Experimental Investigations on Packed Bed Cooling Tower

Rajarajeshwari S and Ramana AS*
Department of Mechanical Engineering, SSN College of Engineering, Kalavakkam, Chennai
***Corresponding author: E-Mail: ramanaas@ssn.edu.in**

ABSTRACT

Energy Efficiency is desirable for the growth of a sustainable economy. Energy efficient working of cooling tower is analysed in the present article. Varieties of cooling towers exist in markets that cater to different cooling requirements. Packed Bed cooling towers offer the advantages of better performance occupying lesser space. Three different flow rates of air and water were varied to determine cooling tower performance. Results indicate the need for selection of optimized parameters for heat rejection.

KEY WORDS: Packed Bed, Cooling tower efficiency.

1. INTRODUCTION

Cooling can be achieved through once-through**,** wet recirculating or closed and dry-cooling techniques.Cooling tower works based on direct contact of air and water by removal of heat by air from incoming hot water. Heat is carried away through both sensible heat transfer and evaporative effect. Cooling tower finds application in variety of process heat transfer equipment's and in power plants. The process heat loads/ heat rejection influences the selection of cooling towers. Larger size and higher costs are associated with greater heat rejection rates. Geometric dimensions of cooling tower, air and water flow rates impact performance of cooling tower. Careful design and appropriate operating conditions are essential for enhanced efficiency of cooling tower. Efficiency of cooling tower provides performance characteristics at different operating conditions. It is the ratio of range to sum of approach and range. Range denotes the temperature difference between inlet hot water temperature and outlet water temperature. Approach denotes the temperature difference between outlet hot water temperature and Wet Bulb temperature of incoming ambient air.

Researchers have carried out experimental, numerical and exergy analysis to study cooling tower characteristics. Lemouari and Boumaza (2010), experimentally investigated the performance characteristics of a direct contact counter flow cooling tower filled with vertical grade apparatus type packing. It was concluded that heat rejection increased with increasing air and water flow rates. Further, cooling tower effectiveness decreased with increased water/air flow ratio. Higher inlet water flow rates and temperatures increased effectiveness of cooling tower. Film-type packed bed cooling towers was experimentally investigated by Bedekar (1998). Efficiency decreased with increased liquid/air ratio and decreased with inlet water temperatures.

Naphon (2005), studied the heat transfer characteristics of a cooling tower experimentally and developed a mathematical modelbased on energy and mass conservation equations. Yoo (2010), investigations on cooling tower revealed increased thermal efficiency and cooling capacity with increase in air velocity, inlet water temperature, WBT of incoming air. Qasimand Hayder (2016), carried out exergy analysis to study the performance. Their study revealedexergy change of water is more than twice the exergy change of air.

In addition to experimental works, CFD simulations have been adopted by researchers towards selection of design and operational parameters. Klimanek (2013), developed a CFD model to predict cooling tower performance of a natural draft cooling tower. Laptev and Lapteva (2016), proposed equalization of the air velocity profile at the input through additional phase contact region using irregular elements "Inzhekhim" for increasing the cooling tower performance. The present article investigates the effect of varied water and air flow rates on cooling tower efficiency.

2. EXPERIMENTAL TEST RIG AND PROCEDURE

Cooling towers are classified as counter-flow or cross-flow based on the direction of air flow and mechanical or natural based on the type of draft. A wet counter flow mechanical type of cooling tower is analysed. Experiments were carried out to find out the effect of the liquid and airflow on the performance of static bed cooling tower under steady state conditions. Figure.1, shows the photographic view of the cooling tower. The cooling tower consists of the water circulating system, air system and the measuring devices. The cooling tower is a forced draft counter flow type. The cooling tower is of 1m in height and 0.3m × 0.3m in cross section. Spherical hollow plastic balls were used as packing elements. It maximizes heat transfer contact area between air and water thus enhancing heat transfer. The cold water basin near the bottom of the tower, collects the cooled water that flows down through the tower and fill. The quantities to be measured in the experiments are the liquid and air flow rates and the dry and wet bulb temperatures of air at inlet and outlet. The quantity of air flow through the cooling tower was measured by the use of an orifice. RTD type thermocouples were used to measure the temperature. Air flow rate was varied through control valve connected in a pipe closer to the blower. Similarly valve was provided to control water flow rate in the cooling tower. After reaching the steady state, DBT and WBT of air and hot water at inlet and outlet are noted. Measurements were observed for three different air and water flow rates.

Figure.1. Photographic view of packed bed cooling tower

3. RESULTS AND DISCUSSION

Cooling tower efficiency was used to determine performance of the cooling tower. Cooling tower performance was determined for 100 LPH, 200LPH and 300 LPH at air flow rates of 0.00911m^3/s, 0.011m^3/s, 0.0168 m^3/s. Fig. 2 shows variation of outlet water temperature with water and airflow rate. The trend in water outlet temperatures at 200 LPH shows difference due to incoming water temperature that lies between the higher and lower inlet temperatures of 100 LPH and 300 LPH. As temperature difference drives the heat transfer, un-optimized air flow rates do not significantly increase temperature range.

$$\text{coolingTowerEfficiency} = \frac{T_{hi}-T_{ho}}{T_{hi}-T_{wb}} \qquad (1)$$

where T_{hi} - Hot water inlet temperature (°C)

T_{ho} - Hot water outlet temperature (°C)

T_{WB} - Ambient wet bulb temperature (°C)

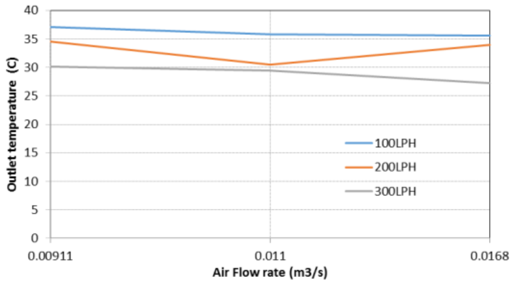

Figure.2.Variation of outlet water temperature with water and airflow rate

Cooling tower efficiency as given in equation 1 was used to determine performance of the cooling tower. The variation in efficiency of cooling tower is shown in fig.3. The cooling tower efficiency increased with increased air and water flow rates of 100 LPH and 300 LPH for the cases considered for air flow rates of 0.00911m^3/s, 0.011m^3/s, 0.0168 m^3/s. This phenomenon is observed because of higher convective heat and mass transfer effects. Variation in efficiency trend for cooling tower with water flow rates of 200 LPH is noted. Hence optimized air flow rate is essential for better performance.

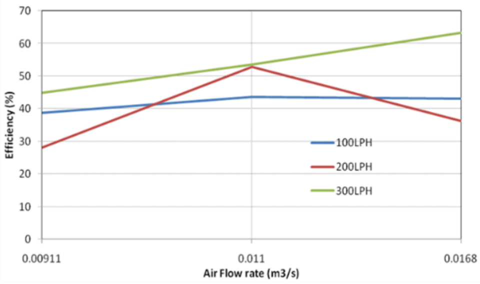

Figure.3. Variation of efficiency with water and airflow rate

3. CONCLUSION

Performance enhancement of cooling towers is essential for overall improvement in system efficiency for power generation and process applications. The performance of cooling tower using spherical shaped elements packing was analysed and tower efficiency increased with higher mass flow rates of air and water at the considered operating limits. However, at 200 LPH water flow rate, optimized mass flow rates of air is required to obtain maximum range and efficiency of cooling tower.

REFERENCES

Bedekar S.V, Nithiarasu P and Seetharamu K.N, Experimental investigation of the performance of a counter-flow, packed-bed mechanical cooling tower, Energy, 23 (11), 1998, 943-947.

Klimanek A, Numerical Modelling of Natural Draft Wet-Cooling Towers Arch, Comput Methods Eng, 20, 2013, 61-109.

Laptev A.G and Lapteva E.A, Mathematical Model and Calculation of Water-Cooling Efficiency in a Film-Filled Cooling Tower,Thermal Engineering, 63 (10), 2016, 724-729.

Lemouari M and Boumaza M, Experimental investigation of the performance characteristics of a counter flow wet cooling tower, International Journal of Thermal Sciences, 49, 2010, 2049-2056.

Naphon P, Study on the heat transfer characteristics of an evaporative cooling tower, Int. Comm, Heat Mass Transfer, 32, 2005, 1066-1074.

Qasim S.M and Hayder M.J, Investigation of the effect of packing location on performance of closed wet cooling tower based on exergy analysis, IOP Conf. Series: Materials Science and Engineering, 145, 2016, 1-6.

Seong-YeonYoo, Jin-Hyuck Kim and Kyu-Hyun Han, Thermal performance analysis of heat exchanger for closed wet cooling tower using heat and mass transfer analogy, Journal of Mechanical Science and Technology, 24 (4), 2010, 893-898.