UNIVERSITI TEKNIKAL MALAYSIA MELAKA

DEVELOPMENT OF MOBILE HEAT DETECTING DEVICE FOR COOLING TOWER

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor of Mechanical Engineering Technology (Maintenance Technology) (Hons.)

by

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ABSTRAK

Penukar haba menara penyejuk adalah alat untuk menolak haba atau menyujuk aliran air ke suhu yang lebih rendah yang menarik keluar haba ke permukaan atas. 'Fouling' adalah masalah yang paling serius dalam operasi penukar haba yang boleh dikesan apabila peningkatan suhu permukaan menghampiri ke suhu yang kritikal. Oleh itu, krew penyelenggaraan harus mendekati penyejukan menara untuk mengukur suhu permukaan pada bahagian atas menara penyejuk yang menyebarkan udara panas yang menyebabkan kurang ketepatan bacaan dan merisikokan keselamatan orang. Kajian ini dijalankan untuk membina pembawa pengesan haba mudah alih untuk memantau dan mengukur suhu permukaan dengan menggunakan RC Quadcopter dan 'thermocouple' menggunakan penambahan pendakap atau penempat. 'Thermography' telah digunakan untuk menentukan bacaan keberkesanan 'thermocouple' dengan membandingkan kedua-dua ketepatan mereka. Pemilihan bahan dan peranti dijalankan sebelum proses fabrikasi dan pemasangan bermula. Pendakap peranti termocouple telah berjaya direka dan digunakan untuk membawa peranti mengukur atas permukaan menara penyejuk. Sementara itu peranti 'thermography' diukur menggunakan kaedah konvensional iaitu dengan teknik memegang. Semua data suhu telah dijadualkan dalam jadual dan dibina di alat pemetaan untuk memudahkan perbandingkan dan pandangan pembebasan suhu. Ciri-ciri taburan suhu permukaan diperolehi di kawasan yang berbeza pada 3 lokasi khusus untuk setiap kipas. CT 1 menunjukkan julat suhu permukaan tertinggi daripada 43.2 °C hingga 53.5 °C apabila diukur dengan menggunakan 'thermography'. 'Termography' menunjukkan nilai yang lebih tinggi berbanding dengan peranti termocouple kerana ketepatan 'thermography' yang tinggi (±0.2 °C).

ABSTRACT

Cooling tower heat exchanger is a device to reject heat or cooling of a water stream to a lower temperature which draw out waste heat to the upwards. Fouling is the most serious problem in heat exchanger operation that could be detected when the surface temperature increase nears to the critical temperature. Thus, maintenance crew is required to approach cooling tower for measuring the surface temperature on the top of the cooling tower which distribute hot air that may result less accuracy reading and harmful to user. This study is conducted to construct a mobile heat carrier detecting device to monitor and measure the surface temperature by using RC Quadcopter and thermocouple device using the addition of custom bracket or mounting. Thermography device was used to determine the effectiveness reading of thermocouple by comparing both of their accuracy. Material and device selection is conducted before fabricating and assembling process begun. Thermocouple mounting device was successfully fabricated and applied for carrying the device to measure upon cooling tower surfaces. Meanwhile thermography device used conventional method which is by hand held technique. All of the temperature data were tabulated in table and constructed in a mapping tool for ease of comparing and temperature distribution view. The characteristics of surface temperature distributions were obtained in different regions of 3 specific points of each fan. CT 1 indicates the highest range of surface temperature from 43.2 °C until 53.5 °C by measuring with thermography. Thermography measured higher value of temperature compared with thermocouple device due to thermography high accuracy of reading (±0.2 °C).

DEDICATION

This thesis is dedicated to my parents for their love, endless support and encouragement.

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LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

.BMP	-	Filename Extension Of Digital Photography
.IS2	-	Format Of Thermal Image
.JPG	-	Filename Extension Of Digital Photography
ABS	-	Acrylonitrile Butadiene Styrene
ACC	-	Air Cooled Condensor
CO2	-	Carbon dioxide
CW	-	Clockwise
CCW	-	Counter-Clockwise
FOW	-	Field Of View
GNP	-	Gross National Product
GPS	-	Global Positioning System
HVAC	-	Heating, Ventilating, And Air Conditioning
NDT	-	Non Destructive Test
PC	-	Personal Computer
RC	-	Radio Control
REC	-	Record
SD	-	Secure Digital
SHE	-	Spiral Heat Exchanger
UAV	-	Unmanned Aerial Vehicle
USB	-	Universal Serial Bus
VTOL	-	Vertical Take-Off And Landing
°C	-	Degree Celsius or Centigrade
g/cm^3	-	Density unit
psi	-	Pounds Per Square Inch

CHAPTER 1
INTRODUCTION

1.1 Heat Exchanger

Heat exchangers are device that transfer or remove heat between two fluids using hot and the cold fluid. The heat transfer process accomplished by conduction from the hot fluid to the tube wall and convection from hot fluid to cold fluid (Geankoplis, 1993). The fluid medium is separated by a solid wall to prevent both fluid from mixing. The types of heat exchangers are double pipe heat exchanger, shell and tube heat exchanger, fin fan cooler and also cooling tower.

Double pipe heat exchanger is the simplest types of heat exchanger which use one pipe within another larger pipe. The hot fluid flow inside a pipe and the cold fluid flows in another pipe that surrounds the pipe with hot fluid. Double pipe heat exchanger can be operated in parallel flow when cold fluid and hot fluid is in parallel direction and in counter flow when direction of both fluids is not same. This design of heat exchanger is not complex and less requirement of maintenance need makes double pipe heat exchanger suitable for small industry.

Another type of heat exchanger is shell and tube heat exchanger which is commonly used in large industry like oil refineries and chemical process. This heat exchanger consists of a shell that contain with a bundle of tubes inside it. One fluid flows through the tubes, and other fluid flows over the pipes and through the shell to

transfer heat between the two fluids. It is suitable for high pressure application due to the shape and big size.

Meanwhile, fin fan cooler is a device to reduce the hot fluid which is gas, water or even oil by using fans and with the addition of the fin. This equipment transfers heat from the fluid to the ambient air. Basically, this equipment designed with multiple rows of finned tubes in a series of surface and required numbers of fans. Fins are normally used from aluminium material due to good thermal conductivity and easy to fabricate. Unlike the other types, fin fan cooler did not use water as the cooling medium, but uses the air flow to reduce the heat with the helps of fin and fan. Other terms for fin cooler is air fin cooler, coil cooler and also air cooled heat exchanger. Fin fan cooler may be forced draft or induced draft types.

Same like other types of heat exchanger, cooling tower is a device to reject heat or cooling of a water stream to a lower temperature which draw out waste heat to the upwards. Evaporation process occurs in the cooling tower operation when a small portion of water being cooled is allowed to evaporate into a moving air flow to provide better cooling effect. High temperature of air is and and 100% of relative humidity produced when the heat from the inlet water stream rejected to upwards of cooling tower (Yahya, 2006). In HVAC (heating, ventilating, and air conditioning) application, cooling tower used to dispose or reject unwanted heat from a chiller.

1.2 Cooling Tower Draft

There are two types of cooling towers mechanical draft which is forced draft or induced draft. Forced draft located the fan in the ambient air flow inside the cooling tower and forced the air to upwards. Meanwhile the fan is located in the exiting air stream that draws out the hot air from the inside of cooling tower for induced draft. The position of the fan of both of the draft and components for cooling tower is presented in Figure 1.1. Creating a cooling tower depends on the customer preferences, installation, power need and several configurations.

Forced draft gives more benefits than induced draft in maintainability, power, cost and space. But the need of specification depends on the workplace situation and environment. For example, in an industrial plant, induced draft fan is generally preferred from forced draft which forms more hot air circulation. However, this potential exposes maintenance group to hot air and huge resistance. In 1950, the serious problem of heat exchanger is the hot air recirculation occurring at the inlet (Gunter & Shipes, 1971). According to Gunter and Shipes (1971), by using a smoke test showed that induced draft creates more outlet air flow better than the forced draft due to blockage of the fan and motor which is produced hot air circulation.

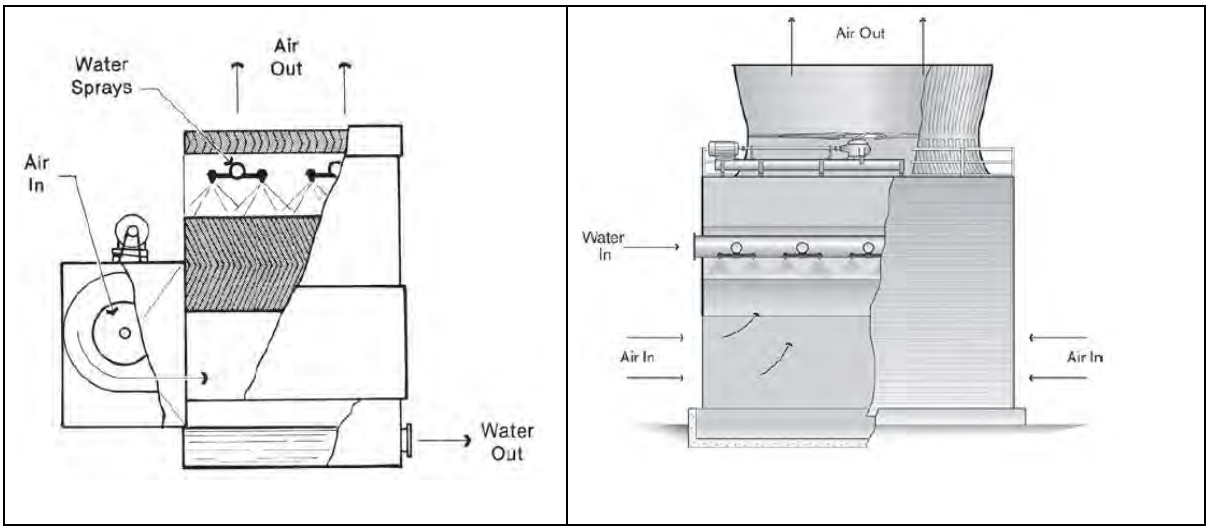

Figure 1.1 Forced draft and Induced draft of cooling tower air flow (Hensley, 2009).

1.3 Cooling Tower Process

Evaporation produce as a cooling water that applied to its fullest extent in cooling towers, which are designed to exhibit the maximum transient water surface to the maximum air flow for the longest possible period of time. Evaporation is defined as a process when water changes from a liquid to a gas (Brown, 2000). The spray-fill, counterflow system demonstrated in Figure 2.6 attempts to achieve this fundamental functionality through spraying out water into good tiny droplets, and

that contains all those tiny droplets in order to fall through a mechanically induced, upward moving stream of air.

In order to increase the contact time between air and water, the installation of fills inside cooling tower is implemented. This technique can obstruct or impede the progress of falling water which is depicted in Figure 2.7. This part is located in the horizontal area below the sprays of the tower and above the air inlet level. In staggered rows, these fills or splash bars slow down the falling water and at the same time increase the surface area exposed to the air and boosting the process of evaporation (Morvay & Gvozdenac, 2008).

1.4 Problem Statement

The most common problem in heat exchanger cooling tower operation is fouling. Fouling is the accumulation of unwanted particle which is not only occur inside of the tubes, but also out of the tubes (Ezgi et al., 2014). There are many effects of fouling that could disturb the output of temperature and air flow and also can contaminate the environment.

Figure 1.2 Fouling occurred at the outside of the tubes (Tucker, 2012).

It has been stated as a universal problem in heat exchanger which has increased heat resistance, reduce effectiveness, reduced of cross sectional area, reduce air flow rate and pressure drop due to fouling layer and deposition (Awad, 2011). Fouling may be detected when temperature increase and decreasing of output

air flow rate. Figure 1.2 proved the outside fouling decrease the air flow rate due to the blockage at the fins.

The common ways to detect faults in the heat exchanger is by measure the heat transfer coefficient, pressure drop and air flow rate (Shah et al., 2009). Apparently, by monitoring the temperature by using sensing device, the heat transfer condition can be detected. Today, maintenance is important to every industry for prolonging the equipment or machine. Condition based maintenance is one of the predictive maintenance, which is depend on continuous condition monitoring equipment or in the other words sensing device to detect the sign of failure. (Kothamasu et al., 2006) stated that condition based maintenance task is performed to detect incipient failures long before their occurrence. For monitoring cooling tower, thermocouple is used as a sensing device. Measuring method using thermocouple devices requires the maintenance crew to approach the cooling tower which is extremely hot. Exposing to high temperature will cause burns to the skin of the maintenance crew. Moreover, if the cooling tower is in forced type, the air outlet is low in air velocity and heat rather than induced type which creates hot hot air circulation spread hot air to the surrounding. The existing method risk the safety of the maintenance crew in both of the draft type.

This study will focus on developing a new method for detecting and measuring the temperature over the heat exchanger by using a mobile device. The thermocouple heat detecting device will be attached together to the RC Quadcopter to measure the surface temperature on a several points over the cooling tower. To know the level of accuracy of this technique, the gained temperature data is compared with the reading of thermography which is measured by hand held method.

1.5 Objectives

Based on the problem statement stated above, the objectives of this study are stated below:

i. To develop a mobile carrier detecting device to monitor and measure the surface temperature.

ii. To differentiate the accuracy of different heat sensors device by using mobile (thermocouple) and manual measuring (thermography).

1.6 Scopes

In order to reach the objectives, a few scopes have been stated:

i. Developing a mobile carrier detecting device using a radio control quadcopter and heat sensor.

ii. Using mobile device to carry thermocouple for measuring surface temperature of the cooling tower surface.

iii. Using manual method by handheld thermography unit at the sides of fin fan cooler.

CHAPTER 2
LITERATURE REVIEW

2.1 Condition Based Maintenance

Maintenance is an important to every industry for prolonging the equipment or machine. Maintenance is an organized activity to keep an item in its best operational condition with the lowest cost. In the fin fan cooler, fouling is difficult to detect, uninterruptible process, and expensive overhaul. Due to the facts, predictive maintenance is the suitable type to detect the condition of equipment and reducing the risk of failure. Condition based maintenance is one of the predictive maintenance, which is depending on continuous condition monitoring equipment or in the other words sensing device to detect the sign of failure. (Kothamasu et al., 2006) stated that condition based maintenance task is performed to detect incipient failures long before their occurrence.

To maintain the performance of the heat exchangers, condition based maintenance is the best maintenance type activity for optimizing output of equipment. Condition of heat exchanger cannot be done with only through visualization because fouling not only appear on outside of tubes, but also inside of the tubes. Thus, specific device is needed as an alternative method to measure the changes of temperature, pressure and air flow to detect if there any fouling occur on the systems.

2.2 Heat Exchangers

Heat exchangers are device that transfer heat between two fluids using hot and the cold fluid. The heat transfer process accomplished by conduction from the hot fluid to the tube wall and convection from hot fluid to cold fluid (Geankoplis, 1993). In other words, the purpose of heat exchangers is to reduce the fluid temperature. The main feature of the heat exchanger is for cooling gas or liquid from approximately 80 to 26 degrees Celsius (Veldman et al., 2011). Application of heat exchangers is extensively applied for application, including heating and air conditioning, power production in large plant and chemical processing. More types of heat exchangers designed these days, however the familiar types tend to be shell and tube heat exchanger, fin fan cooler, double pipe heat exchanger and spiral heat exchanger.

2.2.1 Shell and Tube Heat Exchanger

Shell and tube heat exchanger is commonly used in large industry like oil refineries and chemical process. This heat exchanger consists of a shell that contain with a bundle of tubes inside it. One fluid flows through the tubes, and other fluid flows over the pipes and through the shell to transfer heat between the two fluids (Jer6nimo, 1997). It is suitable for high pressure application due to the shape and big size. Figure 2.1 describes the flow of the fluids in the shell and tubes. The hot fluid is flowing through the tubes from the inlet to the outlet section. In the meantime to reduce the hot fluid, the cold fluid stream from the inlet to the outlet of shell by convection process.

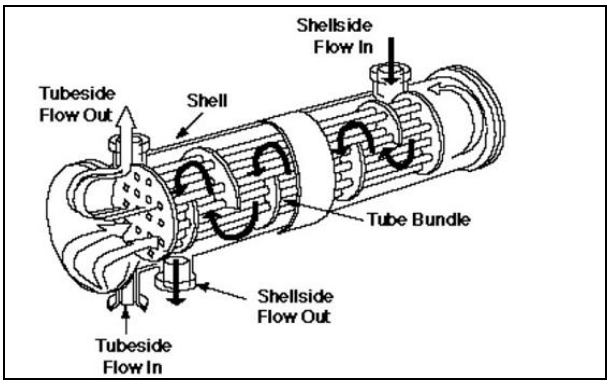

Figure 2.1 Shell and tube heat exchanger flow.

2.2.2 Spiral Heat Exchanger

Spiral Heat Exchangers or (SHE) is a placement of coiled tube, along with two partitions coiled one around the other. These two channels run in a counter-flow design, providing outstanding turn down ratios, while optimizing stream patterns which in turn to improve heat transfer. An additional, Spiral Heat Exchanger not require larger space like conventional Heat Exchanger. An extra-large Spiral Heat Exchanger has other benefits, which includes a reduction in occurrence of pressure decrease, greater thermal efficiency and lowering in overall energy costs. The flow of both fluid for this type of heat exchanger is described in Figure 2.2.

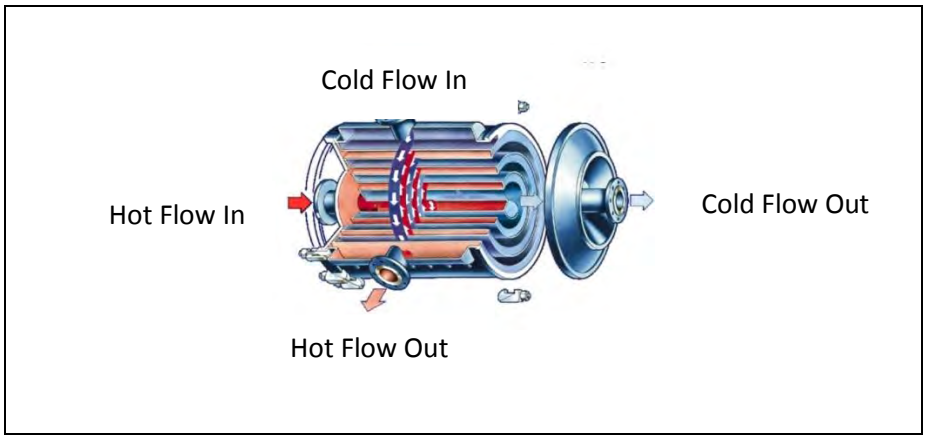

Figure 2.2 Spiral heat exchanger flow.

2.2.3 Fin Fan Cooler

Fin fan cooler is a device to greatly reduce hot fluid which is gas, water or even oil by applying fans and together with the addition of the fin which is covering the tube. This kind of equipment transport heat from the fluid towards the ambient air. Essentially, fin fan cooler designed with multiple rows of finned tubes within a sequence of surfaces and numbers of fans needed. Fins are generally from aluminium material because of good thermal conductivity and easy to fabricate. In contrast to the other types, fin fan cooler unit did not use water as the cooling medium, but uses the air flow to minimize the heat with the helps of fin and fan. Other terms for fin cooler is air fin cooler, coil cooler and also air cooled heat exchanger. Convection, conduction, and radiation process is occurred when heat exchangers operated. The flow of the ambient air which is forced to up sight due to cooling tubes is explained in Figure 2.3.

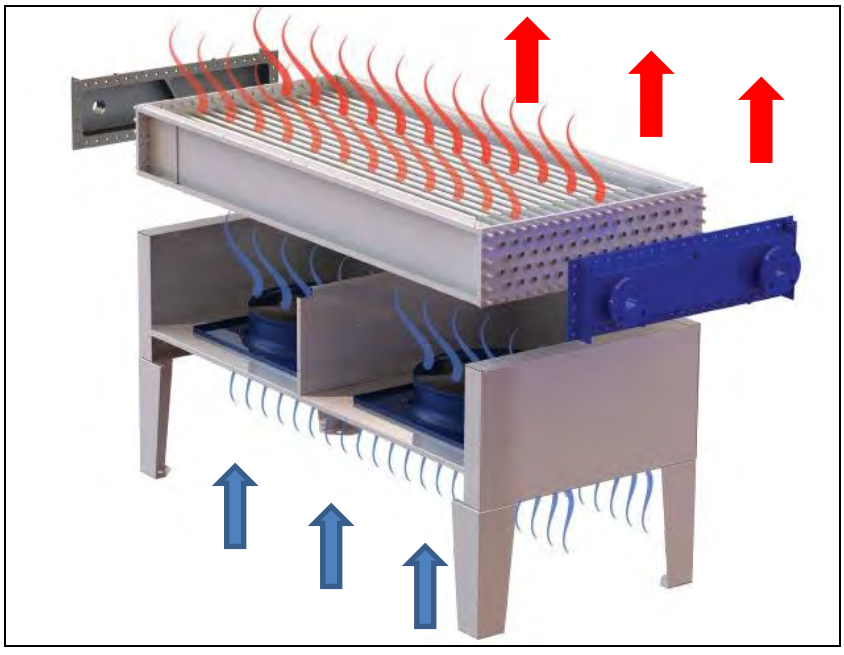

Figure 2.3 Fin fan cooler air flow.

The addition of thin metal or fin at the surface of tubes will helps the convection process. Fins are normally used from aluminium material due to good thermal conductivity and easy to fabricate. Convection process happens when hot air expends from the tube surface become less dense and rises or flow away when the air

flow applied which is described in Figure 2.4. According to Yunus & Michael, the increasing of fluid motion, the better convection heat transfer achieves. Direct contact of wall part with another nearest part will transfer energy which is the heat transfer of the convection process (Kukurugaya et al., 2011). The part which is in contact is including the wall to the fluid due to flowing fluid in the tubes. The conduction at the area is affected by contact pressure, and two surface roughness.

Another process involves in fin fan cooler is conduction and radiation. The heat transfer of material along the tubes and fins is the conduction process. Radiation is the heat transfer method that can take place in a vacuum, although it can take place in a material medium. A hot body produces energy that is beyond the red end of the visual spectrum. The application of fin fan cooler is widely used in refinery, refrigeration plants, air conditioning and car radiators.

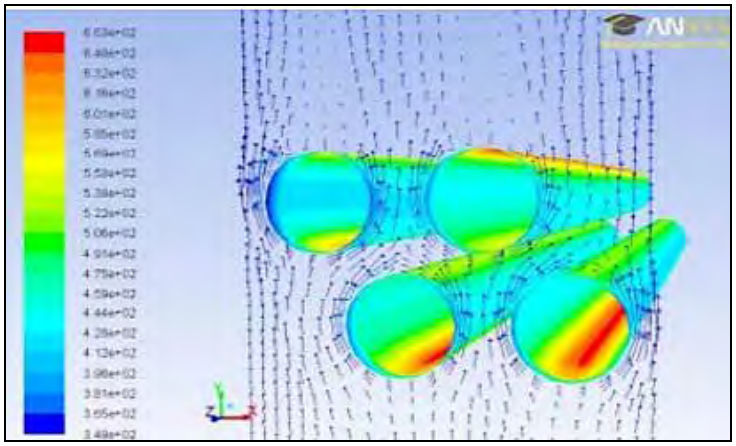

Figure 2.4 Fin fan cooler‟s hot air flow rise upwards (Jain et al., 2012).

Creating an air cooler heat exchanger depends on the customer preferences, installation, power need and several configurations. There are two types of air cooler, which is vertical and horizontal. The common type is the horizontal type that create vertical air flow with horizontal fan. Fin fan cooler may be forced draft or induced draft types. In forced draft type, the fan is located below the fin tube, but induced draft fan is installed on the tube section.

Forced draft gives more benefits than induced draft in maintainability, power, cost and space. But the specification need depends on the workplace situation and

environment. For example, in offshore platform, induced draft fan is generally preferred from forced which forms more hot air circulation. However, this potential exposes maintenance group to hot air and huge resistance. In 1950, the serious problem of fin fan air cooler is the hot air recirculation occurring at the inlet (Gunter & Shipes, 1971). One of the methods to detect the hot air circulation is by using the smoke test method as a useful visual tool. The test method shows induced draft creates more outlet air flow than the forced draft due to the location of the fan position. Forced draft not have high outlet air flow due to the fan installed under the tube bundle. Different features of induced draft and forced draft air cooled heat exchangers is described in Table 2.1.

Usually in fin fan cooler, the speed of the fan is controlled by using speed reducing gearbox to prolong the life of the motor. Although the efficiency at low speed is low, the efficiency improvement does not have energy saving compared to the rated power. The energy saving and efficiency improvement increase when speed is increased, especially above rated speed (Endrejat et al., 1998). Other ways to control the output of the outlet temperature is by controlling the flow rate of the process fluid, by controlling the airflow, additional of water sprays or all of the combinations. The most common fin fan cooler problem faced by many engineers is fouling which can decrease performance and damage the heat exchanger.