UNIVERSITI TEKNIKAL MALAYSIA MELAKA

DEVELOPMENT OF BUILT IN AIR TEMPERATURE MONITORING DEVICE FOR COOLING TOWER

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor's Degree In Mechanical Engineering Technology (Maintenance Technology) (HONS)

by

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DECLARATION

I hereby, declared this report entitled “PSM Title” is the results of my own research except as cited in references.

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APPROVAL

This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfillment of the requirements for the degree of Bachelor's Degree In Mechanical Engineering Technology (Maintenance Technology) (HONS). The member of the supervisory is as follow:

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(MUHAMAD AZWAR BIN AZHARI)

ABSTRAK

Perkembangan peranti mudah alih suhu udara untuk pemantauan fouling pada menara penyejukan dilaporkan dalam laporan ini. Penggunaan pengukuran konvensional boleh menyebabkan kurang ketepatan dan membahayakan pekerja. Peranti mudah alih telah digunakan sebagai medium untuk sensor peranti untuk memantau daripada berlakunya fouling dan mengatasi kelemahan yang berlaku. Pemilihan bahan dan peralatan dilakukan berdasarkan kepada spesifikasi yang sesuai dan diperlukan untuk digunakan di menara penyejukan sebelum mereka-reka dan proses pemasangan dijalankan. Satu reka bentuk konsep telah direka untuk mengenal pasti saiz dan peranti mudah alih suhu udara secara gambaran keseluruhan. Peranti ini digunakan sebagai panduan dalam mengukur suhu udara yang keluar pada menara penyejukan. Pada kedudukan yang berbeza, peranti sensor digunakan sebagai parameter pengukuran untuk menentukan ketepatan dan keberkesanan. Suhu yang dicatatkan telah dijadualkan dan dikira purata bagi setiap kipas di semua bahagian. Keputusan bagi kedudukan kedua-dua kemudian dibandingkan dan dibincangkan. Perbezaan bagi kedua-dua nilai pada setiap kipas di bahagian 1 kira-kira 1.73^{o}C sehingga 1.57^{o}C. Beberapa faktor yang mempengaruhi perbezaan nilai adalah kerana jarak antara sensor ke kipas untuk DS dan US dalam anggaran 10cm. Kemudian, terdapat berlaku halangan oleh kawalan jauh Quadcopter untuk pengukuran AS yang mengurangkan suhu daripada dikesan. Daripada perbandingan keputusan, ia boleh disimpulkan bahawa membangunkan peranti sensor mudah alih boleh mengatasi kelemahan dalam mengukur suhu udara keluar di menara penyejuk.

ABSTRACT

The development of air temperature mobile device for the monitoring of cooling tower fouling is reported in this report. Usage of conventional measurement may cause to less on accuracy and harm the worker. Mobile device was applied as a medium to sensor device to monitor the occurance of fouling and overcome the weaknesses occur. Material and equipment selection is made based on the suitable specification required to use on cooling tower before fabricating and assembling process. A conceptual design was drew to identify the size and overview air temperature mobile device. This device then used in measuring the output air temperature of cooling tower. The different position of sensor device was used as parameter of measurement to determine the accuracy and effectiveness. Temperatures recorded was tabulated and calculated the average for each fan on all trains. The results for both position then being compared and discussed. The difference for both value at each fan on train 1 is about 0.73^{o}C to 1.57^{o}C. Some factors affecting the difference in value because of distance from sensor to the fan between DS and US about 10cm. Then, there is blockage by RC Quadcopter for US measurement which reduce the temperature detected. From the comparison, it can be concluded that developing mobile sensor device can overcome the weaknesses in measuring output air temperature upon cooling tower.

DEDICATION

I would like to dedicate my thesis to both my beloved parents who have supported me all the way since the beginning of my studies. They have been a source of motivation and strength during moments of despair and discouragement. Also, this thesis is dedicated to all those who believe in the richness of learning.

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Besides my supervisor, I would like to thanks to my friends which with same supervisor for the support to complete the writing report and achieve the project. Thank also to my classmates for their idea and help along the project is conducted.

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CBM	Condition Based Monitoring
RC	Radio Control
FDD	Fault Detection and Diognasis
PCA	Principal Component Analysis
UAV	Unmanned Ariel Vehicles
RPM	Rotation Per Minute
CCW	Counter Clockwise
CW	Clockwise
T	Temperature
Q	Heat Flow for Conduction
A	Area
$\frac{dT}{dx}$	Temperature Gradient in the x-Direction
M	Mass Flow Rate
C_p	Heat Capacity
K	Thermal Conductivity
T_o	Output Temperature
T_i	Input Temperature
Cl	Lift Coefficient
Cd	Drag Coefficient

CHAPTER 1
INTRODUCTION

1.1: Heat Transfer

Heat transfer is a transfer of heat from one place to another which from cold to hot or vice versa. Modes of heat transfer determined the types of heat transfer used. There are three basic types of heat transfer often used which is conduction, convection and radiation. (Santanam, et al., 2011) For conduction and convection heat transfer common with air cooled heat exchanger. Example of a system that widely used the heat transfer is on heat exchanger. Heat exchanger is a thermal device that transfer or exchange by adding or removing thermal energy from one fluid to another fluid either in the form of liquids or gases. (Long & Sayma, 2009) There are many types of heat exchanger for example double pipe heat exchanger, shell and tube heat exchanger, and air cooled heat exchanger. Heat exchanger had been applied by many industries to establish or maintain a required temperature. One of the heat exchanger that often been used is cooling tower system.

1.2: Cooling Tower

Cooling tower system has same concept as fin fan cooler which is a device that remove heat from a fluid directly to air without harm the environment because does not require water. The cooler heat exchanger is widely used in industries. Air cooled heat exchanger can be classified into forced draft and induced draft, but forced draft is more often used. Forced draft situation when the tube section is located on the discharge side of the fan and air is pushed by fan to cool the fluid in a tube. Then, induced draft situation when the tube section is located on the suction side of the fan which the air is being pulled by fan to cool the fluids in a tube. (Hall,

2011) Creating an air cooler heat exchanger depends on the customer preferences, installation, power need and several configurations.

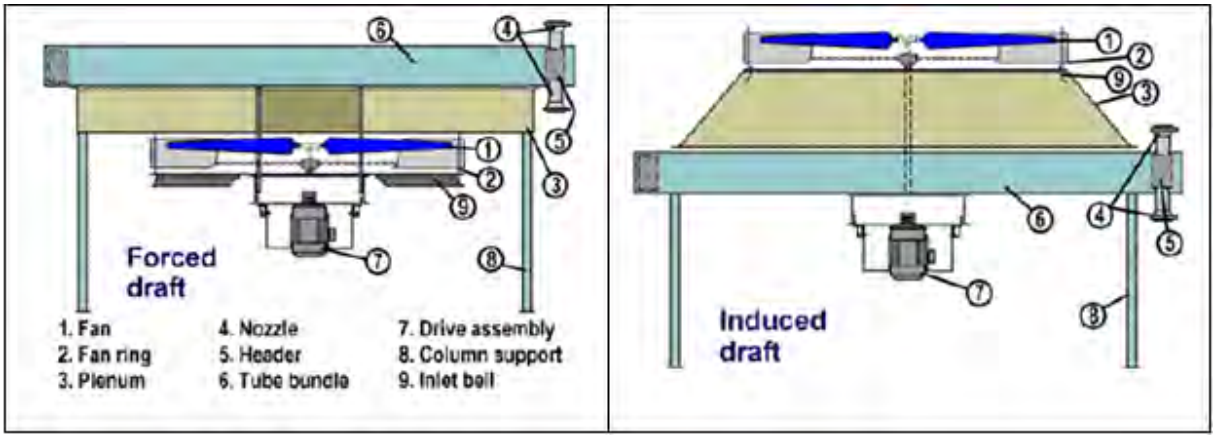

Figure 1.1: Forced draft and Induced draft

1.3: Fouling

While fin fan cooler operating as its function in the system, there will occur some problems that can disturb the operation of heat exchanger that is fouling. Fouling is the formation of fouling layer that appears on heat transfer surfaces either inside or outside of fin fan cooler. (Awad, 2011) Percentage of fouling appears increases when period time usage of the system incraeses. There are few types of fouling that depend on the different physical and chemical processes that occur in the fin fan cooler. The common fouling that occurs in the system are particulate fouling, crystallization or precipitation fouling, chemical reaction fouling, corrosion fouling, biological fouling, and solidification or freezing fouling.

Fouling can affect the output product of the system. Some examples that can be affected from fouling are reduces thermal efficiency, lower heat flux, reduces the output air flow rate, and pressure drop. Fundamentlly, when flow velocity decrease due to fouling, it will reduce thermal performance and increase more further fouling rate. Thus, this fouling problems need to overcome to increase the efficiency of heat exchanger by doing some maintenances like cleaning, replace material, and inspection.

There are few common parameters that can affet fouling on the fin fan cooler system. The parameters are fluid flow velocity, surface temperature, surface material, surface roughness, fluid properties, impurities and suspended solid, heat transfer process and design considerations. (Awad, 2012)

1.4: Condition Based Maintenane

To maintain the heat transfer performance, few maintenace like predictive or condition based maintenance can be done. This is because predictive maintenance can help to figure out the situation and condition of the system or equipment and it can be estimated when the maintenance should be performed. This maintenance can ensure the cost saving because it performed only when needed.

To maintain the heat transfer performance, monitoring of fouling need to be done at certain times. Condition of heat exchanger cannot be done with only through visualization because fouling not appear on outside of tube only. 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 system. For measuring the air temperature, common method that had been used thermocouple, thermography, resistance temperature device (RTD), thermistor and other newest technology (Baker, 1998). These devices can be used on heat exchanger to detect if there any unusual changes of air temperature. So, the aim of this study is to develop new method to measure and monitor air temperature on cooling tower and to compare the reading accuracy based on different gap dinstance on radio control quadcopter to make it easier.

1.5: Problem Statement

Unremarkably, many engineers had been faced fouling on cooling tower which may reduce its performance or damage if used even further. Based on the studies, most of the fin fan cooler will occur fouling problem (Garnett, 1985). It is difficult for people to detect and sense fouling with just doing a visual inspection. This is because fouling can occur both inside and outside the tube. Fouling can cause many effects that can affect the output of temperature and air flow and also can contaminate the environment. Then, fouling has been stated as a universal problem occurs in cooling tower, which is reducing its performance, reduce the air flow rate, pressure drop and effectiveness due to fouling layer and deposition formed on the surface fin or tube (Awad, 2011). Fouling can be detected by changing in cooling tower like increasing in temperature and decreasing of output flow rate. The air temperature condition on heat exchanger can be monitored and measured if there is any fouling occur by using heat detector. To detect faults on cooling tower, the common ways used is by measuring and compare the heat transfer coefficient, pressure drop and flow rate

In order to bring back the operation performance of cooling tower, maintenance of machinery and equipment need to be done. There are many types of maintenance can be done based on the situation and condition of the system, for example preventive maintenace, predictive maintenance, improvement maintenance, corrective maintenace and run to failure maintenance. Due to difficulty in detecting the fouling and expensive of an overhaul and machine of cooling tower, predictive maintenance is the best way to apply on it. Thus, the cooling tower performance can be determined and monitored which usually based on the measurements of temperature (Shah, Liu, & Greatrix, 2009).

A common measuring method is using the heat detecting device and measure it manually that need the maintenance crew to approach the cooling tower to take the measurement which is extremely hot that can cause injury or hazard. If the cooling tower is induced type, the air outlet is high in air velocity and heat. But for forced type, hot air circulation spread hot air to the surrounding. Besides that, temperature of air also can be measured by using thermocouple, thermography, resistance temperature device (RTD), thermistor and other newest technology. Besides that, the

position of the sensor from the surface temperature also play an important role in determining the good accuracy (Baker, 1998). The further distance of sensor device, less accuracy of measurement data obtained.

This study will be focused on developing new method for detecting and measuring the air temperature on the heat exchanger. Then, it focused on the effective way that can prevent maintenance worker from expose from extreme heat and air temperature when taking the measurement. This study also will identify which position of sensor device would be effective to apply in this new method.

1.6: Objectives

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

1. To develop a mobile carrier detecting device to measure air temperature on cooling tower system.
2. To differentiate and identify the accuracy of temperature measurement at different position of sensor device on RC Quadcopter.

1.7: Scopes

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

1. Developing a mobile carrier detecting device using an radio control helicopter and heat sensor which is thermocouple data logger.
2. To test mobile heat detecting device on an cooling tower system.
3. To install sensor device at 2 different positions on RC Quadcopter in measuring temperature.

CHAPTER 2
LITERATURE REVIEW

2.1: Condition Based Maintenance (CBM)

Basically, the fouling and the failure occurred can be prevented by doing maintenance on the system. Maintenance work needs to be considered on criticality and cost effectiveness of the system. Using the wrong maintenance technique may lead to waste time, money and resources, usually with no impact on improving or maintaining availability (Sullivan, Pugh, Melendez, & Hunt, 2002).

There are many types of maintenance can applied on the system which includes preventive maintenance, corrective maintenance, run to failure and condition based maintenance (Baldin, 1986). The predetermined preventive approach has fixed maintenance intervals in order to prevent components, sub-systems or systems to degrade. Corrective maintenance is performed after an obvious fault or breakdown has occurred. Run to failure is performed after the occurrence of failure on system. Condition Based Maintenance (CBM) or predictive maintenance is a technology that strives to identify incipient faults before they become critical which enables more accurate planning. CBM provided the ability to optimized the availability of process machinery and reduce the cost of maintenance.

In heat exchanger system, usage of condition based maintenance is more suitable among the type of maintenance. One of the maintenance that can be done is monitoring the system frequently. In this study, the CBM been applied on cooling tower at industry. The occurrence of fouling can be detected when the unexpected output flow rate decrease from normal condition. Before applying CBM on the system, a few steps need to be considered including cost/benefit analysis, reliability and criticality audit, review and measure effectiveness, select maintenance tasks,

select monitoring method, data acquisition and analysis, determine maintenance action, and carry out equipment audit.

2.2: Heat Exchanger

A heat exchanger is a device designed for efficient heat transfer from one fluid to another either hot to cold or vice versa. Heat exchangers had been applied in many industries as temperature changer. Heat exchanger also may be categorized as concurrent or countercurrent flow type according to the flow arrangement (Dias & Jin, 2009).

Basic type of heat exchangers experienced by us in our daily lives include condensers and evaporators used in air conditioning and refrigerators. Boilers and condensers in thermal power plants are examples of large industrial heat exchangers. There are heat exchangers in our automobiles in the form of radiators and oil coolers (Arora, 2000). Heat exchangers are also been used in chemical and process industries. There is a variety usage of heat exchangers for diverse kinds, thus, the construction also would differ widely. However, in spite of the variety, most heat exchangers can be classified into some common types based on some fundamental design concepts. There are many types of heat exchanger like shell and tube, double pipe, air cooled heat exchanger and many more. Fin fan cooler is included as type of air cooled heat exchanger (Lukitobudi, Akbarzadeh, Johnson, & Hendy, 1995).

2.2.1: Cooling Tower System

The applications for air cooled heat exchangers cover a wide range of industries and products, however generally they are used to cooler gases and liquids when the outlet temperature required is greater than the surrounding ambient air temperature. The basic heat transfer relationships that exist for shell and tube exchangers also apply to the design of an air-cooled heat exchanger. Fins are normally used from aluminum material due to good thermal conductivity and easy to fabricate. The applications include gas compressor packages, gas transmission

facilities, engine cooling, condensing of gases (propane, refrigerants, etc.) and steam condensers (used in power plants & process applications). The only common thread among these users is the need to reject heat from a source into the air (Li, Tang, Zhang, & Wen, 2009). Some of these applications also use the discharge air from the air cooler to help heat buildings or other equipment.

Cooling tower may be forced draft or induced draft types. In forced draft type, one or more fan are located below the fin tube which is at the inlet to force air to the tube, but induced draft fan is one or more fans installed on the tube section which is on the outlet to induced air through the air outlet (Maurer, 2011). Creating an air cooler heat exchanger depends on the customer preferences, installation, power need and several configurations. Table 2.1 below shows the comparison based on it's characteristics between forced draft and induced draft.

Table 2.1 : Comparison of induced draft and forced draft air cooled heat exchangers

Features	Forced Draft	Induced Draft
Distribution of air across section.	Poor air flow over the section.	Better air flow over the section.
Waste air recirculation to intake.	High possibility of hot air recirculation because of low discharge velocity.	Lower possibility because fan blow air upward from the tube.
Influence of weather condition.	Highly exposure of tubes to rain, sun and frozen rain.	Less effect of sun, rain, and hail because 60% of face is covered.
Freezing condition.	Easily adapted for warm air recirculation during freezing conditions.	Warm discharge air not recirculate.
Result of fan failure.	Low natural draft effect on fan failure.	Greater natural draft stacks effect than forced draft.
Power requirement.	Lower fan power usage because the fan is installed in the cold air stream.	Higher fan power usage because the fan is placed in the hot air stream.
Temperature limit – discharge air stream.	No limit.	Limited to about 95°C (200°F) to prevent damage to belts, bearings, fan blades, and other components.
Temperature limit – tube side process fluid.	Limited by tube components.	Limited to 175°C (350°F) because fan failure could subject fan blades and bearings to excessive temperatures.
Maintenance.	Better access to mechanical components.	Difficult to access mechanical component because it above the tubes.

From Table 2.1, the forced draft gives more advantages than induced draft in maintainability, power, cost and space. But the usage of these types of cooling tower is based on the situation and environment of workplace and the purpose using it in industry. 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 smoke test method as a useful visual tool. Figure 2.1 below shows the difference in type of horizontal fin fan cooler for forced draft and induced draft with it components labeling.

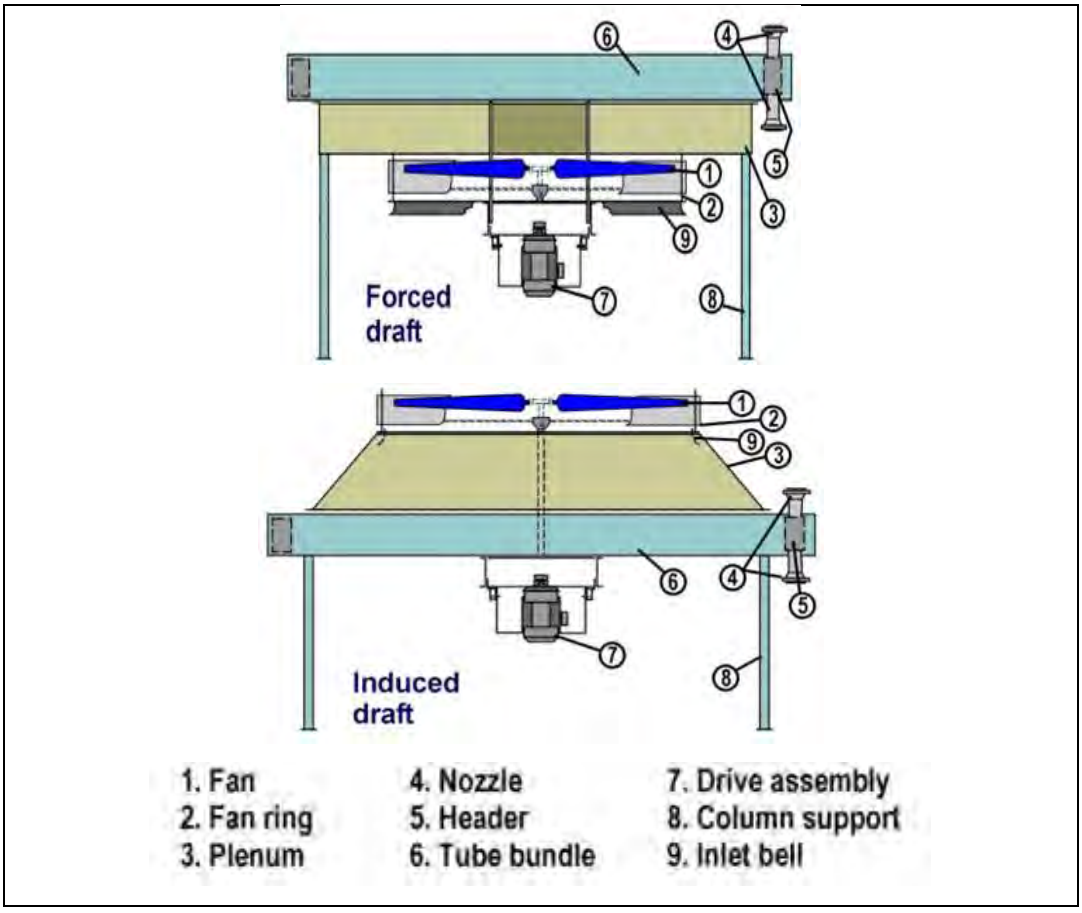

Figure 2.1: Type of horizontal fin fan cooler

2.3: Heat Transfer

The different types of heat transfer are usually referred to modes of heat transfer. This part will cover the three basic types of heat transfer which is conduction, convection, and radiation.

2.3.1: Conduction

Conduction or heat conduction is occurred when the heat energy transfers within a body by microscopic diffusion and collisions of particles or quasi-particles due to a temperature gradient which can either in solid or liquid. Nevertheless, fluid is still travels at very slow motion, the following evaluation for solids is also relevant to conductive heat flow via a fluid. Figure 2.2 shows a schematic form a approach of conductive heat transfer where T, for temperature, Q, for the heat flow for conduction in x-direction and A, for the area through which the heat flow and $\frac{dT}{dx}$ for the temperature gradient in the x-direction.

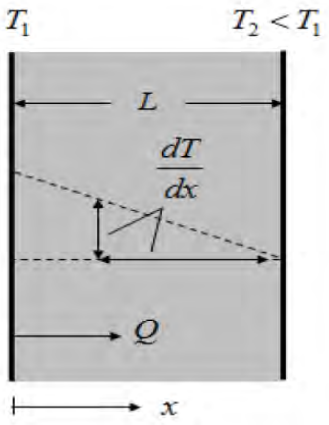

Figure 2.2: One dimensional conduction