Journal of Advanced Mechanical Sciences (JAMS)
ISSN: 2583-3790 (Online)
"J. Adv. Mech. Sci., vol. 1, no. 1, pp. 26-30, March 2022"

Studies on Thermal Performance Analysis on Cooling Towers - A Review

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Article received: 01/03/2022, Article Revised: 24/03/2022, Article Accepted: 25/03/2022
Doi: 10.5281/zenodo.6482153

Abstract

Cooling towers have been in use for different industrial applications for many years. These are a particular class of heat exchangers where industrial process water comes in contact with coolant air, enabling efficient heat rejection from circulating fluid-usually water. There have been many research attempts to improve the overall thermal performance of these systems to develop optimum working methodologies and address current systems' issues. This literature review is done to find out the various thermal performance analysis studies done on various industrial cooling towers.

Keywords: *Cooling towers, Thermal performance, Crosswinds, Drift eliminators, Hybrid model, Natural draft, induced draft.*

1. INTRODUCTION

The advent of various process industries necessitated improved models of heat rejection systems. Cooling towers serve the purpose of heat exchangers in many industrial applications due to their efficient and flexible performance characteristics. Primarily these systems work based on the evaporative cooling technology, which can handle a large quantity of heat transfer. Cooling towers have been classified based on the applications and requirements of industries into different categories. These include cross-flow type, counter flow model, etc., depending on the nature of flow inside the tower. Considering the nature of the driving force, cooling towers have been classified into the induced draft or natural draft systems. Thermal performance studies are being conducted on different cooling tower models to develop optimum working characteristics. These include research attempts to analyze various parameters like factors that can influence heat rejection rate, the mass flow rate of working fluids, finding optimum working fluid, design and shaping of cooling towers, effects of ambient conditions on the system, etc, and various other characteristics.

2. SOME OF THE EARLIER RESEARCH STUDIES ON COOLING TOWERS INCLUDE THE FOLLOWING:

The water outlet temperature measures the tower's performance for fixed cooling tower conditions. The experimental study conducted by Bedekar et al. [1] revealed that the outlet water temperature increased upon increasing the air to mass flow ratio studied under different water flow rates. The increase in water outlet temperature was more profound as the air to mass ratio increased.

Gao et al. [2] tried to understand the impact of crosswind on the performance of natural draft cooling towers. They studied the overall performance with and without the wind conditions. The result obtained suggested that crosswinds influence the system's heat transferability. The circulating water temperature and efficiency could even change up to 5-6 percent upon varying the wind influence over the system.

Amini et al. [3] studied the influence of choosing different nanofluid combinations apart from using pure water alone in cooling tower systems. They could find substantial improvement in the effectiveness and thermal performance with nanofluids like Aluminium oxide (Al2O3)/water and Cupric oxide (CuO)/water and contribute up to around 8 % improvement. However, the thermal performance can again depend upon the inlet temperature at which these are supplied.

Drift eliminators are used in industrial cooling tower applications to filter out the water droplets going out to the atmosphere. The performance of drift eliminators and their configuration also influence the thermal performance of cooling towers. Experimental studies were conducted by Lucas et al. [4], validating the dependency.

Research attempts have been made to find the effect of nanofluid in cooling technologies used, especially in wet cooling towers. Rahmati [5] analysed the use of Zinc oxide (ZnO)/water combination in wet cooling towers and concluded that it contributes to thermal efficiency. They used different weight concentrations ranging from 0.02 % to 0.1% to understand the effect of nanofluid concentration. It was also found that the performance, such as temperature difference and the degree of cooling can be varied by changing the Nano fluid concentration [6].

Merkel number is one of the widely used parameters in cooling towers calculations. This tries to relate the equations between heat and water vapor transfer happening in the cooling tower models. Zhou et al. [7] experimented on super large natural draft cooling towers to study the effect of the axial fan on the enhancement of thermal performance. The study analysed that the use of axial fans could also improve the uniformity of inlet air under crosswind applications, increasing the Merkel number from 0.69 to 5.92 %. Their analysis also states that the temperature drop can be enhanced by using this induced ventilation to the order of 6.46 to 13.35%.

Despite the positive aspects of conventional wet cooling towers, they pose a threat to the environmental risks. Specific other different models are currently in use to ensure safety from the complications generated by drift emissions. However, the thermal performance could vary depending upon the design followed. Ruiz et al. [8] studied one such model called the inverted cooling tower model and found out its drift emissions were relatively lower. Thermal performance was also slightly increased apart from its emission characteristics.

In evaporative cooling towers, the 'fill zone' characteristics play a vital role in the cooling system's performance. According to the study conducted by higher cooling rates were obtained under lower wetting rates of fill packs following the Merkel number [9]. The fill packs were made of metals having perforations to allow good interaction between the phases.

The design of cooling towers is subjected to many different parameters. An experimental study was conducted to analyse the thermal performance of cooling towers with rotational splash packing by Lavasani et al. [9]. The results were such that the cooling temperature range was considerably increased by incrementing the rotational velocity of the packing, although it does not have a considerable impact on the evaporation rate. The speed of packing rotation was further found to aid the heat rejection process.

Constant efforts have been there for a different period from many researchers to improve the cooling efficiency characteristics. Crosswind effects always negatively affect the performance. Gooderzi and Keimanesh [10] concluded that radiator-type windbreakers could improve cooling efficiency, maybe three times more than the usual solid model. Moreover, thermal characteristics of direct contact type cooling towers (wet type) under the different shapes of tubes through numerical simulation and found that elliptical cross-section tubes provided a more uniform velocity field and helped achieve greater thermal efficiency [11].

Zheng et al. [12] also did similar experiments to evaluate the characteristics of oval-shaped bundle tubes on the cooling performance, especially on the wet-type cooling tower model. They further tried to derive relations between the water film heat transfer coefficient and the air-water mass transfer coefficient, which is helpful for heat transfer analysis.

Nourani et al. [13] performed experimental studies on hybrid cooling tower models to evaluate their characteristics. They concluded that hybrid models could save considerable water usage for their operation compared to typical towers and are thus more economical. Their study has good practical significance where the water is scarce as hybrid models help save water usage.

Chiang et al. [14] presented their works to optimize the overall performance of the cooling tower system through mathematical modelling. They tried to develop correlations between different parameters like heat dissipation and water flow rates. The modelling results supported the experimental data generated.

3. CONCLUSION

The literature review enabled the study of various aspects of cooling towers, especially the tower characteristics that could influence the system's thermal performance. Valuable conclusions regarding the crosswind effects, impact of different duct tube cross-sections, the influence of parameters such as 'fill zone,' 'drift emissions,' etc., on the system's thermal performance were also noticed in the review. The study also helped to gain knowledge of different models like hybrid cooling towers which can be used for location-specific applications.

Acknowledgement/Funding Acknowledgement

The author(s) received no financial support for the research, authorship, and/or publication of this article.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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