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Performance testing of COOLMAX materials for evaporative cooling applications

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ABSTRACT

Propose an experimental method for measuring evaporation characteristic parameters of COOLMAX material. Measure the loss weight of the fabric after wetted and time parameters, calculate the evaporation rate of COOLMAX material. The experimental results show that there is no significant difference in evaporation rate and evaporation time between Jersey stitch surface and eyelet surface of COOLMAX fabric. The evaporation rate of fabric samples placed vertically is higher than that of fabric samples placed horizontally, which determine their application potential in evaporation cooling technology.

Keyword: evaporative cooling, dew point air cooler, fiber fabric, evaporation rate

1. INTRODUCTION

Evaporative cooling technology is an energy-saving, economical and efficient cooling method, which uses the heat absorption principle of natural evaporation and does not consume compression work. However, the evaporative cooling process has a high requirement on the surface materials, which must meet the characteristics of fast moisture absorption and fast diffusion, which becomes a bottleneck restricting the evaporative cooling technology. Niyomvasa[1] et al. conducted a comparative study on two types of cooling pads made of knitted fabric and raw cotton fabric through experiments. The results show that the average temperature difference between the inlet and outlet of knitted fabrics and raw cotton fabrics is 2.9 ℃ and 1.7 ℃ respectively, the average saturation efficiency of knitted fabrics is 54.8%, and that of raw cotton fabrics is 33.2%. Xu Peng[2] and others studied research COOLPASS, COOLMAX different fabric materials, such as the impact on the indirect evaporative cooling process, found that most of the textile fabric in terms of ability to evaporate moisture absorption, diffusion, and excellent performance (compared with kraft paper, found some fabric core absorption capacity increased by 171%~ 182%, diffusion ability higher 298%~396%, evaporation capacity higher 77%~93%). In the evaluation of water transfer performance, DuPont ®COOLMAX active fabric was found to be the most suitable for indirect evaporative cooling applications.

In this paper, the changes of evaporation rate and evaporation time of COOLMAX fiber fabrics under different vertical angles are compared through experiments.

2. TEST PROCESS

2.1 Test instrument and test bench

As shown in. 1, the experimental instrument is used to measure the moisture evaporation rate of COOLMAX fabric. In the experiment, COOLMAX fabric samples of

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50mm×50mm were used for testing. Double-rib fabric was selected for the experiment, with different double-side knitting methods, named Jersey stitch surface and Eyelet surface. The double-side evaporation effect was tested in the experiment to determine the influence of different surface on evaporation performance. The measurement balance used was ME104/02, a high-precision balance produced by METTER TILEDO, with a maximum precision of 0.1mg. Handheld anemometer used is testo425 produced by testo company, with a maximum precision of 0.03 m/s.

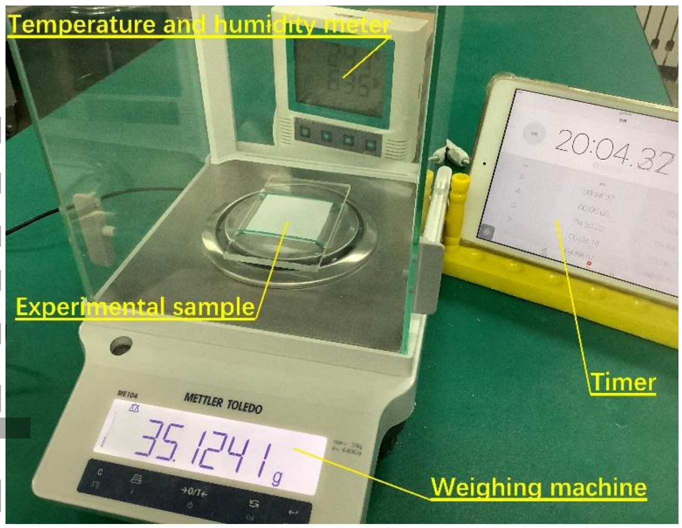


Fig. 1: Test platform appearance

2.2 The performance test standard of evaporation rate

Drop a certain amount of water droplets on the sample and then naturally evaporated in the standard atmosphere, the mass of evaporation per unit time within the linear interval of the time-evaporation curve. According to the stipulation 8.3.4 in GB/T21655.1-2008, the calculation of water evaporation rate is based on the normal time-evaporation curve, which usually slows down the evaporation change significantly after a certain point. A tangent line made on the curve before this point that is closest to the straight line, and the slope of the tangent line is Evi (g/h) [3].

2.3 The performance test standard of evaporation time

The time required for a certain amount of water droplets to be suspended in the standard atmosphere after being placed on the sample until all the water evaporates. For the calculation of water evaporation time, the test samples should be immediately weighed and suspended in the standard atmosphere. The samples should be naturally flat or vertically suspended, and the mass should be weighed every 10min to be accurate to 0.001g. Until the change rate of the mass for two consecutive times does not exceed 1%, this time can be considered as the evaporation time of the sample [4] [5].

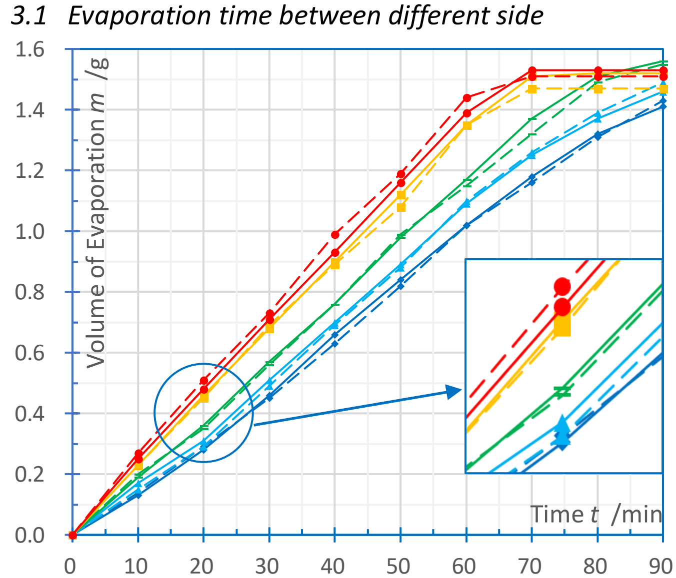
2.4 Test method

Weigh the original mass of the sample to 0.001 g. To the water after lifting, repeated 2 ~ 3 times. The sample is put into a container with three levels of water. After absorbing water, the sample sinks naturally to the water for 5 min and then is taken out. The sample is suspended vertically and horizontally, and the water drops naturally. Pay attention to observation. When the sample no longer drips water, immediately take out the sample with tweezers and weigh the accurate to 0.001g [6]. (Note: when the time interval between two drops of water is not less than 30 s, the sample will be considered to drop no more water.)

The fully soaked samples were placed on the test platform and suspended vertically on the test rack. Measure the change of mass loss with time at a predetermined wind speed, and record the weight was every 10min.

3. RESULTS AND ANALYSIS

3.1 Evaporation time between different side



(a)

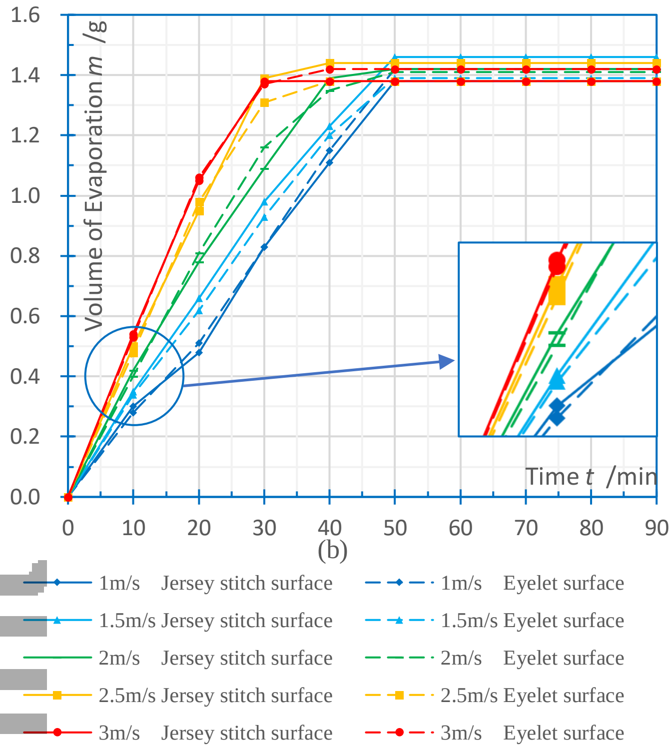


Fig. 2: Horizontal placement (a), vertical placement (b) hygroscopic quick-drying materials Volume of Evaporation - time diagram

As the Fig. 2 shows, the evaporation process in a period of time is approximately proportional to the amount of evaporation. With the increase of time, the amount of evaporation is also increasing. The evaporation rate, i.e. the slope of the curve, increases with the increase of wind speed.

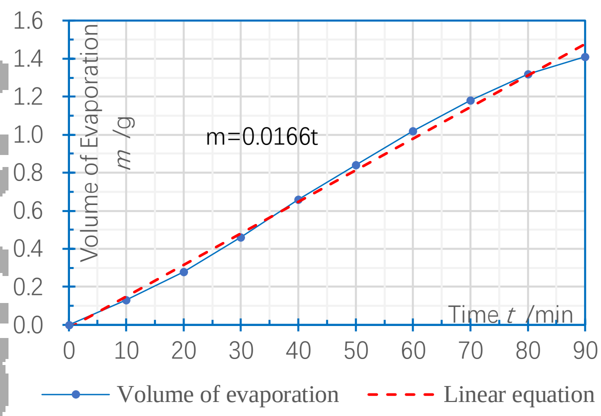


Fig. 3: Evaporation curve and linear regression line in stable section

According to the test performance standards, the evaporation rate Evi (g/H) at each wind speed can be calculated by using the evaporation-time diagram. It can be seen from Fig. 1 that the evaporation of the COOLMAX moisture absorption and quick-drying material changes slowly after a certain time, and then the evaporation quality at constant. It can be considered that the water absorbed by the material evaporates out at this stage, so the curve before the evaporation reaches the stable value is mainly used for analysis. Taking the evaporation curve of 1m/s under vertical placement as an example, this hygroscopic quick-drying material was selected as the fitting curve. It was observed that the evaporation rate tended to be stable between 0 and 80min. This section was selected for linear regression analysis, and the evaporation rate curve obtained was shown in Fig. 3. The slope K of the fitting line is 0.0166g/min, so the evaporation rate Evi under this condition is 1.00g/h. According to this method, the evaporation rates of COOLMAX quick-drying materials placed on different flat surfaces subjected to wind under various wind speed conditions are calculated, and the results are shown in Table 1.

Table 1 Evaporation rate of fabric samples

Air velocity (m/s)	*Jersey stitch surface*		*Eyelet surface*	
	horizontal	*vertical*	*horizontal*	*vertical*
1	1.00	1.64	0.98	1.68
1.5	1.07	1.91	1.06	1.84
2	1.16	2.16	1.15	2.18
2.5	1.35	2.84	1.33	2.73
3	1.41	3.17	1.49	2.90

By comparing the evaporation rates in Table 1, it can be seen that under the same placement mode and wind speed environment, jersey stitch surface and eyelet surface have the same trend in evaporation quality change, and there is not much difference between them in numerical value. In addition, Table 1 shows that under the same wind speed and test environment, the evaporation rate of the jersey stitch surface and eyelet surface obtained by linear regression equation is basically same. However, when the wind speed increases to 3m/s, the evaporation rate of the vertically placed plain surface increases to 3.17g/h, which is about 10% higher than that of the mesh surface under the same wind speed. Overall, there is no significant difference in evaporation rate between the two side, there is also no significant difference in using both side bonded materials.

3.2 Evaporation time between different placement

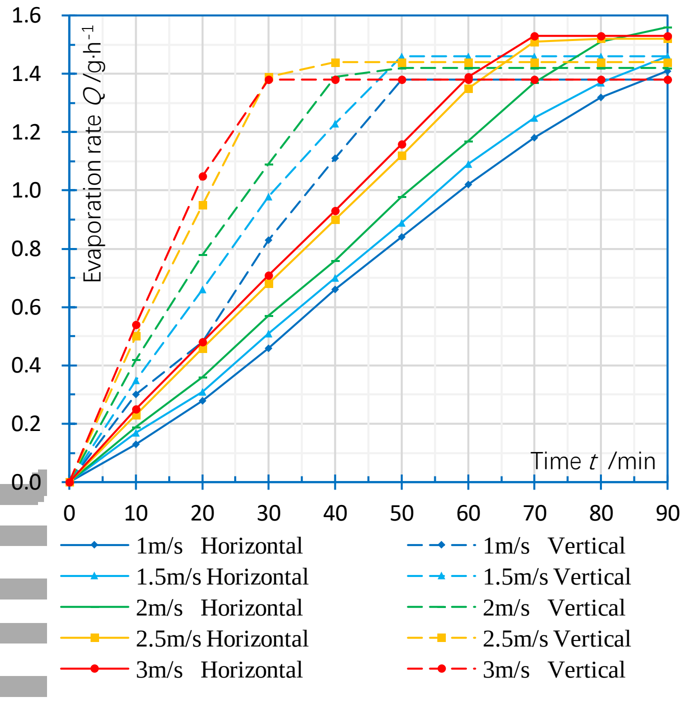


Fig. 4: Variation diagram of evaporation rate and time of water on jersey stitch surface

From the above discussion, it can be concluded that there is little difference in the evaporation rate measured between the jersey stitch surface and the eyelet surface. Therefore, we select jersey stitch surface as the fabric sample to compare the evaporation rate placed in different placement under the same wind speed. As the Fig. 4 shows, at the same fabric side, the fabric placed vertically has a much faster evaporation rate than that placed horizontally under the same wind speed. In addition, as Table 1 shows in terms of evaporation rate under the same wind speed, the evaporation rate of vertically placed samples is nearly double of horizontally placed samples, and with the increase of wind speed from 1m/s to 3m/s, the evaporation rate of vertically placed fabrics increases faster than that of horizontally placed fabrics. When the wind speed increases to 3m/s, the evaporation rate of vertically placed samples increases to 3.17g/h, which is 2.24 times that of horizontally placed samples under the same conditions.

3.3 Evaporation time

As the Fig.4 shows, the comparison of evaporation time that there is no significant difference in evaporation time between fabric samples with jersey stitch surface and eyelet surface. However, by comparing the different placement modes, it can be seen that under the same wind speed, the evaporation time of vertically placed fabric samples between 30~50min, while the evaporation time of horizontally placed fabric between of 70~90min. When the wind speed increases to 2.5~3m /s, the evaporation time of vertically placed fabric reach the level of 30min, only 40% of horizontally placed fabric under the same wind speed. Shorter evaporation time means more evaporation volume and faster heat absorption in the same time.

4. CONCLUSION

Experimentally tested the evaporation rate and evaporation time of different weaving COOLMAX materials under different working conditions, verify its application potential in evaporative cooling technology. The experimental results showed that:

（1） Through COOLMAX material experiment in different placement under different wind speeds of 1~3m /s, when the wind speed increases to 3m/s, the evaporation rate of vertically placed jersey stitch surface increases by about 10% higher than that of eyelet surface. Overall, there is no significant difference in evaporation rate and evaporation time between jersey stitch surface and eyelet surface. In practical application, the desired effect can be achieved by evaporation on both sides of the fabric.

（2） According to the experimental results of COOLMAX material placed in different placement, vertical fabric material has a greater advantage in evaporation rate than horizontally placed fabric material. At the same wind speed, the evaporation rate of vertical fabric material is double of horizontal fabric material at the same wind speed. When the wind speed increased to 2.5m/s, the vertical fabric evaporation rate increased faster.

（3） In terms of evaporation time, the evaporation time of vertical fabric materials is 50~70min, while the evaporation time of horizontal fabric materials is 70~90min at the same wind speed.

（4） In terms of practical application, the current evaporative cooling air conditioners mainly vaporize by the way of parallel air flow passing over the fabric surface. The comparative test results show that the evaporation effect of parallel air flow is not as good as that of vertical air flow. Therefore, the structure of the evaporative cooling air conditioning could be optimized, which will increase the effect greatly.

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