Proceedings of the
International Conference on Mechanical Engineering and Renewable Energy 2019
(ICMERE2019) 11 – 13 December, 2019, Chittagong, Bangladesh

ICMERE2019-PI-031

EXPERIMENTAL STUDY OF FORCED DRAFT CROSS FLOW WET COOLING TOWER

Sourav Barua*, Sukanta Shekhar Paul, Anik Paul, Ullash Sen, Md Rashed, Zia Uddin Mahmud

Department of Mechanical Engineering,
Chittagong University of Engineering & Technology
*sourav0603@gmail.com, sukanta0803034@gmail.com, anikcuet09@gmail.com, ullashsen11@gmail.com
mdrashed.cuet@gmail.com ziamahmud13@gmail.com

Abstract*-Nowadays, almost every industry and power plant need a cooling tower to recycle the water. It is a heat rejection device that is rejected dissipate large heat to the air through the cooling of a water stream to a lower temperature. In this paper, we have presented a cooling tower whose performance will be increased. The ability of a cooling tower depends on many factors such as inlet water temperature, air velocity, inlet air temperature, fill the area, fill spacing. In the system design, we have used splash type fills that are used with changes in fill spacing configuration to increase cooling performance and a heater with thermostat is used for temperature control. Splash packing is made of bars stacked in decks that break the water into drops as it falls down the deck to deck. Having thermostat integrated with it has been used to control the required temperature. After this experiment, we found that cooling tower performance increased but at the same time drift loss also increased. So, for better performance and less drift loss, choosing a perfect air velocity is a must.*

Keywords: Forced draft, Cross flow, Self-designed fin, Splashed type fins, Effects of air velocity.

1. INTRODUCTION

A cooling tower is a heat elimination system that makes use of water to transfer method waste warmth into the atmosphere. All cooling towers function on the precept of removing heat from water by evaporating a small element of water that is recirculated through the unit two [1]. The mixing of warm water and cooler air releases latent warmth of vaporization, causing a cooling effect to the water. When water is used as the warmness switch medium, wet, or evaporative, cooling towers may additionally be used. Wet cooling tower counts on the latent warmth of water evaporation to alternate warmness between the manner and the air passing even though the cooling tower. The cooling tower may additionally be a vital phase of the method or may additionally provide through heat exchangers. Cooling towers can be categorized through the type of warmness transfer, the kind of drafts and place of the drafts, relative to the warmth switch medium, the type of heat switch medium, the relative direction of air and water contact, and the type of water distribution system. Since wet or evaporative cooling towers are the dominant type and their additional air pollutants, the area will tackle only that type of water.

2. RELATED WORKS

The computational model used in the study of cooling tower performance was developed by Zannis and Rogdakis (2006) in order to be comprehensive enough in describing the heat mass exchange inside the counter flow cooling tower without however being computationally time-consuming. This means that the model can be used for examining the thermal performance of cooling tower taking into account all the major implications of the physical mechanism of water evaporation under high time scales, e.g. annual basis [9,10,11].

1. Heat and mass transfer will be considered only in a direction normal to the tower walls.
2. Heat and mass transfer through the tower walls to the environment will be negligible.
3. Heat transfer from the tower fans to the air or water streams will be unconsidered.
4. Heat and mass transfer coefficients will be considered constant throughout the tower.
5. The cross-sectional area of the tower will be considered uniform.
6. Water lost by drift is frictional.

3. MATHEMATICAL FORMULATION

The application of the first law of thermodynamics to an elementary part of the heat exchange area at the gas phase side provides (from fig 2.1):

$$\dot{m}_a h_a + d\dot{Q}_s + d\dot{Q}_L = (h_a + dh_a)\dot{m}_a \qquad (1)$$

In the previous relationship the term h_a stands for the specific enthalpy of moist air

$$h_a = c_{pa}T_a + W(c_{ps}^{sat}T_a + \Delta h_w) \qquad (2)$$

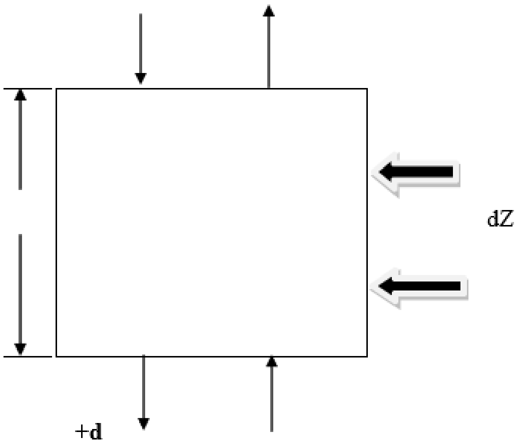

Fig 1: Schematic description of cooling water and air string

After substituting the previous expression to Equation (1) we get the following relation:

$$dh_a = c_{pa}dT_{a+}dW(c_{ps}^{sat}T_a + \Delta h_{w)+}Wc_{ps}^{sat} \quad (3)$$

The term $d\dot{Q}_s$ in Equation (1) represents the sensible heat load, which is transferred from the cooled water to the air stream due to their temperature difference and it can be written as:

$$d\dot{Q}_s = L\alpha_{LA}(T_w - T_a)dZ = d\dot{m}_a c_{pm} dT_a \quad (4)$$

Where the latent heat load $d\dot{Q}_L$ transferred to the air stream due to the water evaporation is

$$d\dot{Q}_{L=} d\dot{m}_w h_{is} = d\dot{m}_w(c_{ps}^{sat}T_w + \Delta h_{w)} \quad (5)$$

Where, h_{is} is the enthalpy of saturated moist air evaluated at air-water interface temperature. The humidity ratio is defined as $W = \dot{m}_w/\dot{m}_a$. Rate of cooled water mass flow rate over height dZ is obtained by differentiating the previous definition [12]:

$$\frac{d\dot{m}_w}{dZ} = \dot{m}_a \frac{dW}{dZ} \quad (6)$$

The specific heat capacity of the moist air:

$$c_{pm} = c_{pa} + Wc_{ps}^{sat} \quad (7)$$

Where c_{ps}^{sat} is the specific heat capacity of saturated steam. Hence, by substituting above relations to Equation (3) the rate of dry bulb temperature of air stream is obtained[13]:

$$\frac{dT_a}{dZ} = (\frac{L\alpha_{LA}}{\dot{m}_a} + \frac{c_{ps}^{sat}}{dZ})\frac{T_w - T_a}{c_{pm}} \quad (8)$$

The term α_{LA} represents the mass transfer coefficient between water film and gaseous phase, which according to Simpson and Sherwood (1946) is given by the following relation:

$$\mathbf{L\alpha_{LA} = L_e K c_{pm}}$$

$$K = (\frac{\dot{m}_w}{A})^{0.45} x (\frac{\dot{m}_a}{A})^{0.6} \quad (9)$$

Where K is the mass transfer coefficient and L_e is the Lewis number (here assuming $L_e = 1$)

The gradient of absolute humidity *dW=dZ* along tower longitudinal axis expresses the rate of water vapor supplied to the air stream by the cooled water within height dZ and can be expressed as follows [7,8]:

$$\frac{dW}{dZ} = \frac{LK}{\dot{m}_a}[W^{sat}(T_w - T_a)] \quad (10)$$

Where W^{sat} is the saturation humidity ratio is defined as

$$W^{sat}(T_w) = 0.622 \frac{c_{ps}^{sat}(T_w)}{p_a - (p_{ws}^{sat})(T_w)} \quad (11)$$

The balance of energy working between falling water film and gaseous phase can be written as follows:

$$\dot{m}_a h_a = (\dot{m}_w + d\dot{m}_w)(h_w + dh_w) + d\dot{Q}_s + d\dot{Q}_L \quad (12)$$

Where the term $\dot{m}_w$, $\dot{h}_w$ is almost negligible. Thus, above relation can be differentiated over Height dZ providing the rate of change of cooled water temperature T_w

$$\frac{dT_w}{dZ} = -\frac{\dot{m}_a}{m_w c_{pw}}(\frac{dT_a}{dZ}c_{pm} + \frac{dW}{dZ}(c_{pw}T_w + c_{ps}^{sat}T_a + \Delta h_w)) \quad (13)$$

Finally, the following set of ordinary differential equations is constituting

$$\frac{dT_a}{dZ} = (\frac{L\alpha_{LA}}{\dot{m}_a} + \frac{c_{ps}^{sat}}{dZ})\frac{T_w - T_a}{c_{pm}}$$

$$\frac{dT_w}{dZ} = -\frac{\dot{m}_a}{\dot{m}_w c_{pw}}[\frac{dT_a}{dZ}c_{pm} + \frac{dW}{dZ}(c_{pw}T_w + c_{ps}^{sat}T_a + \Delta h_w)] \quad (14)$$

$$\frac{dW}{dZ} = \frac{LK}{\dot{m}_a}[W^{sat}(T_w) - W_a]$$

$$\frac{d\dot{m}_w}{dZ} = \dot{m}_a \frac{dW}{dZ}$$

4. EFFECTS OF AIR VELOCITY

The velocity of air got a great effect on the net performance of the wet cooling tower. It varies the efficiency varying with respect to range, approach. The air velocity effects on the cooling capacity, effectiveness, and inlet and outlet relative humidity [6].

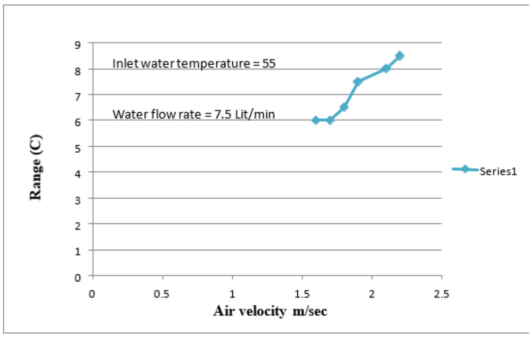

Figure 2: Effect of air velocity on cooling tower range.

5. DIAGRAM

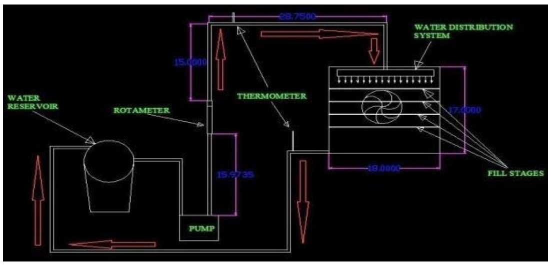

Fig. 3: Schematic diagram of cooling tower setup

6. CONSTRUCTION

6.1 Frame and casing:

Frame and casing are made of different materials such as the casing around the framework of the glass fiber, the inlet air louvers of glass fiber, and the cold-water basin of plastic. The casing is rectangular shaped box of glass fiber with water distribution system of metal sheet [2]. Its length is 18- inch, width is 18 inch and height are 17 inches [5].

Fig. 4: Frame and casing.

6.2 Water reservoir:

Water is stored in the reservoir. For this experiment the water reservoir is one end opened cylindrically shaped plastic reservoir.

Fig. 5: Water reservoir

6.3 Heater with Thermostat:

It is used to heat water restored in reservoir. Having thermostat integrated with it to control the required temperature.

Fig. 6: Heater with Thermostat

6.4 Pump:

A centrifugal pump is used for circulating hot water from reservoir to the cooling tower. Pump capacity is about 0.5Hp or 550W max and minimum speed of 2850rpm [4].

6.5 Fan:

The flow of air through most factory assembled cooling towers is provided by one more mechanically driven fan. The fan can be axial or centrifugal, each type having its own distinct advantages [3].

Fig. 7: Fan.

6.6 Fill:

The fill which provides both good water-air contact for high rates of heat transfer and mass transfer and low resistance air flow considered as efficient. It should provide large surface area for air water contact.

Fig. 8: Fill with proper configuration

6.7 Water distribution system:

It supplies hot water to the fill by distributing it equally to different parts of fill area. Hot water is supplied on the distribution system from the reservoir.

Fig. 9: Water distribution system.

6.8 Thermometer:

Thermometer is used for measuring the temperature of circulating water. Mercury thermometer is used calibrated between 0 to 100.

Fig.10: Thermometer.

6.9 Rota meter:

It is used for measuring the flow rate of water through the pipe. The Rotameter is fitted with inlet pipe of cooling tower. The maximum capacity of the Rotameter is 7.5 liters per minute.

Fig.11: Rotameter

6.10 Final Setup

Fig.12: Final setup (open type).

7. EXPERIMENTAL DATA

Air velocity	Water flow rate	Inlet water temp.	Outlet water temp.	Inlet air dry bulb temp.	Inlet air wet bulb temp.	Inlet air relative humidity	Outlet air dry bulb temp.	Outlet air wet bulb temp.	Outlet air relative humidity
m/sec	Lit/min	C	C	C	C	%	C	C	%
1.6	7.5	55	49	29	27.5	87	35	33.5	91
1.7	7.5	55	49	28.5	27	88	35.5	34	91.5
1.8	7.5	55	48.5	28.5	27	88	36	35	93
1.9	7.5	55	47.5	28.5	27	88	36	35	93
2.1	7.5	55	47	29	27	86	37	36	94
2.2	7.5	55	46.5	28.5	26.5	85.5	37	36	94

8. RESULT

Air velocity	Range	Approach	Effectiveness	Cooling capacity	Evaporation loss	Percent loss
m/sec	C	C	%	KW	kg/hr	%
1.6	6	21.5	27.90	3.15	10.44	2.32
1.7	6	22	27.27	3.15	13.32	2.96
1.8	6.5	21.5	30.23	3.41	15.12	3.36
1.9	7.5	20.5	36.58	3.94	16.2	3.6
2.1	8	20	40	4.2	16.56	3.68
2.2	8.5	20	42.5	4.46	17.62	3.92

With the increase of air velocity up to a certain level the percentage of heat loss and the cooling capacity increases. So, it is important to choose a perfect air velocity which will give better efficiency and less drift loss.

9. CONCLUSION

In recent age, almost every industries and power plants recycle water by using a circulating water system. Cooling is one of the most essential parts of the circulating water system. Hot water coming from the system is cooled in the cooling tower. But the efficiency of cooling towers depends upon many factors such as inlet water temperature, air velocity, inlet air temperature, fill the area, fill spacing. In this experiment, the main objective will be the enhancement of efficiency by rearranging splash types of fill and temperature control devices. It is found that cooling tower performance increased with the increase of air velocity, but at the same time drift loss is increasing which causes the need for extra makeup water. So, it is important to choose a perfect air velocity which will give better efficiency and less drift loss.

10.REFERENCE

1.https://deltacooling.com/resources/faqs/what-is-a-cooling-tower[July30, 2019; 22:30]

2.https://www.glbelt.com/industrial-automation-belts/[July24, 2019;19:30]

3.https://www.thomasnet.com/articles/automation-electronics/automated-conveyors[24 July, 2019;20:40]

4.https://motorviewvic.org/uxcell-motor-/-Motor-15-8V-2900RPM-Electric/dp/B07L11WY29[July 25, 2019;20:35]

5.ASHERE,"ASHERE Equipment's Guide", Refrigerating, and Air-Conditioning Engineers Inc., Chapter 3 American Society of Heating, Atlanta, GA, 1983.

6. V. D. Papaefthimiou, T. C. Zannis and E. D. Rogdakis," Thermodynamic study of wet cooling tower performance", INTERNATIONAL JOURNAL OF ENERGY RESEARCH,Vol: 30:411–426,2006

7.Rosaler and Robert C (1995),"The Standard Handbook of Plant Engineering," 2nd Edition, McGraw-Hill, New York.

8.Green and Don W.,"Perry's Chemical Engineer's Handbook", 6th Edition, McGraw-Hill, New York, 1984.

9.Md. Shfiul Islam (0503008), "Project report on The experimental study of forced draft cross flow wet cooling tower using splash type fill (2010)", Department of Mechanical Engineering, Chittagong University of Engineering & Technology (CUET).2009.

10.Shehabur Rahaman (0403078," Project report on The experimental study of forced draft cross flow wet cooling tower using splash type fill", Department of Mechanical Engineering, Chittagong University of Engineering & Technology (CUET). 2009

11.Sharif Adnan Haque (0503040), "Project report on The numerical study of forced draft cross flow wet cooling tower using splash type fill, Department of Mechanical Engineering, Chittagong University of Engineering & Technology (CUET), 2010.

12.M.M.EI-WAkil,"Power plant technology",2nd Eddition, McGraw-Hill Book Company, New York,1988

13.Power Plant Engineering-by P.K. NAG, Third edition, McGraw-Hill Book Company, New Dilhi, 2008.