Research on Factors Influencing Temperature and Relative Humidity Inside of Shoes

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Abstracts: The study mainly concerns how such factors as kinestate, upper structure, footwear material and external environment influence the temperature and relative humidity inside of shoes. The results indicate that all the four factors can significantly affect the temperature and relative humidity inside of shoes. In whatever states, the temperature and relative humidity increase sharply and reach a dynamic balance in the initial period of wearing. Before reaching the balance, the temperature and relative humidity rise more sharply and reach the balance sooner with the increasingly intense kinestate.

Key words: inside of shoes; temperature; relative humidity; kinestate; upper structure; footwear material

1 Introduction

While being worn, the temperature and humidity inside the shoes will change greatly with the amount of movement, which greatly influence the comfort of wearing. The hygiene of the shoes should not be ignored from the perspectives of both the changing consumption ideology and the marketing of the shoe-making enterprises. The processing ability of the shoe material to micro-environment is the main factor for determining the hygiene of the shoes[1, 2]. The study of the comfort of the shoes can be approached from two perspectives of temperature and relative humidity.

The research studies the regular change of the temperature and the relative humidity of the inside of the shoes under the conditions of various movements, upper structures and materials.

2 Experimental procedures

2.1 Experiment Facilities and Materials

The TESTO-Temperature and humidity instrument (Model 625) made in Germany is applied in line with DP8650 anion electric treadmill made in Qingdao.

Four groups of shoes are tested in the experiment: No. 1 Basketball shoes with high uppers, No. 2 Sand shoe, No. 3 Close leather shoes and No. 4. Reticulation sports shoes.

2.2 Experiment Methods

In line with the facts, three representative conditions are selected: quiescence, walking and virtual movement.

The quiescence: the temperature and humidity of the inside of the shoes are measured for every five minutes or a longer interval. The experiment time lasts for 90 minutes.

The walking (The pace is about 0.7 meters per second.): the temperature and humidity are measured for every interval of 1 minutes or longer. The experiment time lasts about 45 minutes.

The double-quick: The basketball sports for No. 1 shoes; tennis for No. 2 shoes; double-quick at the pace of 1.6m/s for both No. 3 and No. 4 shoes. The temperature and humidity are measured for the interval of 1 minute or longer. The experiment time lasts 45 minutes.

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3 Results and discussions

The experiment is carried out for the four groups of shoes according to the experiment methods in 1.3 and the data are analyzed as in the diagrams.

3.1 Comparison of temperatures and relative humidity of the inside of the shoes in the same movements.

a. Quiescence

The temperature and the relative humidity were measured for an interval of every five minutes or longer.

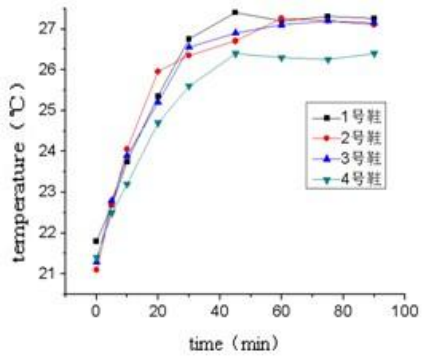

Fig. 1 Temperature change inside shoes with time（quiescence）

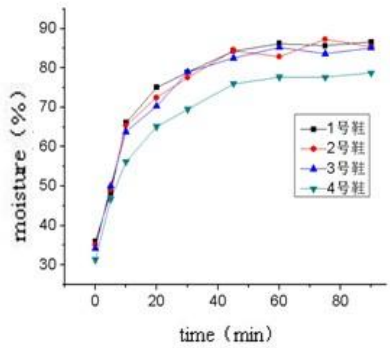

Fig. 2 Humidity change inside shoes with time（quiescence）

It can be shown in Fig. 1 and Fig. 2 that in the first stage of quiescence, the temperature rises sharply. However, it becomes stable 45 minutes later at the temperature of 270℃. Comparatively, the relative humidity rises more quickly. Within 10 minutes, the relative humidity increases by 30 percent compared to the original state. 40 minutes later, the relative humidity increases to 80 percent and remain stable. After the temperature and relative humidity become stable, the data for No. 4 is lower than the other groups.

At the beginning of the experiment, there is great difference between the temperature and relative humidity of the shoes and the feet, there is more heat and humidity conduction in the air of the shoes. So there is a sharp rise in temperature and relative humidity inside the shoes. With the time length, the temperature and relative humidity will reach a dynamic balance between the air inside the shoes and the feet and so they become stable.

The metabolism is slow in quiescence so the shoes will not become slimy and sultry. Therefore, in the whole process of experiment, the maximum of the temperature and the relative humidity remain at a low level.

b. walking

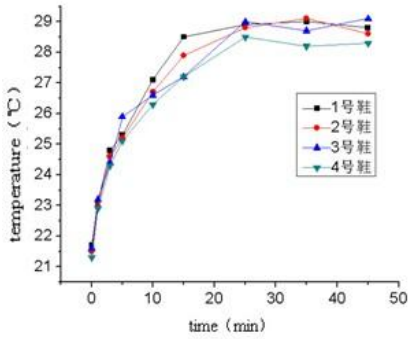

Fig. 3 Temperature change inside shoes with time（walking）

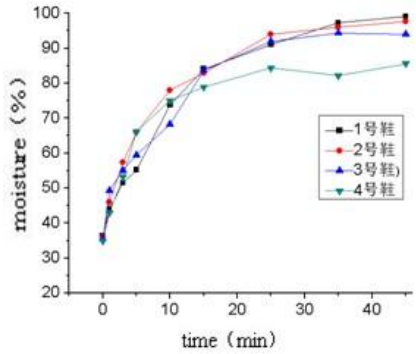

Fig. 4 Humidity change inside shoes with time（walking）

The temperature and the relative humidity inside the shoes are measured for an interval of 1 minute or longer. After walking for 1 hour, the feet of the subject have a slightly slimy and sultry feeling and feel comfortable. The data are shown in the figures (Fig. 3 and Fig. 4).

It can be seen from Fig. 3 and Figure 4 that in walking, the variation pattern of the temperature and relative humidity are very similar to that in quiescence. The temperature turns stable 15 minutes to 20 minutes sooner than in quiescence. The maximal temperature is 20℃ above that in quiescence. The maximal temperature is beyond 290℃ in No. 3 shoes. Meanwhile，the relative humidity changes more sharply than in quiescence. The statistics reaches 80% in less than 10 minutes, and 99% at the end of 40 minutes.

The reason can be analyzed as follows. At the beginning of the experiment, there is a sharp difference between the temperature and the relative humidity of the shoes and the feet so there is a sharp rise in the temperature and relative humidity at the initial stage! In the same way, the metabolism in the feet is faster than that in quiescence. The amount of sweat and heat outlet increases obviously compared to quiescence so that the temperature and the relative humidity rise very quickly!

Because reticulation material is applied in the upper of No. 4 shoes and there are many holes in the upper, part of the heat and humidity can be exchanged directly with the outside world, so the temperature is lower than the other three groups!

c. double-quick

The temperature and relative humidity is measured every minute or at a longer interval. The subjects feel obvious sliminess and sultriness. The data of the experiment is analyzed in figures (Fig.5 and Fig. 6).

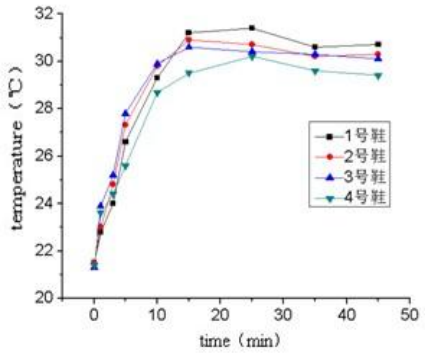

Fig. 5 Temperature change inside shoes with time（double-quick）

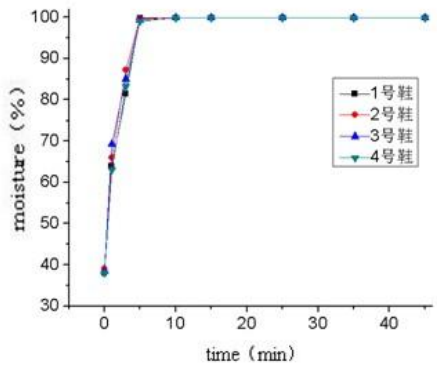

Fig. 6 Humidity change inside shoes with time（double-quick）

As shown in the two figures, t the temperature and relative humidity tend to change in generally similar way to those in walking and quiescence. It takes less time for the temperature and relative humidity to become stable. The maximal temperature can reach 310℃. At the beginning, the temperature inside the shoes rises steadily with the double-quick, but 25 minutes later, the temperature started to decline. The temperature is even lower than that after the double-quick lasts 20 minutes.

At the beginning of the experiment, there is a great difference of temperature and relative humidity between the inside of the shoes and the feet, so the temperature and the relative humidity rise very sharply. In the similar way, the metabolism of the feet is faster in double-quick, so the sweat and heat outlet increases sharply compared to walking. Therefore the rate of temperature and relative humidity is accelerated. The steady movement of the runner makes the heat production increase quickly and the temperature rises correspondingly. In the meantime, the coordination system inside human body begins to take effect and the feet discharge heat via sweating, causing the humidity increase inside the shoes. Therefore, even in continuous double-quick, the temperature inside the shoes will first rise and then declines.

3.2 Comparison of Temperature and Relative Humidity between Different Movements

a. Study on the microclimate inside No. 1 shoes in the three movements

The data obtained concerning No. 1 shoes in quiescence, walking and double-quick are analyzed as in figures (Fig. 7 and Fig. 8).

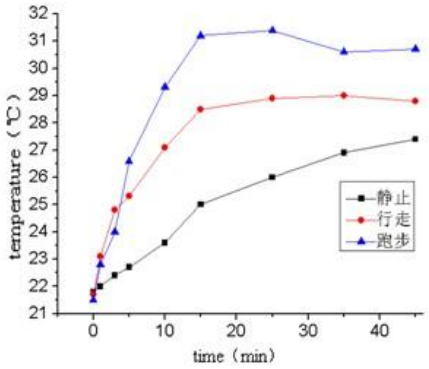

Fig. 7 Temperature change with time inside shoes in different movements (Shoes No. 1)

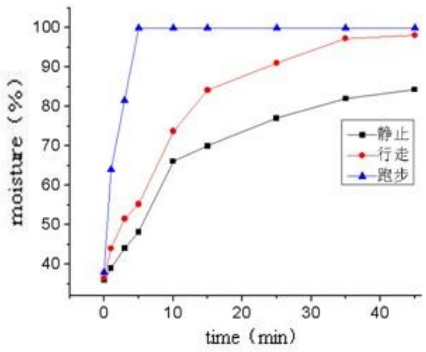

Fig. 8 Humidity change with time inside shoes in different movements (Shoes No. 1)

As can be easily seen from Fig. 7，in the first 15 minutes, the temperature in the three conditions rises very quickly. Besides, the more violent the movement is, the more quickly the temperature rises. The time to reach stability has the following relation: T quiescence>T walking>Double-quick, while the maximal temperature is the opposite: Quiescence<Walking<Double-quick. Fig. 8 shows that the relative humidity is similar to temperature.

This is because that when people are in quiescence, the metabolism become slower and the temperature in feet does not change very sharply and the exchange of heat and humidity is less. In quiescence, the tine to remain stable is the longest but the maximal temperature is lowest and the relative humidity remains within a certain range. The feet feel dry comfortable. With the increase of the movement, the heat become more and the temperature inside the shoes will rise quickly. When the temperature of the feet rise where the feet feel comfortable, the body will exert coordination and the feet begin to sweat. So the stronger is the movement, the more quickly the relative humidity rises and the time to reach stability last the shortest.

b. Study on the microclimate inside shoes No. 2, No. 3, and No. 4 in three different movements

The study suggests that the regularities in these three groups of shoes are the same as shoes No. 1, so the result will not be elaborated on here.

4 Conclusions

(1) In whatever movements, the temperature and relative humidity rise most sharply in the initial stage of the whole process. Under the same conditions, the relative humidity rises more quickly than the

temperature does inside the shoes.

(2) The change of the movements exerts great influence on the temperature and humidity of the inside of the shoes. Before the temperature and humidity become stable, the stronger the movements are, the more quickly the temperature and humidity rise and the less time it takes for them to become stable. In quiescence, the temperature and humidity become stable in 45 minutes and 35 minutes respectively; in walking, they become stable in 30 minutes and 10 minutes respectively; in double-quick, it takes much less time for them to become stable: the temperature fries sharply at first, then will slightly decline with the double-quick and become stable finally.

(3) With the same conditions, the structure and materials of the upper will significantly influence the temperature and relative humidity inside the shoes.

(4) In any movements, the data collected will vary with different subjects. There is also a slight difference of temperature and humidity between the left and right foot for the same subject.

References

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