A Review Paper on Experimental and Numerical Analysis for Performance of Fluidized Bed Cooling Tower

Mr. Vishwanath M M
Asst professor,
Dept of Mechanical Engineering,
SEA College of Engineering and Technology,
Bangalore, VTU

Dr N Lakshamanaswamy
Professor and Chairman,
Dept of Mechanical Engg
University Visvesvaraya College of Engineering,
Bangalore University, Bangalore

***Abstract*—Cooling towers are the heat extraction devices which are applicable in industries like petrochemicals, food processing, dairy, power plant, nuclear stations, etc. for providing continuous supply of cold water. The phenomenon of heat exchange in cooling tower is of direct contact and a complex one involving simultaneous heat and mass transfer. In the present study the papers are reviewed for the different methods of Fluidized bed packing that are incorporated for the conventional cooling tower. The packing in the cooling tower increases the effective contact surface between air and water to promote better heat and mass transfer. The principle of fluidization is utilized in the development of fluidized bed cooling tower. In the three phase counter flow fluidized system, the upward flow of air fluidize the bed material used as packing and the hot water sprayed down from the top is cooled. The paper also review on the different materials used for the fluidization to takes place weather will create a bubbling or turbulent effect which provides larger surface area of heat transfer, thus a state of vigorous contact between the gas and liquid phases may be obtained as they flow through the bed. The main objective of this literature review is to analyze the performance of the cooling tower with the fluidized bed packing by various researchers which leads to study the further investigations. Further, with reference to these papers it is found that various investigations are carried out at low flow rates of water and also at lower liquid to gas ratios which leads to the investigations of performance of the cooling tower by providing the turbulent bed and experimental conduct at higher flow rates.**

***Keywords:* FBCT, L/G ratio, wet bulb temperature, Performance, Condenser temperature**

I. INTRODUCTION

It is estimated that only about 25 to 35% of the energy input to the boiler in the form of heat is utilized by the turbine in the form of kinetic energy to produce electricity, the remaining being rejected to the surroundings, the largest portion of which is rejected in the steam condenser The low temperature hot water from the steam condenser is to be rejected directly to the surroundings; industrial plant must be sited near lakes, rivers or the sea. The direct rejection of hot water to these reservoirs could lead however to thermal pollution problems. Where location of industrial plant is such that cooling water in large quantities is scarce, then the water must be cooled and recycled.

Cooling towers have been with us for a long time replacing power plants from the river banks to nearer the load centers. The cooling tower with evaporative cooling technique was originally developed as a water conservation systems, usually developed to reduce the plants depending on ‘once through’ cooling systems and further replaced many such systems. The development of the cooling tower also expanded the ability of designers to provide efficient cooling in areas without large water supplies. Cooling towers are now applied widely in many industries. The benefits from optimizing designs have never been truer than in the case of cooling tower systems. The opportunities for improved energy and water consumption are undeniable and tower and component manufacturers have risen to the challenge. New designs and innovations, new materials and methods of manufacture have led to considerable improvements in performance and environmental impacts. New methods of system control and new system configurations are also achieving significant operational benefits. Drift is reduced, fan efficiency is improved, fill and tower effectiveness is increased, towers are smaller, lighter and more corrosion resistant than ever before. Previously visible plumes can be made to disappear, water consumption can be reduced, and system energy consumption can be reduced. Advances in cooling tower engineering and design means that towers can be constructed on site faster and cheaper than was previously possible.

I.I HOW DOES FLUIDIZED BED COOLING TOWER WORKS:

Fluidization is the phenomenon by which the solid particles are made to behave like a fluid through contact gas or liquid or both. This principle is utilized in the development of three-phase fluidized bed cooling tower.

At low flow rates of air the low density fluidizing solid particles lie on one another on a mesh or retaining grid at bottom of the cooling tower main body column as shown in *Fig a*. This state of fluidized bed is said to be in static or fixed state. If the velocity of the air flowing upward increases, fluidisation occurs, the low density bed materials forms as bubbles and intensive mixing of the bed materials and the air forms a turbulent action similar to a boiling fluid as shown in *Fig b*. This is the fluidised State. Further increase of the air velocity, will eventually cause entrainment of the fluidized bed particles from the column into the upward moving air. The contact and close proximity of the particles to one another ceases as the solid particles become mobile as shown in *Fig c*. This is the pneumatic or hydraulic transport State.

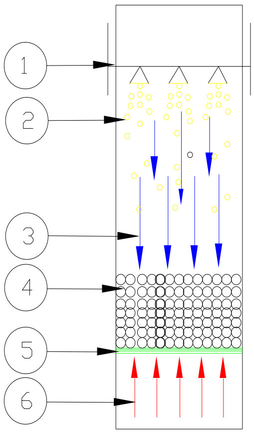

Fig a.

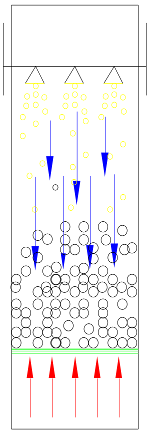

Fig b.

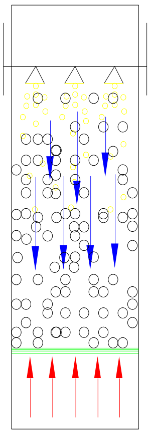

Fig c.

1. Upper retaining grid.
2. Hot water droplets.
3. Downward water flow.
4. Fluidized bed material.
5. Bottom retaining grid.
6. Upward air flow.

I.II IMPORTANT PERFORMANCE PARAMETERS:

The performance characteristics is generally expressed in terms of a dimensionless parameter ***number of diffusion units*** $\boldsymbol{\eta_d}$ and is given by

$$\eta_d = \frac{KaV}{L} = \int \frac{C_p\,dT}{(H-H')_{avg}}$$

The performance of cooling towers is evaluated to assess present levels of approach and range against their design values, identify areas of energy wastage and to suggest improvements. During the performance evaluation following parameters are generally considered for experimental and numerical analysis and the *fig d*. shows the clear idea about the performance parameters:

1. Wet bulb temperature of air.
2. Dry bulb temperature of air.
3. Cooling tower inlet water temperature.
4. Cooling tower outlet water temperature.
5. Water flow rate.
6. Air flow rate.

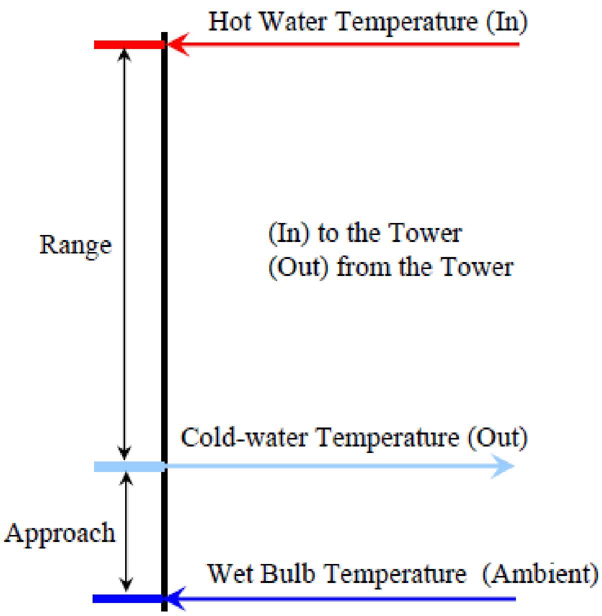

Fig d. General operating parameters of cooling towers

II. LITERATURE SURVEY

Fluidisation phenomenon is generally consider to be two-phase liquid-solid or gas-solid interface. The theoretical investigations for the three phase fluidization are uncommon due to the complexity involved in mathematical formulations hence several investigation and experiments are carried out for Fluidized bed cooling tower. The following are the some of the important literature which leads to the investigations of future work to be carried out which is discussed below in the conclusion session.

Louis MbuaEgbe, Middlesex University, London, UK This thesis discusses the operating characteristics and design of fluidized bed cooling towers (FBCT), which may be used to cool hot water for industrial purposes. Limited data exist for such a three-phase fluidized bed acting as a cooling tower. This motivated some early workers to investigate its usefulness in cooling tower applications and they showed that the FBCT produces heat and mass transfer rates much higher than in conventional fixed-bed towers and concluded that Water can be cooled using fluidized spherical packing in a model FBCT equipment with the view of designing a full-scale model. The tower plenum significantly contributes to the tower KaV/L. A better KaV/L is achieved at plenum conditions than at the grid conditions. FBCT thermal performance is dependent upon the spherical fluidized particle characteristics. The FBCT is smaller in size than conventional fixed bed towers. [2]

K. N. Seetharamu and K. V. S. Varier, carried out Experimental investigations to find out the effect of various configurations of the packing material on the performance of a Fluidized Bed Cooling Tower (FBCT). From the experiments it is observed that the shape of the packing material does have a definite effect on the performance of FBCT and the spherical shape is not the best shape.

The performance of cooling tower usually referred to as the tower characteristic

$$\frac{\mathrm{KaV}}{\mathrm{L}} = \int \frac{\mathrm{C_p dT}}{(\mathrm{H}-\mathrm{H'})_{\mathrm{avg}}}$$

Experimental investigation leads to following conclusions. The experiments conducted in a Fluidized Bed Cooling Tower with various shapes of the packing material show that there is definitely an effect of the shape of packing material on the performance of the cooling tower. The experiments also indicate that the best shape of the packing material is not the spherical. The predictions from the single stage equilibrium model, in the light of the present experiments, are modified which can be used to predict the performance of FBCT when packing materials of different shapes are used. [3]

N. Sisupalan and K. N. Seetharamu, IIT Madras, carried out Experimental investigation on a counter flow three-phase fluidized bed cooling tower (FBCT) with different static bed heights. The efficient static bed height for the present tower is found to be between 1I cm and 13 cm. The pressure drop observed is in the order of 0.6 mm of water column per cm of static bed height within the range of parameters investigated. The performance of cooling tower usually referred to as the tower characteristic, Ka V / L , will depend on the L/G ratio, temperature level of cooling a*nd ambient air wet bulb temperature*

$$\frac{\mathrm{KaV}}{\mathrm{L}} = \int \frac{\mathrm{C_p dT}}{(\mathrm{H}-\mathrm{H'})_{\mathrm{avg}}}$$

Because of the large turbulence level the Lewis number is found to be almost unity and for the derivation of the above relation Lewis number is assumed to be unity.

The experimental investigation leads to following conclusions.
1. The single stage equilibrium model does not truly predict the performance of the FBCT for all values of L/G ratio considered.
2. The optimum static bed height for the range of parameters investigated in the present tower is between 11 and 13 cm.
3. The pressure drop is in the order of 0.6 mm of water column per cm of static bed height.
4. Since the maximum dynamic bed height observed is 26 cm, the height of the column can be reduced. [4]

Hamid Reza Goshayeshi,John MissendenSouth Bank University, London. This paper presents a mathematical model and a computer simulation program for the numerical prediction of the performance of a fluidized bed cooling tower. The mathematical model is based on the heat and mass transfer equations. This model is used to predict the thermal behavior of a fluidized bed cooling tower with experimental data. In this paper experiments have been performed to measure the thermal performance of a fluidized bed cooling tower The previous correlations found in the literature could not predict the volumetric mass transfer coefficient for the tested tower. A mass transfer coefficient correlation was developed and new variables were defined. This correlation can predict the mass transfer coefficient within a maximum of It has been found that the accuracy of 5% obtained using the chosen model can be then taken into account whenever this model is used to predict other characteristics related to the fluidized bed cooling tower. [5]

Ram GopalSeth.1112 Yardley Rd., Cherry Hill. N. J.08034 conducted the experiments on dry cooling tower and concluded A forced draft dry cooling tower is disclosed where in the medium to be cooled passes through the heat exchanger tubes embedded within a bed of inert particles composed of smaller particles composed of smaller particles surrounding and embedded in much larger particles. The forced draft through the cooling tower fluidizes the smaller particles but not the larger particles which stabilizes the fluidization of smaller particles and enhances the fluidization and heat exchange effect thereof. [6]

Alper YILMAZ, Dept of Mechanical Engg, 01330, Balcalı / ADANA In this paper, a simple differential equation for counter flow wet cooling tower is solved analytically taking into consideration the non-linear dependency of the saturated air enthalpy on temperature. The method allows analytical calculation of cooling tower performance with large cooling ranges. The analytically obtained values are compared with the well-known logarithmic mean enthalpy method (LMED) and corrected LMED method. It is seen that analytically obtained values are much more accurate than the values obtained using these two methods. The analytical results are also compared with experimental ones and it is seen that there is a good agreement between them and concluded that Simple analytical equations can be used to calculate cooling tower performance without any numerical integrations. Between 20-70 ˚C, one needs only saturation enthalpies of air at water inlet and outlet temperatures. For water inlet-outlet temperatures less than 20˚C or greater than 70˚C, the saturation enthalpy of water at the arithmetic mean water temperature is needed, besides air saturation enthalpies at water inlet and outlet temperatures for analytical calculations. The analytical equations derived in the present study render results which compare well with the experimental and numerical ones. The presented analytical method yields much more accurate results compared to the results obtained using the well-known LMED and LMED-C methods. [7]

M. LEMOUARI, M. BOUMAZA King Saud University Riyadh, Saudi Arabia.
This paper presents an experimental investigation of the thermal characteristics of a mechanical draft counter flow wet cooling tower filled with an low density material packing. This packing is 0.42m high and consists of four galvanized sheets having a zigzag form, between which are disposed three metallic vertical grids in parallel. The distance between each two grids is 0.05m (width of the cell). The cross sectional test area is, S = 0.15m X 0.148m. This study investigates the effect of the air and water flow rates on the cooling water range as well as the tower characteristic,

KaV/L, for an inlet water temperature of 43°C. During the air and water contact, through the packing in the tower, two functioning regimes were observed: a first regime called pellicular regime (PR) and a second regime called regime of bubble and dispersion (RBD). These two regimes can determine the best way to promote the heat transfer and concluded that During the air and water contact through the packing in the tower, Two functioning regimes of the tower were observed: a pellicular regime: existing with low water flow rates, and a regime of bubble and dispersion: appearing for relatively larger water flow rates. These two regimes can determine the best way to promote the heat transfer. The tower characteristic, KaV/L, decreases with an increase of the water/air mass flow ratio, L/G. This decrease is less pronounced for the bubble and dispersion régime. The cooling water range, R, increases with an increase in the air flow rates, whereas it decreases with an increase in the water flow rates. The highest values of, R, are reached for lower values of L/G. The cooling tower filled with the “A. V. G.” type packing, despite of its low height, compared to systems filled with other types of packing possesses very interesting thermal characteristics. It is recommended to extend the range of variation of the air and water flow rates for relatively higher inlet water temperatures, in towers of higher size, in order to complete the conclusions of this study. [8]

RonaldG. Barile Purdue University Lafayette, Indiana. The purpose of this work is to determine whether the turbulent bed contactor (TBC), a relatively new and efficient device commonly used for gas scrubbing, can be proven as a competitive cooling system in electric power generation. The turbulent bed employs light, hollow plastic spheres as a packing which fluidize as air flows upward through the bed, while water is sprayed downward over the bed. It was desired to demonstrate the feasibility, collect sufficient data to permit scale up design, and estimate the investment and costs involved. Pressure drop and cooling performance of the bed were measured for the air- water system in a vertical column, 0.29 m. I.D. and 2.44 m. high, under conditions typical of industrial cooling tower applications. It was found that the TBC performed marginally as compared with conventional mechanical draft Cooling towers, a primary concern in assessing the turbulent bed cooling tower is to compare it with acceptable towers already being used. Although there appears to be no parameter which reduces all variables to a common basis, the tower characteristic gives one widely recognized basis for comparison, that industrial mechanical draft towers exhibit characteristics approximately 1.5 to 2 times as large as the TBC for one stage packing and 106°F inlet water temperature and also that the comparison is more favorable for eases with similar inlet air wet bulb temperatures and inlet water temperature. Of course, the influence of both these temperatures are included in the tower characteristic but there appears to be some interaction of effects that is not eliminated by using tower characteristic. More questionable is the factor of V (bed height) in the characteristic since conventional vs. TBC towers would have fill or packing ratios of about forty to one. Thus, comparing tower characteristics may not be a critical variable for discriminating between grossly different tower designs but it is useful for crude screening. [9]

Hisham El-Dessouky carried out an experimental study on thermal and hydraulic characteristics of a three-phase fluidized bed cooling tower. The experiments were carried out in a packed tower of 200 mm diameter and 2.5 m height. The packing used was spongy rubber balls 12.7 mm in diameter and with a density of 375 kg/m^3. The tower characteristic was evaluated. The air-side pressure drop and the minimum fluidization velocity were measured as a function of water/air mass flux ratio (0.4–2), static bed height (300–500 mm), and hot water inlet temperature (301–334 K).The experimental results indicate that the tower characteristics *KaV/L* increases with increases in the bed static height and hot water inlet temperature and with decreases in the water/air mass flux ratio. It is also shown that the air-side pressure drop increases very slowly with increases in air velocity. The minimum, fluidization velocity was found to be independent of the static bed height. The data obtained were used to develop a correlation between the tower characteristics, hot water inlet temperature, static bed height, and the water/air mass flux ratio. The mass transfer coefficient of the three-phase fluidized bed cooling tower is much higher than that of packed-bed cooling towers with higher packing height. [10]

A Grandov, A Doroshenko, I Yatskar In this paper the authors have given the grounds for using cooling towers with fluidized beds in contaminated water and air. The results of experimental research into the hydrodynamic and heat and mass exchange processes have been listed in the wide range of water and air velocities with bed elements of different densities. The authors make recommendations for the working regimes and designs of small ventilating cooling towers. The influence of flow non-uniformity on cooling efficiency has been studied in the columns of great productivity (the scale-up effect). The methods and algorithm of engineering calculation for cooling towers with fluidized beds have been worked out. These methods take into account the scale-up effect and a more accurate balance of the column resistance and ventilator head flow. The authors also give the technical characteristics of some designed and manufactured columns with productivity from 2.8 to 27.61 s^{-1} (from 10 to 100 m^3 h^{-1}) of cooled water. [11]

III. CONCLUSIONS OF LITERATURE SURVEY

From the above literature we can conclude many studies are made for the performance study of the fluidized bed cooling tower and concluded that the better performance due to the introduction of fluidized bed is achieved at low flow rates i.e.at L/G ratios less than one and the materials selected in most of the studies are thermocol due to less density and for the adaptability of different shapes. This review extend the work to higher range of flow rates and performance data available relating to fluidised bed cooling towers (FBCT) and also review leads to the and construct an experimental model fluidised bed cooling tower to obtain experimental data covering a wide range of variables and to develop design correlations to evolve a design method which will predict the optimum performance of Fluidized bed cooling tower.

REFERENCES

[1] 'Process Heat Transfer' by Donald Q Kern.Vol 1, 4th Edition(Pergamon)

[2] 'Operating charecteristics and design of Fluidized bed cooling tower' - Louis MbuaEgbe,Middle Sex University, London,UK.

[3] 'Performance of a fluidized bed cooling tower using bed materialsof various configuration'- K. N. Seetharamu and K. V. S. Varier, Madras. India

[4] 'Heat transfer and pressure drop in fluidized bed cooling tower' - N. Sisupalan and K. N. Seetharamu, Madras, India.

[5] 'Mathematical Model and Computer simulation program for numerical prediction of the performance of the fluidized bed cooling tower'- Hamid Reza Goshasyeshi, john Missenden south Bank University,London.

[6] 'Fixed fluidized bed dry cooling tower'- United states Peatent.-Ram Gopal seth.1112 Yardley Rd., Cherry Hill.N.J.08034

[7] 'Analytical calculation of wet cooling tower performance with large cooling ranges' - AlperYilmaz, Cukurova University, Faculty of Engineering & Architecture, Department of Mechanical Engineering,01330, Balcalı / Adana, alpyil@cu.edu.tr

[8] 'An experimental investigation of thermal characteristics of a mechanical draft wet cooling tower'- M. Lemouari , M. Boumaza–King Saud UniversityRiyadh, Saudi Arabia

[9] 'Turbulent bed cooling tower' –Ronald G barile.Perdue University Lafayette Indiana.

[10] "Thermal and hydraulic performance of a three- phase fluidized bed cooling tower" Hisham El-Dessouky.

[11] "Cooling towers with fluidized beds for contaminated environment" A Grandov, A.Doroshenko, I Yatskar.