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Experimental Analysis of the Performance of Indirect Evaporative Cooling System with Water and Nano-fluid

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Abstract

Indirect evaporative cooling, which utilizes the principles of water evaporation to absorb heat, has gained wide acceptance in recent years for use in air conditioning due to its simplicity of construction and effective use of natural energy. In comparison to conventional vapor compression and adsorption/absorption air conditioning systems, this resulted to a considerably better system. Using nanoparticles for a combination of water and nanoparticles as (NP4% + W96%) increased the system's performance. Air cooling is carried out in a system under different conditions. By utilizing range and velocity difference for the samples tested, different parameters such as wet bulb effectiveness (WBT), cooling capacity, humidity ratio, and LMTD (Logarithmic mean temperature difference) are calculated. One sample includes water, whereas the other contains copper oxide (CuO) as nanoparticles with a composition of (NP4% + W96%). It has been properly researched how the performance of IEC (Indirect Evaporative Cooling) systems is affected by changing intake air velocities, various building features, and variable water flow rates. Indirect evaporative cooling has evolved as a long-term, cost-effective, and energy-efficient replacement for conventional air conditioning systems for space cooling. As a cost-effective technique, evaporative cooling has been promoted for the last ten years.

Keywords

Copper oxide, Evaporative cooling system, Nano-fluid

Nomenclature

ΔT is Range; W_c is Weight of copper oxide; W_w is Weight of water; m_a is mass flow rate of air; Q_c is Cooling capacity; c_{pa} is Specific heat of air (J/kgK); ρ_c is Density of copper oxide; ρ_w is Density of water; m_w is Mass flow rate of water; Q_l is Heat loss, ai is Inlet air; ao is Outlet air; w is Water.

Introduction

There are several applications that can make use of the IEC technology, such as pre-cooling and energy recovery units, two-stage indirect/direct evaporative cooling systems, passive cooling units, and desiccant dehumidifier combination systems. Indirect evaporative cooling has emerged as an alternative to conventional air conditioning systems that is more cost-effective, uses less energy, and can be used over a longer period. It has been suggested that evaporative cooling is a strategy that is both cost-effective and efficient [1]. Bellemo conducted research on indirect evaporative cooling systems using solid desiccant materials. In which he evaluated, using the MATLAB software, how the coefficient of performance (COP) of the thermal and electrical system was affected by air movement, water flow, and the absorption of moisture. The study's findings demonstrated that the COP of thermal chiller systems is greater than 1, while the COP of electrically driven chiller systems is greater than 20 [2]. The mass flow rate, air velocity, and space gaping in a system were analyzed in Erens and Dreyer's model of indirect cooling, which they created. They used low air velocity, high mass flow rate, and 3 mm spacing between them in order to maximize the cooling capacity so that it rose by 36% [3]. Yang et al. examined the study development of an indirect evaporative cooling system that featured updated fan and pump stables. The findings showed that lowering the temperature improved the cooling capacity, induced dew point evaporation with varying material strengths, and increased the surface wettability of the cooling system [4]. An experimental investigation into indirect evaporative cooling was conducted by Kabeel for the purpose of evaluating the performance of innovative evaporative coolers with internal baffles. The air flow rate, the air velocity, as well as the model's internal and external baffles, all have an effect on the cooling load. According to the findings, the amount of cooling load in an evaporative cooling system is increased by 35.4% with baffles and by 54.2% without baffles [5]. Shirmohammadi and Gilani went over the enhancement performance and efficiency evaluation of an indirect evaporative cooler in a variety of climates, as well as the thermal comfort optimization method, the finite element method, thermally affected wettability, and the ratio of air flow velocity. The effectiveness of the evaporation system rose by 73%, while its efficiency increased by 40% as a result of the results [6]. A study of the relevant published research reveals that a novel indirect evaporative cooler that makes use of nanoparticles in a novel way has been developed, constructed, and evaluated in the laboratory. When compared to conventional indirect evaporative coolers, the suggested system has a number of advantages, the most notable of which are increased operational reliability, reduced levels of maintenance, and enhanced command and management of the system's operating processes. Additionally, there are several advantages to the design that has been offered because it makes use of modern methods of operation and eliminates the issues that are associated with previous computer systems.

Materials and Methods

In this setup, an evacuated water tube, water tank, air tube, copper wire, aluminum foil, steel sheet, blower, 12-point temperature indicator have been used. Nanoparticles (CuO) were used as a cooling system. For preparation of nano-fluid, CuO has been mixed by weight percentages of 4%. First of all, the design of experimental setup has been done and then fluid is flowed in system by the help of water pump and then air flows in cooling system by the help blower. Heat is transferred through one chamber to another chamber of air in fluid indirectly contacting each other.

Copper oxide: CuO is a chemical compound made up of copper and oxygen. Experimentally designed indirect evaporative cooling systems used nanoparticles of CuO and absorbed different parameters as comparison of water in the evaporation system.

Volume of Fraction: Volume of fraction is the ratio of volume of CuO and volume of water of the concentration in nanoparticles [7].

$$\text{\% Volume of Fraction} = (W_c/\rho_c) / [(W_w/\rho_w)/ (W_c/\rho_c)] \qquad (1)$$

Mixing Process: This work was done experimentally on an indirect evaporative cooling system which mainly required fluid for cooling the system. CuO nanoparticles are mixed with water at a given concentration of nanoparticles. Process used is chemical method to mix nanoparticles with the help of heating mental and magnetic starrier in 2 hours.

Water collecting basin: After travelling through the duct, hot water falls into a water collecting basin on the exterior of the IEC system. The collected water is sent back into the indirect cooling systems [8].

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Nanoparticles sample: 4% of volume fraction, 1200 g of water with 50 g CuO.

Performance indicators

Range: Range is the difference of inlet and outlet air temperature of indirect evaporative cooling systems [10].

$$\Delta T = T_{ai} - T_{a0} \qquad (2)$$

Cooling Capacity: The potential of cooling to near ambient temperature is evaluated by its cooling capacity. The cooling capacity of a system refers to how much heat it can eliminate from a cooled area during times [3].

$$Q_c \text{Ä}T = m_a \text{ x } c_{pa} \text{ x} \qquad (3)$$

Wet bulb effectiveness: The ratio of the temperature variation between the intake and output air to the temperature variation between the intake air and its wet bulb temperature [11].

$$\text{å}_{wbt} = \frac{\text{Ä}T}{T_{ai} - T_{wbt}} \text{ x } 100 \qquad (4)$$

Heat loss by air:

$$Q_l \text{Ä}T = m_w \text{ x } c_{pw} \text{ x} \qquad (5)$$

Results and Discussion

In this work, experimental data is recorded of microparticle weight percentages of nanoparticles in water i.e., fixed concentration. Data has been recorded for sample having nanoparticles weight percentages of 4% along with CuO is also added with a fixed concentration of 1% by weight. The results shown below with different parameters for nanofluid and water as working fluid in indirect cooling system.

Variation of temperature range with heat loss

Figure 2 shows the variation of range of temperature with respect to heat loss. Initially attached has been conducted for water it showed approved linear behavior in terms of heat loss

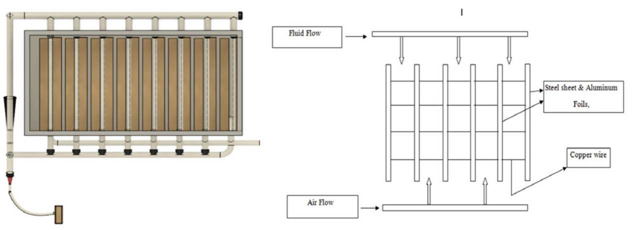

Figure 1: Experimental setup of indirect evaporative cooling.

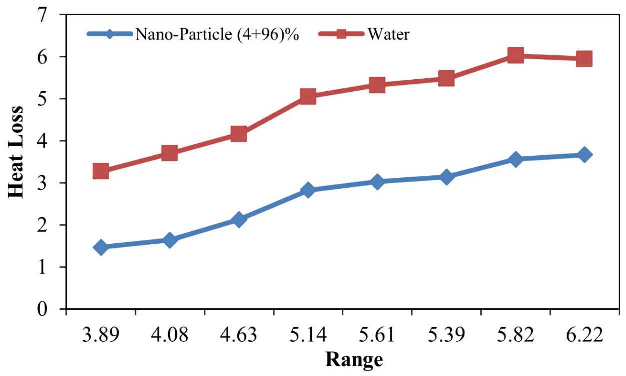

Figure 2: Range vs heat loss.

throughout the temperature range variation. Heat loss for water has been observed by 15% and for nano particle by 42%. When it is concerned as a nanoparticle specimen in most favorable results for specimens having (4 + 96)%. Initial heat loss obtained is highest for (4 + 96)% concentration of nano-fluid, for the specimens tested.

Variation of velocity difference with cooling capacity

Figure 3 shows that cooling capacity variation of specimens used in the experiment with the given velocity difference. For water it showed approved linear behavior in terms of cooling capacity throughout the velocity difference variation. Cooling capacity for water has been observed by 37% and for nanoparticles by 69% for a concentration of nanoparticles of (4 + 96)%. Heat slope increases as the nanoparticle's concentration is mixed in the test specimen. When the velocity difference reaches beyond 10.9 m/sec, a steep increment is found in cooling capacity with respect to water.

Variation of inlet velocity with wet bulb effectiveness

Figure 4 shows that in WBT variation of specimens used in the experiment with the given inlet velocity. WBT for water has been observed by 34% and for nanoparticles by 47% with a concentration of nanoparticles (4 + 96)%. When the inlet velocity reaches beyond 8.6 m/sec, a decrease was found in WBT with inlet velocity variation respect to water.

Variation of inlet velocity with humidity ratio

Figure 5 shows the humidity ratio variation for specimens used in the experiment with the given inlet velocity. The experiment conducted for water showed approved behavior in terms of humidity ratio throughout the inlet velocity variation. The humidity ratio for water has been observed by 70% and for nanoparticles by 32% for a concentration of nanoparticles of (4 + 96)%. When the inlet velocity reaches beyond 12.9 m/sec of dry air, an increment is found in humidity ratio with respect to water.

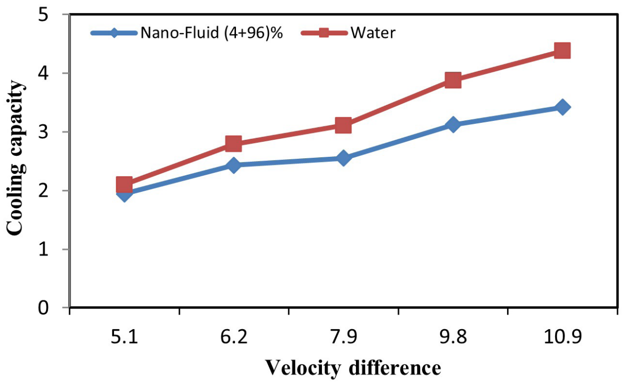

Figure 3: Velocity difference vs cooling capacity.

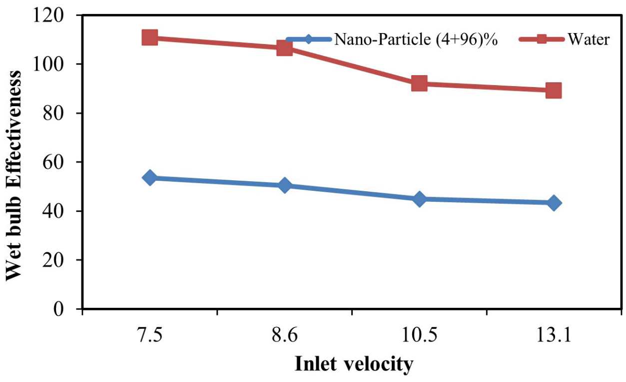

Figure 4: Inlet velocity vs wet bulb effectiveness.

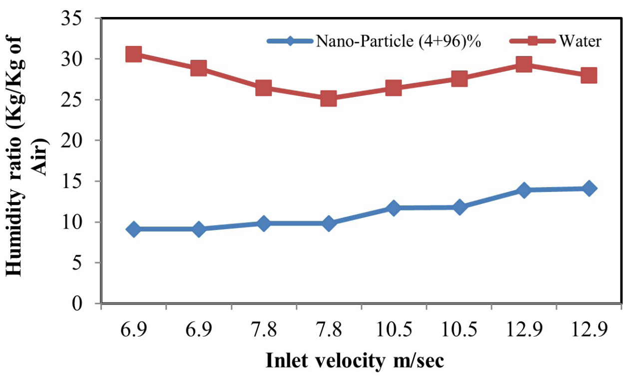

Figure 5: Inlet velocity vs humidity ratio.

Variation of LMTD with capacity ratio

Figure 6 shows the cooling capacity ratio used in the experiment with the given LMTD. Cooling capacity ratio for water has been observed by 20% and for nanoparticles by 48% for a concentration of nanoparticles of (4 + 96)%. When it is concerned for nanoparticles specimen, favorable results are found for specimens having (4 + 96)%. The wet bulb temperature obtained is highest for this concentration of nano-fluid, among the specimens tested. The LMTD of air reaches beyond 6.38 °C of dry air increment found in humidity ratio with respect to water.

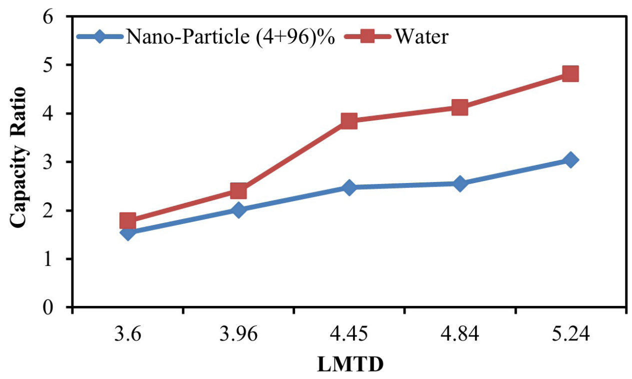

Figure 6: LMTD vs capacity ratio.

Conclusion

In this paper, the relative humidity, range, heat loss of air, cooling capacity, humidity ratio, wet bulb temperature, wet bulb efficiency, and LMTD for water and nano-fluids are examined. 4% of a nanoparticle's mass consists of CuO, while 96% consists of water. The above performance metrics were examined under two distinct conditions, utilizing water in the first and nanoparticles in the second. The greater the temperature range, the greater the heat loss. Temperature range fluctuates from 6.22 ˚C to 3.89 ˚C, resulting in a variance in heat loss between 1.81 kJ/h and 2.28 kJ/h. The correlation between velocity difference and cooling capacity is inverse. Next, the humidity ratio was examined as a performance metric. Temperature range and velocity range have a combined effect on relative humidity. The range of velocity has an inverse relationship with humidity ratio, although the range of temperature is directly proportional to humidity. At a temperature range of 5.14 ˚C and a velocity range of 1.6 m/s, the humidity ratio was found to be the highest. Initially, the effectiveness of nanoparticles degrades at a slow and progressive pace up to 5.14 ˚C; thereafter, it degrades by 19.06% at a rapid rate. The greater the temperature range, the greater the heat loss. Temperature range varies from 3.89 ˚C to 6.22 ˚C, resulting in a variance in heat loss range between 1.46 kJ/h and 3.66 kJ/h. The equation between velocity difference and cooling capacity is inverse. The range of cooling capacity is between 1.54 and 3.04 W. Temperature has an effect on WBT variation performance.

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Conflict of Interest

The authors declare no conflict of interests that are relevant to the content of this article.

Credit Author Statement

Awnish Kumar: Conceptualization, Methodology; Devesh Kumar: Supervision; Ram Ji Tripathi: Writing - original draft preparation; Varun Kumar Singh: Investigation, Formal analysis; Priyankesh Kumar: Writing - review and editing. All the authors read and approved the manuscript.

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