Design of Compact Evaporative Cooler to Improve Cooling Efficiency and To Evaluate Performance of Different Cooling Pad Material

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Abstract— The concept of evaporative cooling to provide comfort to human beings in a building is not new and has been used in different parts of a world by using different ways and materials. Vapour compression refrigeration system and Air-conditioning using gases like CFCs and HFCs reduces the utility of evaporative cooling though they have capacity of ozone layer depletion. So many manufacturers have come with different shaped evaporative coolers and different types of pad materials. In this work new evaporative cooler is designed which is semi-circular in shape instead of rectangular shape (normally used now a days) and the comparison between rectangular shaped cooler and new designed semi-circular shaped cooler is made with Khus as a cooling pad material in terms of temperature drop, humidity rise and cooling efficiency. By using Semi-circular shaped utilisation of water increases, more volume of air comes in contact due to stream line pattern, require less cooling pad material and become compact, thus required less space for installation The newly designed evaporative cooler is consists of two tanks which are perfectly insulated to reduce heat transfer from water and is also incorporated with flow control valve to reduce water consumption and effect of dust mites. The result obtained shows that temperature drop in semi-circular shaped cooler is 5.80C as compared to 3.90C in rectangular shaped and also in rectangular shaped cooler humidity rise is more as compared to semi-circular shaped. The cooling efficiency is improved up to 20.43 % with new design. Also the cost of newly designed Semi-circular shaped cooler is less than rectangular shaped cooler.As well as performance of different cooling pad materials like Celdek, Khus, Coconut coir and Bamboo fiber (new material) is analyzed in terms of temperature drop, humidity rise and cooling efficiency by using normal water and chilled water with newly designed semi-circular shape cooler. Also best cooling pad materials in terms of human comfort and finally best cooling pad materials according to climate of Bhopal is analyzed in this work. The result obtained shows that maximum temperature drop takes place for Celdek followed by Khus, Coconut and least temperature drop is obtained for Bamboo fiber for both normal water and chilled water .While minimum rise in humidity is obtained for Bamboo for both normal and chilled water and maximum for Khus in normal water and Celdek in chilled water. But the humidity rise is less for chilled water than normal water. With respect to human comfort Celdek is a best materials followed by Coconut, Bamboo fiber and Khus. As per weather data of Bhopal, the climate of Bhopal in summer is hot and dry so best material recommended for the evaporative cooling in the climate of Bhopal is Celdek.

Key words: Evaporative cooling, Semi-circular shape, Rectangular shape, Cooling efficiency, Temperature drop, Humidity rise and Celdek

I. INTRODUCTION

Buildings in summer seasons get continuously heated from the sun and dry wind flows during entire day time. Therefore walls and roof of building continuously store heat in its entire volume and transfer it into interior of the house and making the entire house warm and uncomfortable till the evening periods. Evaporative cooling is method of getting natural cooling effect normally observed during a warm period in a day time near the lakes, rivers and seas. Thus to provide comfort and cooling in buildings same technique is realised to be used.

A. *Evaporative cooling*

Evaporative cooling is a thermodynamic process in which hot and humid air passes over a wet surface, thus water evaporates due to hot air and latent heat is gained by air at the expense of sensible heat thereby its temperature is reduced.

According to the principle evaporative cooling can be classified in following ways:

1) Direct evaporative cooling system
2) Indirect evaporative cooling system
3) A combination or multi-stage or mixed evaporative cooling system

B. *Evaporative cooling methods*

As evaporative cooling can be direct, indirect or mixed type. There are three methods by which evaporative cooling can be achieved .All the three systems concerned with the way of supplying water for evaporation and these are as follows

1) Misting or drip method
2) Cool cells or wetted ad method
3) Fogging or misting method

II. LITERATURE REVIEW

Sulaiman Al Faleh [7] design the test setup to estimate the performance of wetted pads in evaporative cooling by using three natural fibers which are date palm fibers (stem), jute and luffa. Here author evaluate performance criteria of selected cooling pad which incorporate cooling efficiency, material performance and cooling efficiency degradation and compare these with widely used commercial wetted pad which is taken as a reference. The experimental setup is designed in such a way that it gives velocity of 6 m/s in the absence of fibers. The air speed of 2.4 m/s is taken for experimental work. The results obtained shows that highest cooling efficiency is for jute among all which is 62.1% followed by 55.1% for luffa fibres cooling pad, 49.9% for commercial cooling pad and 38.9% for date palm fiber cooling pad.

Kulkarni and Rajput [10] investigate the performance of evaporative cooler with different cooling pad shapes and material. The cooling pad shapes used in this study are rectangular, cylindrical and hexagonal with rigid cellulose, corrugated paper, high density polythene packing and aspen as a cooling pad material. In the experimental analysis author estimate the saturation efficiency, DBT of outlet air and cooling capacity.

Result obtained shows that saturation efficiency decreases with increase in air mass flow rate and highest saturation efficiency obtained for hexagonal pad with aspen as a cooling pad material (91%) and DBT at outlet is 26.90c, followed by cylindrical (86%) and the lowest saturation efficiency obtained for rectangular shape with cellulose as a cooling pad material (72.4%) at same DBT.

III. Problem Formulation

Evaporative coolers generally uses axial fan in which air flows along the axis of a fan, thus back side cooling pad completely gets the air for cooling while on other hand, cooling pad on sides not getting air completely due to bluff body pattern. Hence by providing semi-circular shape which is completely streamlined pattern gets more volume of air in contact with pad thus more cooled air will provided in a space. Cooling efficiency of rectangular shape evaporative cooler and semi-circular shape evaporative cooler will be compared. It is commonly observed that in evaporative cooler humidity levels increases continuously until air gets saturated. Hence effect of dust mites increases which provides discomfort to users. So, in order to control humidity level flow control valve is provided .If users feels humidity level are high ,one can reduce water flow rate ,thus humidity level will reduce . Also Performance parameters of different cooling pad materials like Khus, Celdek, Coconut and Bamboo fiber (new material) is to be analysed on the basis of temperature drop, humidity variations and cooling efficiency and best material with respect to human comfort is analysed.

IV. Methodology

A. *Design of new evaporative cooling system*

The new designed of direct evaporative cooler has been proposed in this work. The new evaporative cooler is of semi-circular shape instead of rectangular shape as shown in figure 1and 2. It also consists of two insulated tanks and is incorporated with flow control valve. A circular pipe is provided to drip the water to a cooling pad by getting water from tank through flow control valve. The dimension of cooler is 83 cm × 68.5 cm from front i.e. 83 cm in height and 68.5 cm in width .A semi-circular shape is provided by taking diameter as 68.5 cm. A hole of diameter 40 cm is also provided in front for fan space.

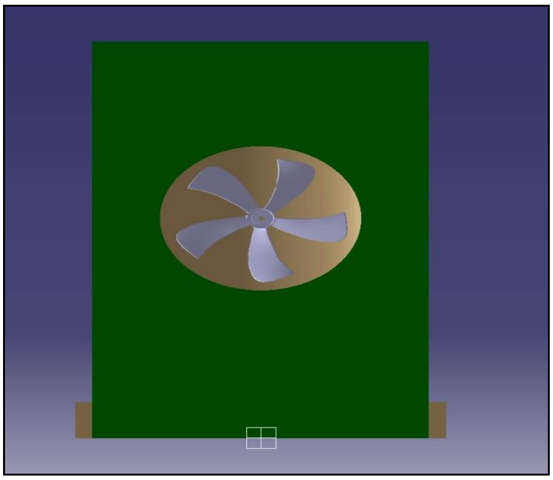

Fig. 1: Front view of new designed evaporative cooler

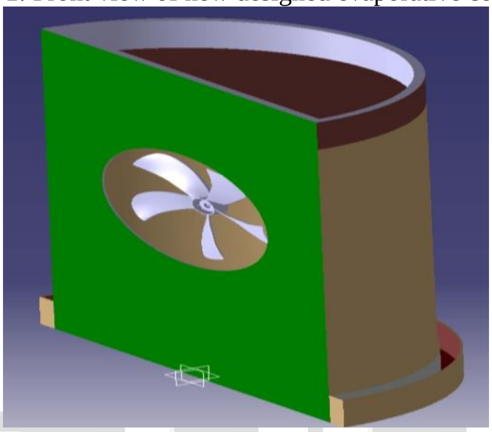

Fig. 2: Isometric view of new designed evaporative cooler

B. *Semi- Circular shape*

In this work semi-circular shape is provided instead of rectangular shape (usually used in evaporative coolers) as shown in figure 3. Evaporative coolers generally uses axial fan in which air flows along the axis of a fan thus back side cooling pad completely gets the air for cooling while on other hand, cooling pad on sides not getting air completely due to bluff body pattern. Hence by providing semi-circular shape which is completely streamlined pattern gets more volume of air in contact with pad thus more cooled air will provided in a space. It is simple in design and construction and required less installation space. It also requires less cooling pad material as well as material of construction, thus economic in manufacturing.

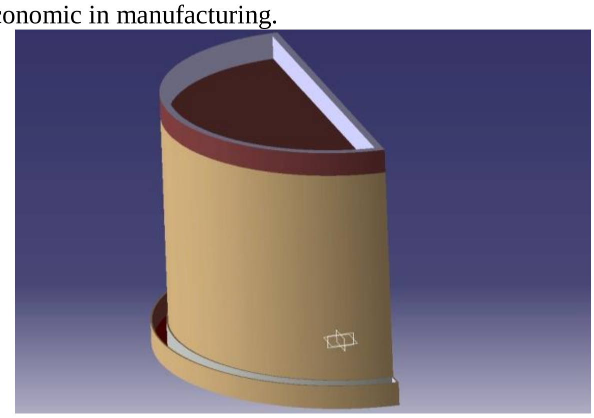

Fig. 3: Back isometric view showing semi-circular shape

C. Circular pipe

A circular pipe is provided on periphery of new designed evaporative cooler to drip water on cooling pads. One end of pipe is connected to flow control valve. A small hole at a fixed distance is provided on entire circumference of a pipe so that water can dip on to the cooling pad. Amount of water comes on to the cooling pad is completely depends upon opening of flow control valve. If opening of valve is full, maximum water comes in the pipe hence maximum water will dip on to the cooling pad or vice-versa.

D. Flow control valve

Flow control valve is provided to control rate of flow of water through tank to a circular pipe as shown in a figure 4. It is commonly observed during the working time of evaporative cooling after some time relative humidity in room increases and it keep on increase .Hence effect Dust mites increases which is harm full to human skin and it also provide discomfort to the users. Thus relative humidity must be decreased or controlled. In order to overcome these difficulties a flow control valve is provided in this work which control water flow rate hence supply less water thus relative humidity decreases as well as effect of dust mites also control up to certain limit..The another advantages of using flow control valve is that water consumption also decreases up to some extent ,which is very useful in those areas where there is a scarcity of water.

Fig. 4: Flow control valve

E. Insulated Tank

Water tank used in this new designed evaporative cooler is insulated from insulating material thermocol to reduce rate of heat transfer from water as shown in a figure 5 and 6. While using normal water, the temperature of water is almost same as that of ambient, thus tank can also be used without insulation .As water consumption in this new designed evaporative cooling system can be controlled due to provision of flow control valve, so we can used chilled water for getting more cooling effect .While using chilled water, as tank is insulated so heat transfer from ambient to water is not possible, thus water remains chilled for maximum time. Hence more cooling effect will obtained with less consumption of water.

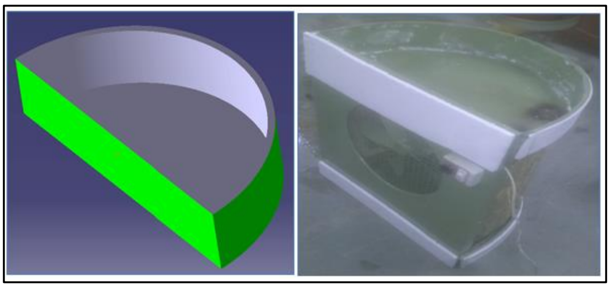

Fig. 5: Insulated tank

F. Experimental procedure

An experimental set up is made as discussed above and temperature and humidity are measured continuously with the help of hygrometer for a different pad material with normal water and cold water. Following are the steps performed during experiment

1) Experiment is performed on rectangular shaped evaporative cooler and newly designed evaporative cooler with khus as a pad material.
2) As new designed evaporative cooler having flow control valve so while performing experiment with new designed evaporative cooler initially flow control valve is fully open to keep water flow rate maximum so that cooling pad is completely wets and then after some times reducing the flow rate to a lower limit so that water consumption can be reduced in order to control humidity .Flow rate is kept 24 litres /hr .
3) Hygrometer as shown in figure 6 is placed in front of both rectangular shape and semi-circular shape evaporative cooler and also a hygrometer is kept outside room .Hygrometer continuously shows temperature and humidity. Note down this temperature and humidity at an interval of 15 minutes.
4) Now comparison is to made between rectangular shape evaporative cooler and semi-circular evaporative cooler on the basis of temperature drop, humidity rise and cooling efficiency.
5) Now perform the experiment only on semi-circular shaped evaporative cooler. Experiment is conducted with normal water and cooling water (170C) and repeats the above procedure
6) Similarly experiment is performed for Celdek, Coconut coir and Bamboo fibre by using normal water and cold water simultaneously only on semi-circular shaped evaporative cooler and finally a comparison is to be made between these pad materials and suitability of best pad material is to be evaluated.

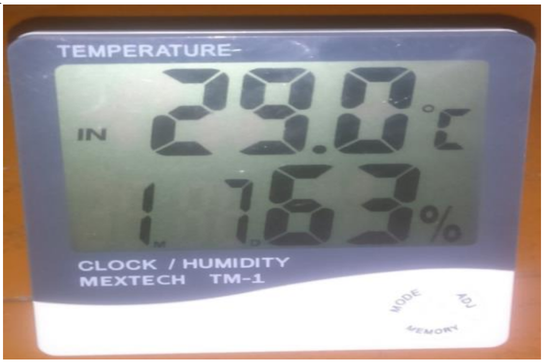

Fig. 6: Hygrometer

G. Experimental result with Rectangular shape by khus as a cooling pad material

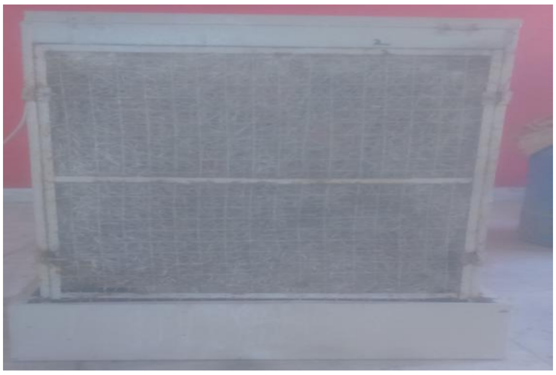

Fig. 7:Rectangular shape cooler with khus

Fig. 8: Semi-circular shape cooler with khus

Rectangular shaped cooler		Semi-circular shaped cooler	
Temperature	Humidity	Temperature	Humidity
23.8	34%	23.8	34%
23.2	46%	22.1	39%
22.9	51%	21.3	45%
22.3	58%	20.4	55%
21.6	64%	19.8	62%
21.1	66%	19.5	67%
20.6	68%	19.1	71%
20.1	76%	18.6	74%
19.9	82%	18.0	78%

Table 1:Experimental result obtained for rectangular shaped cooler and Semi-circular shaped cooler by khus as a cooling pad material with normal water

H. Experimental result performed with different cooling pad material in a Semi-circular shape evaporative cooler Celdek as a cooling pad material

Fig. 9: Celdek as a cooling pad in evaporative cooler

Result obtained from experiment performed with Celdek is as given below in table 2.

With Normal Water		With Chilled Water	
Temperature	Humidity	Temperature	Humidity
34.1	48%	34.1	48%
31.5	50%	31.3	51%
31.0	56%	30.6	59%
30.4	58%	30.3	60%
29.3	63%	29.6	62%
29.0	63%	29.1	63%
28.8	66%	28.6	68%
28.7	68%	27.2	70%
28.6	68%	26.5	72%

Table 2:Experimental result for Celdek as a cooling pad material

Fig. 10: Coconut pad material in evaporative cooler

Fig. 11: Bamboo pad material in evaporative coolers

I. Formula used

Cooling efficiency is determined by using following relation

$$\eta_{cooling} = \frac{T_{dbo} - T_{dbi}}{T_{dbo} - T_{wbo}}$$

Where $T_{dbo} = Dry\ bulb\ temerature\ in$ ℃ of outside air.

$T_{dbi} = Dry\ bulb\ temerature\ in$ ℃ inside drop.

$T_{wbo} = Wet\ bulb\ temerature\ in$ ℃ $outside\ air.$

J. Sample Calculation (For KHUS)

Khus as cooling pad material

(i) Rectangular shaped cooler

$$T_{dbo} = 23.8°C$$

$$T_{dbi} = 19.9°C$$

From psychometric chart

$$T_{wbo} = 14.5°C$$

$$\eta_{cooling} = \frac{T_{dbo} - T_{dbi}}{T_{dbo} - T_{wbo}}$$

$$= \frac{23.8 - 19.9}{23.8 - 14.5}$$

$$= 0.4193$$

$$= 41.93\%$$

(ii) Semi-circular shaped cooler

$$T_{dbo} = 23.8°C$$

$$T_{dbi} = 18°C$$

From psychometric chart

$$T_{wbo} = 14.5°C$$

$$\eta_{cooling} = \frac{T_{dbo} - T_{dbi}}{T_{dbo} - T_{wbo}}$$

$$= \frac{23.8 - 18}{23.8 - 14.5}$$

$$= 0.6236$$

$$= 62.36\%$$

V. RESULT AND DISCUSSION

A. Comparison of rectangular shaped evaporative cooler and semi-circular shaped evaporative cooler using khus as a cooling pad material

1) Maximum Cooling efficiency.

Maximum cooling efficiency for rectangular shaped cooler is 41.93% while maximum cooling efficiency in semi-circular shaped cooler and is 62.36 % which is better.

2) Variation of temperature with time for rectangular shaped and semi-circular shaped evaporative cooler with normal water.

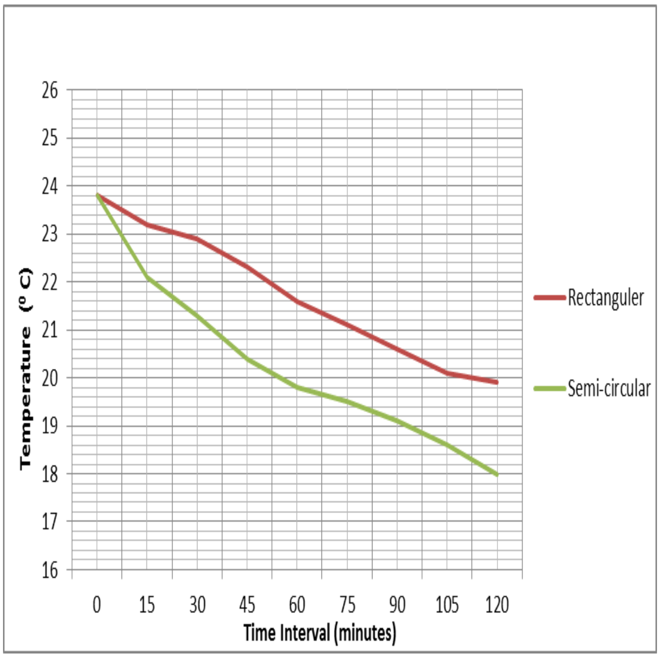

Fig. 12: Variation of temperature with time

From the above graph it can be stated that temperature drop in rectangular shaped evaporative cooler is 3.90 C while temperature drop of 5.80 C is obtained in semi-circular shaped evaporative cooler .

3) Variation of Humidity with time for rectangular shaped and semi-circular shaped evaporative cooler with normal water.

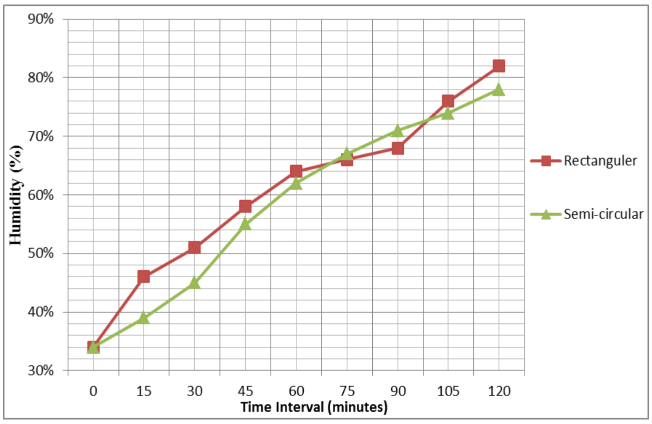

Fig. 13: Variation of Humidity with time

From the above graph it can be stated that humidity rise is less in a semi-circular shape evaporative cooler.

B. Comparison of different cooling pad material in new designed semi-circular shaped evaporative cooler using normal water and chilled water

Here, comparison is made with different cooling pad materials e.g khus, Celdek, Coconut and bamboo fiber on the basis of cooling efficiency, temperature drop and humidity rise.

1) Maximum Cooling efficiency of different pad materials using normal and chilled water

Cooling pad Material	Maximum cooling efficiency (normal water)	Maximum cooling efficiency (chilled water)
Celdek	57.29 %	79.16%
Khus	62%	68.68%
Coconut	36.76%	44.92%
Bamboo fiber	33.87%	40.32%

Table 1: Maximum cooling efficiency for different pad material in semi-circular shape cooler

2) Variation of temperature with time for different cooling pad materials using normal water and chilled water.

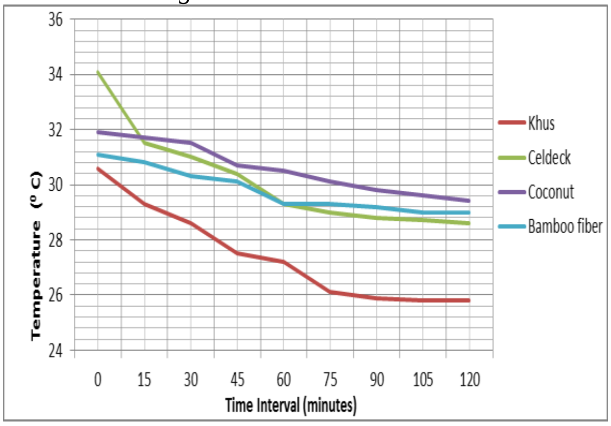

Fig. 14: Temperature-time variations for different pad materials using normal water

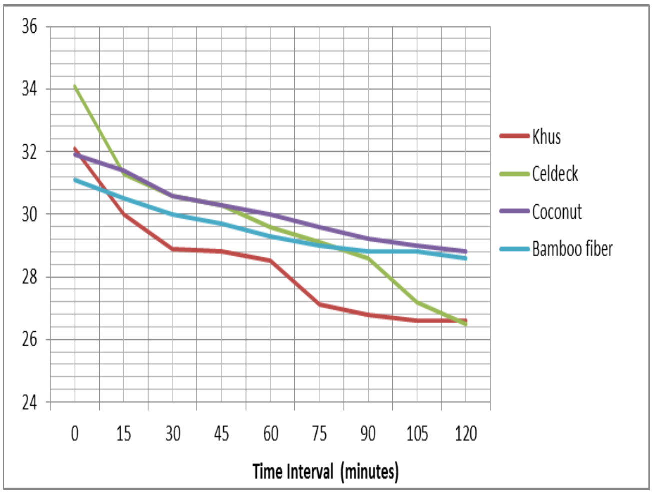

Fig. 15: Temperature-time variations for different pad materials using chilled water

From the above graph it is found that maximum drop in temperature is obtained by using Celdek as a cooling pad material (5.50 C) followed by khus (4.80 C),coconut (2.50 C) and least temperature drop is obtained for Bamboo fiber (2.10 C) for normal water and for chilled water maximum drop in temperature is obtained for Celdek (7.6 0C), followed by Khus (5.50C), coconut (3.10 C) and least drop is obtained for Bamboo (2.50 C).

3) Variation of Humidity with time for different cooling pad materials using normal water and chilled water.

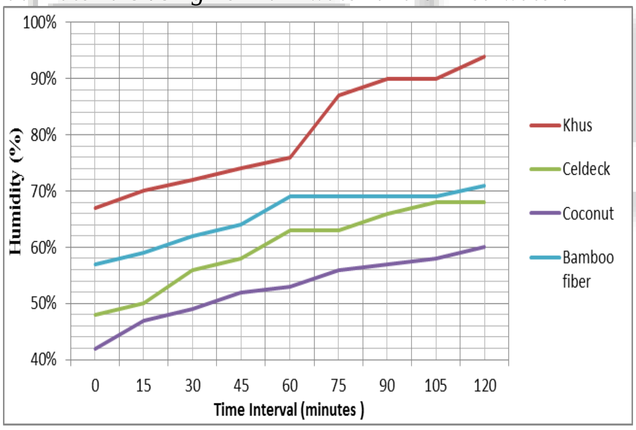

Fig. 16: Humidity-time variations for different pad materials using normal water

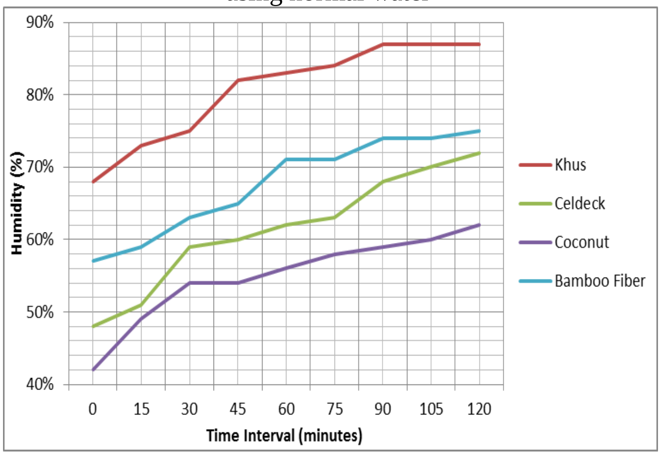

Fig. 17: Humidity-time variations for different pad materials using chilled water

From the graph it is found that minimum humidity rise is obtained for Bamboo fiber followed by coconut, Celdek and highest rise in humidity is obtained for khus with normal water and with chilled water minimum humidity rise for Bamboo followed by coconut, khus and maximum rise in humidity is obtained for Celdek.

C. Manufacturing cost of rectangular shaped and Semi-circular shaped cooler

S.NO	NAME OF COMPONENT	RECTANGUALR SHAPED COOLER COST(Rs)	SEMI-CIRCULAR SHAPED COOLER COST(Rs)
1.	Motor	850	850
2.	Fan	60	60
3.	Pump	100	100
4.	Fabrication and material cost of cooler	2400	2000
5.	Flow control valve		130
	Total cost	3410	3140

Table 3: Manufacturing cost of rectangular shaped and Semi-circular shaped cooer

It is clear from above cost estimation that manufacturing cost of newly designed compact semi-circular shaped evaporative cooler is less than rectangular shaped cooler by an amount Rs 270, which is very useful for person who is willing to buy a cooler. There is also improvement in cooling efficiency .Thus newly designed semi-circular evaporative cooler gives more cooling effect at minimum purchasing cost to a customer.

1) Cost of cooling pad materials used in rectangular shaped and semi-circular shaped cooler

Cost of cooling pad material and overall cost in newly designed semi-circular shaped cooler is less than rectangular shaped cooler.

Cooling pad material	Cost of pad material for rectangular shape (Rs)	Overall Cost of rectangular shape cooler (Rs)	Cost of pad material for semi-circular shape (Rs)	Overall Cost of semi-circular shape cooler (Rs)
Khus	300	3710	200	3340
Celdek	1200	4610	900	4040
Coconut	80	3490	50	3190
Bamboo fiber	90	3500	50	3190

Table 4: cooling pad materials Cost and Overall cost for rectangular shaped and semi-circular shaped cooler

VI. CONCLUSION

A new evaporative cooling system is designed and compared with rectangular shaped cooler with respect to temperature drop, humidity rise and cooling efficiency. Performance of four pad materials i.e Khus, Celdek, Coconut and Bamboo fiber is evaluated by using normal water and chilled water. The performance criterion includes temperature drop, humidity variations and cooling efficiency. The results obtained are as follows

1) Cooling efficiency is improved by using newly semi circular shaped design upto 20.43% with Khus as a cooling pad material.
2) Manufacturing cost of new design evaporative cooler is less by an amount of Rs 270. Also, cost of cooling pad materials is less by using new design. Hence overall cost of new designed cooler is less.
3) Now, performance of four pad materials i.e Khus, Celdek, Coconut and Bamboo fiber is compared using normal water and chilled water in semi-circular shaped cooler.
4) By using normal water maximum temperature drop is achieved in Celdek followed by Khus, coconut, and least in bamboo fiber, While maximum humidity rise is obtained for Khus followed by Celdek, coconut and least rise for Bamboo fiber .Highest cooling efficiency is obtained for Khus followed by Celdek, coconut and least in Bamboo fiber. In order to maintain perfect balance between these parameters Celdek is a best material
5) By using chilled water maximum temperature drop is achieved in Celdek followed by khus, coconut and least in bamboo fiber. While maximum rise in humidity is obtained for Celdek followed by khus, coconut and least rise is obtained for bamboo fiber. Highest cooling efficiency is obtained for Celdek followed by khus, cocanut fibre & least for bamboo fiber.In order to maintain perfect balance between these parameters Celdek is a best material.
6) Human feels comfortable in the humidity ranging from 30 to 60 percent.Thereby, Celdek is preferred followed by Coconut,Bamboo fiber and Khus material.
7) Hence, in case of Bhopal where there is hot and dry climate,evaporative cooler with Celdek as cooling pad materials is recommended.

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