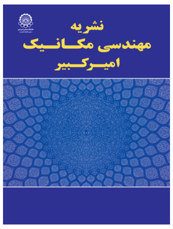

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Experimental investigation of personalized ventilation effects on temperature, velocity, and draught discomfort distribution in an office

S. A. Zolfaghari[1,*], P. Ebrahimi Naghani[1], M. Maerefat[2]

[1] Department of Mechanical Engineering, Univerity of Birjand, Iran
[2] Department of Mechanical Engineering, Tarbiat Modares University, Tehran, Iran

ABSTRACT: In this research, it has been tried to experimentally investigate the effect of a personalized ventilation system on airflow and temperature distribution in a room for two inlet air temperatures (24 and 32°C) and two different arrangements of the inlet diffusers (desk-mounted and under-desk air terminals). The results showed that the penetration depth of heat and momentum due to the inlet diffusers were not the same; So that the effect of inlet diffusers' temperature on the room temperature distribution is significant up to a distance of about 60 cm. However, the effect of inlet velocity is noticeable up to a distance of about 110 cm. Therefore, the occupants' thermal sensations up to the distance of about one meter from the inlet diffusers will be affected by the inlet conditions. Also, the results indicated that the draught discomfort along with the diffusers' centerline is significant to a distance of about 180 cm. Based on the results, the air velocity and turbulence intensity are the two main factors in determining the draught discomfort in the personalized ventilation system and due to the rapid thermal mixing of inlet air with the room air, the effect of inlet temperature on the draught discomfort is not significant.

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INTRODUCTION

Nowadays, people spend about 90 percent of their time in indoor environment. Therefore, designing air conditioning systems to maintain proper indoor air quality and provide optimal thermal comfort conditions for residents is very important. In the recent years, the HVAC designers focused on optimizing the conditions in the occupied zone and thus save energy consumption [1]. One of the systems that has been designed to optimize the thermal conditions and indoor air quality in the occupied zone is the personalized ventilation system. In 2007, Cheong et al. [2] examined the local sensation and thermal comfort conditions of subjects in a room with a personalized ventilation system. He concluded that in the range of near-neutral thermal sensation, local discomfort increases by increasing temperature. In 2015, Veselý et al. [3] examined the performance of a heating personalized ventilation system. They concluded that the use of personalized ventilation system has a significant effect on the occupants' satisfaction. In 2019, Zolfaghari et al. [4] experimentally investigated the effects of air temperature on the air movement acceptability in an office with personalized ventilation system. They found that the arrangement of inlet diffusers at the left and right side of the seat may cause higher level of satisfaction and air movement acceptability. Zolfaghari et al. [5] experimentally evaluated the effect of inlet flow discharge direction on temperature and flow patterns in a room with UFAD system and also predicted the percentage of people's satisfaction and concluded that the level of satisfaction of people in the UFAD system significantly depends on the discharge current and the distance of people from the diffuser. Previous studies indicate the importance of examining the pattern of temperature and velocity distribution in these locations. In the mentioned studies, draught discomfort for the desk-mounted and under-desk air terminals had not been studied. Also, due to the variety of diffusers in the personalized ventilation systems, the type of inlet air diffuser is important. In this study, by measuring the airflow pattern in an office environment for two different inlet air diffuser arrangements and two temperatures of 24 and 32 degrees Celsius, the distribution of temperature and the percentage of draught discomfort had been investigated.

2. METHODOLOGY

To perform the experiments, a climate chamber located in the University of Birjand has been used. The length and width of the room are 3m and its height is 2.7m. Also, the chamber is located inside a larger room, and as a result, weather conditions and sunlight do not affect the chamber. Inside the chamber, there is a temperature measuring sensor that transmits the information inside the chamber instantly to the test operator outside the chamber. Based on this information and available heating devices, the temperature is kept constant in the range of 24 ±0.5°C. Inside the ducts which connecting the air conditioner to the inlet air diffuser, there are sensors that show the velocity inside the ducts during the test. The inlet temperature of the diffusers is controlled at two different temperatures of 24 and 32°C. Temperature and velocity are

*Corresponding author's email: alireza.zolfaghari@yahoo.com

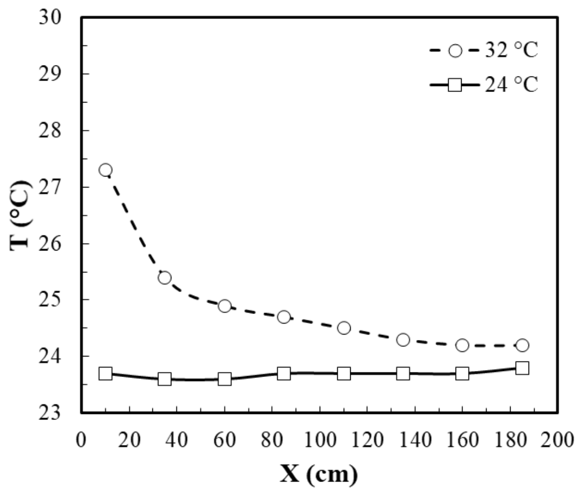

Fig. 1. Temperature distribution along with the under-desk air diffusers' centerline

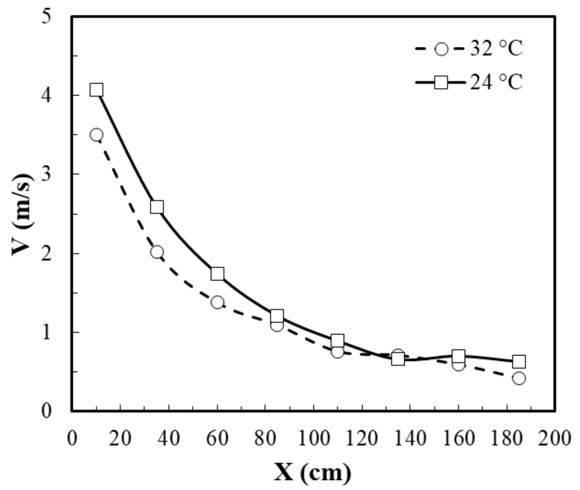

Fig. 2. Velocity distribution along with the under-desk air diffusers' centerline

measured in both vertical and horizontal positions. Along with the vertical measuring line, the sensors were located at distances of 10, 35, 60, 85, 110, 135 and 185 cm from the floor. Also, along with the horizontal line (centerline of the inlet diffuser), the temperature and velocity were measured by the sensors at distances of 10, 35, 60, 85, 110, 135 and 185 cm from the diffuser.

3. DISCUSSION AND RESULTS

Fig. 1 presents the temperature distribution along with the under-desk air diffusers' centerline. By increasing the inlet temperature from 24 to 32°C, the temperature change near the diffusers is significant. The trend of changes up to a distance of 60 cm from the diffusers has a steep slope so that at this distance, the measured temperature decreases from 32°C (at the diffusers) to 24.8°C. Then, by moving away from the diffusers, inlet air mixes with the chamber air, and the measured temperature approaches 24°C.

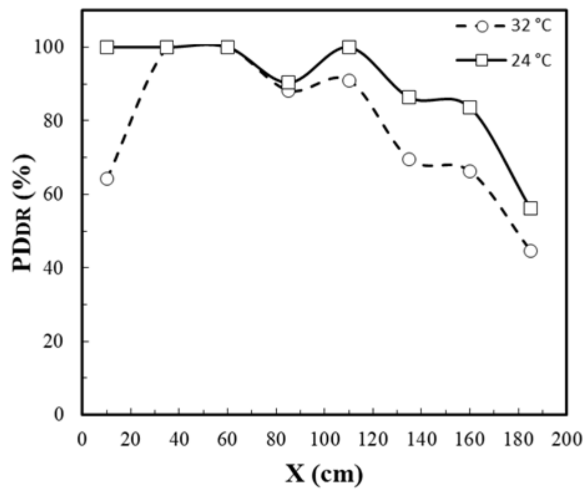

Fig. 3. PD_{DR} changes along with the under-desk air diffusers' centerline

Air velocity distribution along with the under-desk air diffusers' centerline is presented in Fig. 2. Based on this Figure, from 10 to 180cm distance from the diffuser, the velocity magnitude varies from 4.1 to about 0.6 and 3.5 to about 0.4m/s, for the inlet air temperature of 24 and 32°C respectively.

In Fig. 3 draught discomfort percentage distribution along with the under-desk air diffusers' centerline is presented. As expected, due to the high velocity of the airflow near the diffusers, high draught discomfort percentage happened. Based on results, draught discomfort along with the diffusers' centerline is significant to a distance of about 180 cm. It should be noted that depending on the diffusers' arrangement, the body parts such as hands and legs that are exposed directly to airflow, are at high risk of occurring discomfort due to draught.

4.CONCLUSIONS

The results showed that the vertical temperature distribution on the floor did not depend on the arrangement of the inlet air diffusers in the personalized ventilation system. In the horizontal temperature distribution, the effect of inlet diffusers' temperature on the room temperature distribution is significant up to a distance of about 60 cm from the diffuser, and at longer distances, air mixing brought the airflow temperature closer to the average air temperature in the room. However, the results related to the horizontal distribution of air velocity show that the effect of inlet velocity is noticeable up to a distance of about 110 cm. Therefore, thermal sensations will be affected by the inlet conditions up to about one meter from the inlet diffusers. The draught dissatisfaction along with the diffusers' centerline is significant to a distance of about 180 cm. The results showed that the velocity and turbulence intensity are the two main factors in determining the draught discomfort in the personalized ventilation system and due to the rapid thermal mixing of the inlet air with room air, the inlet temperature does not have a significant effect on the draught discomfort.

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