Experimental Study of The Performance Characteristic an Induced Draft Cooling Tower with Variates Fillings

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Abstract. The aim of this research is designing and testing an Induced Draft Cooling Tower (IDCT). The Cooling tower is the main instrument which used to cool the hot water from the condenser and release heat into the atmosphere at a power plant. Temperature is maintaining as cool as original condition. One of the components of the cooling tower is filler. It is very influential on IDCT performance, where the contact surface between water and air is expanded and the contact time is extended. An experimental study to evaluated the heat and mass transfer coefficient is conducted; a new variable is defined. The effect of controlling parameters such as range of temperature, heat rejected rates, effectiveness has been analysed. IDCT was filled with a straight, zigzag and wave filler. The results indicate that the tower characteristics increase with increase cold air velocity, with the variation of filler, the highest tower characteristics get from wave filler arrangement.

1. Introduction
Cooling tower, with preceding advantages, is equipment most widely used to release excess heat loads from these processes, such as electric power generation units, thermal and nuclear power plants, chemical, petroleum industries, refrigeration, and air-conditioning systems, into the atmosphere [1]. This device operating based on mass and thermal energy transfer from high-temperature water to coolant air. In the wet cooling tower, water flows over the fillings and thus a direct interface between warm water and coolant air flow occurs. When the bed is in a fully fluidize state, vigorous movement of the wet particle gives rise to intimate mixing of the two flowing fluids. In addition, the residence time of contact for the two phases is high owing to the liquid hold up in the column. These two factors are the reasons for the very high heat transfer coefficient of this tower.

The type of filling material used in the cooling tower has an important point as it provides a very large surface area for evaporative heat and mass transfer to take place from hot water to ambient air and increase contact time between the two fluids. Based on the prior studies, the influence factor of efficiency is mainly the thermal performance of the filling zone because 70% of the heat dissipating capacity depends on the filling zone [2].
Many studies are dealing with the mathematical modelling system which has many advantages such as saving money, but an experimental study is also necessary to know actual performance. This method with different fillings such as splash, honeycomb, ceramic tile, corrugated, and film are reported in the literature [3-5]. For example, Johannes, S [6] established an experimental investigation of the characteristic cooling tower by utilizing the power of capillarity fibres as splash filling. Niken and Arrad [7] developed the variation of splash filling density with a performance of forced draft counter flow cooling tower.

Many researchers have been pursued in this field in order to improve the transport phenomena in this equipment and therefore enhance their performances since the early sixties. Among the existing filling, there is the “VGA” (Vertical Grid Apparatus) type filling which has been initially developed [8] and used in mass transfer equipment. Lemouari performed an experimental investigation of the thermal performance for wet cooling tower filled with a VGA type filling which is 0.42 m high and consist of four galvanized sheets having a zigzag form. He carried out experiments on heat transfer performance of a cooling tower with different parametric studies and yielded a similar model to Gharagheizi [9] which presented an experimental and comparative study on the performance of mechanical cooling tower with two types of film packing. They used vertical corrugated packing (VCP) and horizontal corrugated packing (HCP) having 0.64 meter in high and 0.25 m$^2$ cross section area. From this research, He reported that the performance of the cooling tower is affected by the water/air mass flow ratio, the type and the arrangement of the packing.

The main purpose of this paper is to carry out an experimental investigation of the performance characteristics of a direct-contact counter flow wet cooling tower filled with a straight, zigzag and wave filler with material acrylic and some variates form in order to increase thermal characteristic with different arrangement than others and to obtain the optimal position pattern.

2. Experimental Setup and Procedure

This research begins with problems in learning. It is a cooling tower performance of energy transfer from hot water and coolant air. This object is, hot water from the condenser assumed that water which is heated by an electric heater. Furthermore, study about the performance of the cooling tower and the developing parameter before. Identification of the influence variable and design of experimental apparatus is to get performance and characteristic.

2.1. Experimental setup

Experimental setup with the identification of boundary variable in order to investigate the characteristic performance of induced draft counter flow wet cooling towers with variated filler conditions is observed. The data reach in the condition equipment and instrument steady.

![Figure 1.](image1)
The purpose of experiments is to consider the optimal position pattern and also find the effect of adding straight, zig zag and wave filler, outlet water temperature and water flow rate on the water temperature difference and cooling tower effectiveness. In what follows, a schematic diagram of the experimental set up is shown in Fig. 1 (a). It consists mainly of a cooling tower which represents the main device used in this test, a cold water basin, a hot water basin which contains electric heaters, a water pump, a flow meter device, a nozzle, a fan, and fillers. The tower’s column has a parallel form of dimensions 400 mm x 400 mm x 1400 mm, and is made of Acrylic with frame.

### Table 1. Monitor parameters and measurement instruments

| Items                      | Measuring Instruments | Accuracy |
|----------------------------|-----------------------|----------|
| Inlet dry and wet bulb     | Thermocouple type-K   | ±1 ºC    |
| temperature               |                       |          |
| Outlet air temperature     | Thermocouple type-K   | ±1 ºC    |
| Inlet and outlet water     | Thermocouple type-K   | ±1 ºC    |
| temperature               |                       |          |
| Circulating water flow rate| Thermocouple type-K   | ±1 ºC    |

Table 1. explained the instrument and accuracy from the instrument which used for selected item. The considered measurements which were taken consist of the temperatures increase (dry and wet) of the air at the entry and exit of the tower, as well as the inlet and outlet water temperatures. The testing procedure is described in Fig. 1

#### 2.2. Geometry and initial variation

Acrylic is the material used to build the cooling tower column, then the casing IDCT is steel. The Spray nozzle is used to spray water throughout the column. On the centre side of the column there is a filler that varies in shape using acrylic. There are three variations of filler geometry used, as shown in fig. 2 (a), (b), and (c).

![Filler geometry](image)

**Figure 2.** Filler geometry (a) straight, (b) zig zag, and (c) wave

Hot water is sprayed from a spray nozzle then passes through the filler in the centre of the column. The water that leads to the bottom of the column is directly contacted with the cooling air that is sucked using counter flow induced fan. Coldwater (in the reservoir) enter the hot water reservoir again to distributed to the column.

### 3. Calculation Models of Thermal Parameter

#### 3.1. Range actual and maximum heat transfer

Heat rejected is defined as the difference between hot water entering the cooling tower with hot water coming out of the cooling tower as formulated in equation (1).

$$q_{\text{max}} = (\dot{m}_{\text{w, in}} \cdot h_{\text{w, in}} - \dot{m}_{\text{w, in}} \cdot h_{\text{w, out}})$$  \hspace{1cm} (1)

Then, maximum heat transfer is defined as the difference between the heats from hot water entering the cooling tower with cold air coming into the cooling tower as formulated in equation (2).
\[ q_{\text{max}} = (m_w, in \cdot h_{w, in} - m_{a, in} \cdot h_{a, out}) \]  

(2)

### 3.2. Effectiveness

The effectiveness of a cooling tower is defined as the ratio of heat rejected to ideal maximum heat, and as a method which used to calculate a capability of heat transfer in the heat exchanger with compared to the calorific value transferred with the possibility of maximum heating value, i.e.

\[ \varepsilon = \frac{q_{\text{out}}}{q_{\text{in}}} \]  

(3)

### 3.3. Number of Transfer Unit (NTU)

In the book of Stockers and Jones, as the heat exchanger, a cooling tower performance is also stated in a function which describes characteristics of the cooling tower and basic to know a performance at inlet water temperature and any other wet bulb temperature. The value of \( h_c A / c_p m \) as known as NTU, commonly known as

\[ NTU = \frac{U \cdot A}{m \cdot c_p} \]  

(4)

Then, by Lu Lu Wenjian Cai, NTU of a counter flow cooling tower i.e.

\[ NTU = \ln\frac{1 - \varepsilon}{1 - m^*} \]  

(5)

\[ m^* = \frac{m_a}{m_w} \frac{C_s}{c_{pw}} \]  

(6)

\[ C_s = \frac{h_{a, in} - h_{a, out}}{T_{w, in} - T_{w, out}} \]  

(7)

### 4. Result and Discussion

Coordinate x and y-axis in Fig. 3 (a) describe the inlet air velocity and heat rejected. From this graph, it is seen that the Chart show the influence of the whole variation form filler arrangement on the heat rejected by using control velocity of the cooling tower. Trend graphics is linear show that increasing velocity air along with increasing heat rejected.

**Figure 3.** Influence of air velocity inlet to (a) Heat Rejected (b) Effectiveness

The heat rejected with waveform filler is higher than other filler. It can be seen that the influence of heat rejected of the arrangement wave filling is the high intake air velocity because the condition of inlet temperature and outlet temperature is the same. Increasing intake air speed influence moist air mass rate which enters cooling tower (\( m_{\text{moist}} \)). When airsspeed terrace step by step from 2 m/s; 4 m/s; and 6 m/s, \( m_{\text{moist}} \) is increased too for all variations. This is in accordance with the
equation that has been described that the value of intake air velocity is proportional to the rate of moist air masses. The rate of humid air will affect the rate of the mass of water comes out (m_{w, out}) of the cooling tower. However, beside all above, heat rejected is also influenced by enthalpy water out (h_{w, out}). The temperature of the water coming out (T_{w, out}) is decrease when airspeed increased.

Influence of intake air velocity to effectiveness in three variates shows in Fig. 3 (b). By adding intake air velocity of cooling tower will affect the effectiveness. In the intake air velocity, 6 m/s is higher than others velocity variation. Then, it was followed by the effectiveness at the velocity of 4 m/s and 2 m/s. Minimum effectiveness showed at the velocity of 2 m/s on the 0.69 compositions straight filler. Furthermore, the highest effectiveness is obtaining when the air velocity of 6 m/s in 0.88 wave filler arrangement. Amount of filler influenced the characteristics it will be increasing trend graphic of effectiveness.

![Figure 4. Influence of air velocity inlet to NTU](image)

The effectiveness value increases with increasing air velocity because heat rejected which generate is greater by nearly the same maximum heat. It finds that linearity both of them. Material acrylic with wave filler arrangement can reach the highest value of the effectiveness because of this structure and mesh can accommodate more water from the spray produced by the nozzle, so that the contact between the water with inlet air will be extended with filler media which full of the column. Fig. 4 show the Influence of intake air velocity to NTU. Variation of intake air speed and filler arrangement is affecting Number of Transfer Unit (NTU). The value of NTU in the intake air velocity 6 m/s is 3.99 and it is higher than others velocity variation and arrangement. Between the effectiveness and ratio air to water effective capacitance rate or m*. When intake air velocity increases the value of m* is increase. It is obtained an increase an NTU in all condition of the same speed when the ratio density of the packing material expanded. Since the composition of filler diminishing in each layer can potentially create a harmer heat which will be transferred to the system. NTU is indicating that heat transfer in that process has the better performance. Similarly, when compared with the conditions of the cooling tower with wave filler arrangement compared to others.

5. Conclusion
Several field tests using different variables were performed for an induced draft cooling tower by addition of straight, zigzag and waveforms as the fill material. It was found that the factors affecting the performance of the cooling tower are the air velocity, outlet water temperature, effectiveness, and NTU. The highest heat rejected that happened on the waveforms filler is 4.92 kW, effectiveness of 0.88 and great value of NTU 3.99 on the cooling air velocity 6 m/s with a variation using a wave arrangement.


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