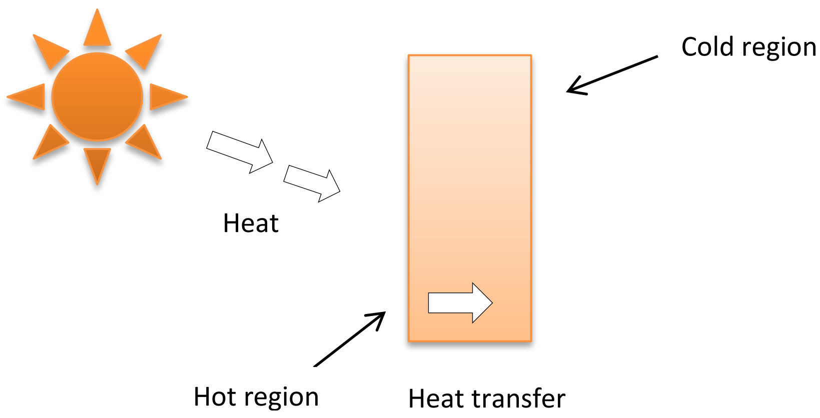

Figure 2.1: Transfer of heat from the higher temperature to lower temperature

Heat transfer has a wide area of application in our life such as the air conditioning system that most of the climate country using it. Without the mechanism of heat transfer, air conditioning system cannot be created and works to deliver the heat from one part to another. There were many advantages that can be applicant of this nature thing. As there are no things that completely perfect in this world, heat transfer also has disadvantages and some limitations. One of the limitations is some metal can be melt when heat supply is too high. Therefore, the study of heat transfer is important for designer and other related people. The limitations can be avoid and being control with the proper actions. Heat transfer can be divided into three modes which are conduction, convection and radiation. Different modes correspond to different mechanism and medium of heat transfer. In order for all the modes to happen, existence of temperature difference between a medium were needed. As mentioned earlier, the transfer of heat was always from the higher temperature medium to the lower temperature one.

2.2.1 Conduction

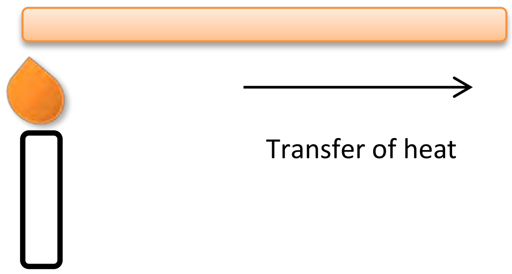

Figure 2.2: Heat conduction through a metal of rod

Conduction occurs through the interactions between particles. When particles interact, energy from the higher energy particles of a substance will transfer to the lower energy ones. The motion of molecules and electrons was the basic microscopic mechanism of conduction (Vlachopoulos & Strutt, 2002). This mechanism can occur whether in solids, liquids or gases. Through solids, heat transfer was happened due to two combinations of factors which were the vibration of molecules in lattice structure and from the energy transport by free electrons. Meanwhile, for liquids and gases cases, conduction can occurs during molecules move in random motion. They will collide between themselves and process of diffusion takes place. There are many examples of conduction mechanism occur throughout our surrounding. One of the examples is temperature of cooling tube wall will increases as the supply air flows through it as a result of heat transfer through the metal by conduction.

Several factors were important for their contributions to the rate of heat conduction through a medium. The factors are thickness of a medium, its geometry, the material of the medium and the temperature difference through the medium (Cengel & Afshin J. Ghafar, 2015). For example, the justification for the factor can be seen on the piping of air conditioning systems. By looking towards the piping connection, there was an insulating material wrap up the pipe. This is because the designer wants to minimize the amount of heat transfer to the pipe. The better and the thicker the insulation, the lesser the tendency for heat transfer takes place on the pipe. Next factor can be identifying through the fact that different material gives different ability to absorb and loss heat in a specific time. Usually, better material will cost highly as we known because of its ability to maximize the amount of heat transfer takes place. Larger surface area also will correspond to higher amount of heat transfer.

Besides that, another fact that can be used to justify the factor is when the temperature difference between a medium is greater, the rate of heat transfer also will be higher. Based on all the facts above, we can conclude that rate of heat transfer were inversely proportional to the thickness of a medium but directly proportional to the temperature difference across the medium and surface area of a medium (Cengel & Afshin J. Ghafar, 2015).

$$\text{Rate of heat conduction} \infty \frac{\text{(Area) (Temperature difference)}}{\text{Thickness}}$$

From the above relationship, all the parameters can be expressed as:

$$\dot{Q}_{cond}\ (W) = kA\,\frac{T_1 - T_2}{\Delta T} = -\,kA\,\frac{\Delta T}{\Delta x}$$

where the k above represents the value of thermal conductivity for the material (Table 2.1). Thermal conductivity is a measure on the ability of the material to conduct heat.

According to Fourier"s law of heat conduction, equation above can be reduces when a limiting case of Δx were approximate to zero (Cengel & Afshin J. Ghafar, 2015). The equation is:

$$\dot{Q} = -\,kA\,\frac{dT}{dx}$$

The $\frac{dT}{dx}$ above represents the temperature gradient. Temperature gradient is the slope of the temperature curve for the graph of temperature against distance between two temperature measurement points (T against x). From the equation above, it can be seen that the rate of heat conduction is directly proportional with the value of thermal conductivity. Besides that, the rate of heat conduction also can become higher when the temperature gradient is increasing. As the heat is conducted in the direction of decreasing temperature, temperature gradient will be negative because of the linear shape of graph is decreasing towards the increasing distances. So, in order to make the value of heat transfer becomes a positive value, there is a negative sign in the latest equation.

Table 2.1: Thermal conductivities of some materials at room temperature (Cengel & Afshin J. Ghafar, 2015)

Material	k, W/m.K
Diamond	2300
Silver	429
Copper	401
Gold	317
Aluminium	237
Iron	80.2

For the calculated area involved in the equation, the area must be the contact surface area that facing towards the heat transfer direction (Figure 2.3). This statement means that the thickness of the material not required to be considering in the calculation of area. A represents the area normal to the direction of heat transfer in heat conduction analysis (Cengel & Afshin J. Ghafar, 2015).

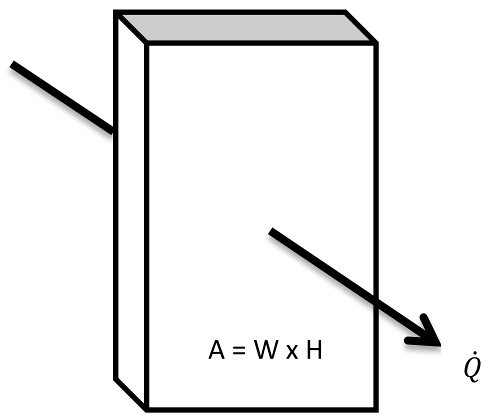

Figure 2.3: Area at which the contact surface facing towards direction

2.2.2 Convection

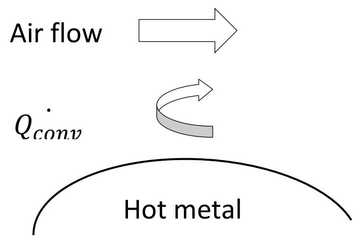

Figure 2.4: Heat convection from a hot metal to air

Convection is a process that occur when energy transfer between a solid surface with the adjacent liquid or gas that is in motion happens and also involves the combined effects of conduction and fluid motion (Cengel & Afshin J. Ghafar, 2015). The modes of energy transfer can be conduction if there is no fluid motion between the solid surface and the surrounding fluid. Meanwhile if there is a presence of fluid motion over the solid surface, the heat transfer process can be called as the combined effects of conduction and fluid motion (Figure 2.4). In addition, it also can be conclude that the change of phase of a fluid were also being assumed to be convection because this type of heat transfer process involved the motion of fluid such as the forced air through the coil of heat exchanger devices in air conditioning system called evaporator will be condense to a liquid state and the liquid droplets fall down. Same as the heat conduction, there is a temperature difference required between one area and the other in order for the convection process to occur (Annaratone, 2010).

There are two types of convection called forced convection and natural convection. This two convection types have a different mechanism and different rates of heat transfer. Forced convection occurs when there is an external force pushing the fluid to flow over the solid surface such as a fan, pump or the wind. Forced convection process can be looked at the structure of the heat exchanger devices in air conditioning system. A draw through or blow through fan rotates to force air pass through the coil in order to maximize the rates of heat transfer between the medium of heat transportation to the surface of coil"s wall and then remove the air in a certain temperature to the surrounding space. This system shows that faster fluid motion produces greater heat transfer of convection.

Natural convection occurs without an external forces but the motion of fluid happens by the density differences between the variations of temperature. A buoyancy forces triggered the motion of the fluid when there is a variation of temperature in the fluid. Different value of temperature corresponds to the different density. In the room space, hot air will move upwards and the colder air will remains downward as the hot air has low density compared to the colder air. Then, the hot air is replenished by the colder air which gets hot and rises again causing natural circulation in the room (Vlachopoulos & Strutt, 2002).

The example of combined effects can be seen through the application of heat exchanger in air conditioning system where heat transferred from the coil surface is carried away by the medium of heat transportation flowing inside the cooling tube. Heat energy is first distributed through the metal wall of the cooling tube by conduction. Another example of convection heat transfer, consider the cooling of a hot body of car by blowing cool air towards the body surface. By conduction, heat is transferred to the air moving near the car body. Then, heat is carried away from the surface by convection when there is a motion of air. The determination of heat transfer rates will be complicated for the combined effects. If the temperature difference between the air and the car body is not large enough to overcome the resistance of air to movement and for initiating natural convection currents, heat transfer between them is by conduction (Cengel & Afshin J. Ghafar, 2015).
Father of classical mechanics, Sir Isaac Newton was attributing the law of cooling that governs the rate of heat transfer from a hot surface to a cooler surrounding fluid. The rate of convection heat transfer is expressed by Newton"s law of cooling: