International Engineering Journal For Research & Development
Vol.4
Issue 7

E-ISSN NO:-2349-0721

Impact factor : 6.03

PERFORMANCE OF A DIRECT EVAPORATIVE COOLER OPERATING IN KHANDESH REGION IN MAHARASHTRA

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Abstract-

The present work analyze the performance of a direct evaporative cooler in Khandesh region in Maharashtra. The experimental study is based on weather data from Khandesh region in Maharashtra. In this region in summer temperature and humidity in the range of 37 to 48 C and 40% to 70% respectively and in rainy season relative humidity reaches to more than 90%.The direct evaporative cooler consists of a aspen pads are mostly used.The performance of the evaporative cooler is evaluated using the output temperature, saturation efficiency.The output temperature of the air varies between 27.8°C and 26°C, while the cooling capacity is between 1.84 kW and 2.56 kW.

Keywords— Cooling capacity. Evaporative cooler, Saturation efficiency,

INTRODUCTION

Air conditioning identifies the conditioning of air for maintaining specific conditions of temperature, humidity, and dust level inside an enclosed space[1].Evaporative cooling is widely used in hot and dry regions. Two common types of evaporative cooling systems are the direct and indirect systems. In the direct evaporative cooler (DEC), the air comes into direct contact with water. The direct evaporative cooling system adds moisture to the cool air, while an indirect evaporative cooling system (IEC) provides only sensible cooling to the processed air without any addition of moisture. Therefore, the indirect evaporative system is more attractive than the direct evaporative system. However, the cooling effectiveness is generally low. Many studies have dealt with the performanceof direct evaporative cooling. In India, Kulkarni and Rajput [2] made a theoretical performance analysis of direct evaporative cooling. Different materials were considered in the analysis; rigid cellulose, high density polythene, aspen fiber and corrugated paper material.

The results of the analysis showed that the aspen fiber material had the highest efficiency of 87.5%, while the rigid cellulose material had the lowest efficiency at 77.5%. The outlet temperature and cooling capacity varied between 28.8°C and 26.5°C and 13408 KJ/h and 56686 KJ/h for the two materials, respectively. Kachhwaha and Suhas [3] designed, fabricated medium. The pad thickness and height were achieved for maximum cooling. Chenguang and Agwu [4] evaluated the effect of speed and the dry-bulb temperature of frontal air, and the temperature of the incoming water on cooling performance of a direct evaporative cooling combined with a wetted medium. The results of the analysis showed that direct evaporative cooling efficiency decreased with frontal air velocity and incoming water temperature, and increased with frontal air dry-bulb temperature. A simplified mathematical model was used by Fouda and Melikyan [5] to discuss the heat and mass transfer between the air and water in a direct evaporative cooler. A comparison between the model results and the experimental results was presented. The results indicate that during a steady state condition, the cooling efficiency is decreased by increasing the inlet frontal air velocity, and increased by increasing the pad thickness. This is because the contact surface between water and air is increased. Moien et al.[6] studied a two-stage cooling system that consisted of a nocturnal radiative unit, a cooling coil, and an indirect evaporative cooler. The investigation was conducted in weather conditions for the city of Tehran. The results showed that the first stage of the system increased the effectiveness of the indirect evaporative cooler. Also, the regenerative model provided the best comfort conditions. Dai and Sumathy [7] developed a mathematical model to predict and discuss the interface temperature of falling film in a cross-flow direct evaporative cooler. Analysis results indicated that the system performance could be improved by optimizing the mass flow rates of the feed water and processed air, as well as the different dimensions of the pad. Wu et al.[8] proposed simplified cooling efficiency based on the energy balance analysis of air to analyze the heat and mass transfer between air and water film in the direct evaporative cooler. The analysis showed that the frontal air velocity and thickness of the pad module are two key factors influencing the cooling efficiency of a direct evaporative cooler. A model of the dew point evaporative cooling system was developed by Riangvilaikul and Kumar [9] to simulate the heat and mass transfer processes under various inlet air conditions and the influence of major operating parameters. The model was used to optimize the system parameters and to investigate the system effectiveness when operating under various inlet air conditions. This paper aims to verify the experimental results of a direct evaporative cooling system operating under hot and humid climate conditions.

EXPERIMENTAL SET UP

The direct evaporative cooling unit that is used for this study consists mainly of an exhaust fan at the end of the unit and a re-circulating pump to drip water on the upper side of the pad. As shown in Fig. 1, the air enters the pad in a horizontal configuration. The evaporative cooler is made of M.S.FRAME; it has two cooling pads of height 94cm, width are 48cm, and one cooling pad of height 94cm, width are 88cm, and it has a sump with dimensions, 66 cm long, 20 cm width, and 25 cm depth. A aspen pad is used as the packing material which has a thickness of 2 cm, as shown in Fig.1. the exhaust fan of 14 inch blade diameter is used.

MEASUREMENTS AND INSTRUMENTATION

Performance test is carried out to evaluate the performance of the direct evaporative cooling unit. To measure the air temperature and relative humidity at inlet and outlet points of the evaporative cooling unit, two thermometer with an accuracy of ±0.1°C and two humidity sensors with an accuracy of ± 3% RH are used, respectively.

PERFORMANCE PARAMETERS

A direct evaporative cooler (DEC) is a simple air-conditioning system widely used in dry and hot regions. The air and water are in direct contact; the hot, dry air passes over a wet pad's surfaces; the air will lose its sensible heat, thereby reducing its temperature. The performance parameters of DEC are calculated based on the following relation:

Saturation efficiency is the rate between the real decreasing of the dry bulb temperature and the maximum theoretical decreases (dry bulb temperature would be equal to the wet bulb temperature of the inlet air) as seen by Camargo et al. [10] and [11].

$$\varepsilon_{DEC} = 1 - exp\{h_c\, A_w/m_a\, C_{pa}\ \}\text{---------(1)}$$

Fig.2 shows the process of evaporating cooling on a psychometric chart; this process is seen to be a constant wet bulb temperature process.The cooling efficiency (saturating efficiency) can be calculated as:

$$\eta = \frac{t_1-t_2}{t_1-t_{wb}} \qquad \text{------------ (2)}$$

Cooling capacity is given by :

$$Qc = m_a C_{pa} (t_1 - t_2) \text{ --------(3)}$$

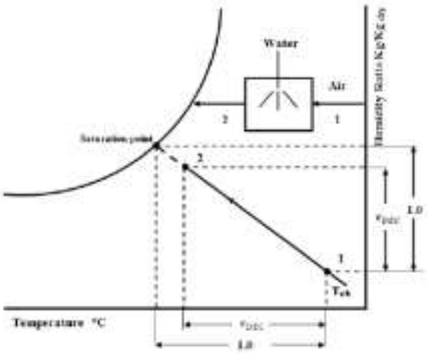

Fig.2 Process of evaporating cooling on a psychometric chart

RESULTS AND DISCUSSION

The values of the experimental test; dry-bulb temperature of the inlet and outlet air, saturation efficiency, and cooling capacity are shown in Table 1and Table 2. During experimentation, the inlet air conditions were as follows: the dry bulb temperature 28.5°C to 31.6°C, the air relative humidity 67% to 51%. Fig. 4,5 represents the variation of DBT with time and fig.6,7 represents the RH with time. It is noted that, when water pump was stopped, relative humidity and DBT of air increases as sensible heat of air converts to latent heat. It is seen that in the morning and afternoon, the maximum cooling capacity is observed after minimizing water flow rate over the pads. there is 5% rise in humidity after stopping the mass flow rate over the cooling pads. The maximum cooling capacity is recorded at the time 3.15 PM, while the minimum cooling capacity is recorded at the time 10.32 AM. The outlet dry-bulb temperature has a direct effect on the saturation efficiency of the evaporative cooler. The variation of saturation efficiency with time is shown in Fig.10,11. the efficiency ranges from 31% to 73%. The maximum saturation efficiency was recorded at the time 3.15 PM, with a dry-bulb temperature and relative humidity of 31.6°C and 51%, respectively.

TABLE I

Time (a.m.)	Atm. Temp. (t_1)	Web Bulb Temp.	Temp.after cooler (t_2)	RH after cooler	Efficiency	Cooling Capacity
	DBT °C	WBT °C	DBTo °C	%	%	KW
9	28.5	23.1	27.8	70	13	0.35938
9.1	28.5	23.1	28.3	72	4	0.10268
9.15	28.5	23.1	28	74	9	0.2567
9.2	28.5	23.1	27.8	75	13	0.35938
9.3	28.5	23.1	26.8	81	31	0.87278
9.35	28.5	23.1	26.8	79	31	0.87278
9.39	28.5	23.1	26.8	81	31	0.87278
9.41	28.5	23.1	27	78	28	0.7701
9.53	28.5	23.1	27	78	28	0.7701
9.57	28.5	23.1	26.7	82	33	0.92412
10.1	29.6	24.7	27.8	75	37	0.92412
10.14	29.6	24.7	27	79	53	1.33484
10.16	29.6	24.7	26.8	81	57	1.43752
10.2(PS)	29.6	24.7	26.7	81	59	1.48886
10.25	29.6	24.7	26.7	82	59	1.48886
10.31	29.6	24.7	26.1	84	71	1.7969
10.32	**29.6**	**24.7**	**26**	**85**	**73**	**1.84824**
10.39	29.6	24.7	26.3	87	67	1.69422
10.46	29.6	24.7	26.6	83	61	1.5402
10.5	29.6	24.7	27	79	53	1.33484

10.54	29.6	24.7	27.6	74	41	1.0268
10.59	29.6	24.7	28.3	71	27	0.66742
11.01	29.6	24.7	28.6	68	20	0.5134
11.04	29.6	24.7	29.2	65	8	0.20536
11.06	29.6	24.7	29.5	64	2	0.05134

TABLE II

Time (p.m.)	Atm. Temp.	Web bulb temp.	Temp.after cooler (t_2)	RH after cooler	Efficiency	cooling capacity
	DBT °C	WBT °C	DBTo °C	%	%	KW
2.45	31.6	23.6	30.8	57	10	0.4107
2.47	31.6	23.6	31	62	8	0.308
2.48	31.6	23.6	30.4	65	15	0.6161
2.5	31.6	23.6	29.5	66	26	1.0781
2.51	31.6	23.6	29.1	69	31	1.2835
2.52	31.6	23.6	28.6	72	38	1.5402
2.53	31.6	23.6	28.4	72	40	1.6429
2.56	31.6	23.6	28	74	45	1.8482
2.58	31.6	23.6	27.8	75	48	1.9509
3.05	31.6	23.6	27.1	78	56	2.3103
3.08(PS)	31.6	23.6	27.1	77	56	2.3103
3.1	31.6	23.6	27	78	58	2.3616
3.13	31.6	23.6	27.1	77	56	2.3103
3.15	31.6	23.6	26.6	80	63	2.567
3.17	31.6	23.6	26.7	82	61	2.5157
3.19	31.6	23.6	26.9	83	59	2.413
3.22	31.6	23.6	27.2	81	55	2.259
3.25	31.6	23.6	27	82	58	2.3616
3.26	31.6	23.6	26.8	83	60	2.4643
3.3	31.6	23.6	27.6	75	50	2.0536
3.33	31.6	23.6	28.2	71	43	1.7456
3.38	31.6	23.6	29.3	64	29	1.1808
3.42	31.6	23.6	29.9	62	21	0.8728
3.45	31.6	23.6	30.4	61	15	0.6161
3.48	31.6	23.6	30.6	60	13	0.5134

CONCLUSIONS

An experimental study was carried out to evaluate the performance of a direct evaporative cooler in the month of August. In this month, mostly air remains humid. From the analysis of the experimental data, the following conclusions can be summarized:

- Experiments indicate that a dry bulb temperature decrease up to 4.6°C is obtainable by using a direct evaporative cooling unit in humid days.
- Saturation efficiency varies from 73% to 53 % and cooling capacity ranges from 1.84 KW to 2.56 KW.
- A direct evaporative cooler may be made to work in humid months like July, August in Khandesh region by drying the air before the evaporative process using the desiccant dehumidification concept.

Nomenclature

Aw	Wetted area, m^2
Cpa	Specific heat of air, J/kg K
hc	Heat transfer coefficient, W/m^2K

ma	Air mass flow rate, kg/sec
Qc	Cooling capacity, kW
t_1	Evaporative inlet dry bulb temperature, °C
t_2	Evaporative outlet dry bulb temperature, °C
t_{wb}	Evaporative inlet wet bulb temperature, °C
PS	Pump Stoped

Greek symbols

DEC ε	Evaporative saturation efficiency (%)

Subscripts

DEC	Direct evaporative cooler
DBT	Dry bulb temperature
IEC	Indirect evaporative cooler
RH	Relative humidity

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