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The Personal Ventilation System with Air Temperature Customization Using a Peltier Effect

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Abstract

The paper deals with design of the personalized ventilation system with possibility of air volume and temperature customization, using a Peltier module for heating and cooling of the supply air in a scale of few degrees.

Ventilation and air treatment in the open space offices are always a really problematic issue, because every people has specific needs and feelings. This problem occurs more intensively in the operations, where work requires high rate of focus, and low quality environment may cause a strong distraction. In these causes, the personal ventilation system comes with possibility of customization of the work place environment and provide a better comfort and focus on work.

First part of the paper is focused on air supply system. Analyses the effectivity of air distribution, supply elements and impact on the work space environment. It mainly reviews the previous work on this issue, present personal ventilation system and diffusers, and the measurements using a thermal manikin. The result is effective layout of distribution element on specific workplace.

Second part of the paper is mainly about the air treatment and customization using a thermoelectric effect, which is used in our prototype of personalized ventilation system. It describes the system design and components and shows the primary results of measurement.

Keywords – personal; ventilation; Peltier effect; temperature customization

1. Introduction

Ventilation as itself forms an integral part of all buildings and significantly contributes to the creation of indoor environment and therefore affects the quality of stay in the building and influences the working efficiency. Besides the effective reduction of heat losses it plays the crucial role in the power consumption and these two factors usually contradicts each other, because creation of quality environment for all the building's residents is very expensive and often technologically complicated. Today's most frequently used central ventilation systems have their limits in methods of air supply to individual person. Even if we provided perfectly equal distribution of air in the room, the system isn't able to take into account user's subjective demands, which can be very diverse. The inconvenient personal environment causes decrease of personal comfort, which affects not only concentration, but also carries the risk of illness due to uncomfortable thermal conditions or sharing of the biological contamination with others. Personalized ventilation attempts to remove these deficiencies of central systems by the direct distribution or air conditioning in the workplace of individual user with ability to change parameters and amount of air. This causes that every workplace creates its own microenvironment following the demands of individual user. Besides the personal regulation this method of ventilation has also positive impact on the energy consumption. Central unit doesn't need to adjust the entire air in the room to the unnecessarily high or low temperatures. The required environment is only in the place where user spends the majority of his time - in his workplace. Amount of incoming air is also not formed for the room itself, but it follows the occupancy of the workplaces. Because of that, personalized ventilation can save up to 35 percent of energy for the air conditioning. [1]

a. Advantages of personal ventilation systems

The impact of personalized ventilation on microenvironment has been widely studied by the Danish university in Lyngby [9]. It has been studied from lot of view and aspects, for example the PPD (Predicted Percentage Dissatisfied) index [1], spreading of viruses and exhalations [7], working performance of room occupants, energy savings [8], etc. It has been proved, that in all of that cases personalized ventilation systems achieve better results than mixing air conditioning [7]. We can see the results on two example graphs in the figure 1, one for the PPD evaluation, and second for illnesses spreading in the open space.

In the first graph, there is PPD index comparing mixing and personalized ventilation in different indoor air temperature. We can see significant rising of the first column, reaching up to 25 percent dissatisfied in 26 ° Celsius, while for personalized ventilation it barely reach 10 percent.

The second graph shows spread of two different types of illnesses – influenza and measles – in the open space. Mixing ventilation, displacement ventilation and personalized ventilation are compared together.

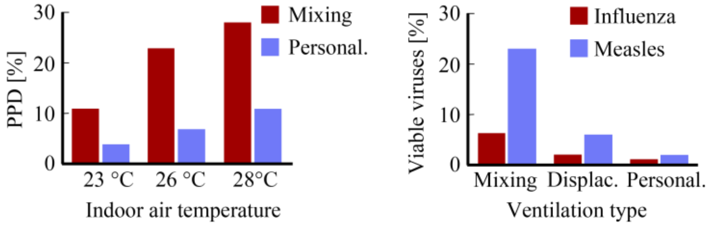


Figure 1 – comparison of ventilation systems [5] [1]

The potential of energy savings has also been mentioned before. It is based on better control of amount of fresh air supplied to the room, and direct distribution to the user, because personalized ventilation supply only the occupied workplaces with fresh air.

The study of Stefano Shiavon and Arsen K. Melikov [8] is focused on possible savings of the personalized ventilation. It has been made in IDA software (Indoor Climate and Energy) and result shows, that personalized ventilation is more adaptable for changes of occupancy, and can save up to 50 percent of cooling energy needed with the same PPD index.

b. Basic types of personalized ventilation

There is wide scale of ventilation systems we can call a personalized ventilation. First, and the simplest way to achieve local air customization is personal diffusers mounted on central ventilation system, which can be separately controlled and can change the local environment by different air flow rate. Main advantage is technological simplicity, but it has lower impact to the personal area.

More personalized variant of this system is diffusers mounted directly to the working desks (for example [5] [6]), distributing the fresh air to the small area around the user and with customized direction and amount. It is similar to the systems we know from the cars. It is the most effective variant, with higher impact to the occupants, but connect all workplaces to fresh air distribution can be technically complicated, especially in older buildings.

The technically opposite solution is not directly personalized ventilation, it could be called personalized air treatment. These are systems with local air treatment units and don't distribute the fresh air, only change parameters of the surrounding environment. It can be the local cooling panels mounted on the desk and connected to the refrigerant circulation [2], or local air purifiers, distributing freshened air to the respiratory area of user [3].

The last variant is combination of two previous types. It distributes the fresh air, but also customize the parameters. This variant isn't used very much in practice, because of the more complicated technological solution, but it has higher potential of comfort and energy savings.

2. Efficiency of air distribution

Personalized ventilation system is air distribution directly aimed to user, which is by itself more efficient than central ventilation system. But still there is a lot of ways how to distribute the fresh air inside the personal area and it has significant impact to how effective and how adaptable the system is. Measurement of efficiency of different distribution types was made by Arsen K. Melikov, Radim Cermak and Milan Majer [4] and we are using their study as a foundation for our next research and design of layouts of air distribution elements.

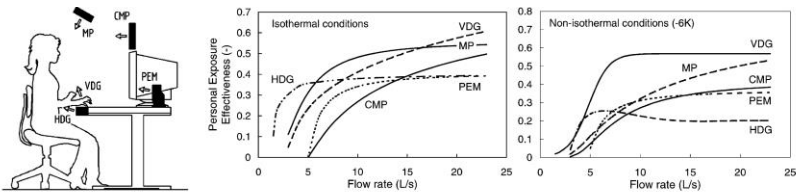


Figure 2 - effectivity of the diffusers in differen flow rate [4]

In the above mentioned study different air diffusers widely used for personal ventilation were evaluated, as showed on figure 2, and a thermal manikin was used to simulate the user, and to measure amount of marked fresh air successfully distributed to the person. It was measured for different flow rates, and for different temperature conditions: isothermal winter condition, with same temperature (20 ° Celsius) of supply and indoor air and non-isothermal summer conditions, with indoor air 26 ° Celsius and supply air 20 ° Celsius. Still the one state we would like to evaluate is missing, when the supply air is warmer than indoor air, which is not widely used, but our device will allow it. We would like to measure that state in our following research.

3. The possible effective layouts of air distribution

As you can see in the figure 2, the efficiency curves is really dispersed and every diffuser is most efficient in different flow rates. We tried to combine the diffusers built to the table to maximize the efficiency for most of the flow rates, but make it easily adaptable for other sitting positions. Those conditions led us to combine one very efficient diffuser (VDG, or MP) and adaptable side panels for higher airflow (marked as PEM in previous figure).

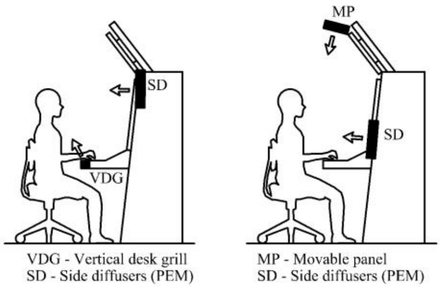


Figure 3 – design of diffusers position

4. Thermoelectric heating and cooling

The other part of the system is possibility to change supply air temperature for every user, in the scale of approximately 5 ° Celsius to both sides. We tried to find a device, which can do both, the cooling, and the heating of supply air, and which is small silent and cheap enough to be built in every workplace. We have found Peltier module to be a satisfactory solution. Peltier module is device using thermoelectric effect which is transferring the heat from one side of the module to the other, making one side cool, and the other side really hot. The direction of the transfer can be easily change by exchanging poles of direct current source, so one device can be used for both energy supply. It hasn't any mechanical parts, so it's totally silent and in low power, it's also cheap enough. The only disadvantage is that it doesn't directly creates heat and cold, it just transform it from one side to other, so the energy of the other side have to be led away.

Another disadvantage is, that there is a difference between produced heat and cold. The electricity used for heat transfer from cold to heated side of the module produces heating by itself, so for the 70 Watts of cold, there is about 40 Watts of electricity, which means about 110 Watts of produced heat. If there isn't a well-balanced heat transferring system of the heat part of the module, whole body starts to heat up.

5. Physical model of personal ventilation system

a. Requirements

The design of the system is based operation and requirements of the specific building. The main specifications are:

- Underfloor distribution of supply air
- Acoustic comfort requirement, limiting the usage of mechanical elements and air velocity in pipes.
- High indoor air quality requirement and possibility to customize the microenvironment of the personal area.

b. Design of the personal ventilation system

The system of personal ventilation system is connected to the underfloor air distribution system, where is the only mechanical element of the system – ventilator for customization supply air flow rate. The middle part is the thermoelectric system capable of heating and cooling the supply air. One heat exchanger is in the ventilation pipe, heating or cooling the air distributed to the user and the second exchanger is outside the pipe, drain away the energy created on the other side of the Peltier module and disperse it in the separated place.

Whole system is controlled by personal control panel, placed in the user desk. User can change the air flow rate and temperature. Swapping between cooling and heating is done automatically by reversing the polarity of Peltier module input.

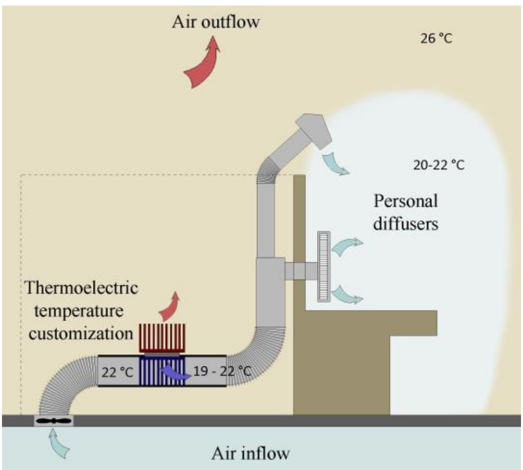


Figure 4 - main scheme of the prototype

c. Building of the first prototype

The first prototype is focused on the thermoelectric module and its effective control. It contains from the thermoelectric part with heat exchangers, main control box and personal control panel and it can be seen in the figure 5. The main device is installed on rectangular pipe with dimensions 110 x 55 millimeters. Peltier modules are controlled by devices, modifying the power input to maintain the stabile temperature. Temperature is set by potentiometers and measured by temperature probes, and setting off and switching between mods are through the three-position switch in this prototype. In the next prototype, there will be a linear control device to switch between mods automatically.

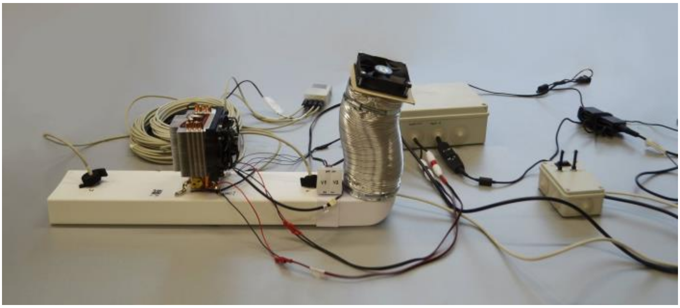


Figure 6 – the first prototype

6. Primary measurement of cooling and heating

The primary measurements were done by four temperature probes, set out as is shown in figure 6, and a power supply measuring device. The measurement was monitoring temperature change of the supply air, and the temperature of both exchangers. Ambient air temperature was 22 ° Celsius, and flow rate was approximately 35 cubic meters per hour. And Peltier module power input was 40 Watts. Measurement was done in one hour measuring cycles and with both cooling and heating modes. The goal of the measurement was to find out the maximum temperature difference of the two mods, and ability of control devices to maintain stable output temperature and time needed for temperature change.

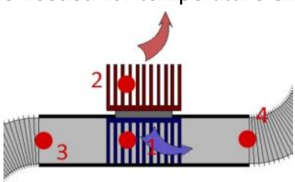
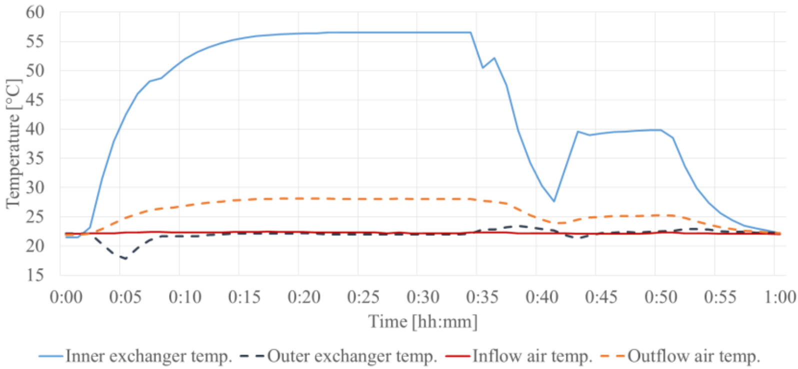


Figure 7 – teperature probes layout

a. The first mode – heating, graph 1

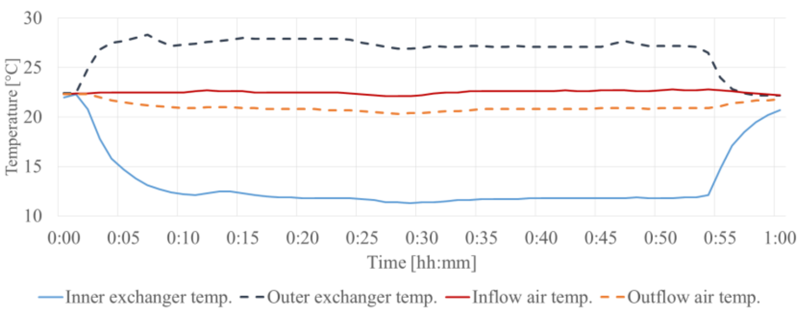
System was started after temperature stabilization at second minute of the measurement and after 15 minutes it reached the maximum, with 5 ° Celsius difference between inlet and outlet air. At 0:37, the system was lowered to minimal till the 0:42, when temperature was set to 25 ° Celsius of supply air. We can see, that reaction of the system is quite fast and able to adapt to new conditions, but temperature difference could be higher.



Graph 1- heating mode

b. The second mode – cooling, graph 2

In the second graph we can see, that the capability of cooling is much lower, than heating. Maximum temperature difference with the same supply power is only the one third of difference in heating mode. So the cooling mode should be the one the system should be projected for. In the ideal case, the cooling system should lower the temperature at least for 6 °Celsius.



Graph 2 – cooling mode

7. Conclusion

Personalized ventilation is the great opportunity to improve the indoor air conditions for every person, especially in open space offices. It can reduce the illnesses and make the users more satisfied with their surrounding environment, which leads to better productivity and focus on work. Though the personal systems is more expensive, than central ventilation, it can repay the cost back with efficiency and energy saving.

The most of the systems of personalized ventilation are focused to distribute fresh air directly to the user, but there is a possible solution to more ways of customization. Our prototype is capable to heat up or cool down the air, to create more comfortable environment for the user. There is still a lot of work and research to make it efficient and economic enough to find its place in practical usage.

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