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Thermal Analysis of Cooling Tower using Computational Fluid Dynamics

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ABSTRACT

The automotive, chemical and other plants employs use of cooling tower dissipating heat from water in to the atmosphere. The performance of cooling tower can be enhanced by various water modelling and energy consumption analysis. The current research reviews previous studies conducted in determination of effectiveness of cooling tower subjected to different operating conditions. The analytical equations are presented along with experimental data on evaluation and improvement of cooling tower performance.

KEYWORDS: *Cooling tower, thermal analysis*

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1. INTRODUCTION

The cooling tower is one of the key components in industries such as power generation including renewable [1] geothermal and solar thermal [2] and non-renewable [3] power plants, chemical and petrochemical plants [4], refrigeration and air-conditioning plants. Thermoelectric generation and its required cooling are responsible for approx. 10% of the total water demand in the world. The role of the cooling tower is dissipating heat from the hot stream of the process into the air in power plants, district cooling plants, and cooling systems. To address the water scarcity for a sustainable future (in smart cities) cooling towers have to receive special attention. Replacing the evaporation of water for dissipating the heat with another method, or capturing the vapor, or both are the ideas to support water conservation. Considering several cooling towers that are installed already highlights the importance of capturing the vapor and/or reducing evaporation studies. The design of cooling towers focuses on the water distribution system, fill, and drift elimination. The water distribution system introduces and spreads the process water as evenly over the fill through the use of water canals and nozzles. The fill is a system of packing that delays the fall of water and improves heat transfer, and drift eliminators at the air exit change the direction of airflow to reduce the volume of water transported out. Within cooling towers, water is lost through three main modes. These modes are drift, blowdown, and evaporation. Drift is the water losses associated with wind, evaporation loss occurs due to the heat transfer taking place, and blowdown is utilized to avoid the buildup of minerals and sediments within the cooling water that may damage other components within the system, and. blowdown is also a byproduct of the evaporation processes increasing the concentration of the minerals [5].

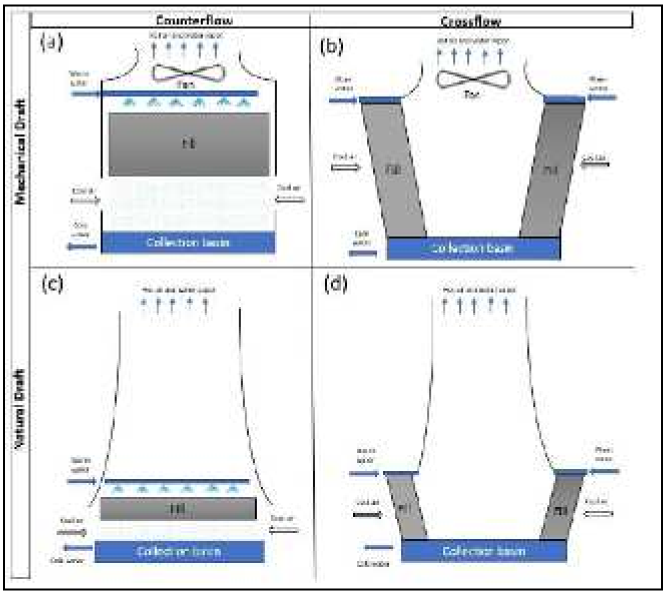

Figure 1: The schematic of different types of wet cooling towers

Wet cooling towers are also categorized by the movement of water and air inside of the cooling tower as follows:

1. Crossflow towers: air flows horizontally across the falling water as it shows in Figure 1 (b) and (d),
2. Counterflow: the upward airflow that directly opposes the downward flow of the water providing which is shown in Figure 1 (a) and (c) [19].

2. LITERATURE REVIEW

Klopperset al. [6] have worked on development of empirical equation for determination of efficiency of cooling tower. When the outlet air from the cooling tower was saturated, Merkel and e-NTU models were capable of predicting the temperature of that, while the Poppe model did not need any assumption for estimation of the outlet air temperature from the cooling tower.

Ayoubet al. [7] When the draft in the cooling tower was the same, the outlet water temperature from the cooling tower in the three models were the same. A small difference in the outlet water temperature from the cooling tower was observed in Merkel and Poppe models over the outlet air from the cooling tower since outlet air assumed saturated in the Merkel model.

M Rothet. al. [8]have worked in development of water evaporation rate. The water evaporation rate in the cooling tower was underestimated by the Merkel model compared to the Poppe model. Since evaporation was an important factor in designing the hybrid cooling towers, using the Poppe model was preferred.

Klopperset. al. [9] have proposed a modelbased on a reliable equation to determine the Lewis factor value. While in the Merkel model the Lewis factor was a constant number of 1. Most researchers believed that Merkel's assumption was not accurate since the Lewis factor was between 0.6 to 1.3.

Jaber and Webb [10] put forward the number of heat transfer unit (ε-NTU) model, which provides another method for the calculation of the cooling tower. It is worth noting that the model, like the Merkel enthalpy model, ignores the effect of water evaporation.

Gan [11, 12] put forward several mathematical models. These models take into account the mass, momentum, and energy transfer simultaneously. These models are based on the Merkel theory and its modified form, and they can analyse the thermal processes of different cooling towers. They also carried out numerical simulation analysis of closed cooling towers and obtained an earlier relatively mature simulation experience.

Ronak Shah, TruptiRathore[13] had done thermal design of industrial cooling tower and determined the complete performance parameters with given inlet and outlet conditions and considering several possible losses. they investigated that cooling tower performance increases with increasing air flow rate and cooling tower characteristic decreases with increase in water to air mass ratio.

Plasencia et al [14] developed a new model which is based on transfer of heat and mass for IEC; few simplifications were incorporated to make this model as user friendly used for analysis of energy as well as adaption of system.

Camargo et al [15] presented an operational concept for both type of cooling systems and generated equations for mass and heat transfer between warm air and wetted media. Above researches and mathematical models has been limited up to the conditioning of air coming out of the coolers, and to increase the saturation efficiency or effectiveness of cooler; however, the use of cooled water stored in tank was not at all explored. This gap of not using the coolness of cooler water has been identified as a research gap and thus becomes the main objective of the present work.

Pushpa B. S, VasantVaze, P. T. Nimbalkar [16] have evaluated performance of cooling tower in thermal power plant by varying water inlet temperature, air inlet temperature and mass flow rate of water. They found that efficiency of cooling tower increases by increasing water inlet temp, air inlet temperature and decreases by increasing mass flow rate.

S. ParimalaMurugaveni, P. Mohamed Shameer[17] in their research have analyzed a forced draft cooling tower by varying air inlet parameters and by varying air inlet angles in horizontal and vertical direction and both. The cooling tower model has been prepared in solid works 2013 and it has been meshed using icemCFD 14.5 software and meshed models have been analyzed using fluent software. On the basis of temperature contours obtained, they found that outlet temperature of water increases as the air inlet angle increases which will lead to decrease in effectiveness.

Manoj Kumar Chopra, Rahul Kumar[18] in their research carried out the cfd analysis on a counter flow cooling tower reference model. the model has been prepared in Creo and meshed and analyzed through Ansys 12.1. The analysis is carried out by simultaneous varying of three parameter inlet water flow rate, inlet air rate and fills porosity and applied taguchi method to carry out the optimization. They investigated that cooling tower gives best performance at lower mass flow rate of water, high mass flow rate of air and fill porosity of 50%.

3. CONCLUSION

The performance of cooling towers depends upon various operational and design parameters. The empirical equations are presented by various scholars which can accurately predict the efficiency of cooling towers under different operating conditions which includes air inlet temperature, water inlet temperature and mass flow rate. The present study elaborated the history of energy-water modeling methods of cooling towers through the Markel, the Poppe, and the Effectiveness–(NTU) Models since water and energy are deeply connected in cooling towers.

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