Studies and Experimentation on Cooling Towers: A Review

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Abstract - ***Cooling tower is one of the important utility in chemical industries. Normally they are used to dissipate heat from heat sources to heat sink. The cooling of hot effluent and process water is required from reuse and environmental point of view. Induced, forced and natural draft cooling towers are used according to the requirements in industries. Natural draft cooling towers use atmospheric air. In forced draft cooling air is forced into the tower using blower. In induced draft cooling towers, air is sucked from other end. The water cooling happens because of humidification of air. The heat lost by water is heat gained by air. Water recirculation is also important aspect in the cooling towers. The effectiveness of cooling tower depends on flow rates of air and water and water temperature. Minimization of heat loss is one of the important aspect of studies carried out by various investigators. The interfacial area between air and water is also crucial factor in cooling towers. Three types of packings used in cooling towers are film, splash and film-grid packings. Also it was observed that drift is one of the important losses in cooling towers. Various shapes of cooling towers are tried by various investigators to study effectiveness. Hyperbolic shape was advantageous due to higher area at bottom. It provides aerodynamics, strength, and stability. The present review is aimed at summarizing studies and research on cooling tower for increasing efficiency and power savings to make it more economical and efficient.***

Key Words: *induced draft, forced draft, heat, flow rate, temperature.*

1. INTRODUCTION

In the chemical industries, utilities play an important role in plant operations. Two types of utilities are used in industries. Cooling utilities and heating utilities. Cold water is required for condenser, heat exchangers , reactors and other cooling purposes. Hot utilities include steam and other hot liquid used for heating in heat exchangers and to maintain reaction conditions. Cooling towers are used to cool the water for its various applications. The used water from various applications at higher temperature can be cooled and reused. Various types of cooling towers include Natural draft, induced draft and forced draft cooling towers. In cooling towers, air is passed cocurrently or counter currently with water. The heat gained by air is the heat lost by water. The efficiency of cooling tower depends on air and water flow rates and operating temperatures. Various researchers have carried out studies and investigation on various aspects of cooling tower which influence the effectiveness and working of cooling towers. The current paper reviews this research work on cooling towers.

2. STUDIES AND EXPERIMENTATION ON COOLING TOWERS

Lu and Cai presented a universal engineering model for cooling towers [1]. It was applicable for both counter flow and crossflow cooling towers. They used fundamental laws of mass and energy balance to approximate the effectiveness of heat exchange by a second order polynomial equation. The two major advantages of this model compared to old one were, less variables, better description of the cooling tower operation and no need of alternate computations. Qi et.al. provided a descriptive mathematical model of energy and exergy for a shower cooling tower (SCT).They used this model to predict the variation in temperature and exergy along the tower length. They validated the method by experimental data. According to their studies, the exergy of water is not completely absorbed by air and a notable portion of the exergy is always destroyed. With increase in droplet diameter, the energy destruction increased. A review on closed cooling tower was carried out by Qian et.al.[3]. According to the studies, domestic closed cooling tower is restricted to material performance and design and manufacturing level. According to them there is space for improvement in closed cooling towers wirh respect to energy and efficiency. This is not matured and there is huge scope for improvement and hence research. Shah and Rathod carried out studies on thermal design of cooling tower[4]. According to them, the design of cooling tower is affected by tower characteristics and different types of losses generated in cooling tower. Ideally heat loss by water is heat gained by air. So these two amounts must be equal. With air flow rate, cooling tower performance increases. Randhire studied the natural draft cooling towers for performance improvement[5]. Their research indicated that the performance of a natural draft cooling tower can be improved by optimizing the heat transfer along the cooling tower packing. For this purpose, suitable water distribution across the plane area of the cooling tower is required. Air and water contact is important for improving the performance. It can be observed that the proper distribution to ensure the homogeneity of the heat transfer and a reduction of entropy generation is critical for the cooling tower.

Gholizadeh and Momayyeza, in their research used cooling towers of Arvand and Boualisia Petrochemical plants[6]. They conducted experimental study to model the heat and mass balance equations and their. Raghuvanshi and Singh developed a new strategy to improve maintenance and for performance enhancements[7]. According to them, downtime and associated losses can be prevented by proper operation and maintenance. Proper water treatment is important for the maximum efficiency. Proper use of operating manual and optimum shutdown policies are key to the economical operation.They were able to save 12.93% labour cost which was associated with shutdown maintenance activity. In cooling tower maintenance, they saved 34.28% time which is associated with shutdown maintenance activity. Ramkumar and Ragupathy presented an experimental investigation of the thermal performance of forced draft counter flow wet cooling tower with expanded wire mesh type packing[8]. They used expanded wire mesh as a packing for the cooling tower. Wire mesh provides minimum restriction for flow. The packing used in their work was wire mesh with vertical [VOWMP] and horizontal [HOWMP] orientations. They observed that the efficiency of the cooling tower and cooling tower characteristics were higher in VOWMP due to higher contact area of water to air. Asadzadeh and Alam carried out review on hyperbolic cooling towers[9]. Pushpa et.al. carried out work on performance improvement of cooling tower in thermal power plant[10]. They carried out performance enhancements for Raichur Thermal Power Station (RTPS). This plant contributed about 40% of the total electricity generated in Karnataka. According to these studies increase in wind speed increased evaporation. The parameters such as air temperature, water temperature, relative humidity and rate of heat loss affected the cooling tower performance. Murugaveni and Shameer carried out studies on forced draft cooling tower[11]. They took 50 tons cooling capacity model as reference model.They modeled and assembled convergent nozzle as the inlet nozzle.They compared the effectiveness value of four cooling towers. It was observed that the cooling tower with air inlet pipe at 0^o and the cooling tower with air inlet pipe inclined at 30^0 about both horizontal and vertical axis have nearly same effectiveness. Lakovi et.al. analyzed the evaporative towers cooling system of a coal-fired power plant[12]. A theoretical analysis of the cooling system of a 110 MW coal-fired power plant located in Central Serbia was presented by them. They carried ou research in order to show the theoretical analysis of the tower heat and mass balance, taking into account the sensible and latent heat exchanged during the processes which occur inside these towers. According to them these cooling towers have 5 percent less efficiency than once through cooling toters. According to these studies, cold end operating conditions are important for a steam power plant. Abbas carried out studies on cooling towers by using different packings[13]. He studied the effect of different shapes (corrugate, and grid) of packing on the performance in air -water-cooling tower. He constructed a mechanical draft cooling tower. Over all volumetric mass transfer coefficient(K_{Ga})and volumetric heat transfer coefficient in gas phase (h_{Ga}) and volumetric heat transfer coefficient in liquid phase were observed to be functions of the water and air flow rates simultaneously.

Ramakrishnan and Arumugam carried out work on performance analysis of cooling tower using Taguchi Method[14]. Water flow rate, air floe rate and water temperature were important factors. They observed that the error between predicted values and confirmation test results was only 2.49%. They concluded that tower effectiveness was achieved at lower water flow rate, higher air flow rate and medium water temperature. Chhaya et, al. carried out review on effect of wind loading on natural draught hyperbolic cooling tower[15]. According to them, hyperbolic shape of cooling tower was usually preferred because of its strength, stability and large available area near the base. Badola and Prajapati carried out studies on performance enhancement of air cooled heat exchanger in winter conditions[16]. They observed that ambient conditions in winter were limiting the operation of air cooler due to temperature drop and low sweet gas flow.

Singh et.al. studied performance analysis of natural draft wet cooling tower at optimized injection height[17]. According to them, temperature and humidity inside the tower are having main influence on the performance of natural draft cooling tower. They analyzed the influence of injection height with key design and constant operating parameters such as the fill depth, tower inlet height, water flow rate, ambient air temperature and humidity and the initial water droplet diameter and distribution in the rain zone. Their studies indicated that the air flow was quite uniform through the fill and spray zones under the range of parameters considered in this analysis. S. Kulkarni and A. Kulkarni carried out the studies on seismic analysis of hyperbolic cooling towers [18]. They studied two towers available at Bellary thermal power station (BTPS). For the cooling towers, top end was free and Bottom end was fixed. They observed that ground acceleration increased the stresses developed in shell. The stresses developed in shell portion depends upon the shell thickness.Costelloe and Finn carried ou studies on open cooling towers used under low and variable approach conditions for indirect evaporative cooling of buildings[19]. They analyzed experimental energy performance. They observed that there was a significant potential for improved annual energy performance. They concluded that the energy performance is signicantly superior to that of modern vapour compression plants in general and particularly to air cooled reciprocating plants. Calautit et.al. carried out studies on passive cooling[20]. Their work was aimed at incorporating heat transfer devices in a wind tower to meet the internal comfort criteria in extreme external conditions. They installed heat transfer devices inside passive terminal of the wind tower unit. They conducted that computational fluid dynamics(CFD) modeling and experimental wind tunnel testing. They observed that, due to heat transfer configuration, the achieved indoor air speed was reduced by 28 – 52 %. Also the CFD simulation and the experimental results agreed with each other.

3. CONCLUSIONS

The studies on cooling towers have been carried out on various aspects of cooling towers aimed at optimizing the operation. A suitable water distribution across the plane area of the cooling tower can increase efficiency of natural draft cooling towers. The deterioration of filling material is one of the concerns. Proper shutdown strategy can save the manpower. It was observed that vertical orientation of packing increases performance, inlet conditions of flow rate of water, air and inlet water temperature are important factors for cooling tower operations. It can be concluded that proper packing, shut down strategy and water distribution are important for optimization of cooling towers. It is important to identify such factors and optimize these for efficient working of cooling towers.

REFERENCES

[1] Lu, L. And Cai, W., "*A Universal Engineering Model For Cooling Towers*" (2002). International Refrigeration And Air Conditioning,Conferencep, aper 625.,Http://Docs.Lib.Purdue.Edu/Iracc/625.

[2] Xiaoni Qi, Yongqi Liu, Zhenyan Liu, "*Exergy Based Performance Analysis Of A Shower Cooling Tower*", Strojniški Vestnik - Journal Of Mechanical Engineering, vol.59, no.4,pp.251-259,2013.

[3] Jianfeng Qian, Lina Li, Yankun Tan And Dayu Zheng, "*Research And Application Of Closed Cooling Tower*", 2nd International Conference On Electronic & Mechanical Engineering And Information Technology (Emeit-2012),1-3.

[4] 4.Ronak Shah, Trupti Rathod, "*Thermal Design Of Cooling Tower*", International Journal Of Advanced Engineering Research And Studies, vol.1, pp.26-29,/April-June, 2012.

[5] Randhire Mayur A., " *Performance Improvement Of Natural Draft Cooling Tower*", International Journal Of Engineering Research And Reviews,vol. 2, no. 1, pp.7-15, January-March 2014.

[6] Mortaza Gholizadeh And Mosen Momayyeza, "*The Estimation Of The Cooling Tower Height By Modeling The Water And Air Contact Situation In Cooling Tower Falling Film*", Journal Of Chemical Engineering And Materials Science, vol. 2, no.2, pp. 21-27, February 2011.

[7] Neetesh Singh Raghuvanshi, Dr. Alok Singh,"*Development Of Maintenance Strategy To Improve Performance Of Natural Draft Cooling Tower*",International Journal Of Scientific And Research Publications, vol. 4, no. 8, pp.1-7,August 2014..

[8] R. Ramkumar, A. Ragupathy, "*Thermal Performance Of Forced Draft Counter Flow Wet Cooling Tower With Expanded Wire Mesh Packing*", International Journal On "Technical And Physical Problems Of Engineering" , vol. 3, no. 1,pp.19-24, Mar. 2011.

[9] E. Asadzadeh, M. Alam,"*A Survey On Hyperbolic Cooling Towers*", International Journal Of Civil, Structural, Construction And Architectural Engineering, vol:8, no:10, pp.1027-1039, pp.1027-1039, 2014.

[10] Pushpa B. S, Vasant Vaze, P. T. Nimbalkar, "*Performance Evaluation Of Cooling Tower In Thermal Power Plant - A Case Study Of Rtps,Karnataka*", International Journal Of Engineering And Advanced Technology , vol.4, no.2, pp.110-114,December 2014.

[11] S. Parimala Murugaveni, P. Mohamed Shameer, "*Analysis Of Forced Draft Cooling Tower Performance Using Ansys Fluent Software*", International Journal Of Research In Engineering And Technology, vol. 04 no. 04, pp.217-229, Apr-2015.

[12] Mirjana S. Lakovi, Slobodan V. Lakovi, And Milos, J. Banjac,"*Analysis Of The Evaporative Towers Cooling System Of A Coal-Fired Power Plant*", Thermal Science, vol. 16, Suppl. 2,pp. S375-S385,2012.

[13] Mohammed Nsaif Abbas, "*Study The Performance Of Different Packing In Open Cooling Towers*", Journal Of Engineering And Development, vol. 16, no.2, pp.193-210, June 2012.

[14] Ramkumar Ramakrishnan, Ragupathy Arumugam,"*Experimental Study And Performance Analysis Of Ceramic Packing Cooling Tower Using Taguchi Method*", Int. J. Of Thermal & Environmental Engineering, vol.8, pp.45-53,2014.

[15] Parth.R.Chhaya, Nizam.M.Mistry, Anuj.K.Chandiwala, "*A Review On Effect Of Wind Loading On Natural Draught Hyperbolic Cooling Tower*",International Journal Of Advance Engineering And Research Development, *vol.1,no. 12,pp.47-50, December -2014.*

[16] Neeraj. P. Badola, Swati V. Prajapati,"*Performance Enhancement Of Air Cooled Heat Exchanger In Winter Conditions*", Global Journal For Research Analysis,vol.3, no.7,pp.96-98,2014.

[17] Alok Singh, Sanjay Soni, R. S. Rana,"*Performance Analysis Of Natural Draft Wet Cooling Tower At Optimized Injection Height*", Proceedings Of 02nd Itr International Conference, 07th September-2014, Bhubaneswar, Isbn: 978-93-84209-50-6, Ppp.61-65.

[18] Sachin Kulkarni, Prof A.V. Kulkarni,"*Case Study Of Seismic Effect On Hyperbolic Cooling Towers*", Civil And Environmental Research, vol.6, no.11,pp.85-94, 2014.

[19] Ben Costelloe, Donal Finn, "*Experimental Energy Performance Of Open Cooling Towers Used Under Low And Variable Approach Conditions For Indirect Evaporative Cooling Of Buildings*", *Building Serv. Eng. Res. Technol., vol.*24, no.3, pp.163-177,2003.

[20] John Kaiser Calautit, Ben Richard Hughes, Saud Abdul Ghani,"*Integration And Application Of Passive Cooling Within A Wind Tower*", First International Conference On Energy And Indoor Environment For Hot Climates, Doha,Qatar, 24 Feb 2014 - 26 Feb 2014.

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