Study Experimental of Cooling Tower Forced Draft With Variation of Ratio Obstacle in Film Filler

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Abstract: This study aims to build and test the Cooling Tower of the Forced draft type. Cooling Tower is a heat exchanger that functions to cool water with high temperatures from the condenser and remove heat into free air or atmosphere in the power plant. It aims to bring the water back to its normal temperature or original condition. To cool, supplier components are needed, one of which is filler. The filler is a very influential compoent, because the contact between liquid (hot water) and gas (cooling water) occurs in fillers with heat transfer of conduction. This research was conducted by changing or varying the type of obstacle ratio. The variation of the filler film is to calculate the ratio of the resistance area and surface area of the filler film with a variation value of 1 without filler, a variation of 2 times 0.31 , with the type of material used which is Steinleesstell 0.75 mm. The results showed their effectiveness of 0.47 and 2.43 and the resulting efficiency of 29.53% and 54.48%.

1 INTRODUCTION

The cooling system plays an important role in maintaining the temperature of the production machine so that it can work optimally. An example of a cooling system is a cooling tower which is a heat exchanger to lower the temperature the of wateairflowir flow. One type of cooling tower is a forced draft cooling tower (Mugisidi et al., 2021). In the forced draft type, hot water flows down through a barrier in the form of ,filler and from under the airflowir flow is blown. The performance of cooling towers is greatly influenced by filler materials (fillers) both in the form of arrangements and types of raw materials (fillers).

The type of filling material used in the cooling tower has an important point because it provides a surface area factor that affects the efficiency especially the thermal performance of the charging zone of 70% of the heat dissipation capacity depending on the charging zone (E. Novianarenti et al., 2019).

Research on the type of cooling tower type forced draft is still rare because many studies use cooling tower type wet and type induced draft. Many wet-type studies are widely used toperformanceomancy values and NTU values (Mirabdolah Lavasani et al., 2014).

The factor that affects the rate of heat transfer from hot water to air as a cooling medium is when the two fluids meet in the filler. Filler functions as a barrier and breaker of water droplets and slows down the motion of waterfalls so that the contact time between fluids is longer and the contact area is also greater, it will increase the amount of heat transfer that occurs. Some of the studies that have been carri ouof support for cooling towers include varying the composition of fillers to obtain cooling tower performance characteristics (Pita & Sob, 2020),

For the cooling tower performance, several things must be considered, including the value of the heat transfer rate,number of trans the fer units (NTU), and the effectiveness of the cooling tower. In previous studies, cooling tower induce drafts developed variations in filler shapes with variations in straight, zigzag, and wavy fillers and resulted in highest efthe fectiveness in wave filler variations (Eky Novianarenti & Setyono, 2019).

This research will compare cooling tower forced draft by comparing cooling towers without fillers (empty) with cooling towers containing fillers which have a obstacle ratio value of 0.31. The data taken are the discharge of incoming water, the temperature of

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water in and out, the temperature of wet and dry air in and out, and the speed of air. After data collection, data processing is carried out to obtain calorific values, effectiveness values, NTU values, efficiency and evaporation that occur.

2 EXPERIMENTAL APPARATUS AND PROCEDURE

The cooling tower made is a forced draft type cooling tower. With cooling air conditions using a fan / blower. The hot fluid used is water by raising the temperature to a temperature of 60 °C with a heater of 1000 watts. The hot fluid is then pumped into the cooling tower with a cooling tower size of 0.15 x 0.15 x 1.1 m.

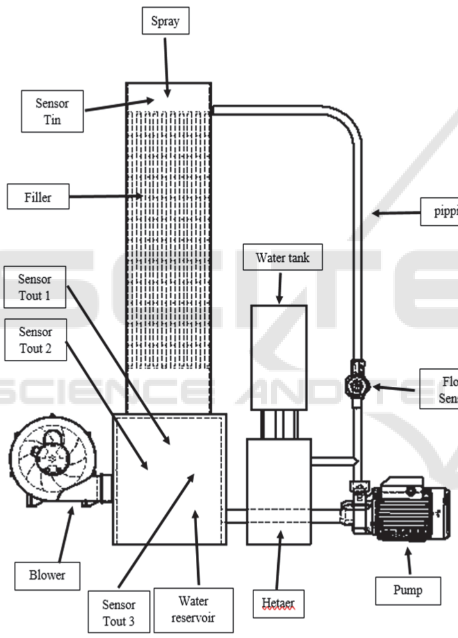


Figure 1: Scheme Cooling tower.

Seen As seenig.1 there is a filler in the cooling tower which functions as a barrier to the flow of hot fluid (hot water) and cold fluid (air). The fifillersed has dimensions of 0.13 x 0.1 m with a total of 6 filler layers and has 8 levels and the type of material used is an aluminum plate with a thickness of 0.75 mm.

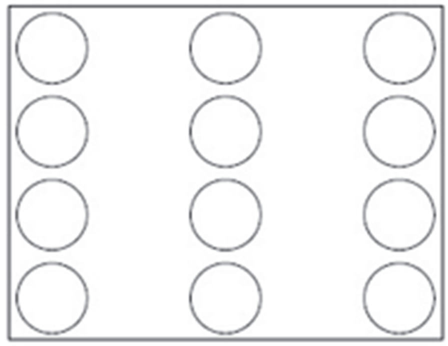
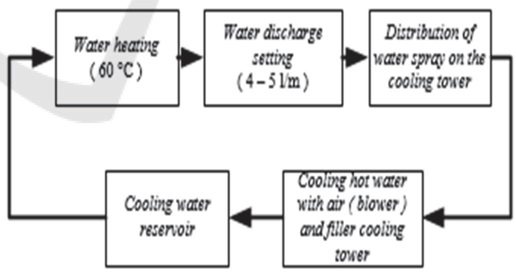


Figure 2: Filler ratio 0.31.

In fig.2 is an image of one filler layer with a anbstacle ratio of 0.31. The obstacle ratio is obtained by adding obstacles (rounds on fig.2) with dimensions of 21 mm in diameter and 3 mm invulnerability using acrylic with an amount of 24 pieces (front layer and back layer), and the ratio value is obtained by a comparison of the area of the total obstacle divided by the total area of 1 filler layer.

In fig.1 there is the placement of sensors used for data retrieval and data processing. For the temperature sensor, namely using a thermocouple sensor, for the water discharge sensor using a flow meter ,and everything is connected to the Arduino. Data collection includes the temperature of the heated fluid in and out, the discharge of hot fluid flow, the temperature of wet bulbs in and out, the dry temperature out and in, and the speed othe f incoming wind.



Figuro 3: retrievalrival process.

On fig. 3, namely the stages for data retrieval for data processing. The first stage ensures that the cooling tower and filler used are perfectly installed, fill the water into the heater and then heat the water by adjusting the temperature set point to a temperature of 60 waiting and wait for the water temperature to reach the set point value, then turn on the pump and blower and adjust the valve opening with a range of 4-5 l / min. do data collection, data collection is carried out as much as 10-12 times data collection with the condition that if the water temperature decreases and the temperature wett is always lower, then the next data collection can be continued. After all the data retrieval on variation 1 is done, turn ofpertains peraltans and replace them with the second variation.

3 ANALYSIS METHOD

The performance of the cooling tower can be known by the following equations and can also be analyzed with the approach of the value of the range and the value of the approach. And the equations used are as follows the range

- Range

Range is the value of the difference between the temperature of the heat fluid entering and leaving the cooling tower, and if the difference in value is high, the coolong tower can be said to be effective in performance, and the formula is (H et al., 2014) :

$$\text{Range } (°C) = [T_{in} - T_{out}] \quad (1)$$

- Approach

Approach is the value of the difference between the temperature of the hot fluid out of the cooling tower and the twet bulbure of the wetbulb in, the lower the value, the better the performance of the cooling tower. and the formula is (H et al., 2014) :

$$\text{Approach } (°C) = [T_{out} - T_{wet,\ in}] \quad (2)$$

The paradeterminingeded in determing the value of heat transfer rate (q), effectiveness (ε) , number of a transfer unit (NTU), efficiency, and evaporation loss are the following values: temperature water inlet (T_{in}), temperature water outlet (T_{out}), Temperature wet-bulb in and out (T_{wetin} and T_{wetout}), temperature dry in and out (T_{dryin} and T_{dryout}), water mass flow rate ($\dot{m}_{,}$), and inlet air flow rate (V)

- Inlet air Characteristic

From fig.4 it is used to find the value of the calculation value of the inlet air characteristic which includes realtive humirelativen), absolute humidity (ωin), the rate of incoming moist air ($\dot{m}_{,moist\ in}$),the rate of w ater vapor in the air ($\dot{m}_{,vin}$), the flow rate of dry air masses($\dot{m}_{,dry\ air}$)And from fig4. Can be used to find relative humidity by using temperature dryin (T_{dryin}) and temperature wet in (T_{wetin})(Singh & Das, 2016)

- Absolute humidity (ω_{in}) the formula is (3).

$$\boldsymbol{\omega_{in} = 0{,}622\,\frac{p_{v,\,in}}{p - p_{v,in}}} \quad (3)$$

$$\boldsymbol{p_{v,\,in} = \phi_{in} \times p_{g,in}} \quad (4)$$

The rate of incoming moist air ($\dot{m}_{moist\ in}$) the formula is (5).

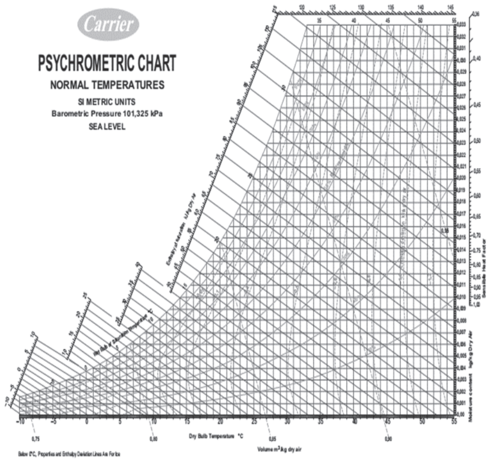


Figure 4: Psychometric chart.

$$\dot{m}_{moist,in} = \rho_{air} \times V \times A_u \quad (5)$$

Based on table A-2 of Stoecker's book the nature of humid air at measured temperatures (T_{dryin}) to find a specific volume (m³/kg) so that Pudara = 1/v.

The flow rate of dry air masses(($\dot{m}_{dry\ air}$) the formula is (6).

$$\dot{m}_{v,in} = \frac{\dot{m}_{moist,in}}{\left(\frac{1}{\omega_{in}}\right)+1} \quad (6)$$

$$h_{air,in} = C_p T_1 + \omega_{in} h_{v,in} \quad (7)$$

and the h_{vin} value is obtained using a psychometric chart table at T_{dryin} temperature.

The flow rate of dry air masses ($\dot{m}_{dry\ air}$) the formula is (8).

$$\dot{m}_{dry\ air} = \dot{m}_{moist,in} - \dot{m}_{v,in} \quad (8)$$

Outlet Air Characteristics

On the calculation of the outlet air chareteristicharacteristics Fig. 4, by using the dry out temperature ($T_{dry\ out}$) and wet out temperature (T_{wetout})parameters to find out the value of the relative humidity(ϕ_{out}), while to find other parameters using the following equations: (Singh & Das, 2016).

$$\boldsymbol{\omega_{out} = 0{,}622\,\frac{p_{v,\,out}}{p - p_{v,out}}} \quad (9)$$

$$\boldsymbol{p_{v,\,out} = \phi_{out} \times p_{g,out}} \quad (10)$$

how to find $\boldsymbol{p_{g,out}}$by using the A-2 stoecker table Mass flow vapour out vaporrmula is

$$\dot{m}_{v,out} = \omega_{out}\ x\ \dot{m}_{dry\ air} \quad (11)$$

Mass flow rate evaporation $(\dot{m}_{evap})$ the formula is (12).

$$\dot{m}_{evap} = \dot{m}_{v,out} - \dot{m}_{v,in} \quad (12)$$

Mass flow rate outlet moist air $(\dot{m}_{moistout})$ the formula is (13).

$$\dot{m}_{moist,out} = \dot{m}_{moist,in} + \dot{m}_{evaporation} \quad (13)$$

- Water Characteristics

The result of the difference between the inflow rate $(m_{w\ in})$ and the magnitude of the evaporation rate $(\dot{m}_{evap})$ and the formulated as follows (14).

$$\dot{m}_{wout} = \dot{m}_{win} - \dot{m}_{evap} \quad (14)$$

and how to find $(m_{w\ in})$ i.e. by using the conversion from discharge (l/m) to (kg/s)

- Heat mass transfer or kalor

$$q = (\dot{m}_{win} \times h_{win}) - (\dot{m}_{wout} \times h_{wout}) \quad (15)$$

enthalpy values are searched using tables *A-2 properties of saturated water (liquid vaporliquid-vapor*water temperatures in and

- Maximum Kalor

$$\dot{q}_{max} = (\dot{m}_{win} \times h_{win}) - (\dot{m}_{wout} \times h_{wwb}) \quad (16)$$

h_{wwb} is the enthalpy obtained from the temperature of the water outlet (T_{out}) coupled with the wetbulbin temperature (T_{wetin}) in then divided by 2.

- Effectiveness

Effectiveness is a comparison between the actual heat released by the cooling tower and the maximum heat that the cooling tower may be able to remove and formulated such as (17).(ghani saitra et al., 2016; Ramkrishnan & Arumugam, 2013).

$$\varepsilon = \frac{q}{q_{max}} \quad (17)$$

- Number of Transfer Unit (NTU)(Jaber & Webb, 1989)

- $$NTU = -\frac{\ln\left(\frac{1-\varepsilon}{1-\varepsilon m^*}\right)}{1-m^*} \quad (18)$$
- $$m^* = \frac{\dot{m}_{moistin}}{\dot{m}_{moistout}} \times \frac{C_s}{C_p} \quad (19)$$
- $$C_s = \frac{h_{win} - h_{wout}}{T_{in} - T_{out}} \quad (20)$$

- Evaporation loss

is the evaporation loss per mass conditioned subduction every 1 °C at each unit of time. Evaporation loss usually represents the efficiency of cooling towethe r and the heat of equipment. There is a formula to calculate evaporation loss volume:(Tower, n.d.) (21)

$$\text{Evap loss} = 0.00085 \times 1.8 \times \text{circulating rate}\left(\frac{m^3}{hr}\right) \times (T_{w,in} - T_{w,out})$$

4 RESULT AND DISCUSSION

After data collection, data processing can be carried out to determine the performance of the cooling tower which is influenced by the obstacle ratio on the filler film which includes data: range and approach, maximum calorific value and calorific value, effectiveness and Number of Transfer Unit (NTU), as well as efficiency values and evaporation loss.

Table 1: Data Process Result.

PARAMETER	variation of filler		UNIT
	No Filler	0,31	
Range	7,34	11,45	°C
Approach	17,52	13,38	°C
Q	2,47	4,18	kJ/s
Q max	5,29	5,91	kJ/s
efektivitas	0,47	0,71	
NTU	0,87	2,33	
efisiensi	29,53	54,48	%
evaporation loss	5,006446688	8,517358735	mlC/min

Based on the results of data processing above Tab. 1 can be known to be graphed as shown below.

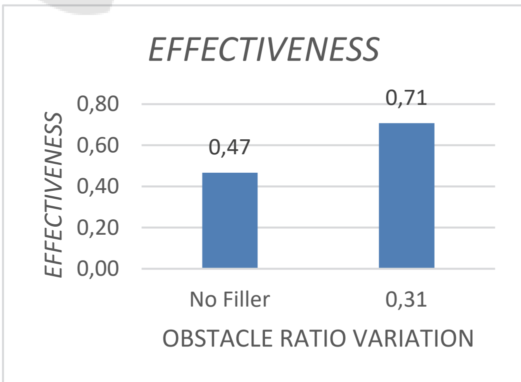


Figure 5: Graph of the effectiveness of Obstacle ratio variation.

Effectiveness is a depiction of the performance of the cooling tower which can be seen from the range value and approach value. The greater the value of the resulting range value, the cooling tower can be said to be effective but also must pay attention to the approach value also because the smaller the value of the approach, the cooling tower can be called an effective cooling tower. The range and approach values of the cooling tower without fillers are 7.34 °C and 17.52 °C and can be seen from Tab.1 that with the addition of fillers at the obstacle ratio level of 0.31 resulting in range and approach values of 11.45 °C and 13.38 °C, this indicates that fillers with a obstacle ratio level of 0.31 can improve the performance of this cooling tower.

Figure 5. is to illustrate that the effectiveness of the cooling tower, with an empty condition and with a filler condition whose variation in the ratio of the obstacle is 0.31 . It can be seen that the effectiveness value has increased quite significantly due to the obstacles that occur in the cooling tower due to the filler. With an effectiveness value of no filler of 0.47 and with filler an obstacle ratio level of 0.31 resulted in a value of 0.71.

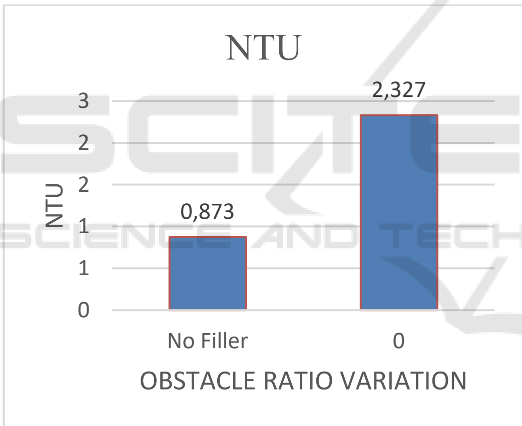


Figure 6: Graph of the NTU of obstacle ratio variation.

From fig.6 is a graphic depiction of the number of transfer unit (NTU) values which show that in cooling towers nilia NTU is so small because the transfer of heat resistance is so small that it can be seen that it is only worth 0.87, while for cooling towers with fillers with an obstacle ratio of 0.31 it produces a value of 2.33, this is due to the contact of hot fluid and cold fluid in the installed filler so that the energy transfer that occurs between 2 fluids is increasing.

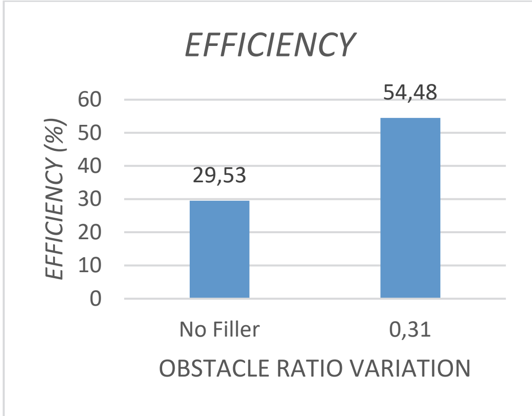


Figure 7: Graph of Efficiency of obstacle ratio variation.

From fig.7 is a graph of the cooling efficiency of the tower. The cooling efficiency of the tower without filler only resulted in 29.53% and the efficiency of the cooling tower filled with a filler ratio of 0.31 resulted in an efficiency of 54.48%. This is caused by the exhaustion of the inlet temperature and outlet temperature of the cooling tower.

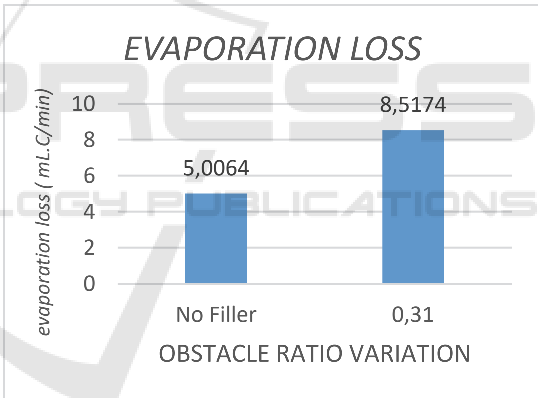


Figure 8: Graph of Evaporation loss of obstacle ratio variation.

Figure 8 is a graph of evaporation loss from cooling towers. Evaporation loss is a condition where the evaporation loss (fluid volume) at a temperature change (°C) in a unit of time. Evaporation loss usually describes the efficiency of cooling towers and the heat of equipment. As seen on fig 8. The evaporation loss value in the cooling tower without filler is 5.0064 (mL°C/min) and the nilia evaporation loss in the cooling tower with a filler ratio of 0.31 which is 8.5174 (mL°C/min) there is an increase caused by the contact between the hot fluid and the cold fluid more and more due to the filler.

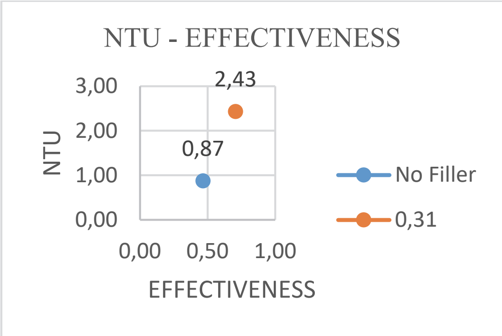


Figure 9: Graph of the NTU of Effectiveness.

Figure.9 shows a graph of the value of the NTU cooling tower against the value of the effectiveness of the cooling tower. The NTU value is directly proportional to the effectiveness value, because the higher the heat transfer value or energy transfer in a cooling tower, the higher the effectiveness value of the cooling tower. It can be seen here that with the influence of the addition of fillers (variations in obstacle ratio) the effectiveness value increases. At the time of cooling tower without filler, it was seen in fig.9 NTU was valued at 0.87 with an effectiveness of 0.47, while when the cooling tower was filled with filler with an obstacle ratio of 0.31 NTU was worth 2.43 and the effectiveness value was 0.71. Therefore, fillers in cooling towers are very important for their role to improve the performance in cooling towers.

5 CONCLUSION

Based on the results of experiments and data processing on each variation in the obstacle ratio, it can be concluded that:

1. Filler (obstacle ratio) in the cooling tower is a very important influence, because it can improve the performance of the cooling tower.
2. The effectiveness and efficiency of the cooling tower can be seen from the range and approach values.
3. The addition of filler (obstacle ratio) affects the efficiency and effectiveness of cooling tower which have increased with successive values : 54.48 % and 0.71 values.
4. The higher the NTU value of the cooling tower, the highger the value of uts effectiveness.

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