Performance improvement of cooling tower by using various types of fins

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***Abstract*—** Cooling towers are a really important a part of many chemical plants. The primary task of a cooling system is to reject heat into the atmosphere. They represent a comparatively inexpensive and dependable means of removing low-grade heat from cooling water. The make-up water source. Cooling towers are ready to lower the water temperatures of devices that use only air to reject heat, just like the radiator during a car , and are therefore more cost-effective and energy efficient. to enhance the heat transfer rate is required higher surface area for dissipation of heat. here to increase the performance of cooling tower, we are use fins. Fin are the extended surface protruding from a surface or body and they are meant for increasing the heat transfer rate between the surface and the surrounding fluid by increasing heat transfer area. we increase the rate of heat transfer as good as possible by use of different fin geometry, in this paper we uses rectangular fin and circular shape fin geometry. On comparison, rectangular configuration provides the best heat transfer than that of other configurations. The effectiveness of rectangular fin more as compare to other configuration of fin.

***Keywords*—**Cooling tower, fin, Draft, Geometry, efficiency, effectiveness.

1. Introduction

A cooling tower is a semi-enclosed device for evaporative cooling of water by contact with air. it is a wooden, steel or concrete structure and corrugated surfaces or baffles or perforated trays are provided inside the tower for uniform distribution and better atomization of water in the tower. the hot water coming out from the condenser is fed to the tower on the top and allowed to tickle in form of thin drops. the air flows from bottom of the tower or perpendicular to the direction of water flow and then exhausts to the atmosphere after effective cooling. to prevent the escape of water particles with air, draft eliminators are provided at the top of the tower.

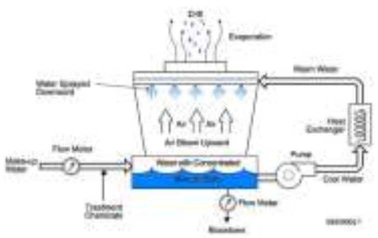


Fig. no. 01 Schematic diagram of cooling tower

Cooling tower reduces temperature of circulating water so that water may be used in heat exchange equipment and condensers. Cooling towers are equipment devices Commonly used to dissipate heat from power generation units, water-cooled refrigeration, air conditioning and industrial processes. Cooling towers offer an excellent alternative particularly in locations where sufficient cooling water cannot be easily obtained from natural sources or where concern for the environment imposes some limits on the temperature at which cooling water can be returned to the surrounding.

There are several important factors that govern the operation of cooling tower:

- The dry-bulb and wet-bulb temperatures of the air
- The temperature of warm water
- The efficiency of contact between air and water in terms of the volumetric mass transfer coefficient and the contact time between the air and the water
- The uniformity of distribution of the phases within the tower
- The air pressure drop
- The desired temperature of the cooled water.

Air might enter the tower driven by a density gradient (natural draft), might be pushed into the tower (forced draft) at the base or drawn into the tower (induced draft) assisted by a fan.

VARIOUS TYPES OF COOLING TOWERS:

The cooling tower might be classified into several types, but they are broadly categorized by following considerations:
1. Whether there is direct or indirect contact
2. The mechanism used to provide the required airflow
3. The relative flow paths of air and water
4. The primary materials of construction
5. the type of heat transfer media applied
6. The tower’s physical shape

GENERAL CLASSIFICATION OF COOLING TOWERS

Classification based on air draft:

1) Atmospheric tower 2) Natural draft tower 3) Mechanical draft tower

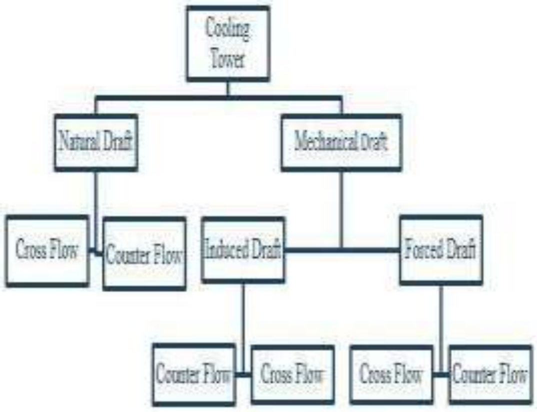


Fig. no. 02 classification of cooling tower

Mechanical draft tower: Mechanical draft towers have large fa to force or draw air through circulated water. There are t different classes of mechanical draft cooling towers

FORCED DRAFT COOLING TOWER

a. **Forced draft**: It has one or more fans located at the tower bottom to push air into the tower . During operation, the fan forces air at a low velocity horizontally through the packing and then vertically against the downward flow of the water that occurs on either side of the fan. The drift eliminators located at the top of the tower remove water entrained in the air.

INDUCED DRAFT COOLING TOWER

b. **Induced Draft**: A mechanical draft tower with a fan at the discharge which pulls air through tower. The fan induces hot moist air out the discharge. This produces low entering and high exiting air velocities, reducing the possibility of recirculation in which discharged air flows back into the air intake.

Fin- A fin is a surface that extends from an object to increase the rate of heat transfer to or from the environment by increasing convection. For the principle of conduction, convection, radiation of an pin configuration determines the amount of heat it transfers Increasing the temperature difference between the fin configuration and the depends on the environment, slightly increasing the convection heat transfer coefficient, or slightly increasing the surface area of the pin configuration of the object increases the heat transfer. Sometimes it is not economical or it is not feasible to change the first two options. Adding a fin configuration to the object, however, slightly increases the surface area and can sometimes be economical solution to heat transfer problems. Circumferential fins around the cylinder, square and rectangular shape of a motor cycle engine and fins attached to condenser tubes of a refrigerator are a few familiar examples only occurs when there is a temperature difference, Flows faster when this difference is higher, Always flows from high to low temperature, Is greater with greater surface area. in our paper study, we uses circular shape fin and rectangular shape fin.

Circular fin-

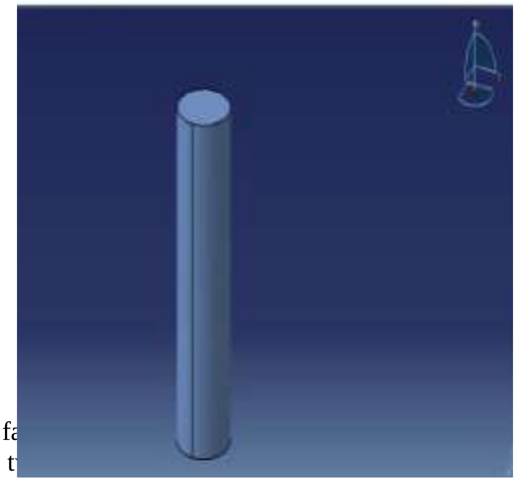


Fig. no-03 Circular shape fin

Rectangular fin-

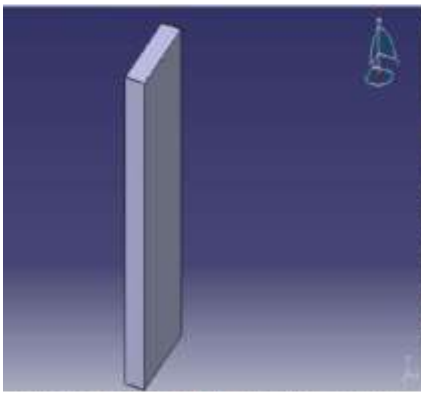


Fig. no-04 Rectangular shape fin

2. Literature review

Gaurav agrawal et al. explain a development of simple and efficient mathematical model, in which energy, draft and pressure equation solved simultaneously. Model was validated with experimental data collected from an induced draft counter flow rectangular cooling tower of refrigeration plant (capacity 220 tons) in dairy industry. In a parametric study, Wet bulb temperature of inlet air plays a significant role on air and water outlet temperatures, evaporation loss, fan power, thermal efficiency and energy distortion. This study presents numerical procedure for simultaneous solution of heat and mass transfer formulation incorporated with draft equation[01]

Dhaval P Patel et al. explain a detailed energy study is shown for 210MW, of coal fired thermal power plant to evaluate the plant and subsystem [feed water heaters (high pressure and low pressure)], etc. efficiencies. Research represent cooling tower effectiveness of thermal power and gives suggestion for improvement of cooling tower performance. Measurements of the temperature and velocity fields in a cooling tower were performed for the given power plant parameters, cooling tower constructional characteristics and ambient air velocity conditions in the vicinity of the cooling tower[02]

M. Goodarzi, and S. Moradi Maryamnegari explain a new natural draft dry cooling tower with better cooling efficiency during the windy condition has been introduced. A numerical method has been used to simulate and predict the thermo hydraulic performance of the proposed cooling tower in comparison to the usual cooling tower. The details of the flow field and also outlet water temperature have been presented comparatively. A new geometry with different arrangement of the radiator sectors has been proposed to improve the cooling efficiency of the natural draft dry cooling tower[03]

B Bhavani Sai et al. explain detailed methodology of an Induced draft cooling tower of counter flow type in which its efficiency, effectiveness, characteristics are calculated. The technical data has been taken from a mechanical draft cooling tower. Cooling towers are heat removal devices used to transfer process waste heat to the atmosphere. Cooling towers make use of evaporation whereby some of the water is evaporated into a moving air stream and subsequently discharged into the atmosphere. As a result, the remainder of the water is cooled down significantly. [04]

H. Chilton et al. explain the most important feature of their performance is the temperature of the re-cooled water, which depends on the water rate to the tower, the temperature range through which it is cooled, the wet-bulb and dry-bulb temperatures of the ambient air and the dimensions and design of the tower. The object of the paper is to show how the observed relationships between these variables may be expressed in a form suitable for practical calculations. [05]

T. Jagadeesh and Dr. K. Subba Reddy explain we use a natural draft counter flow cooling tower in investigating the performance of cooling tower in different seasons. The humidity is defined as water particles present in air. The humidity is the major factor in the atmosphere, it depends upon ambient temperature. Humidity is high in winter season and low in summer season. The performance of the natural draft cooling tower is dominated by wind speed, ambient air temperatures and humidity in the atmospheric conditions. When the humidity is high in atmosphere, large quantity of water is required for cooling condensate. When humidity is low in atmosphere, small quantity of water is required for cooling condensate. The value of relative humidity in the atmosphere varies from place to place and season. The different losses in the cooling tower such as drift losses, evaporation losses and blow down losses can be calculated. The maintenance of cooling tower in the form of removal of scale or corrosion plays important role in the performance of the tower[06]

Dileep KJ et al. explain cooling tower is a heat rejection device. It is used to dissipate waste heat into the atmosphere. This paper is all about the developing a cooling tower that cools the hot water coming from the different equipment in energy conversion lab. In energy conversion lab, there are total five equipment's from which we are getting hot water while conducting the experiment. Due to hotness the water is not suitable for experimentation. So the hot water is directly released into the ground without being re-circulated. This necessitates the development of cooling tower to cool the water. For this purpose a tank used where the hot water coming from the different equipment gets collected. The hot water is then supplied to the cooling tower for cooling by the use of motor pump. The cooling effect is obtained by the natural air which is entering in the gap provided by the louvers. After the water is cooled it gets collected in another tank which is kept at the bottom of the cooling tower. The cooled water is re-circulated into the equipment for conducting the experiment. **[07]**

Prof. Ajit Prasad Dash et al. explain a detailed methodology for thermal design of cooling tower. The technical data is taken for Mechanical draft cooling tower. A cooling tower is a heat rejection device which rejects waste heat to the atmosphere through the cooling of a water stream to a lower temperature. The principle of operation of cooling towers is very similar to that of the evaporative type of condensers, in which the warm water gets cooled by means of evaporation. Water evaporates as a result of the hot water droplet coming in contact with the air (which is being pumped out by means of a fan). This evaporating water also absorbs the latent heat from the water surrounding it. By losing latent heat, the water is cooled. Cooling towers offer an excellent alternative particularly in locations where sufficient cooling water cannot be easily obtained from natural sources or where concern for the environment imposes some limits on the temperature at which cooling water can be returned to the surrounding. [08]

Sunil J. Kulkarni and Ajay giri K. Goswami explain cooling towers have been carried out on various aspects of cooling towers aimed at optimizing the operation. A suitable water distribution across the plane area of the cooling tower can increase efficiency of natural draft cooling towers. The present review is aimed at summarizing studies and research on cooling tower for increasing efficiency and power savings to make it more economical and efficient. [09]

3. COOLING TOWER DESIGN

i. Heat Transfer Rate of Water , (Qth)

$Q_{th} = m\, C_{pw} \Delta T$

(Assume mass flow rate of water, ṁ 100 lit/hr)

ṁ=100lit

hr

100 kg

ṁ= 0.2778

3600 sec

Specific heat of water Cpw

= 4.187 KJ KgK

Assume the temperature drop should be 3°c and initial temperature of Water 50°c

$\Delta T = T_{w1} - T_{w2}$

T_{w1} = Initial temperature of water

Tw2 = Final temperature of water
Qth = 0.2778 × 4.187 ×(50–47)
Qth = 0.3489 kw

ii. Heat Transfer Rate of Air, (Qth)

Mass Flow Rate of Air, ṁa=ρ Af V
Density of air, ρ= 1.225kg/m³
Velocity of Air, V
(Velocity of air measured by Anemometer=4.7 m/sec)
Area of Fan, Af
A = π × d ²
f 4 f
Diameter of fan df=6inch=0.1524m
A = π
×(0.1524)²
f 4
Af= 0.01828 m²
ṁa = 1.225 ×0.01828 ×4.7
ṁa = 0.1052 kg/sec
Considering Input temperature of air at room temperature (27°c)
Q = ṁa Cp ΔT
ΔT=Ta2−Ta1
Ta1= Initial temperature of air (27°c)
Ta2= Final temperature of air
0.3489=0.1052 ×1.005 ×(Ta2−27)
Ta2 =30.29°c

iii. Calculation for Length of Tube

LMTD
Ø1=Tw1−Ta2 Ø1= 50 − 30.29
Ø1=19.71°c Ø2=Tw2−Ta1 Ø2= 47−27 Ø2=20°c
Øm= ∅1−∅2
ln ∅1∅2
Øm =19.71−20

Øm=19.51
Heat transfer rate of tube Q=UAtubeØm
U=0.401 (for Copper)
Since the number of passes is more than one Øm(LMTD) needs correction factor F
Temperature Ratio (P)
Ta 2−Ta 1
P =
Tw 1−Ta 1
30.29−27
P =
50−27
P =0.14304
Capacity Ratio (R)
Tw 1−Tw 2
R =
Ta 2−Ta 1
50−47
R =
30.29−27
R=0.9118
By using the graph of Correction factor plot single cross flow heat exchanger F=1.0
Qth=FUAtubeØm
Atube =
Qth FUØm
Atube=
0.3489
1×0.401×19.85
A tube=0.0438m² Area of Tube A tube= π× dt ×lt
0.0438= π×(1× 0.01× lt)
lt= 1.39 m
lt = 139 cm
n = No. of Tube
lt = Total length of tube

l = lt/ n
139
l =
5
l = 27.8 cm=10.85 inch
for Actual model the length of tube is 13 inches
10.85 ≅ 13 inches

iv. Area of Heat Exchanger without Fins

A (without fins) = π×dt×lt
A = π×(0.01)×1.664
A = 0.05227 m²

v. Area of Heat Exchanger with Rectangular Fins

A fin
= (0.03 ×0.03)− π
4
×(0.01) ²
A fin = 0.00164292 m ²
Neglect thickness area of fin
Total Area (with fins) = (Total no. of fin × Area of fin) + Area of tube without fin
= (55× 0.00164292) + 0.05227
Total Area = 0.14263 m²

vi. Area of Heat Exchanger with Circular Fins

A = π × d²
fin 4
Afin
= π × (3.5)²
4
A fin= 0.00164292 m²
The Fins Area of Rectangular fins is equal to Circular fins

4. RESULT

i. Actual Heat Transfer Rate of Water without Fins, Qact

Qact = ṁwCpwΔTmean
Mass flow rate of water, ṁw = 100 lit/hr
= 100/3600 = 0.0277 kg/sec
Specific heat of water, Cpw= 4.187 KJ/Kg K
ΔT = Tw1− Tw2
Initial temperature of water, Tw1 = 60°c Final temperature of water, Tw2 = 58.0°c Initial temperature of water, Tw1 = 60°c Final temperature of water, Tw2 = 58.1°c Initial temperature of water, Tw1 = 60°c Final temperature of water, Tw2 = 57.9°c
ΔTmean=(Tw 1−Tw 2)+(Tw 1−Tw 2)+(Tw 1−Tw 2)
3
ΔTmean
= (60−58.0)+(60−58.1)+(60−57.9)

3

ΔTmean= 2°c Experimental investigation and Analysis of cooling tower to enhance its efficiency by using various types of fins with variable material

ii. Heat Transfer Rate of Water with Rectangular Fins, Qact

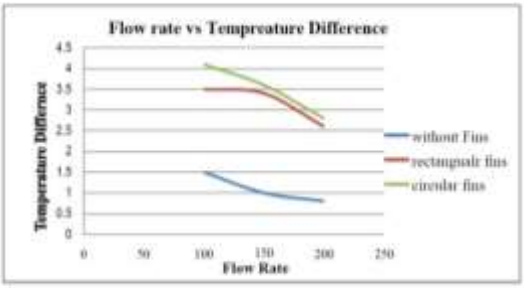
Qact = ṁwCpwΔTmean
Mass flow rate of water, ṁw = 100 lit/hr
= 100/3600 = 0.0277 kg/sec
Specific heat of water, Cpw= 4.187 KJ/Kg K
ΔT = Tw1− Tw2
Initial temperature of water, Tw1 = 60°c Final temperature of water, Tw2 = 55.4°c Initial temperature of water, Tw1 = 60°c
Final temperature of water, Tw2 = 55.7°c
Initial temperature of water, Tw1 = 60°c
Final temperature of water, Tw2 = 55.8°
ΔTmean
=(Tw 1−Tw 2)+(Tw 1−Tw 2)+(Tw 1−Tw 2) 3
ΔTmean
= (60−55.4)+(60−55.7)+(60−55.8)
3
ΔTmean= 4.36°c
Qact = 0.0277 × 4.187 × 4.36
Qact = 0.50648 Kw
Capacity = 0.50648
3.516
Capacity = 0.14405 Tons

iii. Heat Transfer Rate of Water with Circular Fins, Qact

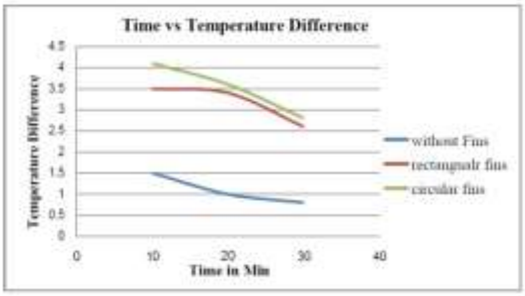
Qact = ṁwCpwΔTmean
Mass flow rate of water, ṁw = 100 lit/hr
= 100/3600 = 0.0277 kg/sec
Specific heat of water, Cpw= 4.187 KJ/Kg K
ΔT = Tw1− Tw2
Initial temperature of water, Tw1 = 60°c Final temperature of water, Tw2 = 55.1°c
Initial temperature of water, Tw1 = 60°c Final temperature of water, Tw2 = 55.3°c Initial temperature of water, Tw1 = 60°c Final temperature of water, Tw2 = 55.7°c
ΔTmean
=(Tw 1−Tw 2)+(Tw 1−Tw 2)+(Tw 1−Tw 2) 3
ΔTmean
= (60−55.1)+(60−55.3)+(60−55.7)
3
ΔTmean= 4.633°c
Qact = 0.0277 × 4.187 × 4.633
Qact = 0.53733 Kw
Capacity = 0.53733
3.516
Capacity = 0.15282 Tons

4.1 RESULTS ON GRAPH

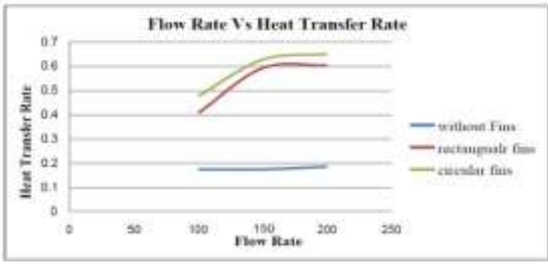
i. Flow rate vs. Temperature Difference



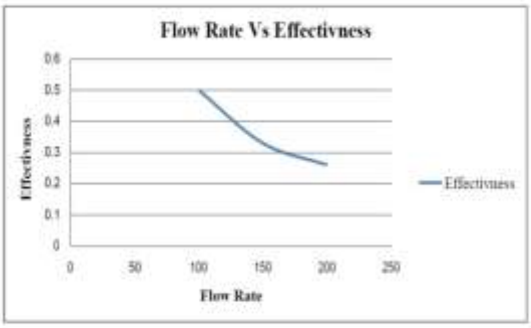
ii. Time vs Temperature Difference



iii. Flow Rate Vs Heat Transfer Rate



iv. Flow Rate Vs Effectiveness



5. Conclusion

In order to express the heat exchanging capacity of an extended surface relative to the heat exchanging capacity of the primary surface with no fins, it is useful to define fin effectiveness. Considering the effectiveness of the fins the heat transfer is found out to be better in the rectangular fin and varies with the change in the fin's thickness, based on the results obtained the fin thickness and the distance between the fins plays a major role in its effectiveness and heat transfer. The use of fin (Rectangular and circular), provide efficient heat transfer: Fin provide near about 5 % to 13% more enhancement of heat transfer as compare to without fin. Heat transfer through rectangular fin higher than that of circular fin. Temperature at the end of rectangular fin is minimum as compare to circular fin. The effectiveness of rectangular fin is greater than circular fin. Choosing the minimum value of ambient fluid temperature provide the greater heat transfer rate enhancement.

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