PERFORMANCE ANALYSIS OF DIRECT EVAPORATIVE COOLERS USING VARIOUS COOLING PAD MATERIALS: A COMPARATIVE STUDY

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ABSTRACT

Evaporative cooling is an energy-efficient and environmentally friendly air cooling technology. Evaporative cooling has many benefits over other cooling processes. Due to the non-pollution creating environment. It is considered as one of the suitable ways to cool one's workplace or living place because it uses fresh air and replaces the air from time to time to maintain room temperature. Due to the recirculation of air, smells and allergens are expelled out. It is based on a natural process of air cooling by water, it won't dry out the air, or irritate human skin, eyes, or other external parts of the human body. Moreover, evaporative cooling is an inexpensive cooling option that enhances the lifestyle of people. However, evaporative cooling requires abundant water and is efficient when the relative humidity is low. Experimental and theoretical research work on feasibility studies, performance tests, and optimization as well as heat load calculations are considered and then reviewed in detail. Always an attempt is made to obtain the saturation efficiency by changing the optimum cooling material (cooling pad).

This research aims to examine the performance of the direct evaporative cooler, by changing the cooling pad materials. The efficiency of direct evaporative cooler mostly depends on the cooling pad and hence, the material used in the cooling pad plays a very important role. Here, the performance of the cooler is analyzed by using cooling pads of four different materials like cellulose paper pad, wood fibers, coconut fibers, and an earthen lamp with POP.

KEYWORDS: Evaporative cooling, Humidity, Temperature, Pad, Cooler & Analysis

INTRODUCTION

As global temperatures rise and the demand for sustainable living grows, finding energy-efficient and environmentally friendly cooling solutions becomes increasingly crucial. One promising technology that addresses these concerns is evaporative cooling. Unlike traditional air conditioning systems that rely on refrigerants and compressors, evaporative cooling operates on a simple, natural principle: the absorption of heat during the evaporation of water. This process not only consumes significantly less energy but also ensures a continuous supply of fresh, cool air, making it an attractive option for residential and commercial cooling. Evaporative cooling stands out for its ability to maintain comfortable indoor environments without contributing to air pollution. It works by drawing in warm outdoor air and passing it through water-saturated pads, where the air loses heat as the water evaporates. This cooled air is then circulated into the living or working space, replacing stale air and expelling and allergens. Importantly, this method avoids the dryness associated with conventional air conditioning, preserving indoor humidity levels that are gentle on the skin and respiratory system. In addition to its health and environmental benefits, evaporative cooling is also cost-effective. The operational costs are significantly lower due to the reduced need for electricity and the absence of complex mechanical systems. This affordability, combined with the system's ability to enhance indoor air quality, makes it a valuable asset in improving living standards, particularly in regions with dry climates. However, the efficiency of evaporative cooling systems is highly contingent on environmental conditions and the materials used in their construction. Optimal performance is achieved in areas with low relative humidity, and the choice of cooling pad material plays a pivotal role in the system's effectiveness. Cooling pads are critical components as they directly affect the rate and efficiency of the evaporation process. This research focuses on evaluating the performance of direct evaporative coolers by experimenting with various cooling pad materials, including cellulose paper, wood fibers, coconut fibers, and an earthen lamp combined with Plaster of Paris (POP). To provide a comprehensive assessment, this study also explores the use of different combinations of cooling pads on multiple sides of the cooler. The analysis is cantered on two primary metrics: temperature reduction and humidity control. By systematically recording and comparing the performance of each cooling pad material, this research aims to identify the most effective solutions and outline potential areas for future enhancement. Ultimately, this investigation seeks to advance our understanding of how to optimize evaporative cooling systems, ensuring they remain a viable, sustainable alternative to conventional cooling methods. Through detailed experimentation and performance comparison, this study contributes valuable insights into the development of more efficient and adaptable evaporative cooling technologies.

This research aims to examine the performance of the direct evaporative cooler, by changing the cooling pad materials. The efficiency of direct evaporative cooler mostly depends on the cooling pad and hence, the material used in the cooling pad plays a very important role. Here, the performance of the cooler is analyzed by using cooling pads of four different materials like cellulose paper pad, wood fibers, coconut fibers, and an earthen lamp with POP. Apart from these four sorts of cooling pads, also the performance of the direct cooling system is analyzed by using three different types of cooling pads simultaneously on three sides of the cooling pads, which are made up of cellulose paper, coconut fiber, and wood wool (Aspen). The two most important terms considered in this analysis are temperature and humidity. The readings of these two terms are taken for each type of the cooling pad and also, the further calculations are done based on these readings. The results of the different cooling pad have also been compared.

METHODOLOGY

Step 1:

Test Rig Development and fabrication: It includes body, blade, pump, pipe & joint speed regulator, motor, cooling pads, voltmeter, and ammeter, sensors like an anemometer, humidity sensor, and temperature sensor. All the parts are assembled correctly for proper working.

Step 2:

Material Change: Different cooling pads are used like wood fibers, aspen wood wool, cellulose paper pad, coconut fibers are used to study the effective cooling of cooler.

Step 3:

Observation and Reading: Reading is taken with the help of sensors like voltmeter, ammeter, humidity sensor, temperature sensor.

Step 4:

Optimization: The optimization is done by observation taken by sensors and by using mathematical calculations or by a mathematical model like topics for finding the best alternative of the problem.

Step 5:

Result and Evaluation: Data from the test is recorded for further evaluation.

Step 6:
Conclusion: Conclusion of the study.

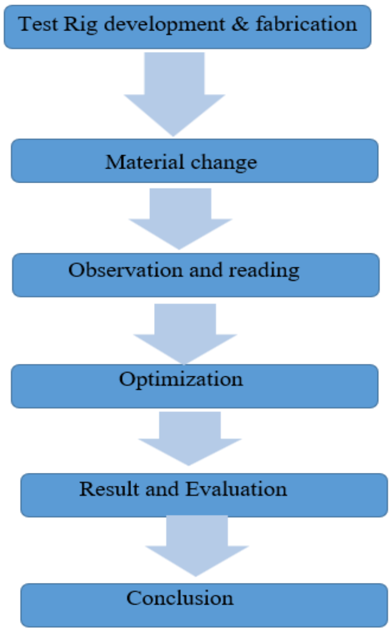

Figure 1. Research path adopted

EXPERIMENTAL DETAILS

This work consists of three sections - one senses the humidity and temperature by using humidity and temperature sensor DHT11 temperature and humidity values into a suitable number in percentage and Celsius scale. And the third part of the system displays humidity and temperature on LCD.

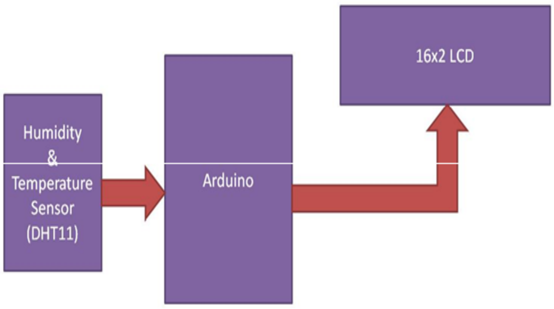

Figure 1 working

The working of this work is based on single-wire serial communication. First Arduino sends a start signal to the DHT module and then DHT gives a response signal containing temperature and humidity data. Arduino collects and extracts in two parts one is humidity and the second is temperature and then sends them to 16x2 LCD. Here in this project, we have used a sensor module namely **DHT11**. This module features a humidity and temperature complex with a calibrated digital signal output means the DHT11 sensor module is a combined module for sensing humidity and temperature which gives a calibrated digital output signal.

- The experimental test rig of low-cost desert cooler available in the market is tested in the laboratory at various conditions.
- The desert cooler with aspen wood pad and with coconut coir pad is tested separately.
- The aspen wood pads are tested as per standards available in the market but coconut coir pads of different thicknesses are made for testing purposes.
- The pad's thickness varies from 2cm to 7cm.
- The report shows the theoretical Analysis of Heat and Mass Transfer in Direct Evaporative Cooler.
- The numerical relation between Cooling efficiency and the geometric parameters of the cooling pad indicates that the dimensions of the cooling pads can affect cooling performance.

Table:-1 Setup

Parameters	Summer
Room up to	10×11 ft2
Blower/Fan	Fan
Fan diameter	20 cm
Speed regulator	constant speeds
Supply	230V/50HZ
Tank capacity	--------
Cooling media	Aspen, coconut coir, etc.
Area of pad	cm^2
Air velocity	In March and April Months

Table 2: Aspen Fiber

Time	Initial temp. (t_1)	Final temp. (t2)	Initial humidity (w_1) %	Final humidity (w_2) %	WBT (Ts)
Morning	30.9	26.2	36	80	20
Afternoon	30.8	25.2	46	77	21.7
Night	31.1	24.2	37	81	21.2

Table 3:Coconut Coir Fiber

Time	Initial temp. (t_1)	Final temp. (t_2)	Initial humidity (w_1) %	Final humidity (w_2) %	WBT (Ts)
Morning	32.1	25.6	42	74	22
Afternoon	35.2	27.4	37	62	23.2
Night	33.3	28.7	35	70	21.5

Table 4: Aspen Fiber and Coconut Coir Fiber

Time	Initial temp. (t1)	Final temp. (t2)	Initial humidity (w1) %	Final humidity (w2) %	WBT (Ts)
Morning	29.9	24.9	51	89	22.1
Afternoon	33.5	26.8	37	80	22.2
Night	32.8	25.9	44	86	23

Table 5: Experimental Analysis of Evaporative Cooler

Sr. No	Type of cooling pad (material)	Thickness (cm)	Inlet DBT (^{0}C)	Initial Humidity (%)	Out let DBT (0C)	Final Humidity (%)
1	Aspen wood wool pad	2	30.93	39.66	25.2	79.33
2	Coconut Coir fiber	2	33.53	38	27.23	68
3	Combination of 2 different pads	2	32.06	44	25.86	85

RESULTS AND DISCUSSION

An experimental analysis of a direct evaporative cooler by varying material an of cooling pads is done and the following results are obtained from the analysis.

Table 6: Cooling efficiency

Sr. No.	Type of cooling pad (material)	Cooling efficiency (%)
1	Aspen wood wool pad	57.13
2	Coconut fiber pad	55.7
3	Combination of two Different Pad	64.38

Table 7: Saturation efficiency

Sr no.	Type of cooling pad (material)	Increase in Humidity (%)
1	Aspen wood wool pad	39.67
2	Coconut fiber pad	34.47
3	Combination of two Different Pad	41

Table 8: Temperature Drop Achievable

Sr. No.	Type of cooling pad (material)	Temperature drop achievable (0C)
1	Aspen wood wool pad	5.73
2	Coconut fiber pad	6.2
3	Combination of two Different Pad	6.1

Table 9: Saturation efficiency

Sr. No.	Type of cooling pad (material)	Temperature drop achievable (0C)
1	Aspen wood wool pad	5.73
2	Coconut fiber pad	6.2
3	Combination of two Different Pad	6.1

CONCLUSION

In present study following are the results and concluding remarks which have been obtained during the above research attempt:

- An experimental analysis of direct evaporative cooler by varying materials of cooling pads is performed.
- The cooling pads of materials such as Aspen wood wool and coconut fibers are used in the model of cooler for doing the analysis.
- The efficiency of the combination of two different cooling pad (Aspen & Coconut) is more than that of separate aspen and coconut cooling pad.
- The humidity of the coconut cooling pad is less than as compared to the combination of two different cooling pad (Aspen & Coconut) and separate aspen cooling pad.
- The water consumption of the coconut cooling pad is less as compared to the combination of two different cooling pad (Aspen & Coconut) and separate aspen cooling pad.

REFERENCE

1. Sontakke K, Ghode S, Dhabliya A, Mendhule M. A Review Paper on Effectiveness of Evaporative Cooling System. 2023;4(8):6–10.
2. Dhakulkar KT, Hinge V, Kolhe S, Chaudhari R, Mahalle5 S. An Experimental Analysis of Direct Evaporative Cooler by Changing its Cooling Pads. Int Res J Eng Technol. 2023;5(5):292–9.
3. Kapish P, Pavan TD, Kiran R, Pritam M. Review on Performance of Direct Evaporative Cooler. 2022;6(03):612–4.
4. Dr. R. S. Bindu, Akshay Naik, Neeraj Kumar, Nirmal Choudhary, Prakhar Gupta. Design of Indirect Evaporative Cooler. Int J Eng Res. 2020;V6(06):253–60.
5. Bahobail MA. Evaporative Cooler: Self Salt Clean. J King Saud Univ. 2013;25(1):1–12.
6. Kongre U V, Shirgire ND, Bagade PA, Neware NT, Professor A, Professor A. Testing and Performance Analysis of Two Stages Evaporative Cooler cum Cold Storage. IJSRD-International J Sci Res Dev [Internet]. 2015;3(02):2321–0613. Available from: www.ijsrd.com
7. Gohane G, Chaudhary VD, K.Wanjari R, N.Manwatkar S, Anmol .P.Ambade. Study , Design and Analysis of Two Stages Evaporative Cooling System. Int J Sci Res Dev. 2015;3(01):325–8.
8. Amer O, Boukhanouf R, Ibrahim HG. A Review of Evaporative Cooling Technologies. Int J Environ Sci Dev. 2015;6(2):111–7.
9. Vairagade SG, Shrivastava P, Wandhile P, Kale S. A Review Paper on Evaporative Cooling Methods. Ijariie-Issn. 2017;(2):801–6.
10. Singh NK, Balaguru S. Experimental Analysis of Foaming Agent Contents in AA7075/SiC Closed Cell Aluminum Composite Foam. In: Sethuraman B, Jain P, Gupta M, editors. Recent Advances in Mechanical Engineering. Singapore: Springer Nature Singapore; 2023. p. 567–75.

11. Rathore RAMK, Awasthy M, Himte R. RESPONSE SURFACE OPTIMIZED ROBOTIC SPRAY-PAINTING METAMODELING FOR FANUC PAINT. 2022;21(9):5163–71.
12. Singh NK. A Comprehensive Report on the Thermal , Static and Dynamic Behavior of Spline Shaft. Int J Sci Res Dev. 2019;7(01):3–8.
13. Singh NK. Study of Mechanical Property of Sintered Iron Preform. Int J Res Appl Sci Eng Technol. 2018;6(2):351–4.
14. Singh NK, Pradhan SK. Experimental and numerical investigations of pipe orbital welding process. Mater Today Proc [Internet]. 2020;27:2964–9. Available from: https://doi.org/10.1016/j.matpr.2020.04.902
15. Rathore RK, Singh NK, Xavier JF. Characterization of AA7075 Alloy Foam Using Calcium and Magnesium Carbonate as Foaming Agent. In 2021. p. 289–97. Available from: https://link.springer.com/10.1007/978-981-16-3937-1_30
16. Singh NK, Balaguru S, Rathore RK, Namdeo AK. Multi-Criteria Decision-Making Technique for Optimal Material Selection of AA7075 / SiC Composite Foam using COPRAS Technique. 2023;71(10):0–5.
17. Singh NK, Sethuraman B. Development and characterization of Aluminium AA7075 hybrid composite foams (AHCFs) using SiC and TiB2 Reinforcement. Int J Met [Internet]. 2023; Available from: https://doi.org/10.21203/rs.3.rs-1718478/v1
18. Singh NK, Balaguru S. Fabrication and Mechanical Characterization of Al-Zn-Cu Alloy /SiC/TiB2 Hybrid Reinforced Metal Matrix Composite using Top Loaded Bottom Pouring Stir Casting Method. Silicon [Internet]. 2023;(0123456789). Available from: https://doi.org/10.1007/s12633-023-02648-4
19. Rathore RK, Singh NK, Sinha AK, Panthi K, Sharma AK. Mechanical properties of lightweight aluminium hybrid composite foams (AHCFs) for structural applications. Adv Mater Process Technol [Internet]. 2022;00(00):1–15. Available from: https://doi.org/10.1080/2374068X.2022.2048498

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