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Design Analysis and Fabrication of Cooling Tower using Different Packing Materials

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Abstract: A cooling tower is a heat and mass transfer device commonly used to dissipate waste heat from devices like condensers in power plants, compressors, pumps in industries. Cooling tower works on the principle of evaporative cooling in which sensible heat of water is given to air result in an increase in the latent heat of air. It offers an effective alternative at locations where there is cooling water scarcity and where hot water discharge causes an environmental concern. The effective cooling of water depends on various process parameters like a dry bulb and wet bulb temperature of the air, fill material and its size, inlet air flow rate, air inlet angles, water flow rate, and temperature, etc. The present paper is a detailed analysis of the counter flow cooling tower by changing the packing material. Considering a common application to design a simple evaporative- counterflow cooling tower. The cooling tower is then modeled in Solidworks. The approach of this project is to check the effect of change in packing material over the effectiveness and range of the cooling tower. The experimental setup of the physical model of the cooling tower is to be analyzed to study the real-time effect. All the required data is taken from the Steam table by R.S. Khurmi and S. Chand and Refrigeration and psychrometric properties handbook by M. L. Mathur and F. S. Mehta

Keywords- Packing Material, Counter Flow Cooling Tower, Range, Effectiveness, Solidworks 2018

I. INTRODUCTION

Coolingtower is a heat extraction device which is applicable in the industries like Petrochemicals, Food Processing, Dairy Power Plants, Stations for providing a continuous supply of cold water which can be reused several times. the cooling tower is one of the 'zero pollution technologies' which make this concept important from the future point of view. In large plants like a nuclear plant, litters of water is used just to maintain the temperature of the plant.

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This water absorbs heat so that overheating can be prevented. This hot water is passed to the cooling tower where the temperature of the water is loweredon the basis of the exchange of heat. the cooling tower is a heat and mass transfer device commonly used to dissipate waste heat from devices like condensers in power plants, compressors, pumps in industries.Cooling tower works on the principle of evaporative cooling in which sensible heat of water is given to air result in an increase in the latent heat of air. It offers an effective alternative at locations where there is the cooling of water where hot water discharge causes an environmental concern.

The effective cooling of water depends on various process parameters like a dry bulb and wet bulb temperature of the air, fill material and its size, inlet air flow rate, air inlet angles, water flow rate, and temperature, etc.

The present project is a detailed analysis of the counter flow cooling tower by changing the packing material. Considering a common application to design a simple evaporative- counter flow cooling tower. The cooling tower is then designed in CAD software and then fabricated. The approach of this project is to check the effect of change in effectiveness by packing material

There are mainly two types of cooling tower

- **Natural draft cooling tower**
- **Mechanical draft cooling tower**

a) Natural Draft Cooling Tower

The natural draft or hyperbolic cooling towers are huge cooling towers in which cooling of water is taking place naturally. the difference in densities of hot air and cold air

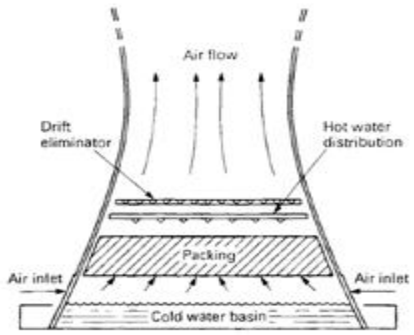

Fig 2.1. Natural draft cooling tower

results in the circulation of air from bottom to the top of the cooling tower generated bythe difference in temperatures. As Heated air is less dense hence it moves upward and due to low pressure cold air enter into the tower through air inlet at the bottom.

b) Mechanical Draft Cooling Tower.

The mechanical draft cooling towers shown in fig.2 this tower is built using artificial mechanical components are used for increasing effectiveness and lowering the area. As we area using blower and fan for circulation of water the tower become forced and induce cooling Many types of fill packing Honeycomb packing, P.V.C pipes, plastic waste, coconut fiber types are used which plays an important role in increasing area for cooling.

Types of Mechanical Draft Cooling Tower.

- Counter Flow.
- Cross Flow.

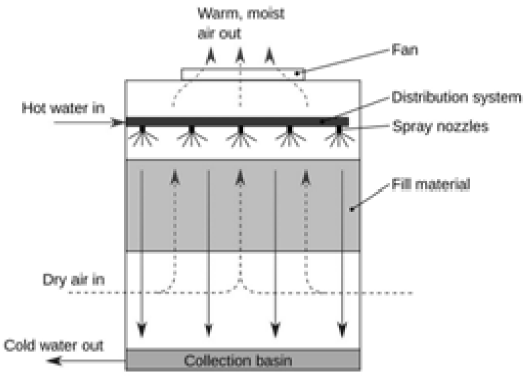

Fig. 2.2. Mechanical Draft Cooling Tower

Depending upon the direction of flow,coolingtowerscan be specified in these types. in crossflow cooling tower water and air come in contact with each other in the opposite direction. This can be said as in 180º. While in crossflow intersection of air and water flow is perpendicular. This can be said as in 90º. Crossflow cooling towers are widely used as more air can be passed by sideways. The demand for mechanical draft cooling tower is increasing day by day.

II. LITERATURE REVIEW

[1] Mohammad N saif Abbas, Al-Nustansiniah university/COE, Environmental Engineering Department, **Study Performance of different packing in an open cooling tower.** This paper gives a beautiful explanation of the various packing material and their curves and the cooling characteristics. According to this research review, Maximum performance (Kgl and Z/L) in the given volume of lower packing material with minimum water airflow ratio. The temperature variation along with the tower for the given inlet water temperature and cooling range is a function of air inlet enthalpy as well as the position, but not a function of air-water flow rate

[2] Mrvishwanath mm, dr.n.kakshamanswamy Sea College Of Engg ,BangloreVtu.In this paper, many studies that have already done on the cooling tower are discussed. The main focus was given on the cooling tower containing a fluidized bed with (L/G) ratio of less than 1. In most cases, thermocol is used due to less density and adaptability to different shapes. He gave a simple enclosure on how does fluidized bed works.Fluidization is a phenomenon by which solid particles behave like a fluid. His work also focused on an important parameter 'performance Characteristics' which is generally expressed in terms of diffusion units(N_d)

$N_d = \frac{KAL}{L} = \int \frac{Cp.dT}{(H-H')avg}$

[3] M kalpana d. Muniprasad. Savita institute of medical and technical Science.This paper gives the complete idea of the natural draft and induced draft cooling tower. Natural draft type cooling tower ranges from 150-200 m height and can cool up to 4-5 degrees in a single pass of 200m height.As natural drafts are usually used in large power plants and industries these towers are high and tall in size and has the hyperbolic shape

[4] Ricardo f. F. Pontes, willan m. Yamauchi and evelink.g. **the behavior of the cooling tower on various different climate conditions**. Since the design has to take the most critical situation, the hottest day and coolest day.Reducing the cost reduced fan motor power consumption either variable frequency drive is installed. This method should reduce annual electric consumption.

[5] arashmirabdolahlayasani, zahranamdaebaboli, mohsenzumani laden and mosoudzareh

in paper **Experimental study on the thermal performance of the mechanical cooling tower flats type packing** provides the various interesting and useful conclusion that that range increases with an increase in packing rotational velocity, packing rotational velocity does not have any impact on a corporation rate.

The natural type cooling tower range from the 150 to 200-meter height as their natural cooling tower their cool up to 4 to 5 degree Celsius in a single pass of the 200-meter height. A fan is located at the top of the tower. Hot water from the source is sprayed with the help of a nozzle which results in increase in the surface area of the hot water for the operation. When it comes in the contact with the packing material, the time of the contact between the air and hot water increases the more surface area will give a chance for the evaporation results in the cooling of hot water.

[6] manas.m.patilsanket.j.patil, prashant.s.patil, suneet.j.mehta, vjva institute of technology, Maharashtra.

Experimental study of design and analysis of cooling tower.

In this paper study has been done on the way of increasing the efficiency of the cooling tower by enabling more volume of air to pass through the tower and hence more heat will be dissipated. The zigzag water flows pattern has made the water movement to slow down and longer time of water exposure to air is achieved.

[7] mirajanalakovic, Slobondonlakovicmilicajovic, university of Nis, faculty of mechanical engineering. Experimental **Study of design and performance analysis of the cooling tower in the adhesive factory.**

In this paper study done is that the design of the cooling tower is closely related to cooling tower characteristics which are unique for a particular tower and loading factor which depends on hot water temperature. The rate of heat loss by water never equals to rate of heat gain by air due to different types of hat losses. It is almost impossible to use CFD to carry about performance analysis of the cooling tower in terms of effectiveness.

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Results clearly demonstrate that with an increase in air inlet angle in any direction outlet water temperature increases and thus cooling effectiveness get reduced

[8] **Experimental Study Of Thermal And Exergy Analysis Of Counter Flow Induced Draught Cooling Tower** By Abdul HadiN.Khalifa,Engineering Technical College ,Middle Technical University ,Badhdad-Iraq

In this study merkel assumption, which states that saturated air is leaving the cooling tower gives curvature path for saturation process through cooling tower instead of a straight line. The ratio of the mass flow rate of water to that of air (L/G) for such tower was in a range of 1.25 to 1.5. In a cooling tower, the exergy of air is consumed to destroy the exergy of water, the more exergy destruction gives, the higher efficiency for cooling tower. As the moisture content of the air increases the chemical energy increase, on the other hand, as the temperature approaches to water temperature air thermal exergy tend to reduce

III. DESIGN OF COOLING TOWER

Cooling tower is simply made up of thin sheet of stainless steel. And dimensions of cooling tower are mentioned below.

I. Dimensions:

- Height of tower: 100 Centimeter
- Cross section area: 25*25 cm^2
- Height of packing material: 60 cm

Fig 4.1. Designed Cooling Tower

IV. PACKING MATERIALS

1. P.V.C PIPES

Fig 5.1. P.V.C

2. COCONUT FIBER

Fig 5.2. COCONUT FIBER

3. HONEYCOMB PADS

Fig 5.3. HONEYCOMB PADS

V. SPECIFICATIONS

Further paper is a comparison of packing material on the base of effectiveness, Range and approach. For this purpose, each packing material is observed individually. All the surrounding conditions are tabulated below. On the basis of Boundary conditions some data is taken from the psychrometricproperties handbook by M. L. Mathur and F. S. Mehta

For a better understanding of result and for ease of use, some nomenclatures are given below

NOMENCLEATURES

- T1 temperature of inletwater.
- T2 temperature of outletwater.
- T3 dry bulb temperature of inlet air.
- T4 wet bulb temperature of inlet air.
- T5 dry bulb temperature of outlet air.
- T6 wet bulb temperature of outlet air.
- V volume of circulating water
- Φ relative humidity.
- M_a mass of air flow.

VI. CALCULATIONS

1. **P.**V.C PACKING MATERIAL

Table VII.1.1. TechnicalSpecification

Enthalpy of air at inlet temperature (H_{ai})	78.5 $\frac{kj}{kg}$
Enthalpy of air at outlet temperature (H_{ai})	83$\frac{kj}{kg}$
Specific humidity of air at inlet (w_i)	0.01808 $\frac{kg}{kg\ of\ dry\ air}$
Specific humidity of air at outlet (w_o)	0.01987 $\frac{kg}{kg\ of\ dry\ air}$
Enthalpy of water at inlet temperature T1 (H_{wi})	205.1$\frac{kj}{kg}$
Enthalpy of water at outlet temperature T3 (H_{wo})	121.5$\frac{kj}{kg}$

Table VII.1.2.Data from Psychometric Chart and Steam Table

Volume of circulating water (V)	14 (L/Hr)
Inlet temperature of water(T1)	49°C
Outlet temperature of water(T2)	29°C
Dry bulb temperature of inlet air (T3)	32°C
Wet bulb temperature of inlet air (T4)	25°C
dry bulb temperature of outlet air (T5)	32°C
wet bulb temperature of outlet air (T6)	26°C

Thermal Calculations

Cooling Tower Approach (CTA)

CTA = T2–T4

=29 – 25

CTA = 4 °C

Cooling Tower Range (CTR)

CTR = $T_1 - T_2$

= 49 - 29

CTR = 20°C

Mass of Water Circulated In Cooling Tower

M_{w1} = 14.06 L/Hr

= 14.06 X 1

M_{w1} = 14.06 Kg/Hr

Heat Loss By Water (HL)

HL= M_{w1} X C_{pw} X $(T_1 - T_2)$

= 14.06 X 4.186 X (49 – 29)

HL= 1175.416 Kj /Hr

Effectiveness Of Cooling Tower (€)

$$€ = \frac{range}{range+approach}$$

= 20 /(20+4)

€ = 83.33 %

2. COCONUT FIBER PACKING MATERIAL

Table VII.2.1. TechnicalSpecification

Volume of circulating water (V)	14.06 (L/Hr)
Inlet temperature of water(T1)	49°C
Outlet temperature of water(T2)	31°C
Dry bulb temperature of inlet air (T3)	32°C
Wet bulb temperature of inlet air (T4)	25°C
dry bulb temperature of outlet air (T5)	32°C
wet bulb temperature of outlet air (T6)	26°C

Table VII.2.2. Data from Psychrometric Chart AndSteam Table

Enthalpy of air at inlet temperature T3 (H_{ai})	$78.5\frac{kj}{kg}$
Enthalpy of air at outlet temperature T6 (H_{ai})	$83\ \frac{kj}{kg}$
Specific humidity of air at inlet (w_i)	$0.01808\frac{kg}{kg\ of\ dry\ air}$
Specific humidity of air at outlet (w_o)	$0.01987\frac{kg}{kg\ of\ dry\ air}$
Enthalpy of water at inlet temperature T1 (H_{wi})	$205.1\frac{kj}{kg}$
Enthalpy of water at outlet temperature T3 (H_{wo})	$129.8\frac{kj}{kg}$

Thermal Calculations

Cooling Tower Approach (CTA)

CTA = T2–T4

=31 – 25

CTA = 6°C

Cooling Tower Range (CTR)

CTR = $T_1 - T_2$

= 49 - 31

CTR = 18°C

Mass Of Water Circulated In Cooling Tower

M_{w1} = 14. 6 X 1

M_{w1} = 14.06 Kg/Hr

Heat Loss By Water (HL)

HL= M_{w1} X C_{pw} X $(T_1 - T_2)$

= 14.06 X 4.186 X (49 - 31)

HL= 1059.39 Kj /Hr

Effectiveness Of Cooling Tower (€)

$$€ = \frac{range}{range+approach}$$

= 18/(18+6)

= 0.75

€ = 75 %

3. HONEYCOMB PADS PACKING MATERIAL

Table VII.3.1. TechnicalSpecification

Enthalpy of air at inlet temperature T3 (H_{ai})	$78.5\frac{kj}{kg}$
Enthalpy of air at outlet temperature T6 (H_{ai})	$83\frac{kj}{kg}$
Specific humidity of air at inlet (w_i)	$0.01808\frac{kg}{kg\ of\ dry\ air}$
Specific humidity of air at outlet (w_o)	$0.01984\frac{kg}{kg\ of\ dry\ air}$
Enthalpy of water at inlet temperature T1 (H_{wi})	$205.1\frac{kj}{kg}$
Enthalpy of water at outlet temperature T2 (H_{wo})	$125.7\frac{kj}{kg}$

Table VII.3.2. Data from Psychrometric Chart AndSteam Tabl

Volume of circulating water (V)	14.06 (L/Hr)
Inlet temperature of water(T1)	49°C
Outlet temperature of water(**T2**)	30°C
Dry bulb temperature of inlet air (**T3**)	32°C
Wet bulb temperature of inlet air (**T4**)	25°C
dry bulb temperature of outlet air (**T5**)	32°C
wet bulb temperature of outlet air (**T6**)	26°C

Thermal Calculations

Cooling Tower Approach (CTA)

CTA = T2–T4

=30 – 25

CTA = 5°C

Cooling Tower Range (CTR)

CTR = $T_1 - T_2$

= 49 - 30

CTR = 19°C

Mass Of Water Circulated In Cooling Tower

M_{w1} = 14. 6 X 1

M_{w1} = 14.06 Kg/Hr

Heat Loss By Water (HL)

HL= M_{w1} X C_{pw} X ($T_1 - T_2$)

= 14.06 X 4.186 X (49 - 30)

HL= 1118.24 Kj /Hr

Effectiveness Of Cooling Tower (€)

$$€ = \frac{range}{range+approach}$$

= 19/(19+5)

= 0.7916

€ = 79.16 %

Form the above observations honeycombpacking material is giving best effectiveness.The result is taken by keeping constant baundry conditins like specific humidity, inlet water temperature, inlet air temperature, flow rate of water, flow rate of air etc.

So that above result can be said a proper comparision of three packing material.

For further observations we will be using the best packing material. That is P.V.C packing material with effectiveness **€ = 83.33%**.by using this material, we are taking observations for conditions mentioned below.

I. Effect of humidity on effectiveness

II. Effect of inlet temperature water

III. Effect of flow rate

EFFECT OF HUMIDITY ON EFFECTIVENESS

For determining the effect of humidity on effectiveness, other parameters like inlet temperature of water and flow rate are kept constant.

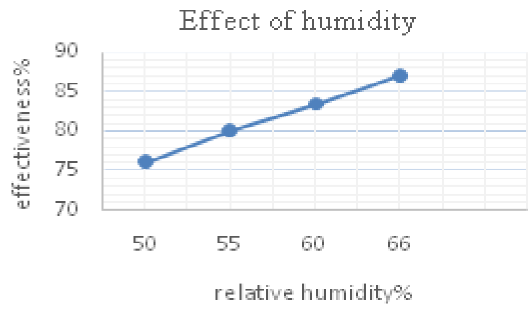
Flow rate **(V)** = 14L/Hr

Inlet water temperature **(T1)** = 49 °C

Outlet water temperature **(T2)** = 29 °C

Table VIII.I effect of relative humidity

Sr. No.	T3 (°C)	T4 (°C)	W Kg/kg of dry air	€ %
1.	32	23	50	76
2.	32	24	55	80
1.	32	25	60	83.33
2.	32	26	66	86.95



VII. EFFECT OF INLET WATER TEMPERATURE

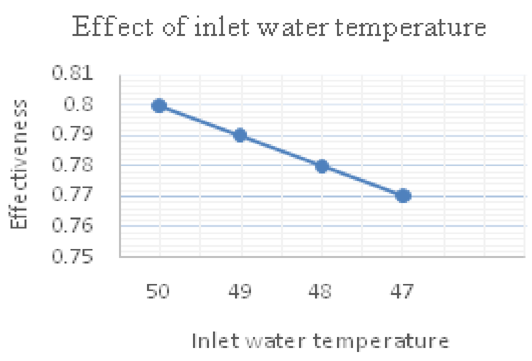
To determine effect of inlet water temperature effectiveness, other parameters like specific humidity temperature of inlet air and flow rate are kept constant.

Flow rate **(V)** =14.06 L/Hr

Specific humidity **(Φ)**=0.01808Kg/kg of dry air

Table VII.I effect of inlet water temperature

Sr. No.	T1 (°C)	T2 (°C)	T3 (°C)	T4 (°C)	€ %
1	50	30	32	25	80
2	49	30	32	25	79
3	48	30	32	25	78
4	47	30	32	25	77



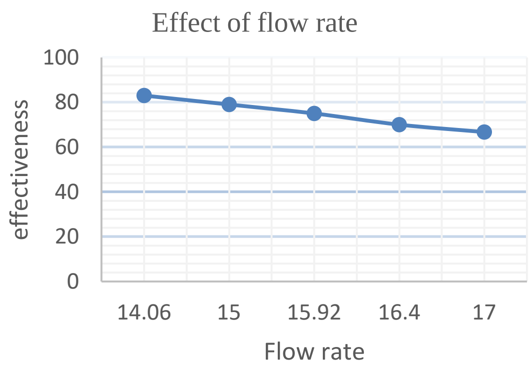
VIII. EFFECT OF FLOW RATE ON EFFECTIVENESS

To determine effect of inlet water temperature effectiveness, other parameters like specific humidity temperature of inlet air and flow rate are kept constant.

Inlet water temperature = 49°C
Outlet water temperature= 29°C
Inlet air temperature = 32°C
Wet bulb temperature = 25°C
Specific humidity (Φ) = 0.01808Kg/kg of dry air

Table X.I effect of inlet water temperature

Sr. No.	Flow rate (V)	€
1	14.06	83
2	15	79
3	15.92	75
4	16.4	70
5	17	667



IX. CONCLUSION

Form the above described result paper comes to the conclusion that:

- PVC packing material gives good results and cheap and can be taken from the scrap
- Effectiveness of packing material is directly proportional to specific humidity.
- Effectiveness of packing material is directly proportional to the inlet temperature of water.
- Effectiveness of packing material is inversely proportional to the flow rate of water

AKNOLEDGEMENT

We are very glad to present this research paper on "Design Analysis And Fabrication Of Cooling Tower Using Different Packing Materials". Manypeoplehavecontributeddirectlyorindirectlyin the successfulmakingofthisproject.Sowewould like to express our gratitude towardsthem. We are very much obliged to our project guide Prof. Komal Chilwal of the mechanical engineering department for guiding us. Her valuable suggestionscontributedtothesystematicandtimelycompletionofourprojectwork.Wearethankful to our beloved H.O.D. Dr. G. P. Deshmukh, who helped us to gain valuable insight into the topic. He always inspired us, motivated us. We are highlyobliged! Last but not least we are thankful to our PARENTS who inspired us and made all the facilities available for us

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