

A Review to Optimize the Heat Transfer Rate and Increase the efficiency of the Cooling Tower

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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. This equipment used to reduce the temperature of a water stream by extracting heat from hot water and emitting it to the atmosphere. They are used in a variety such as power generation and refrigeration. Cooling towers are also designed for industrial plants for various purposes and sizes to provide cool water. Typically, a condenser of a power plant and or of heating ventilation, and air conditioning (HVAC) system has been cooled by water. 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.

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

Introduction

Cooling towers are commonly used to dissipate heat from water needed for condenser, heat exchanger, and other processes equipment. A cooling tower cools the 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 absorbs heat and it is changed to a vapor at constant pressure. This latent heat has been long used to transfer heat from water to the atmosphere. Cooling towers are widely used in the power generation system, refrigeration and air conditioning industries. Cooling towers can be classified by the movement of water and air as counter-flow and cross-flow types. Moreover, they can also be classified by means of air flow into mechanical draft and natural draft types.

A lot of work has been done for modeling cooling towers mathematically in the past century. **Walker** proposed a basic theory of cooling tower operation. **Merkel** developed the first practical theory including the differential equations of heat and mass transfer, which has been well received as the basis for most work on cooling tower modeling and analysis.

Dr. Jalal M. Jalil, Dr.Talib et al. worked on “**CFD Prediction of Forced Draft Counter-Flow Cooling Tower Performance**”. They conducted a Numerical and experimental Results in this study for open type forced draft water cooling tower. The numerical part in these studies includes a three dimensional computational solution of air and water simultaneous equations, which represents the heat transfer, fluid flow and mass transfer. Finite volume method with staggered grid and ke- turbulent model has been used. Experimentally, mechanical forced draft counter-flow cooling tower was used to validate the numerical results. They compare the numerical and experimental results of this study. ^[1]



Fig.7. Schematic layout of Hilton forced draft water cooling tower

Ashraf Kotb presented “Determination of Optimum Height for Counter Flow Cooling Tower”. They presented a model for counter flow cooling tower with treatments to recover the simplifications. The Bosnjakovic formula, water and air properties are used to relax the constraints. The finite volumes of water and moist air are defined separately in a counter flow directions. Mass and energy balances are evaluated for control volume; heat and mass transfer has

been considered between control volumes. 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. [2]

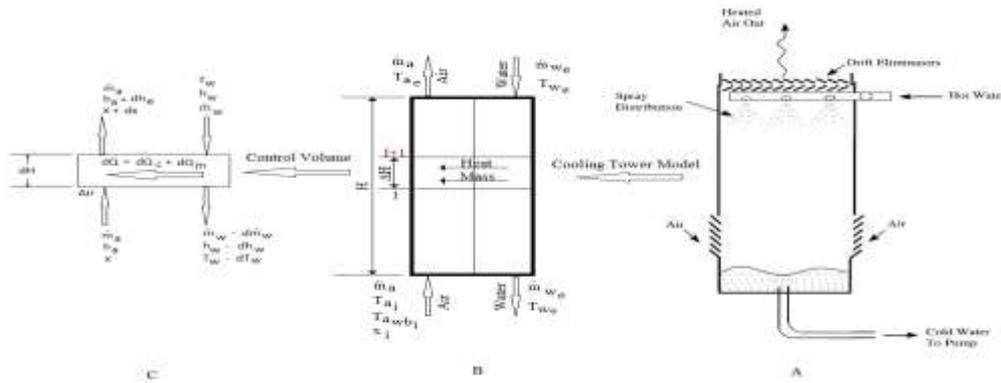


Fig.8. (A.) Schematic dia. of Cooling Tower. (B). Model of Cooling Tower. (C.) Control volume of counter flow Cooling tower

Eser Can KARA et al. presented “Heat and Mass Transfer Analysis of a Counter Flow Cooling Tower under Various Air and Water Flow Arrangements”. In this study the thermal performances of a forced draft counter flow wet cooling tower is experimentally investigated. Air and water are used as working fluids and the experimental runs are carried out by the air and water mass flow rate ranging in-between 0.017 and 0.064 kg/s, and between 0.03 and 0.05 kg/s, respectively. The inlet air wet bulb temperature at 23 °C, and water inlet temperatures are between 38 and 47 °C. The factors effecting on the cooling tower performance such as water inlet and outlet temperatures, air and water mass flow rates, heat load, and effectiveness of the cooling tower are investigated. The effect of the different air and water mass flow rates on water

inlet and outlet temperatures is significant. The effect of air mass flow rate on approach and range of the cooling tower, for different water mass flow rates has been investigated. The variation of air mass flow rate on pressure drop for different water mass flow rates has been presented. Other cooling tower parameters are Merkel number (Me) and number of transfer unit (NTU) to analyze the cooling tower performance. The number of transfer units (NTU) and Merkel number show the heat transfer capability of the cooling tower. Cooling tower effectiveness (ϵ) relation with Merkel number for different air and water mass flow rates are calculated and all the results are presented in the form of graphs. These results show that cooling tower performance increases with an increase in air mass flow rate. [3]

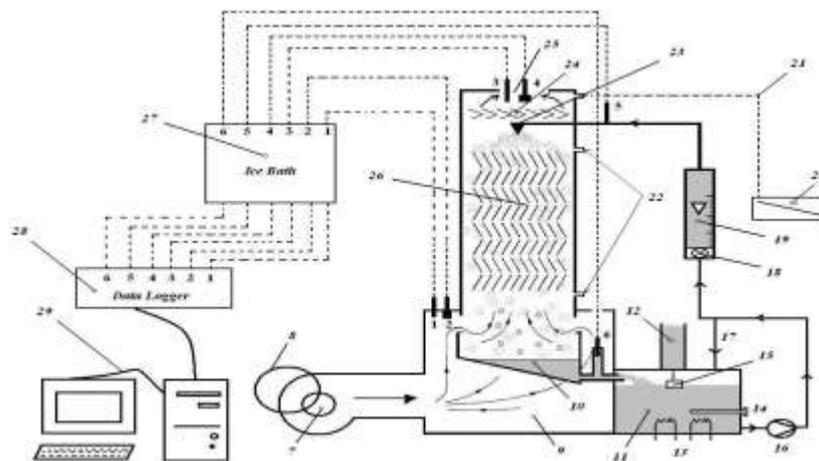


Fig.9. Schematic of the experimental apparatus

Y. E. Abdel-Ghaffar et al. worked on “Effect of Operating Parameters on the Performance of Counter Flow Type Cooling Towers”. This paper presents an experimental work, which studies the performance of a counter flow type cooling tower. The experimental results have been carried out at a test rig which designed and investigated in Misr Oil and Soap Company. It consists of 12 cooling towers from these types. Three types of film fill packing, used during experimentation, were made of PVC with height range 800 – 1200 mm. During the experimentation the following quantities were varied: air

flow velocity in the range 10.5-17.5 m/s and water flow rate in the range of 80-150 m³/h. The variation of temperature along the height of packed was measured by means of 16 appropriate placed thermocouples. 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. From this study the characteristic equation is in the form: which can be used in designing the counter flow cooling towers.^[4]

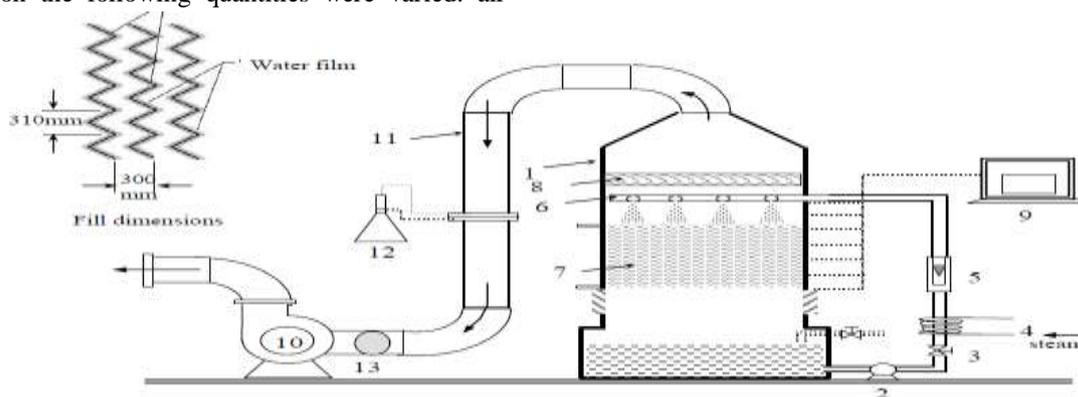


Fig.9. Layout of experimental apparatus

Farhad Gharagheizi, Reza Hayati, et al. worked on “Experimental study on the performance of mechanical cooling tower with two types of film packing”. They worked with an 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 are presented for a wide range of water to air flow ratio from 0.2 to 4. The packing’s used in this work are vertical corrugated packing and horizontal corrugated packing. The obtained results showed that the performance of the cooling tower is affected by the type and arrangement of the 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).^[5]

wire mesh packs with different configuration. From numerical and experimental results they concluded that the EWMDHSP have better performance than WMSSHSP. It happens because the pressure drop on WMSSHSP is higher as compared to the EWMDHSP, due to air resistance of the former pack is higher than the latter pack. In the WMSSHSP configuration the discharged of water is low, and of air flow at the top of the tower is become water abundance, with poor water at the bottom of the tower compare with EWMDHSP. The air to water contact is good in EWMDHSP, so better heat transfer has been occurred and the outlet water temperature is reduced compared with WMSSHSP. From the experimental study the cooling tower characteristic and volumetric mass transfer coefficient are higher in EWMDHSP due to high contact area of water to air.^[6]

Dr. D. Al. D.H. Alwan Dr. I. W. Maid A. H. Soheel worked on “Numerical and Experimental Study of Counter Flow Cooling Tower Performance with Difference Packs Porosity and Configuration”. This study presents an experimental and numerical investigation of the performance of a forced draft counter flow cooling tower with two Types of wire mesh packing. The packing used in this study is wire mesh with small square holes and expanded wire mesh with diamond holes configurations. The Numerical model and experimental results have been carried out to compare the performance of the two types

R. Ramkumar A. Ragupathy et al. “Thermal Performance of Forced Draft Counter Flow Wet Cooling Tower with Expanded Wire Mesh Packing”. They presents an experimental investigation of the thermal performance of forced draft counter flow wet cooling tower with expanded wire mesh type packing. The packing used in this work is wire mesh with vertical [VOWMP] and horizontal [HOWMP] orientations. The packing is 1.25 m height and having a zigzag form. From the experiments they concluded that the vertical orientation of the packing gives the better performance of the cooling tower.^[7]

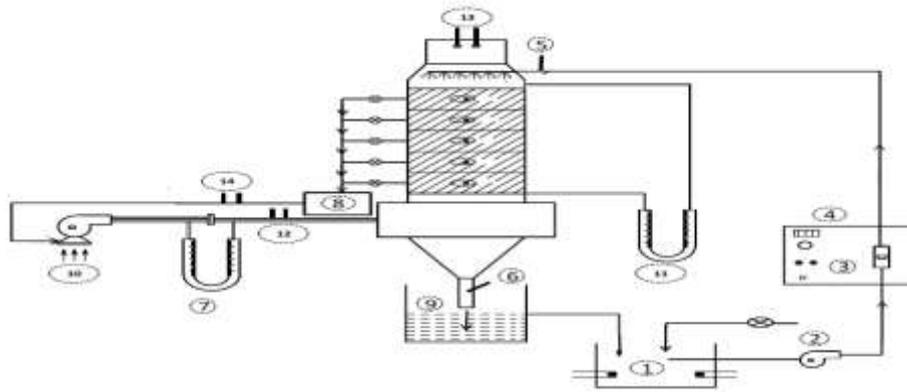


Fig.10. Experimental setup of forced draft cooling tower

Adel Alyan Fahmy, Loula A. Shouman et al. worked on “Deterministic Study on the optimum performance of counter flow Cooling Tower”. They work on theoretical study and parametric analysis of counter flow cooling tower has been presented by optimizing the thermo-hydraulic–performance. By simple mathematical formula using for estimating the optimum performance of counter flow cooling towers at different operating conditions. Based on a

number of transfer unit (NTU) and the effectiveness, the effect of the wet bulb temperature on the performance of cooling tower has been studied. It is induced that there are different optimal (L/G) values for the best performance of counter flow cooling towers for each mean water temperature. They found that the wet bulb has a great influence on NTU and effectiveness.^[8]

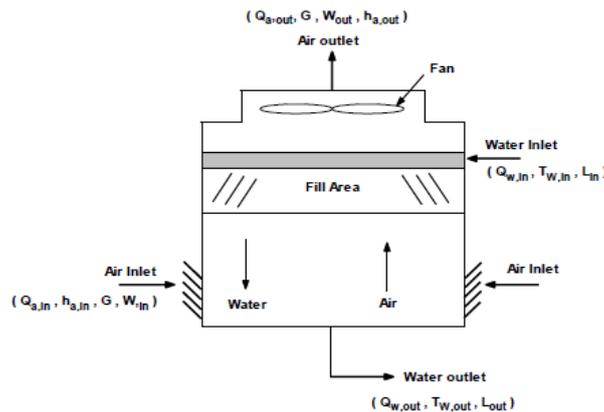


Fig.11. Schematic diagram of counter current flow cooling tower.

Eusiel Rubio-Castro, Medardo Serna-González et al. worked on “Optimization of mechanical draft counter flow wet-cooling towers using”. In this research study, an optimal design algorithm for mechanical draft counter flow wet-cooling towers based on the rigorous Poppe model and mixed-integer nonlinear programming (MINLP) have been presented. Unlike the widely used Merkel method, the Poppe model takes into consideration the effects of the water loss by the evaporation and the nonunity of the Lewis factor. As a result, the Poppe model is able to predict the performance of wet-cooling towers very accurately as

compared to the Merkel method. The optimization problem is formulated as an MINLP model by considering all the mass and energy balances, equations for physical properties, and empirical correlations for the loss and overall mass transfer coefficients in the packing region of the tower, in addition to feasibility the constraints. The objective function to be minimized is the total annual cost, which includes capital and operating costs. The mathematical programming problem has been solved with the GAMS software. Six case studies are used to show the application of the proposed algorithm.^[9]

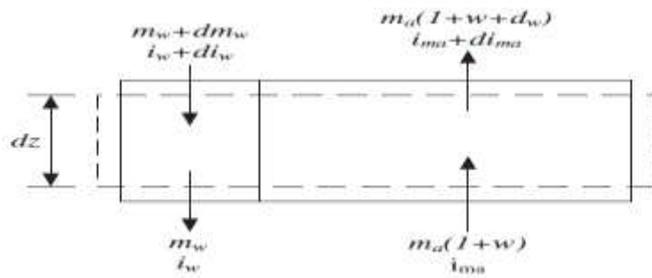


Fig. 12. Control volume of the counter flow fill.

Mr.S.D.Patil, Prof. A.M. Patil et al. worked on “**Analysis of Twisted Tape with Straight winglets to improve the Thermo-Hydraulic Performance of Tube in Tube Heat Exchanger**” An Experimental investigation of heat transfer and friction factor characteristics in a double pipe heat exchanger has been fitted with Straight delta winglet and typical twisted tape elements were studied. The inner and outer diameters of the inner tube are 20.5 and 26 mm respectively and cold and hot water were used as working fluids in the shell side and tube side. The twisted tapes were made up of the Aluminum strip with thickness of 2.01 mm and the length of 1500 mm. They inserted in the test tube section in two different cases as following: (1) Straight delta winglets twisted tape at the different twisted ratios ($y/w=3.5, 4.5$ and 5.5) and the depth of cut ratios ($d/w=0.1, 0.2$ and 0.3), and (2) A typical twisted tape with twist ratios ($y/w=3.5, 4.5$ and 5.5). The results, obtained from the tube with straight delta twisted tape inserted, were it’s compared with those typical twisted tape. The results show that the heat transfer coefficient has been increased with decrease in twist ratio (y/w). Whereas the increase in the depth of cut ratio (d/w), it would improve both the heat transfer coefficient and the friction factor. The results from each case were correlated for Nusselt number and friction factor. Subsequently, the predicted Nusselt number and friction factor from the correlations were plotted to compare with the experimental data. It has been found that Nusselt number was within $\pm 20\%$ and $\pm 15\%$ for friction factor. [10]



Fig.13. Twisted Tape

S. Naga Sarada1 , A.V. Sita Rama Raju1 et al. worked on “**Enhancement of heat transfer using varying width twisted tape inserts**”, This work shows the results obtained from experimental investigations by the augmentation of

turbulent flow heat transfer in a horizontal tube by means of varying width of twisted tape inserts with air as the working fluid. In order to reduce excessive pressure drops associated with full width twisted tape inserts, with less corresponding reduction in heat transfer coefficients, reduced width twisted tapes is widths ranging from 10 mm to 22 mm, which are lower than the tube inside diameter of 27.5 mm are used. This Experiment has been carried out first with plain tube with/without twisted tape insert at constant wall heat flux and different mass flow rates. The twisted tapes are of three different twist ratios (3, 4 and 5) each having five different widths (26-full width, 22, 18, 14 and 10 mm) respectively. The Reynolds number has been varied from 6000 to 13500. The heat transfer coefficient and pressure drop has been calculated and the results were compared with those of plain tube. It was found that the enhancement of heat transfer with twisted tape inserts as compared to plain tube varied from 36 to 48% for full width (26mm) and 33 to 39% for reduced width (22 mm) inserts. They developed Correlations for friction factors and Nusselt numbers for a fully developed turbulent swirl flow, which are applicable to full width as well as reduced width twisted tapes, using a modified twist ratio as pitch to width ratio of the tape.

Conclusion:

From the part of this Literature Study it has been observed that the cooling tower efficiency has been increased with increasing the heat transfer area, with fins, with wired mesh, with applied certain geometry. This will increase the heat transfer rate of the cooling tower. If we use the spiral type fin geometry/twisted tap than its gives the better results as compared to the previous case study.

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