

Comparison on cooling efficiency of cooling pad materials for evaporative cooling system.

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ABSTRACT

This research aims to examine on cooling efficiency of different type natural based material as a cooling pad for evaporative cooling system. Efficiency of direct evaporative cooling system mostly depends on the cooling pad and hence, the material used in the cooling pad plays a very vital role. Here, two types of natural based materials (activated carbon foam and luffa pad) were selected to be used as cooling pad. Those materials pad are then fabricated to fit into the evaporative cooling setup. Temperature, and humidity are the most important data in this experimental analysis. The readings of these terms are taken for each type of cooling pad using data logger and also, the further calculations are done based on these readings. The material of the cooling pad and the air flow rate are varied to observe the effect on their cooling efficiency. From the analysis, the ACF cooling pad shows better cooling efficiency compared to that of luffa pad.

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INTRODUCTION

Direct evaporative cooling process is known as the most efficient and economical techniques used in air conditioning applications such as cooling towers, humidifiers and evaporative coolers[1]. It has many environmental benefits which include reduction of CO₂ and chlorofluorocarbon(CFC)-Hydrochloroflouorocarbon(HCFC) emissions[2], reduction of power consumption[3], and modest technology for cooling air application[3]. The basic principle of this process is, the water and air are in contact with cross-flow arrangement where vertical channels for water flow and horizontal channels for air[1,4] (Fig. 1). 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 temperature is reduced as latent heat is gained by air at the expense of sensible heat thereby its temperature is reduced[5].

Cooling pads efficiency have a very high impact on the performance of a direct evaporative cooler. Cooling efficiency and humidity of a cooling pad are the two important factors to be considered while analysing the performance of a direct evaporative cooler[6]. These two factors mostly depend upon the type of cooling pad used. Meanwhile, the efficiency of evaporative pad systems is affected by many factors including surface area and thickness of pad, the type of material used in the pad, the size of perforations, flow rate and relative humidity of air passing through the pad, and volume of water used[1,7].

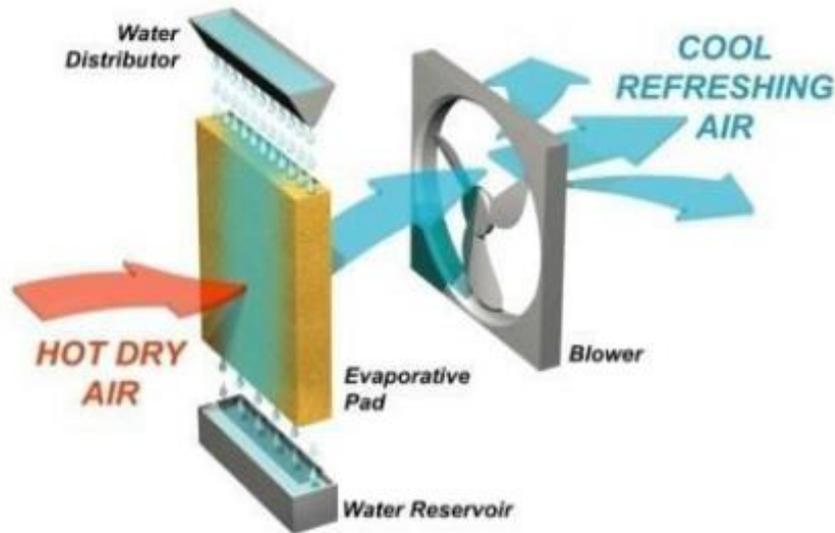


Fig. 1: Basic principle of evaporating cooling [6]

Evaporative pads were made from different materials such as Aspen [8], metal [8–10], cement [11], ceramic materials [9], coconut coirs [8,10,12–14], wood wool fibers [10,12,15], jute fiber [8,16], date palm fibers [17], khus fibers [4,9,10,15], cellulose paper pad [12,18], plastic [19], and glass. Cellulose pads are mainly superior these days for their light weight, low cost, and high saturation efficiency, typically, greater than 80 % [7]. They have an excellent cooling efficiency, but they also increase the humidity. So, this increased humidity is the major problem today in case of these direct evaporative coolers. Besides, manufacturing of commercial pads made of these materials are complicated and costly. Aspen pad also is widely used, but it very sensitive to algae infestation that could lead to decay and compaction, which makes it difficult to maintain its efficiency without frequent and costly pad replacement [20]. Therefore, evaluating the locally available cheap materials for use as pads, particularly in rural agricultural areas is essential.

In this paper, an attempt was made to evaluate the performance of activated carbon foam pad experimentally and compared to the other type of natural based cooling pad material which is luffa pad. A special test setup was designed to appraise the activated carbon foam pad's performances such as the cooling efficiency and the relative humidity difference. No similar work has been done on activated carbon foam pad.

METHODOLOGY

The cooling pads of all the above two types of materials (activated carbon foam and luffa pad) (Fig.2) were prepared and tested experimentally one by one in a prepared model of a direct evaporative cooler. The size of pad material used is 200 mm x 200 mm and such three sides contribute area of 2.25 m. Thickness of pad material is made of 60 mm. The arrangement of cooling pad is designed; to be facing forward to the air source. In this way, three times experimentations were performed by varying the cooling pad material, air flow speed and position of the cooling pad. The experiments were carried out in the same conditions.

Experimental test set up was developed and fabricated using acrylic sheet as shown in Fig. 3 to determine the saturation effectiveness of cooling pads. The schematic diagram of the evaporative cooling box is shown in Fig. 4. The set up includes a square tunnel, a fan, rigid pad media (activated carbon foam

and luffa pad), a water tube, air straightener, hair dryer and a water collecting tank. The evaporative cooling box is fabricated with the dimension of 20 cm× 20 cm cross section and 85 cm long was used to accommodate pads of desired thickness. A fan is placed in front of the test section to supply the air flow. An ambient air was forced to circulate through the tunnel by fan. Flowing water was streamed from above the test section by distributing through small holes which are connected onto the top surface of each cooling pad. The falling water was collected in the water collecting tank. A provision was made for easy changing of cooling pad of different materials and arrangement. A number of calibrated thermocouples were fitted to measure dry bulb and wet bulb temperatures at the inlet and outlet of the test section. The thermocouples were connected to data logger for recording various temperatures. Digital anemometer was used for measuring air speed.

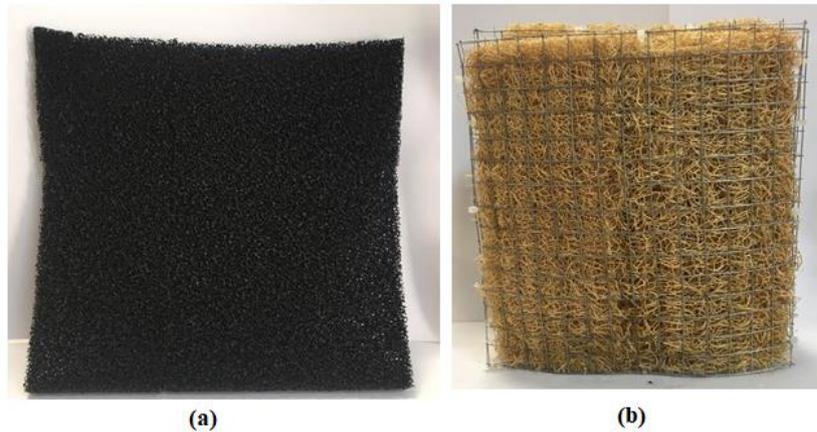


Fig. 2: Cooling pad materials (a) Activated carbon foam pad, and (b) Luffa pad.

The evaporative cooling box is fabricated using acrylic sheet. The schematic diagram of the evaporative cooling box is showed in Fig. 3. The side and angle view of the evaporative cooling box is showed in Fig. 4.

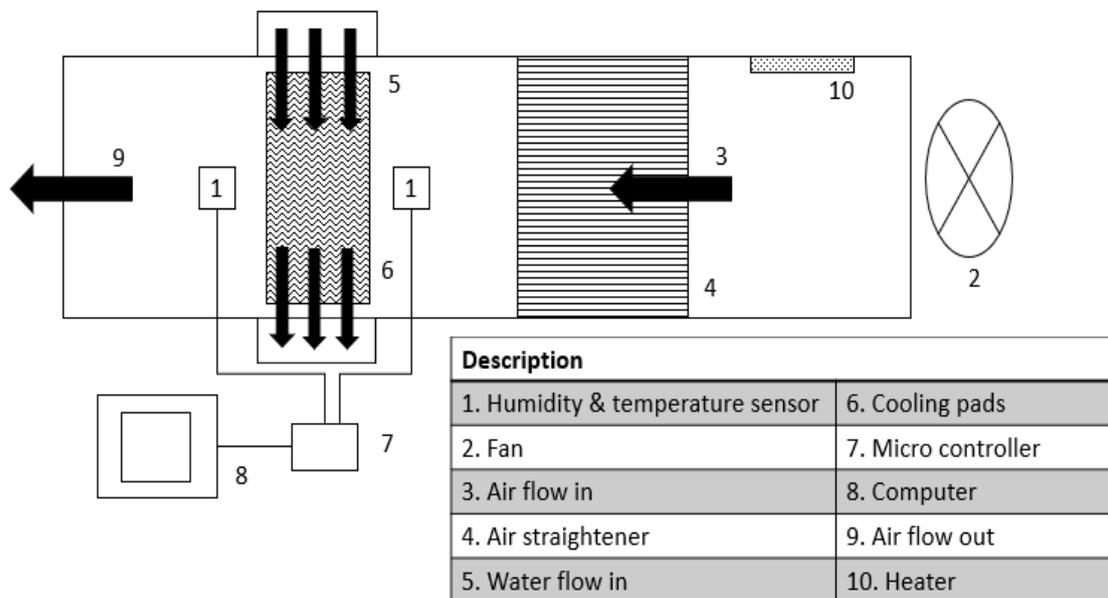


Fig. 3: Schematic diagram of evaporative cooling box.

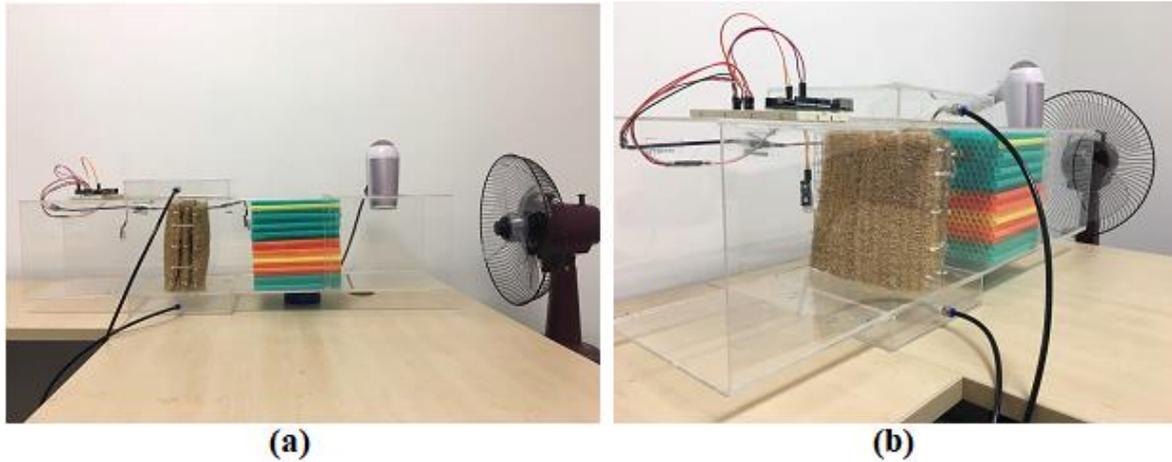


Fig. 4: (a) Side view and (b) angle view of evaporative cooling box.

Two different materials namely activated carbon foam and luffa pad were tested one by one. The thickness of each type of pad is set to be 2 cm for each sheet of pad. Initially set up was run for about 10 min to ensure near steady state condition. Then dry bulb and wet bulb temperatures of air at inlet and dry bulb temperature at outlet were measured using thermocouples and recorded using data logger. The saturation effectiveness of cooling pads was calculated using the following relation as mentioned in equation (1) below:

$$\eta_s = \frac{T_1 - T_2}{T_1 - T_1'} \times 100 \quad (1)$$

Where T1 is the dry bulb(DB) of air at inlet, T1' is the wet bulb temperature of air at outlet, and T2 is dry bulb temperature at outlet. The wet bulb temperature is the temperature measured by using a thermometer whose glass bulb is covered by a wet cloth. The wet bulb temperature indicates the moisture content of air. Relative humidity was also measured before and after cooling box using humidity sensor which connected to data logger for recording various humidity reading. Then, the readings of temperature and humidity were taken. The comparison between the readings of various types of cooling pad materials, air flow speed and position of the cooling pad is recorded.

Besides, the wettability test of the pad material also be done before starting the cooling efficiency test. The test was done by weighing the dry pad material, followed by immersing the pad material into water for several times to reach saturated level of water absorption in the pad material. Then, the pad material was hanged for period of time until all the surface water which attached to the pad material removed. Lastly, the final weight and the difference of weight (between before and after immersion) is recorded.

Another important property of pad material to be as cooling pad is its evaporation ability. Evaporation ability is evaluated by evaporation rate of moisture from the wet surface. This was carried out by measuring the dry weight of pad material, followed by placing the wetted pad under sun exposure for several minutes. Then, the weight is recorded and this repeated for several times. The rate of evaporation of each pad material is calculated to determine its evaporation ability.

RESULTS AND DISCUSSIONS

Experimentation was conducted under varying speed of fan, pad materials. Then, the temperature and humidity change during the cooling system running were measured. The cooling efficiency was calculated using equation (1). All the results were plotted in graph to see the relationship between cooling pad material, pad arrangement and air speed with the cooling efficiency of the system. In this study, the change in temperature and humidity due to evaporative cooling process is showed in the graph of Fig. 5(a) and 5(b).

It was experimentally proven that ACF cooling pad shown the highest difference between inlet and outlet temperature due to the evaporative cooling process, compared to those obtained by using luffa pad. It is also in good agreement with the highest humidity changes due to the evaporative cooling process of ACF cooling pad, compared to those obtained by luffa pad. It could be attributed to the foam structure and the water absorbability of the ACF was better than the luffa pad as shown in Fig. 6.

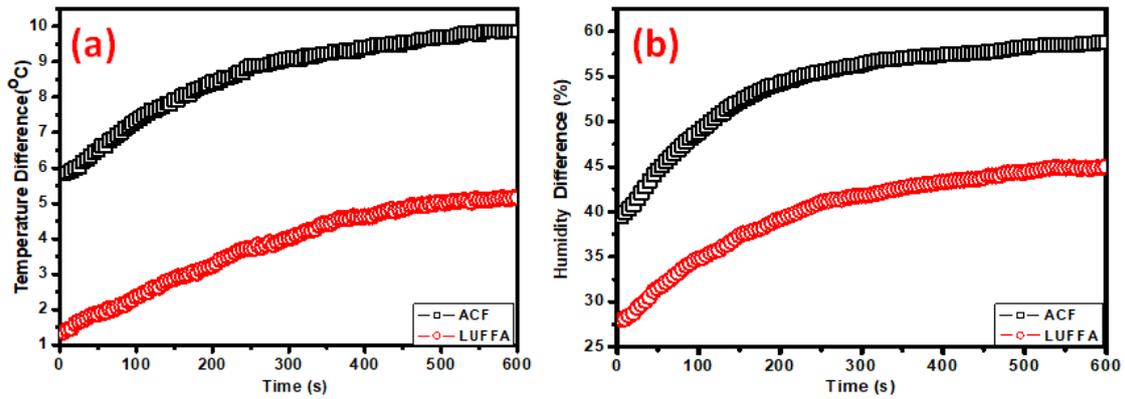


Fig. 5: Change of (a) temperature and (b) humidity due to evaporative cooling by different type of pad material.

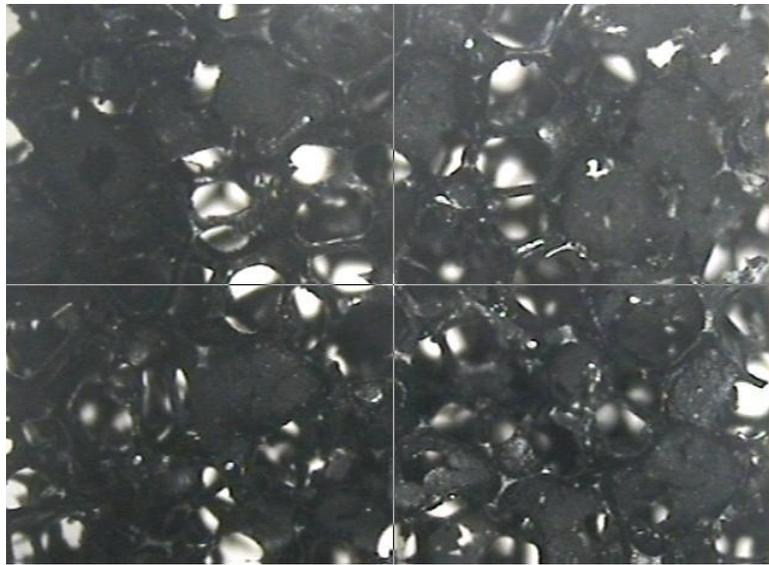


Fig. 6: Optical image observation of ACF

Fig. 7 shows cooling efficiency, η_s of ACF and luffa cooling pad under similar condition of air speed. It was observed that η_s of ACF cooling pad was higher than that of luffa pad. Noted that the η_s of the pad depends upon the wettability of the pad because an excellent wettability pad material causes greater evaporation of water into air, thereby decreasing the air temperature [21]. The performance of ACF cooling pad is satisfactory as it has good water wettability and evaporation ability compared to that of luffa cooling pad. The wettability test obtained for ACF cooling pad was better than luffa cooling pad when the water absorbed by the ACF was higher (112.45 g of water) than luffa cooling pad (55.1 g of water). The evaporation ability of ACF cooling pad (44 %) was higher than that of luffa (22 %). The moisture evaporation rate from the wet surface directly affects evaporative cooling efficiency [21].

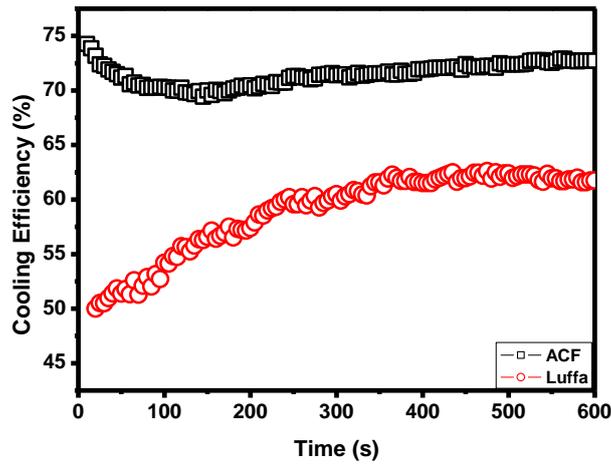


Fig. 7: Cooling efficiency of ACF and luffa cooling pad under similar of condition.

Fig. 8 and 9 show cooling efficiency, η_s of the cooling pad with respect to the various of air speed applied. It was observed that the highest η_s obtained by ACF cooling pad at the lowest speed of air flow. It can be seen that the η_s decreases with increasing the inlet air flow speed (Low-medium-high). It can be deduced that with an increase in air flow speed, the time for heat and moisture transfer between water and air is shortened [1]. ACF cooling pad is efficient at low speed of air flow due to good wettability that contributes to the higher water content on the ACF cooling pad. In addition, greater evaporation ability contributes to lesser evaporation time need for the wetted cooling pad become dry. Therefore, at low speed the ACF cooling pad showing an excellent cooling efficiency as the pad needed only less time to evaporate the water.

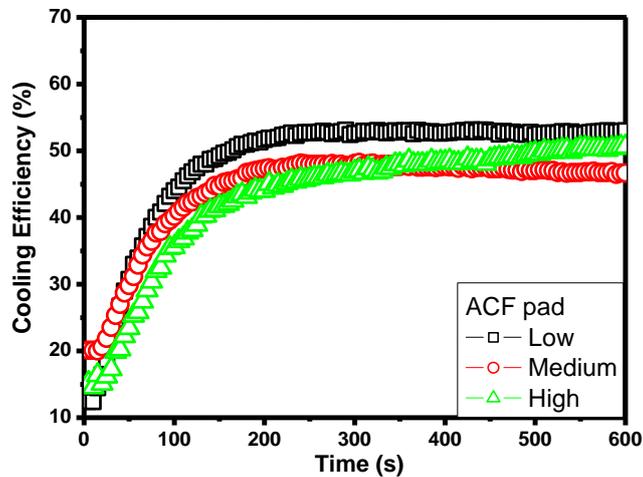


Fig. 8: Variation of cooling efficiency due to various speed of air for ACF pad.

Inversely, the highest η_s can only be obtained by luffa pad at the highest speed of air flow and the η_s decreases as the inlet air flow speed decreasing. This is attributed to the weak wettability and evaporation ability of the luffa cooling pad.

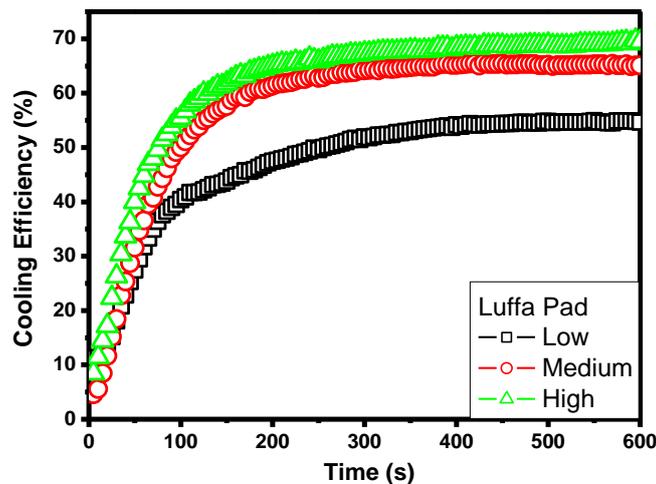


Fig. 9: Variation of cooling efficiency due to various speed of air for luffa pad.

CONCLUSIONS

This study set out to determine the cooling efficiency of different type natural based material as a cooling pad for evaporative cooling system. The study shows that ACF cooling pad has the highest difference between inlet and outlet temperature as well as highest humidity changes compared to luffa cooling pad. Moreover, the results for cooling efficiency of pad material under the same conditions show that ACF cooling pad has greater efficiency than luffa cooling pad. Furthermore, efficiency of cooling pad with respect to various air speed flow finds that ACF cooling pad efficiency is the highest at the lowest inlet air flow speed as compared to luffa cooling pad. On the other hand, the efficiency of luffa cooling pad is highest at highest inlet air flow speed. From these results, it can be concluded that the ACF cooling pad has better foam structure and wettability compared to luffa cooling pad. As an agenda for future research, water flow rate and pressure drop can be included to determine the cooling efficiency.

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