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RESEARCH ARTICLE OPEN ACCESS

Effect of Nano-particles on the Performance of Two Stage Evaporative Cooling System

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Abstract:-

This paper discusses the effect of nano-particles on the performance of a two stage evaporative cooling system (ECS). The ECS is one of simplest cooling techniques and also an ancient method. It is an ecofriendly cooling system that cools the supply air with the help of water and reduces the temperature. The supply air temperature can be significantly reduced with the help of two stages of the ECS. The two stages of the ECS are indirect and direct cooling which helps to reduce the dry bulb temperature of the supply air. The efficiency of this cooling system can also be increased with help of nano-particles. The nano-particle improves the heat transfer in evaporative cooling system as nano particles have higher specific area to volume ratio. From this experimental work we observe that the performance of two stage evaporative cooling can be increased with aluminum oxide nano particles.

Keywords:- Evaporative cooling system, Nano-particles, temperature, performance.

1. INTRODUCTION

An Evaporative cooler is a simplest cooling device which cools air through the evaporation of water. Single stage evaporative cooling system is most widely used. However in recent years, two stage ECS are used for residential and commercial application. In two stage evaporative cooling system, indirect and direct evaporating stages are used to get lower temperature. In this type of systems, water is used as the coolant and helps to cool the supply air. The temperature of the air can be dropped significantly due to phase change of water from liquid phase to vapour phase. In indirect type heat transfer stage, the evaporation of water reduces the surface are of the media and there is no direct contact between water and the air. When the air flows through this low temperature heat transfer surface, it temperature reduces due to heat transfer between air and cool surface. The heat transfer in this stage is sensible heat transfer. In the second stage direct heat transfer takes place between air and water. The water is sprayed in the form of mist and it evaporates. When it evaporates, it absorbs the heat from the flowing air. The mixing of air and water particles reduces the air temperature significantly. In this stage, latent heat transfer takes place. The temperature difference between dry and wet bulb temperature is called as wet bulb depression. It significantly impacts the ECS efficiency. The cooling effect of ECS dependents mainly on wet bulb depression [1].

The indirect evaporative coolers can be used to reduce the temperature of air or any fluid using wet surface heat exchangers. The cooling air passage surface are wetted by nozzles which spray water. When the water film evaporates it cools and reduces the temperature of the wetted surface. The air is forced to flow through the alternative passages which are cooled by the heat exchanger's separating wall [2].

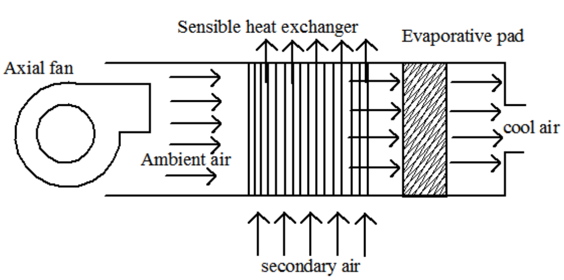

Figure 1 Direct and Indirect evaporative cooling system

Figure1 shows the working principle of evaporative cooling system. The ambient air is supplied to the sensible and latent evaporative cooling units using the axial fan.

When the air flows over the sensible heat exchanger, air temperature is used. In this process, indirect heat transfer takes place between air and water. The cross flow heat transfer is used for effective heat transfer. In evaporative pad, heat transfer takes place between air and water directly. In this process temperature of air is reduced significantly due to latent heat transfer. The water is sprayed on the evaporative pad such that effective heat transfer takes place. Also it ensures constant wetting of the evaporative pad surface. During this process the humidity of the air increases due to evaporation of water.

The ECS can be used for various residential and industrial applications. It can be used to improve the fruits and vegetables shelf life with moderate respiration rates with less energy consumption [3]. The evaporative cooling system consumes 50 % energy less than the conventional vapour compression system for the same cooling capacity and under the same climatic conditions [4]. It is reported that the indirect evaporative cooler (IEC) is suitable for residential, commercial, industrial and data centre applications. The IEC is environmental friendly and its global warming impact is negligible [5]. The dew point evaporative coolers are having good potential for cooling purpose, however further research work is needed to improve performance and reduce energy consumption [6]. It is suggested that the effect cooler effectiveness on the exergy efficiency is insignificant. The exergy efficiency of direct ECS can be improved with integrating it with indirect ECS [7]. The heat absorption rate of the absorption cooler can be improved with higher velocity. Also the cross flow of fluids results in higher cooling capacity. The introduction of regenerative evaporative cooler of the solid desiccant wheel increase the overall system efficiency of the system changing the sensible heat and desiccant wheels [8]. It is suggested that the evaporative cooling systems can be used in engine thermal management in engines to improve efficiency and also to reduce carbon dioxide emission [9]. The computation fluid dynamics is the powerful tool to analyze the performance of the evaporative cooling system [10].

In Nashik, rooftop ventilators were installed in the classrooms of a school to reduce the class room temperature as Nashik is located in a hot and arid zone [11]. A two stage ECS was developed and tested in the Kuwait environment. [12]. A water based Al2O3 hybrid nanofluid was prepared and its thermal characteristics were determined at different weight concentrations [13]. The nano fluid is prepared by dispersing nano particles in fluid [14]. It is reported that the thermal conductivity of CuO is lower than Al_2O_3 nano fluid [15]. The thermal conductivity of nanofluids is two times higher than the conventional fluids which are used in heat transfer applications. The thermal properties of Al_2O_3 is better than other nanofluids [16]. Many techniques are used for the measurement of thermal conductivity of nano particles is available [17]. Few researchers [18,19] used Al_2O_3 nano particles for their research work due to superior its thermal property enhancements. Hence in this work, we have used Al_2O_3 nano particles to enhance the performance of the two stage ECS.

2. MATERIALS AND METHODOLOGY

The material used in evaporative cooing system is water tank with heat exchanger, blower and motor, sensible heat exchanger, evaporative cooling pads, filters and enclosure. The nano particles are coated on wire which is placed in sensible heat exchanger, as heat transfer in sensible heat transfer is less. The evaporative cooling unit enclosue is made of galvanized steel with aluminium die cast corner joints, double skin panels to conceal the blower, motor, heat exchangers, pump etc. The water tank is made of stain steel. The blower used in an evaporative cooling system is dynamically balanced. The nano particle coated on wire mesh is placed on the indirect ECS. The indirect ECS is a sensible heat exchanger and is made of engineering polymer. The evaporative cooling pad is fabricated by bonding together with cellulose sheets. The high quality synthetic media was used for the fabrication of air filter used in this ECS.

Figure 2. Aluminium oxide nanoparticles

There are many nano particles such aluminium oxide, zinc oxide, silver, silica, titanium oxide and silicon carbide are used in various applications. The aluminium oxide is the best suitable nano particles in the evaporative cooling system as it has good properties such as large surface area to volume ratio, good thermal conductivity, easily dissolved in water, less toxicity, less cost etc. Figure 2 shows the Al_2O_3 nano particles used in this work.

The dry and wet bulb temperatures of supply air were measured using a sling psychrometer. The velocity of the supply air was measured using a anemometer. Figure 4 shows the sling psychrometer and anemometer.

Figure 3 Sling psychrometer and Anemometer.

3. Experimental setup

The components of experimental setup are air handling unit, heat exchangers, blower and other supporting measuring instruments. The air handling unit is the main part of the system is a centrifugal blower where a high velocity of air passes through the wire mesh coated with nano particles of aluminium oxide and then to the heat exchangers. In first set of sensible heat exchanger which is also called as dry air moist air. The second set is latent heat exchanger. The combination of sensible and latent heat exchangers reduces the supply air to great extend.

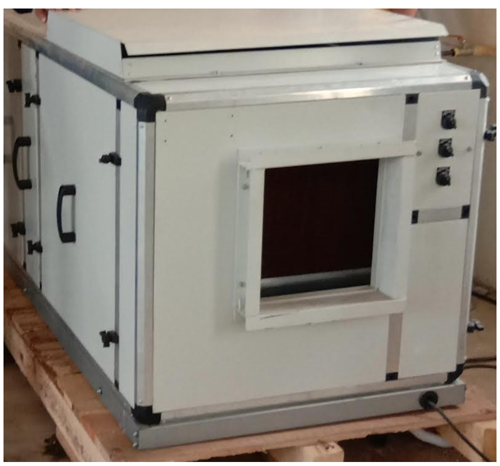

Figure 4 Experimental setup of evaporative cooling system

Figure 4 shows the experimental setup of ECS. The main blower supplies the ambient air to the ECS. This air flows through sensible heat exchanger and indirect heat transfer takes place between air and water. The cross flow arrangements in this stage ensure improvement in indirect heat transfer. Then this cooled air passes through the next set of heat exchanger (evaporative cooling pads). A number of nozzles were used to supply water in mist form so as to ensure better evaporation and reduction in supply air. In this stage the relative humidity of the air increases. Finally the cool air is supplied to the room. The two stage ECS provides low temperature air to the room.

4. Results and Discussion

The experiments were conducted successfully on the two stage ECS. The psychometric properties of air were measured before entering and leaving the ECS. The efficiency of the two stage ECS was determined using the following formula.

$$e = \left(\frac{\text{ti} - \text{to}}{\text{ti} - \text{twi}}\right) * 100\%$$

Where

$t_{i=}$ *Inlet* Dry bulb temperature (°C).
$t_{o=}$ *Outlet* Dry bulb temperature (°C).
$t_{wi=}$ *Inlet* Wet bulb temperature (°C).
e = efficiency (%).

Also the variation in enthalpy, relative humidity, humidity ratio and dry bulb temperature were noted. The above values were recorded with different nanoparticles dosage.

Figure 5 shows the effect of Al_2O_3 nanoparticles on the efficiency of the two stage ECS. This figure shows that the efficiency of the ECS increases with increase in Al_2O_3 dosage. The Al_2O_3 acts as a catalyst and heat transfer is increased between water and the indirect ECS. The Al_2O_3 dosage of 3% gives highest efficiency. The lowest efficiency was observed with 1% Al_2O_3 dosage.

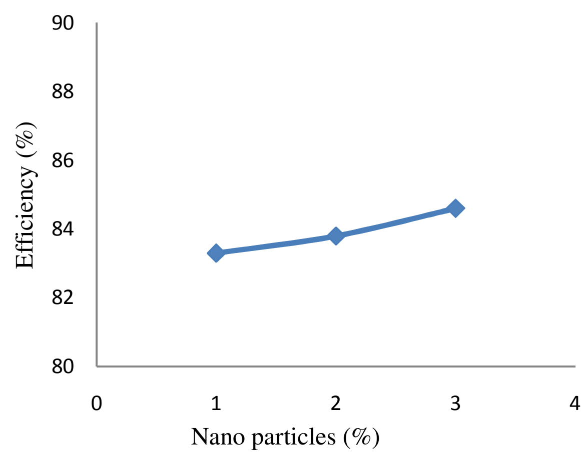

Figure 5 Effect of Al_2O_3 on efficiency

The effect of Al_2O_3 nanoparticle on the enthalpy of the two stage ECS is shown in the Figure 6. This figure depict that the addition of nanoparticle decreases the enthalpy of the system as the air is cooled and its energy content is reduced. The increase in Al_2O_3 dosage reduces the enthalpy of the supply air. Since Al_2O_3 facilitates the heat transfer, the enthalpy of the supply air decreases.

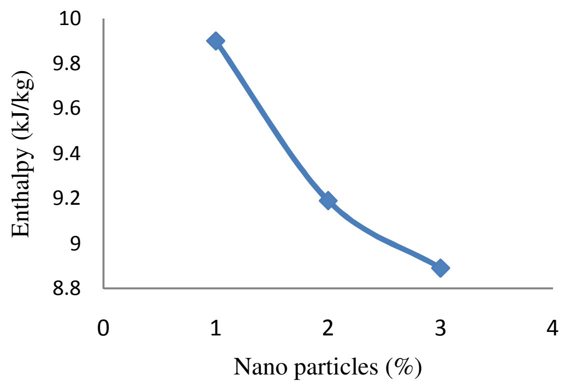

Figure 6 Effect of Al_2O_3 on Enthalpy

Figure 7 shows the effect of Al_2O_3 nanoparticle on the relative humidity of the ECS. It is observed that the increase in nanoparticle dosage increases the relative humidity of the supply air. The higher surface area to volume ratio of the Al_2O_3 increases heat transfer area and increases heat transfer. The Al_2O_3 dosage of 3% results in higher relative humidity as compared to other dosages.

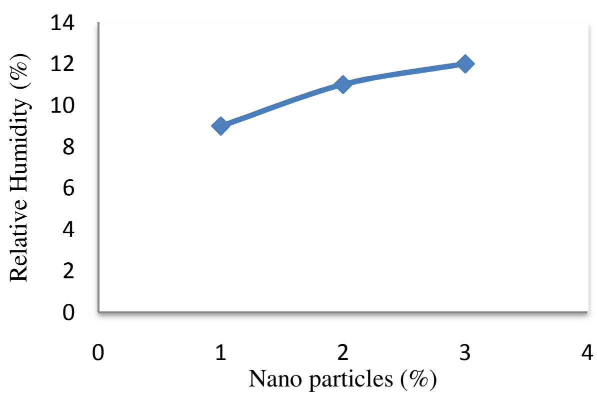

Figure 7 Effect of Al_2O_3 on relative humidity

Figure 8 represents the influence of Al_2O_3 on the humidity ratio of the ECS. The humidity ratio value decreases with increase in Al_2O_3 dosage. The Al_2O_3 dosage of 1% results in higher humidity ratio as compared to other dosages.

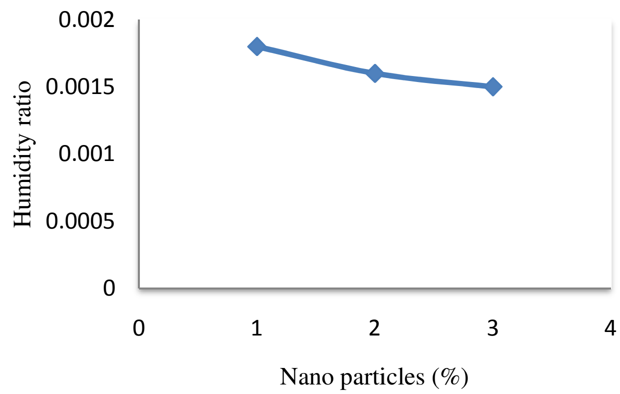

Figure 8 Effect of Al_2O_3 on humidity ratio

The impact of nanoparticle on the dry bulb temperature of the supply air is shown in the Figure 9. This figure depicts that increase in nanoparticle dosage decrease the dry bulb temperature of the air. This is due to higher heat transfer developed by the nanoparticle which increases the heat transfer rate and reduces the dry bulb temperature. The Al_2O_3 dosage of 1% and 3 % results in highest and lowest dry bulb temperature.

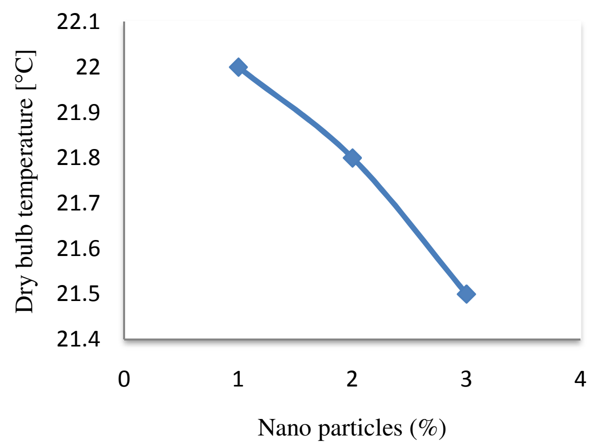

Figure 9 Effect of Al_2O_3 on the dry bulb temperature

CONCLUSION

The ECS is environmental friendly and cheaper cooling system. In this work, two stage ECS was developed and experiments were performed successfully. In the indirect evaporating stage, the heat transfer is less and hence Al_2O_3 was used to improve the heat transfer. From the experimental work, we observed that the increase in Al_2O_3 dosage increase the efficiency of the ECS. Also the dosage of Al_2O_3 decreases the dry bulb temperature significantly. This is due to higher thermal conductivity of the Al_2O_3. We recommend the Al_2O_3 dosage of 2% for the two stage ECS as the cost of Al_2O_3 is slightly high and may increase the operating cost. The use of Al_2O_3 is one of the ways of improving the performance of the two stage ECS. The operating cost of ECS is low as compared to conventional cooling system which generally pollutes the environment

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