Journal of Advanced Research in Mechanical Engineering and Technology
Volume 8, Issue 1 - 2021, Pg. No. 1-4
Peer Reviewed Journal

Research Article

Direct and Indirect Evaporative Cooling Strategies: An Analysis

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DOI: https://doi.org/10.24321/2454.8650.202101

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How to cite this article:
Mishra S, Geete P, Kundu AM. Direct and Indirect Evaporative Cooling Strategies: An Analysis. *J Adv Res Mech Engi Tech* 2021; 8(1): 1-5.

Date of Submission: 2021-03-04
Date of Acceptance: 2021-04-06

A B S T R A C T

Evaporative cooling can be understood as natural response of human body to effective climate control. It is the similar to the cooling principle that human body practices when moisture/ sweat vaporizes and cools off the skin. Needing less energy input, evaporative cooling is perfectly fit for uses in which decreasing high temperatures as well as energy consumption is the requisite. Evaporative cooling is an energy competent resolution for trades, where hot inside environments lead to low output, productivity and discontented employed workers. This could also upsurge the amount of faults and mishaps in the production lines. There are many technologies in place used in poultry, horticulture, swine and dairy industries such as in-duct direct evaporative cooling, exhaust air evaporative cooling, in-direct evaporative cooling and direct air evaporative cooling. In this paper, different evaporative cooling technologies have been discussed.

Keywords: Evaporative Cooling, Direct Evaporative Cooling Systems, Indirect Evaporative Cooling Systems, Hybrid Evaporative Cooling Systems

Introduction

In evaporative cooling technology, air is cooled by vaporizing the water it is at variance from usual air conditioning systems based on vapor-compression or absorption refrigeration cycles. For evaporation of 1 kg of water into the atmosphere, energy of 680 W is needed. This energy for steam humidifiers is supplied either from electricity or gas which is utilized for boiling the water. Conversely, this energy in case of cold water humidifiers is occupied from the air as heat leading to decrease in temperature of air. A large marketable cold water humidifier in addition to increasing humidity, supplying 1,000 kg of moisture in an hour to an atmosphere is providing evaporative cooling of 680 kW. Since few humidifiers are capable of operating on as low as 0.3 kW of current, their prospective for supplying low energy and low cost cooling is significant and this potential can be utilized in HVAC systems. Therefore digging deep into direct, indirect and hybrid evaporative cooling systems to understand them better for commercial application is the need of the hour (Figure 1).

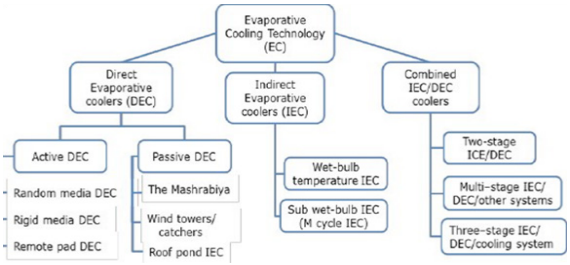

Figure 1.Arrangement of Evaporative cooling systems in cooling the houses[13]

Direct Evaporative Cooling Systems

Direct Evaporative Coolers are the systems in which water is vaporized into the air through an engineered pad to deliver adiabatic cooling. Indirect Evaporative Coolers are the systems in which vaporizing water is used to decrease the temperature of outgoing airstream travelling via HE and there by retaining same dampness of treated air (Figure 2). Direct as well as indirect evaporative cooling systems are enormously energy efficient, refuting the requirement of compressors in the cooling cycle. Data centers, factories, livestock and greenhouses can be benefitted with the application of this technology.

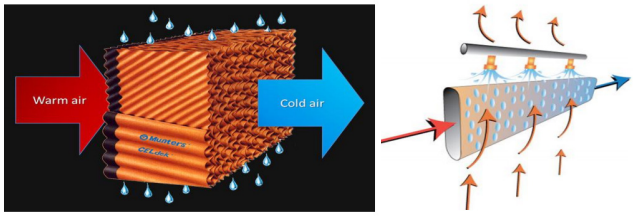

Figure 2.Direct and Indirect Evaporative Cooling[14]

Indirect Evaporative Cooling

Indirect evaporative cooling operates on similar concept as direct evaporative cooling reducing temperature of air by vaporizing the water. The foremost modification in an indirect system is for cooling the air delivered to the living space, a heat exchanger is used. The evaporative cooling sequence happens in heat exchanger.

Hot air from outside is carried using a heat exchanger and it is provided along with water. A design consists of sequence of metal tubes which is made damp on its exterior sides. These tubes are cooled as hot air flows over them thus evaporating the water and cool air thus produced is supplied to the building interior without attaining any extra humidity (Figure 3).

Indirect evaporative cooling offers cooled air to inside spaces which is less damp from direct evaporative cooling thus increasing its suitability for regions where surplus humidity is not desired for inside air. But it consumes more electricity since it uses two fans as compared to direct evaporative cooling.

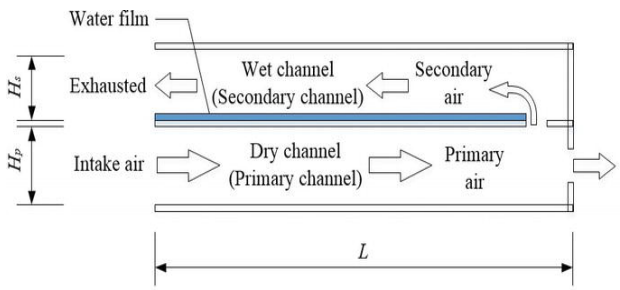

Figure 3.Representation of an indirect evaporative counter-flow regenerative HEX[5]

Advantages of Evaporative Cooling System over VCRS

The evaporative cooling system possesses these benefits in comparison to VCRS:[1-4]

- Curtailing energy consumption
- Reducing costs
- Dropped peak power requirements
- Zero CFCs
- Subsiding pollutant discharges
- Easy merger with current systems

Limitations of Conventional EHX

- Direct evaporative cooling systems leading to uneasy thermal atmosphere for people in room due to increase in air moisture content
- Less cooling efficiency of indirect evaporative cooling system
- Speculative final temperature for cooled air is the wet-bulb temperature

Energy Efficient and Novel Hybrid Evaporative Cooling System

Use of indirect evaporative cooling system bids disadvantage of low efficiency and also by using direct evaporative cooling system, the temperature of air to be supplied once cooled would be on the verge of ease and by the time it is passed through the spaces, it might go up by few points to perhaps go outside the comfort zone. Hybrid cooling system augments the usage of the dual cooling technologies in distinct operational systems.[11]

In this kind of system, the air is first cooled without addition of any moisture to it, in binary stages. In the principal stage, air-to-air sensible HE is utilised to decrease air DBT. In next stage, air is furthermore cooled sensibly by a cooling coil which is supplied water through a cooling tower. After that the air is passed via DECS to attain a lesser temperature. Subsequently, in Hybrid Evaporative Cooling system (HEC), lowermost temperature that could be achieved can be lesser than the WBT of the outside air (Figure 4).

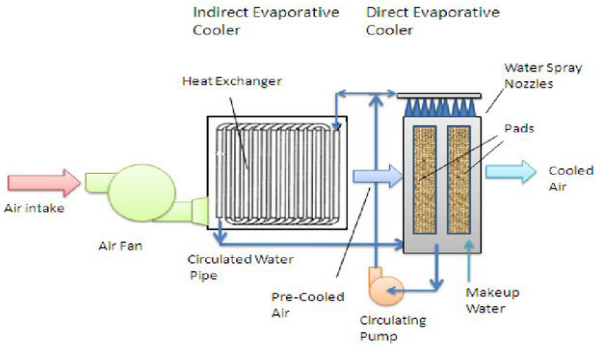

Figure 4.Indirect-direct evaporative hybrid cooling system[12]

ISSN: 2454-8650
DOI: https://doi.org/10.24321/2454.8650.202101

Literature Review

Following is the review of related literature and studies.

Dorwat et al. (2020) studied the experimental and theoretical work of indirect evaporative cooling. Energy demandworldwide has increased rapidly. 30% to 40% of total energy consumption is in building sector. To reduce the exhaustion of fossil fuel and as well as pollution, the indirect evaporative cooling is the best option. It is a convenient method because working fluids are used as air and water.[6]

Thermal performance of direct evaporative cooling used in office building was studied by Tewari et al. (2019) in their study. During summer season in the month of April to July in year 2016 in Jaipur city of India, the experimentation was done. The mathematical correlation and estimate of supplying air to the indoor air temperature is carried out by Multiple Linear Regression technique (MLR) and L-16 orthogonal array design which was developed by Taguchi design. Finally the result were compared between ASHRAE standard 55 and Climate Specific Adaptive Thermal Comfort Zone (CCATCZ) and it was established that DECS gives extra comfort about 52% times in the summer season.[7]

Xin Cui et al. (2019) concluded in their review about a hybrid indirect evaporative pre-cooling system for several type of weather. In this paper, the study of the mathematical formulation of indirect evaporative cooling is done. This paper compares the mathematical and experimental results for parameters of exit temperature and heat flux. Simulation results are fulfilling for 57% of the pure air cooling load.[8]

The three-stage cooling system was studied by Hussain et al. (2016) in their study. These three stages were: 1) Water to air cooling coil 2) indirect evaporative cooling 3) direct evaporative cooling system. Condensate cooling water made in the Air Heating Unit (AHU) is used for first, second, and third stage respectively and collects in a tank that is thermally insulated.[9] The heating has a considerable capacity of power and cost parsimonies as compared to traditional VCC based device air conditioners for an area in summer, months having lower relative humidity, and also it is energy conservative as compared to conventional small unit air conditioners. Also concluded that 50% power and cost savings are attained in comparison to conventional ACs.

Porumb et al. (2016) explained in DECS there is direct interaction of air and water. While in indirect evaporative cooling there are both streams air and water are alienated through heat exchanger surface.[10] IEC technology is playing a role in lower power consumption and high competence. The various indirect evaporative cooling techniques are as follows. Regenerative indirect evaporative cooling – it is used to reduce the temperature of primary air at the outlet less the WBT of the secondary air at the inlet and here some of the primary air is utilized as secondary air. Maisotsenko indirect evaporative cooling system has a substitute opportunity for chilling the primary air nearby the DPT of inlet air. It mainly consists of horizontal plates. IEC application- application of IEC is in cinemas, building, industrial building, supermarkets, and sport facilities.

Conclusion

Most of the study is done on types of evaporating cooling systems, types of flow in heat exchanger, types of heat exchanger and the cooling agent used. Besides studies are focused on simulation and types of evaporating cooling system and explained the variations in performance according to climatic conditions. Researchers mostly concentrated on parameters such as increment in performance, component reduction, designing according to climatic conditions, development in design in easier and economical way and reduction in electricity consumption.

Subsequently reviewing all these international and national research, we found that the direct or indirect evaporative cooling system alone is unable to offer effective human comfort and cooling effect so integrating these two to develop hybrid system could be a way out to overcome the disadvantages of both and augment the benefits. Also counter flow HE in place of parallel flow HE can be used for incrementing the COP. The direct or indirect evaporative cooling system alone is incapable to offer effective human comfort in variable climatic conditions, but this hybrid system is able to provide required human comfort.

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