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PERFORMANCE EVALUATION OF PET PANEL FOR DIRECT EVAPORATIVE COOLING

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Abstract. This work aims to the investigating the performance of ethylene terephthalate (PET) fillets direct evaporative cooling panels when compared to commercial cellulosic. PET fillets were pre-treated by sanding its surface to reduce its hydrophobicity. Four types of abrasive paper with three granulations (60, 80 and 100) were used and the evaluated analyzing the amount of water (g) retained on the their surface of the PET plastic samples was measured to find the best surface treatment for improved water retention. With this information, evaporative panels of different compaction will be constructed in which the effectiveness of direct evaporative cooling compared to the commercial cellulose panel were evaluated with encouraging results.

Keywords: Evaporative Cooling, PET plastic, Pad Cooling, Media Cooling, heat transfer

1. INTRODUCTION

Thermal comfort is an increasingly important aspect in people's lives as it influences not only the feeling of comfort but also work performance, health and quality of life. In contrast to mechanical compression refrigeration cycle, evaporative cooling is an interesting option to provide thermal comfort since it represents reduction of installation and operating costs. The direct evaporative cooling efficiency is inversely proportional to air humidity and thus favourable to hot and dry regions, such as semi-arid Brazilian. However, evaporative cooling requires evaporative panel, typically made of cellulosic material, a high-cost component. The search for alternative evaporative panel with lower cost and environmentally friendly is a factor that could extend the range of these devices to the poor areas of the region. This work aims to investigate the performance of ethylene terephthalate (PET) fillets evaporative cooling panels when compared to commercial cellulosic..

2. DIRECT EVAPORATIVE COOLING

Ambient air is a mixture of dry air and water vapor with a maximum concentration of water vapor in this mixture that is dependent on temperature and pressure. In this way, evaporative cooling takes advantage of the ability of air to retain water in the form of vapor and operates using water and air as working fluids. Evaporative cooling is a technique or natural phenomenon of heat and mass exchange that uses evaporation of the water to reduce the temperature of a certain place or material. This mass exchange is achieved by putting in contact circulating air and wet surface keeping the total enthalpy constant (adiabatic cooling). The direct evaporative cooling process essentially works with the conversion of sensible heat to latent heat (Castro and Pimenta 2004). It's not a new technology. Evaporative cooling was known to the ancient Egyptians. Frescoes from about 2500 B.C. show slaves fanning jars of water to cool them. The

vessels were porous enough to maintain wet surfaces to facilitate the process (Riangvilaikul and Kumar 2010; Watt 1986).

In evaporative cooling the cooling effect is achieved by the evaporation of liquid water, which has large enthalpy of vaporization. The underlying principle is to convert the sensible heat to latent heat during the evaporation of water, causing a decrease in the temperature and an increase in humidity of the surrounding air (Guan, Bennett, and Bell 2015). Compared to the conventional air conditioning system, it is estimated that evaporative cooling systems may only require around one quarter of the electric power that mechanical vapour compression used in air conditioning (Riangvilaikul and Kumar 2010). The effectiveness (η) of an evaporative cooler is defined as the rate between the actual dry bulb temperature drop and the maximum theoretical fall that the dry bulb temperature could have if the cooler were 100% efficient and the air exits the device saturated (Eq.1).

$$\eta = \frac{T_{BS_{in}} - T_{BS_{out}}}{T_{BS_{in}} - T_{BU}} \times 100 \quad (1)$$

The basic operation of a direct evaporative cooler (DEC) is characterized as follows (Fig. 1): external air enters the panel, exchanges heat with water, which evaporates, and leaves with a lower dry bulb temperature. The water used to keep the panel wet after successive recirculations reaches an equilibrium temperature close to the wet bulb temperature of the intake air and thus can be used for other cooling purposes. A DEC, in a simplified form, is basically a cooling tower in which the cooled element of use will be the cold air intended for thermal comfort. The minimum possible outlet air temperature in a DEC is the wet bulb temperature of the inlet air (Santos, Camargo, 2010).

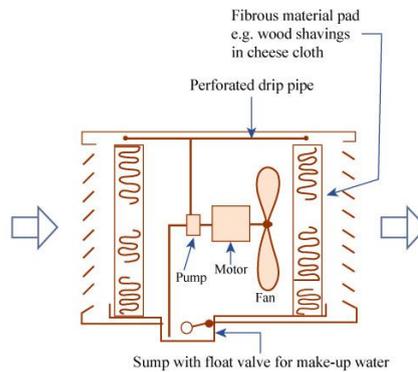


Figure 1: Direct evaporative cooling (source: MIT, 2010)

3. EXPERIMENTAL PROCEDURE

PET is mainly used in food packaging and, despite its versatility, their disposal is a significant ecological problem. PET in its original form is hydrophobic (low water retention). However, when the surface is sanded, there is a decrease of the hydrophobicity that allow PET retain a thin layer of water by capillarity. The water retained in the plastic surface comes into contact with the air promoting a latent heat exchange between air and panel - direct evaporative cooling. Four types of abrasive paper (wood sandpaper, mass sandpaper, iron sandpaper and water sandpaper) with three granulations (60, 80 and 100) were used to build test samples, shown in Fig.2, which were evaluated by analyzing the amount of water (g) retained on the their surface. Figure 3 shows pet fillets used for evaporative panel built.



Figure 2: Sanded PET sample



Figure 3: PET panel

This test were done to verify which combination of sandpaper type and granulation would provide best hydrophilic characteristic. With this information, evaporative panels of different compaction were built in which the effectiveness of direct evaporative cooling was compared to the commercial cellulose panel such as the one shown in Figure 4.



Figure 4: Cellulose sample

The experimental work was carried out in four stages: making of PET plastic samples, measurements of dry mass and wet mass, built of the evaporative panel and analysis of the panel. The samples were made from soft-drink bottles sanded with three different types of granulations (60, 80 e 100). The sanded PET plastic panels were made with the fillets of the bottles sanded with the granulation water sandpaper 60. This sandpaper determined the best water retention result on the surface according to the dry and wet mass experiment in which 10 PET samples were evaluated (smooth and sanded) and cellulose for each type of sandpaper and grit size (Table 1). The panels were constructed in 3 (three) compaction levels, defined as "Sanded 00, Sanded 01 and Sanded 02". The initial PET panel ("00") was constructed such that the pressure drop within the panel was similar to one of the cellulose panel. The following panels ("01 and 02") were built adding 105g of fillets, progressively. The compaction was defined by dividing the estimated area of the panels by the volume of the panels. The characteristics of the panels (cellulose and PET) can be observed in the table 3.

Table 1: Difference between dry and wet mass of samples (sanded plastic PET and cellulose)

Grits	Mass of water (g) retained on the surface of samples					Cellulose
	Wood	Mass	Iron	Water	Smooth	
60	0.829	0.783	0.928	0.995	0.149	1.043
80	0.747	0.814	0.779	0.747	-	-
100	0.775	0.799	0.793	0.767	-	-

Table 2: Pressure drop. μ is average temperature and σ standard deviation.

Panels	μ	σ
Sanded PET 00	4.42	1.28
Sanded PET 01	6.61	2.01
Sanded PET 02	8.97	1.0
Celulose	4.36	1.06

Table 3: Characteristics of sanded PET panels

Parameters	Sanded PET 00	Sanded PET 01	Sanded PET 02	Cellulose
Mass	446.0 ± 6.0g	555.0 ± 6.0g	666.0 ± 6.0g	460.000 ± 6.0g
Volume	0.0163 ± 0.0001 m ³			
Fillet width	5.0 ± 1.0mm	5.0 ± 1.0mm	5.0 ± 1.0mm	-
Dimensions	0.330 x 0.330 x 0.150 ± 0.001m			
Inlet air angle	-	-	-	15°
Outlet air angle	-	-	-	45°
Estimated surface area	2.231 ± 0.030 m ²	2.781 ± 0.030 m ²	3.331 ± 0.030 m ²	6.318 ± 0.030 m ²
Compaction	136.6 ± 2.1 m ² /m ³	170.2 ± 2.3 m ² /m ³	203.9 ± 2.4 m ² /m ³	387.6 ± 2.12 m ² /m ³

4. EXPERIMENTAL APPARATUS

The tests of the evaporative cooling efficiency of the panel were performed in CUSSONS air conditioner (Figure 5) at 3 different temperature levels (27, 32 and 37°C) and relative humidity (30, 40 and 50%) keeping the air velocity constant at 1.1m/s measured by an orifice plate. The temperature and humidity sensors (7) and a differential pressure manometer are arranged between the test panel to check the dry bulb air temperature, relative humidity and pressure difference. The panels were placed in the chamber (14) in which they are continuously wetted. The effectiveness of the panels is calculated by Eq. 1.

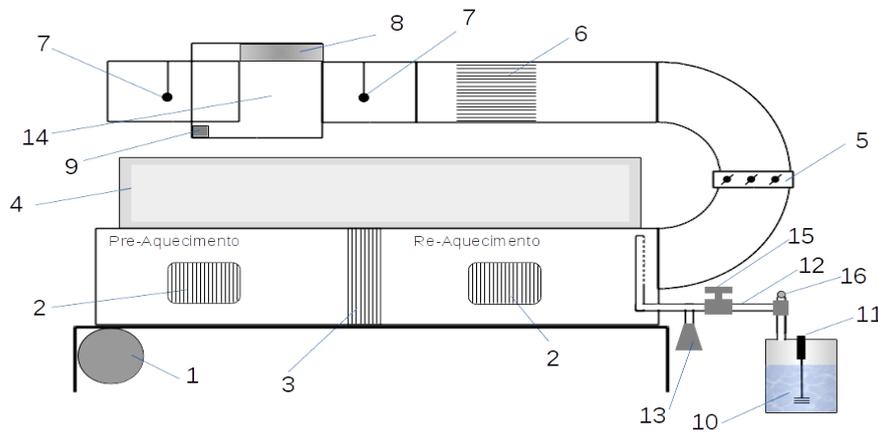


Figure 5: Bench CUSSONS: (1) fan, (2) resistor, (3) cooling serpentine, (4) panel, (5) damper, (6) Flow conditioner, (7) sensors, (8) , (9) water pump, (10) container water, (11) boiler, (12) pipe, (13) condensed water bottle, (14) conditioner chamber, (15) switch, (16) ball valve (cussons.co.uk)

5. RESULTS AND DISCUSSION

The results of the cooling efficiency test are now presented in the Figs. 6 to 11. A comparative reduction of temperature (Δt) and evaporative cooling effectiveness between the panels, for different inlet temperature (27, 32 and 37°C) and humidity (30, 40 and 50%) conditions, can be seen in Figs 6,7,8. The temperature reduction observed in the graphs below is in agreement with the theoretical reference. The results confirm the influence of the dry bulb temperature and the relative inlet humidity on the reduction of the air temperature 4. It is observed that the higher the dry bulb temperature and the lower the relative inlet humidity, the lower the output air temperature, which is a very important characteristic for this type of cooling system when applied to hot climates and dried. These factors favor the exchange of heat and mass between the wet surface of the panel and air passing through it. Thus, the reduction of dry bulb temperature in an evaporative cooling system is strongly dependent on the evaporation of the water contained in the surface of the panel. Due to this, the higher evaporation rate of the water occurs the inlet air presents higher dry bulb temperature and lower relative humidity, as there is higher kinetic energy of the water molecules and lower vapor concentration in the air. In addition, the amount of water evaporated from a moist surface is dependent on the vapor pressure of the moist air, such that by keeping the dry bulb temperature constant and by varying the humidity of the air, the greatest temperature difference will occur at the point of low air humidity.

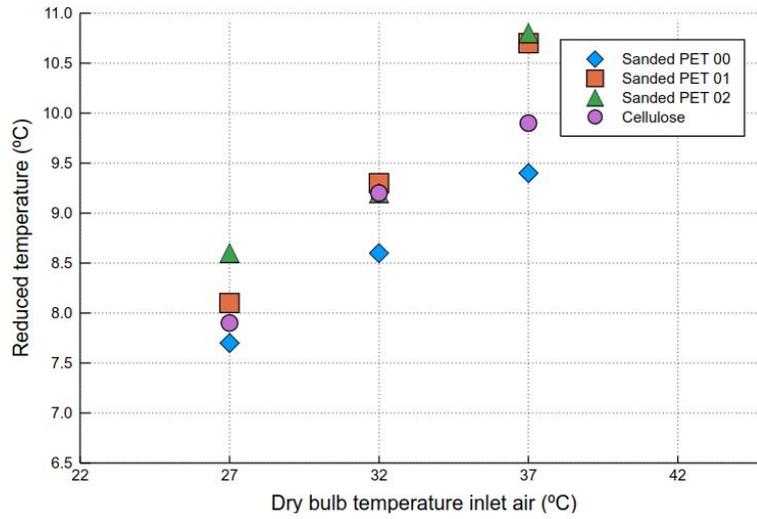


Figure 6: Reduction of temperature evaporative panel output at the inlet dry bulb temperature of 27°C.

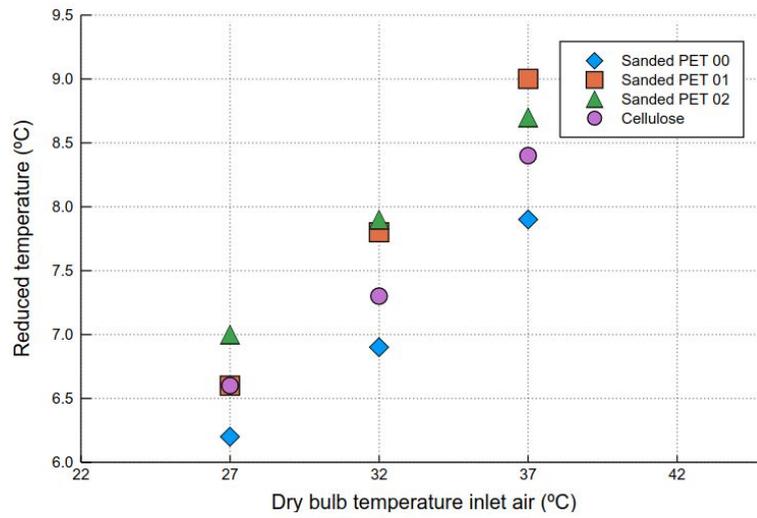


Figure 7: Reduction of temperature evaporative panel output at the inlet dry bulb temperature of 32°C.

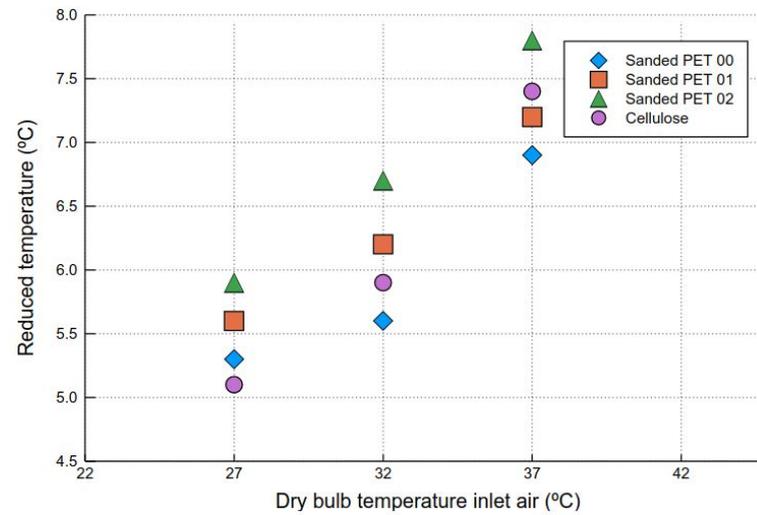


Figure 8: Reduction of temperature evaporative panel output at the inlet dry bulb temperature of 37°C.

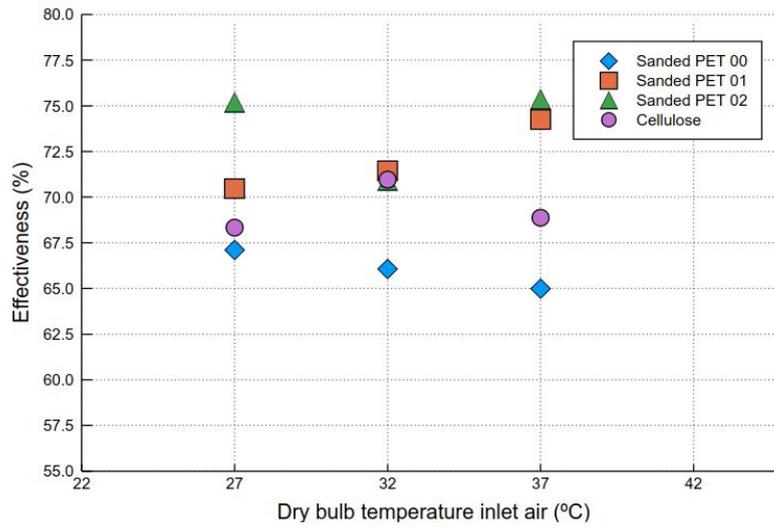


Figure 9: Effectiveness of the evaporative panel at the inlet dry bulb temperature of 27°C.

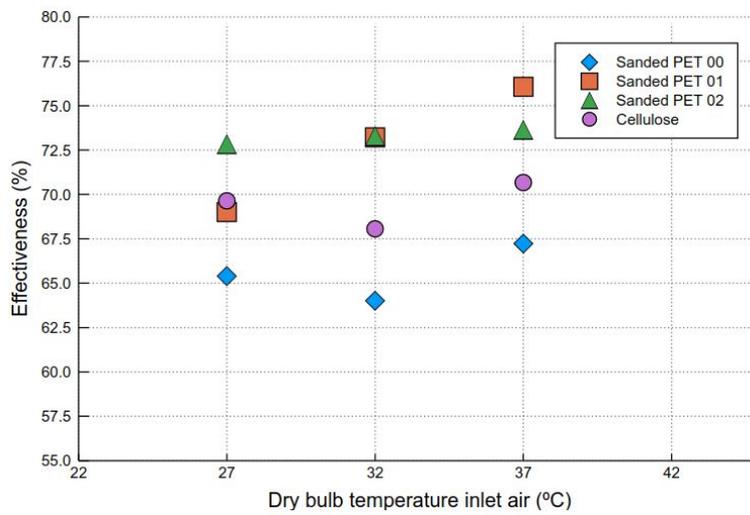


Figure 10: Effectiveness of the evaporative panel at the inlet dry bulb temperature of 32°C.

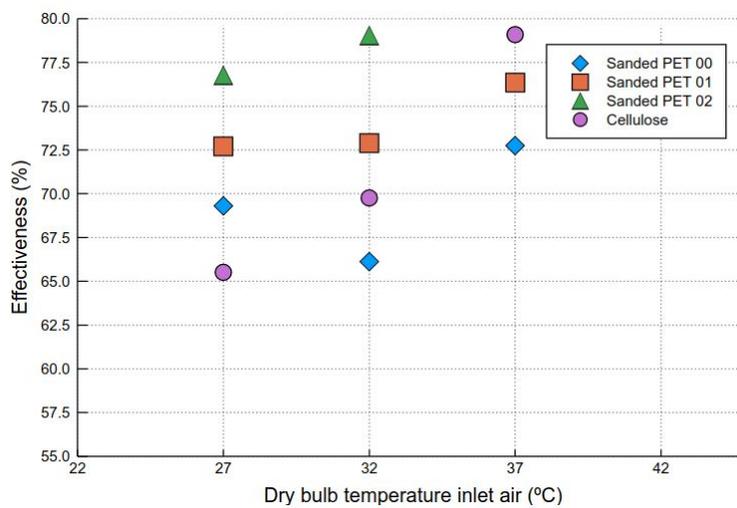


Figure 11: Effectiveness of the evaporative panel at the inlet dry bulb temperature of 37°C.

6. CONCLUSIONS

Sanding the PET surface increased considerably the water retention property. The PET material in the original form is very hydrophobic. However, the mechanical sanding treatment of the surface caused the retention of a thin layer (film) of water on the surface important in the process of heat and mass transfer. The dry mass and wet mass experiments demonstrated a significant advantage of the samples sanded with granulated water sandpaper 60. The sanded panel "02" presented greater temperature reduction with a difference of up to 0.9°C relative to the cellulose panel. The effectiveness of the sanded PET panel "02" is also superior to the cellulose panel under various conditions of temperature and humidity. PET panel, demonstrated promising results as a replacement for cellulose evaporating panel, with lower cost. Besides, this could be an interesting destination for PET disposal.

7. ACKNOWLEDGEMENTS

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