ISSN: 2321-8169
2795 - 2798

Experimental Investigation of Forced Draft Counter Flow Cooling Tower with Twisted Tape Insert: Horizontal & Vertical

[1]Krunal patel, [2]Mr. N.V.Mohite,
[1].ME Theermal Student, Mechanical Engineering Department, SPIT, Piludara, Mehsana, Gujarat, *krunalpatel1611@gmail.com,*
[2]Assistant Professor, Mechanical Engineering department, SPIT, Piludara, Mehsana, Gujarat

Abstract:- Cooling towers are commonly used to reject heat from condenser water, heat exchanger, and other processing equipments. A cooling tower cools the hot water by a combination of heat and mass transfer. The hot water to be cooled is distributed in the tower by spray nozzles, splash bars, or film-type fill, which exposes very large water surface area to atmospheric air. A portion of the water will absorbs heat and converted in to a vapor at the constant pressure. This latent heat has been long used to transfer heat from water to the atmosphere. Lots of work have been carried out with wire mesh, zig-zag type fins and etc and measure the significant improvement in the efficiency and heat transfer rate of the cooling tower. So, if the spirals section or twisted tape types fins used in the cooling tower than it gives the better results in the enhancement of heat transfer rate or efficiency of the cooling tower. In this experimental work twisted tape has been mounted in vertical and horizontal direction with 5 sets of 4 raw and 4 columns. The maximum efficiency has been gained in cooling tower with vertical mounting twisted tape insert with 0.0208 kg/s mass flow rate of air.

Keywords: *cooling tower, twisted tape, HVAC, condenser, spray nozzles.*

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1. Introduction:

Cooling towers are commonly used to reject heat from condenser water, heat exchanger, and other processing equipments. A cooling tower cools the hot water by a combination of heat and mass transfer. The hot water to be cooled is distributed in the tower by spray nozzles, splash bars, or film-type fill, which exposes very large water surface area to atmospheric air. A portion of the water will absorbs heat and converted in to a vapor at the constant pressure. This latent heat has been long used to transfer heat from water to the atmosphere. This research study has been gives a new way to the researchers for cooling tower with twisted tape insert. It will give the different effect on output water temperature with different direction of mountings. In this research study the effect of twisted tape mountings with vertically and horizontally has been observed by researchers. Twisted tape has better heat transfer coefficient so that it will gives the better output and efficiency of the cooling tower.

For this research study certain research work has been followed as under;

[1]Dr. Jalal M. Jalil, Dr.Talib et al. worked on three dimensional computational solutions of air and water simultaneous equations, which represent the heat transfer, fluid flow and mass transfer. Finite volume method with staggered grid and ke- turbulent model has been used. **[2]Ashraf Kotb** presented counter flow cooling tower with treatments to recover the simplifications. They compare experimental model to the data from literature. This model determines the cooling tower optimum height, evaporation rate and distribution of air and water temperatures, humidity, water flow and Lewis factor along the tower height. From this studies they conclude that the height is affected by the inlet air humidity; the heat transfer mode is dominated by evaporation, and Lewis factor ranges from 0.91 to 0.924. [3] **Eser Can KARA et al.** presented forced draft counter flow wet cooling tower. The inlet air wet bulb temperature at 23 °C, and water inlet temperatures are between 38 and 47 °C. The variation of air mass flow rate on pressure drop for different water mass flow rates has been presented. These results show that cooling tower performance increases with an increase in air mass flow rate.[4] **Y. E. Abdel-Ghaffar et al.** worked on counter flow type cooling tower. The results show that when the mass flow rate ratio decreased, the number of transfer units (NTU) was increased. Also by decreasing the inlet air wet bulb temperature, the tower range would be increased. [5] **Farhad Gharagheizi, Reza Hayati, et al.** worked on experimental and a comparative study in the terms of tower characteristics (KaV/L), water to air flow ratio (L/G) and efficiency for two film type packing's. The tower performance showed a decrease with an increase in the (L/G) ratio as is also observed in other types of cooling towers. The results showed the tower with vertical corrugated packing (VCP) has higher efficiency than the one with horizontal corrugated packing (HCP).

2. Experimental Setup:

This experiment has been carried out for counter flow forced draft cooling tower with twisted tape insert. In this research study flow of water and flow of air is in opposite direction. The air has been through in the cooling tower with the help of centrifugal forced draft blower. In which the air flow has been varied by variac. The water has been fed in to the source tank in which small capacity heaters has been fitted

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to heat the water from normal temperature to the required temperature limit. Water from the primary source tank has been pumped to top of the cooling tower by PVC pipe. Pumped water flow rate has been measured and controlled by rotameter located between pump and cooling tower. This flow water has been distributed with the help of spray nozzle and falling film over the twisted tape. at the end of the PVC pipe five small holes of 2mm diameter has been put to spray of water inside the cooling tower to increase the contact surface area between air and water. The twisted tape which ha twist ratio P/D of 3.5. A cooling tower is made up of 0.3m X 0.3m X 1.5m of working size in cross sectional from galvanized iron sheet. The front top of the cooling tower has been made up of FRP material which used as a transparent material for visualize the process inside the cooling tower. Twisted tape made up of 3mm thick and 19mm wide aluminum tape. The pressure drop at fill zone is measured by U-tube manometer. J type thermocouple has been used to measure the water inlet, outlet dry bulb and wet bulb temperature has been measure by hygrometer, psychrometric gun.

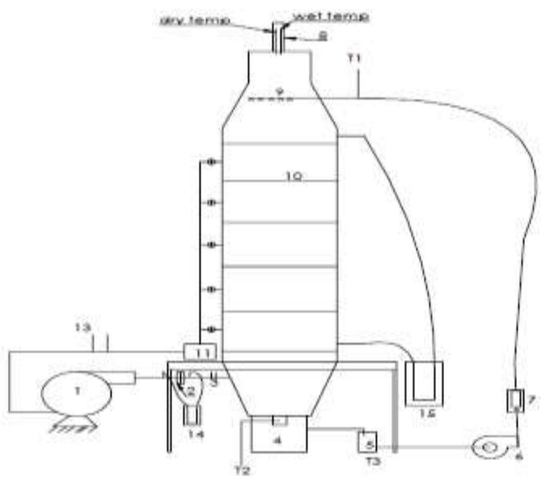

Figure 2.1 A Schematic diagram Experimental setup diagram

(1-blower, 2-orificemeter, 3-psychrometer, 4-source meter, 5-secondary tank, 6-pump, 7-rotameter, 8-psychrometer,9-spray,10-main unit of cooling tower,11-psychrometric gun,13- wet-bulb dry-bulb temp, 14-15 manometer

Manometer has been used to measure the pressure difference between two points. And certain temperature has been measured with the help of j-type thermo couple at inlet and outlet water temperature. J type temperature indicator has been used to indicate the digital output of temperature. Regulating valves has been provided to equally distribute the working media. Two different pressure drops has been measured at an orifice meter and at the two end of the main working height of cooling tower. All leakages and gaps have been fills with the help of silicon and emsile.

This experiment has been completed in the two steps:

- First step twisted tape with 3.5 twisted ratios has been inserted vertically such as in four raw and four columns of 300mm X 300mm in dimensions. Five equal sets have been inserted in the main unit of the cooling tower. All affected parameters, flow rate, temperatures and pressure differences have been measured and collected. These data also measured at different air flow rate from the blower.
- Second step twisted tape with 3.5 twisted ratios has been inserted horizontally such as in four raw and four columns of 300mm X 300mm in dimensions. Five equal sets have been inserted in the main unit of the cooling tower. All affected parameters, flow rate, temperatures and pressure differences have been measured and collected. . These data also measured at different air flow rate from the blower.

Figure 2.2 Experimental Setup Photograph

3. Methodology:

These two results have been compared and find out the optimum air flow rate. Also, compare and measure the effect of horizontal and vertical mounting of twisted tape in the cooling tower.

Lots of work has been done on cooling tower to improve the efficiency of it. This study gives a new way to the researchers to improve the efficiency of the forced draft counter flow cooling tower.

This work has been divided in to the two main steps,

- Put the vertical mounted twisted tapes inside the cooling tower working passage. Measure the effect of this on the experimental setup.
- After that remove the vertical mounted twisted tape and insert the horizontal mounted twisted tape. Measure the effect of horizontal mounted twisted tape on the experimental setup.

- Compare the both results with each other and find out the best one.
- Measure the effect of variation in mass flow rate of water and the effect of vaiation in air flow rate on the cooling tower efficiency.

A Psychometric gun has been manufactured to measure the dry bulb and wet bulb temperature of the inlet and outlet air. One 2hp blower has been provided to circulate the fresh air to the downward direction to the upward direction in the system. Horizontal / vertical twisted tape mounted in the working passage in number of sets (4 X 4) to increase the heat transfer rate of the cooling tower. The water has been flowing from the upward direction to the downward direction by which it is in the counter direction to the air flow, so that it is called as a counter flow forced draft cooling tower. During the experiment the orifice meter has been provided at the inlet to measure the mass flow rate by pressure drop and manometer to measure the pressure drop across the two end points of the working passage of the cooling tower and in the orifice meter. We measure the effect of different mass flow rate of water on the cooling tower and the effect of air flow rate on the cooling tower or experimental system.

4. Calculation Steps Used for This Experimental Results:

$$dV = dq_s + dq_L \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where,

$$dq_s = LC_{PW}dt = U_g \times a \times dV \times (T_i - T_a) \ldots\ldots\ldots\ldots (2)$$

$$dq_L = h_{fg} \times k \times a \times dV \times (w_i - w) \ldots\ldots\ldots\ldots (3)$$

$$m_{ew} = G(w_2 - w_1) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Energy Conservation demand that heat lost by water must be equal to heat gained by air,

$$LC_{PW}dt = G.dh = k.a.(h_i - h_a).dV \ldots\ldots (5)$$

$$\int_0^V \frac{k.a.dV}{L} = \int_{Tw_1}^{Tw_2} \frac{C_{Pw}}{h_i - h_a}.dt = \frac{k.a.V}{L} \ldots\ldots\ldots (6)$$

Where,

$$\frac{k.a.dV}{L} = NTU = \frac{C_{Pw}}{h_i - h_a}(Tw_2 - Tw_1) = 0.875(\frac{L}{G})^{-0.12}$$

For Effectiveness of Cooling Tower,

$$\varepsilon = \frac{Range}{Range(R) - Approch(A)}$$

$$\varepsilon = \frac{(Tw_1 - Tw_2)}{(Tw_1 - Tw_{b1})} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

$$Range = (Tw_1 - Tw_2)$$

$$Approch = (Tw_1 - Tw_{b1})$$

Liquid and gas (L/G) Ratio

$$L(Tw_1 - Tw_2) = G(h_{a2} - h_{a1})$$

$$\frac{L}{G} = \frac{h_{a2} - h_{a1}}{(Tw_1 - Tw_2)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (8)$$

Heat Rejection Rate

$$Q_w = L.C_{Pw}.T_1 - (L - m_{ev}).C_{Pw}.T_2 \ldots\ldots\ldots\ldots\ldots\ldots\ldots (9)$$

Efficiency of the cooling tower

$$\eta = \frac{Tw_{in} - Tw_{out}}{Tw_{in} - Tw_{wb}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (10)$$

5. Result And Discussion:

A lot of work has been carried out by researchers to improve the performance of the cooling tower. In this dissertation work researchers exposed a new concept of twisted tape inserted in the cooling tower working passage. Measure the effect of twisted tape situated inside the cooling tower in horizontal position and in vertical position. Insert of twisted tape inside the cooling tower is such as number of raw and column. All the data have been measured with the help of measured instrumentation. A dry bulb and wet bulb temperature have been measured with the help of psychometric gun with sling type psychomotor. Temperatures have been measured with the help of J-Type thermocouple. Air mass flow rate have been measured with the help of orifice meter.

All the resultant charts have been plotted as shown in following:

Where,

V1, V2 , and V3 – resultant chart for vertical mounting of twisted tape with different flow rate of air 0.0208, 0.0198, and 0.0188 kg/s respectively.

H1, H2 , and H3 – resultant chart for horizontal mounting of twisted tape with different flow rate of air 0.0208, 0.0198, and 0.0188 respectively.

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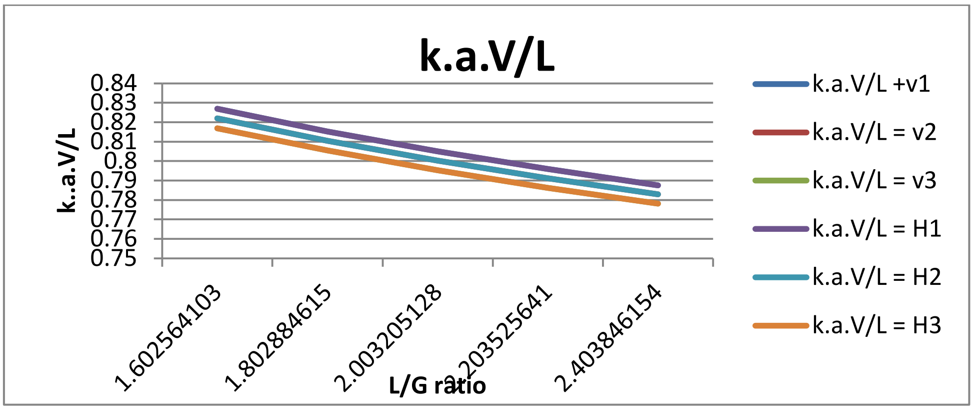

Figure 5.1 Effect of L/G Ratio on k.a.V/L or NTU

NTU is equal to the ratio of k.a.V and Land its results have been shows that the values of this NTU decreases with increase in L/g Ratio gradually. The value of NTU has been varied in between 0.82 to 0.83 for this experimental study.

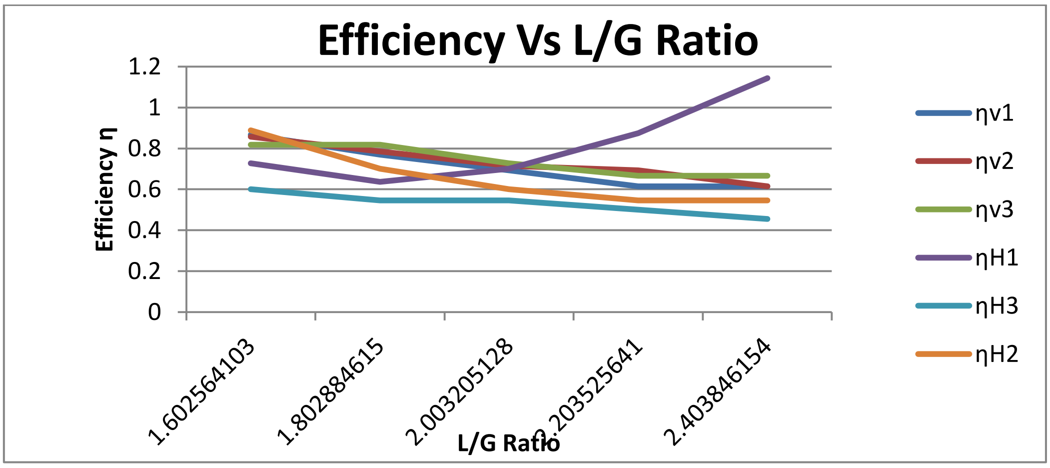

Figure 5.2 Effect of L/G Ratio on Efficiency of Cooling Tower

Efficiency of the cooling tower has been calculated by ratio of (Twin - TWout) to the (Twin - TWwb) The efficiency of the cooling tower has been decreases as increase in the L/G Ratio. The efficiency has been gradually decreasing with increasing the L/G ratio in the cooling tower. The maximum efficiency has been achieved by twisted tape insert in the cooling tower is around 0.9.

6. Conclusion:

From the above research study, it has been conclude that the twisted tape insert is more effective in vertical mounting twisted tape as compared to the horizontal mounting.

Efficiency in the vertical mounting twisted tape has been greatest achieved as compared to others.

Effectiveness has been observed maximum in the twisted tape insert with vertical mounting.

All parameters of the cooling tower has been varied when varying the L/G ratio.

7. Future Scope of Thesis Work:

Twisted tape insert give the more efficiency as compared to the others.

If twisted tapes mounting raw and Colum will increased that means if the number of twisted tape inserts in the cooling tower will increased then it will gives the more effective results of the cooling tower.

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