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PERFORMANCE ANALYSIS OF COOLING TOWER: A REVIEW

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ABSTRACT

In the present study performance and effectiveness of Cooling Tower (CT) are reported based on the various methodologies available in the literature. The researchers are worked on performance of fill area of CT using various methods such as Mathematical Model, Numerical Analysis, CFD, Engineering Equation Solver (EES) Software and Experimental Analysis. They found that the heat and mass transfer (HMT) of cooling tower (CT) influence by the parameters like water inlet temperature, humidity and air WBT. They investigate that Evaporation Loss (EL) reduced by drift eliminator and $CaCl_2$ solution and performance of CT drastically reduced by formation of scaling and fouling and it can be reduced by using chemical dosing and ClO_2 generator but both methods have some limitations which can be overcome by using side stream filter.

Keywords- Cooling Tower, Effectiveness, Entropy, Evaporation loss, Side Stream Filter, WBT.

I. INTRODUCTION

Cooling tower is equipment to reduce outlet temperature of water stream by extracting heat from water by addition of sensible heat to air up to Saturated condition and evaporation of water itself which dissipate to environment and CT used in chemical, petrochemical industries, air conditioning and refrigeration system. In the last decade numerous reseachers have work on the performance of cooling tower with different parameter like WBT, entropy, exergy and temperature of water involve which affected the component such as drift eliminator,fill area[1-4] and purpose is to increase heat transfer rate of water with direct contact of air[8-12].The main cause to reduce heat transfer is scaling and fouling of each component of cooling tower[24-25],reseachers investigate method to remove scaling and fouling[29].

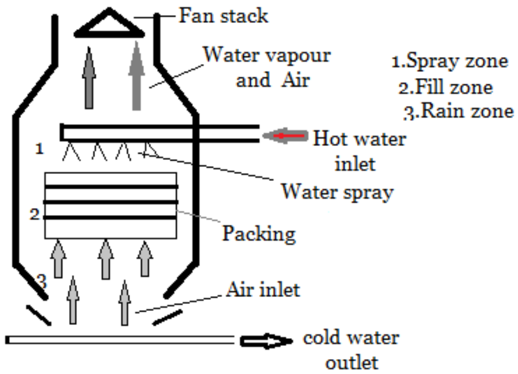

Fig. 1 "Basic Component of CT"

1.1 Fill Area Performance in Cooling Tower:

Fill or packing is heart of CT to transfer heat from water-air contact in a plane area mainly it is made up of plastics material.

The fill performance of Natural Draft Cooling Tower (NDCT) using CFD has been analyzed by Grobbelaar et al. [1], to measure the heat transfer rate and flow mechanics of fill characteristics. Kranc [2] analyzed the thermal performance of CT, non uniform water flow pattern generated with the help of circular spray nozzle fitted in square manifold with cellular packing. He found out radial spray pattern of individual nozzle give best thermal performance by optimization. In Cooling Tower (CT) mainly three zones was present to reject heat namely spray, rain and packing zone if rain and spray zone neglect and calculated error was 6.5% and solved by Engineering Equation Solver (EES) software has been used by Bilal et al. [3] to calculate the normalized fill performance index of CT, which is the function of weight gain by fouling. A relationship has been established by Goshayshi et al. [4] between packing mass transfer coefficient and pressure drop through experimental test. Qureshi et al. [5] presented a fouling model using data available in the literature and found that effectiveness of CT significantly degrade with time. Kloppers et al. [6] produced an empirical equation for fill loss coefficient and they concluded that it is more efficient than common available methods in the literature. The experimental investigation was carried out by Cortinovis et al. [7] on CT and they found that mass transfer phenomenon in packing of CT as function of liquid and gas flow rate.

1.2 Heat and Mass Transfer (hmt) Analysis in Ct

In CT primary requirement is reduced the water outlet temperature it is done by heat and mass transfer of water to the air and dissipated to atmosphere this phenomena study in paper.

Heat and mass transfer has been analyzed by Lemouari et al.[8] observed, two regime during air/water contact inside the tower, a Pellicular Regime (PR) and Bubble and Dispersion Regime (BDR) in this investigated that BDR to be more efficient than PR as it enable to achieve more Evaporation rate and higher HMT coefficient using experimental method. Muangnoi et al. [9] identify HMT properties of water and air and calculate Exergy based on mathematical model to result shows that Exergy supplied by water in larger than absorbed by air because of producing entropy by system. According to second law, Exergy analysis, thermodynamic ambient temperature and humidity influence the performance of counter flow cooling tower founded by Muangnoi et al.[10]. A numerical analysis of closed wet cooling tower has been performed by Jiang et al. [11]. They concluded that plate fin heat exchanger HMT coefficient and cooling Efficiency is a function of flow rate of air, process water temperature, spray water and process water. The results derived from numerical method are validated with experimental data. Qi et al. [12] have derived HMT characteristics of Shower Cooling Tower (SCT) without any assumptions without assumption but many authors have taken assumptions in literature to reduce complexity and computational time. The optimization of heat transfer rate and CT packing through proper water distribution of plane area has been done by Smrekar et al.[13] to improve the efficiency of NDCT. They found that it is possible by reduction of entropy generation and minimizing the exergy destruction. Kloppers et al. [14] have derived HMT equation for CT. Various governing equations are derived from different methods such as poppe method, merkel method and effectivess-NTU method and results compared together and also given its suitable application for different CT. Asvapoositkul et al.[15] predicted cooling tower performance by specification of mass evaporation rate equation and also Evaluate acceptance test for new tower and monitor change in tower performance. Fisenko et al.[16] have calculated HMT between water droplet and damp air, design parameter and ambient condition influence on efficiency of CT and describe boundary value problem of a system by ordinary differential equation using mathematical model. Facao et al.[17] has Developed correlation between mass transfer coefficient and spray heat transfer coefficient and also evaluates error in CT efficiency. Heating ventilation and air conditioning system have been optimized by Lu et al.[18] with genetic algorithm where constraints is mechanical limitation, component interaction, outdoor environment and indoor cooling load and minimizing total operating cost of energy consuming device and obtain result compared with conventional operation data. Yaqub et al. [19] observed that thermal performance influenced by varying air, water temperature, and driving potential for convection and Evaporation Heat Transfer (HT) along height of tower.

1.3 Evaporation Loss (EL) in CT:

In CT the circulating water is evaporate continuously due to HMT of water and air this water vapor loss to the environment and depends on temperature difference of inlet and outlet water shown in equation.

$$EL = 0.0008 \times (T_i - T_o) \times R.P.C \qquad (1)$$

Where R.P.C is Extend for Running Pump Capacity (m^3/hr).

To improve the performance of NDCT, Calcium Chloride ($CaCl_2$) solution has been used by Liu et al. [20] in the circulating water to reduce Evaporation loss by different working condition of water consumption and water outlet that is simplified by mathematical model. Lucas et al. [21] have evaluated the thermal performance of force draft cooling tower by using different drift eliminator for reducing evaporation loss by mass flow rates of air and water. Hajidavalloo et al.[22] have found approach, range and evaporation loss increase with increase WBT and predict thermal behavior of cross flow cooling tower under variable WBT using conventional mathematical model. The WBT of inlet air play important role on air and water outlet temperature, evaporation loss, exergy destruction and second law efficiency has been proposed by Aggarwal et al. [23].

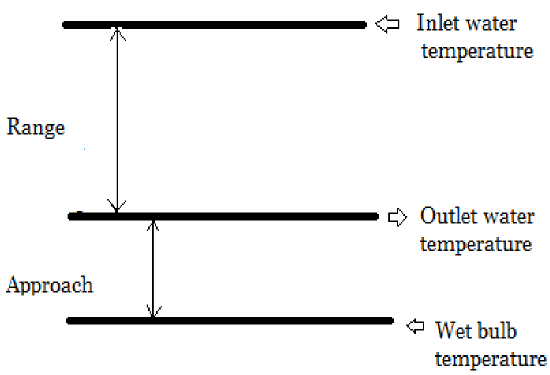

Fig. 2 “Evaluate Effectiveness of cooling tower”

Formula used to calculate the Effectiveness of Cooling Tower:

$$Effectiveness = \frac{Range}{Range + Approach} \quad (2)$$

1.4 Scaling and Fouling Phenomenon in CT:

Scale mean deposition of mineral such as calcium carbonate, calcium phosphate and magnesium silicate on the surface of condenser tube and fill, where fouling occurs when suspended solid such as dirt, dust and internal source like by product of corrosion form an insulated layer. scaling and fouling both are reduced drastically heat transfer which adversely affected effectiveness of CT this problem short out by using side stream filter to control total suspended solid particle, turbidity and free from chemicals that mean environment friendly which is essential requirement of today.

The water quality parameter, scaling indices, corrosion, microbiological and aquatic toxicity presented for different operating condition have been analyzed by Kitzman et al.[24] through two non chemical water cooling treatment technologies, one pulse power system and other hydrodynamic cavitations device against conventional chemical water treatment method. Howell et al. [25] have investigated the root cause and mitigation of fouling and failure in condenser tube. Tube fouling adversely affect on efficiency and capacity CT. The municipal waste water treated by Poly-Maleic Acid (PMA) to control severe mineral deposition (scaling) on pipe surface given by Li et al. [26]. The potential of membrane distillation tested by Koeman-Stein et al. [27] on cooling tower and showed the performance regarding to fouling behavior and distillate quality which reduce chemical demand, intake of make-up water and cooling water capacity. Fouling resistance has been measured by Wu et al.[28] "Tubes in tube" heat exchanger due to mineral precipitate and deposit on heat transfer surface, with experimental facility and correlate data with water quality and heat flux in tube. Pal et al. [29] installed chlorine dioxide generator which replaces chemical dosing in NDCT and calculate effectiveness of CT and found that effectiveness increased by 4-5%.

1.5 Cooling Tower (CT) Performance Depend Upon Climate Condition:

The climate condition define as particular place have its WBT, dry bulb temperature and air condition these parameter influence the performance of CT.

To evaluate Performance of two stage evaporative cooling unit consist of Indirect Evaporative Cooling Unit (IEC) followed by a Direct Evaporative Cooling (DEC) experiment has been carried out by El-Dessouky et al. [30] in the Kuwait environment at summer season with dry bulb temperature higher than 45^0c and result found that IEC/DEC efficiency is 90-120%,IEC efficiency range is 20-40% and DEC efficiency is 63-93% that is related to Nussult number to find out corresponding heat transfer coefficient results compared with literature. Badran et al.[31] have conducted experimental work in the Amman and Jordan environment for application of cooling tower to the air conditioning system that mean to cooled inside air by density difference between outside and inside air in and calculate that those climate need the height of tower less than 9m which result in realistic performance of CT. To calculate the partial blockage of Solar Enhanced Natural Draft Dry Cooling Tower (SENDDCT) and limitation of solar collector size in SENDDCT design with fixed area of heat exchanger that system numerical analyzed by ANSYS FLUENT Software have been done by Zou et al.[32]. The optimization scheme for SENDDCT design including capital, labour, maintenance and operation cost of each component through case study have been done by Zou et al. [33]. Has evaluate NDCT thermal performance using CFD model by Goudarzi et al.[34] numerical results are validate with proposed method in which wind load properly reduce by structure design without considerable reduction of CT performance. The performance evaluate of NDCT by fabricating windbreaker in CT radiators under condition of crosswind with CFD approach based on finite volume method has been analyzed by Goodarzi et al.[35] have found that windbreaker improve efficiency of cooling.

II. CONCLUSIONS

In present study last few year papers is considered in the field of cooling tower. It is observed that various authors are used mathematical model, numerical analysis, EES, CFD software work and experimental work for analyzing the performance of CT.

Scaling and fouling deposited in condenser tube and fill area can be prevented by using following methods:

(1)Chemical dosing in which chemical has highly solubility in chilled water, chemical doses are converted into ClO_2 gases this is not compressed or stored commercially and also Explosive in high temperature.

$$\underset{\{\text{Sodium Chlorite}\}}{2NaClO_2} + \underset{\{\text{Chlorine}\}}{Cl_2} \longrightarrow \underset{\{\text{Chlorine Dioxide}\}}{2ClO_2} + \underset{\{\text{Sodium Chloride}\}}{2NaCl} \qquad (3)$$

(2)ClO_2 generator the chemical (HCl, sodium hypochlorite, sodium chlorite and sulphuric acid) used is hazardous and generator is complex and expensive.

$$\underset{\{\text{Sodium Chlorite}\}}{2NaClO_2} + \underset{\{\text{Hydro-Chloric Acid}\}}{HCl} + \underset{\{\text{Sodium Hypochlorite}\}}{NaOCl} \longrightarrow \underset{\{\text{Chlorine Dioxide}\}}{2ClO_2} + \underset{\{\text{Sodium Chloride}\}}{2NaCl} + \underset{\{\text{Sodium Hydroxide}\}}{NaOH} \qquad (4)$$

Further with reference of these paper various investigation done on the field of scaling and fouling on tube and fill these technique have disadvantage mention above is remove by side stream filter, on this technique research paper is not available but this conclusion given on the basis of literature review.

(3)Side Stream Filter to control total suspended solid particle, turbidity and free from chemicals.

Above method for removal of fouling and scaling are concluded that side stream filter is best substitute of chemical dosing and ClO_2 generator.

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