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MODERN METHODS OF THERMAL COMFORT MEASUREMENTS

NOWOCZESNE METODY BADAŃ KOMFORTU CIEPLNEGO

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Abstract

The issue of thermal comfort and its subjective feelings inside a building is becoming more and more important in the modern world. It is caused by the desire to create optimal conditions in places where people stay. The article presents two methods, indirect and direct, which are typically used in the research projects. These methods enable to assess the thermal sensations of people and compare the feelings of the respondents with the value of PMV (the value of human thermal sensations) calculated using the formula from the ISO 7730 standard and the questionnaire surveys.

Keywords: thermal comfort, measurement methods, PMV

Streszczenie

Zagadnienie komfortu cieplnego oraz jego subiektywnych odczuć wewnątrz budynku staje się coraz ważniejsze we współczesnym świecie. Spowodowane jest to chęcią stworzenia optymalnych warunków w miejscach przebywania ludzi. W artykule przedstawiono dwie metody, pośrednią oraz bezpośrednią, które powszechnie stosuje się w badaniach. Metody te umożliwiają ocenę wrażeń cieplnych ludzi i porównanie odczuć osób ankietowanych z wartością PMV (wartością wrażeń cieplnych człowieka) obliczoną za pomocą wzoru z normy ISO 7730 z danymi z kwestionariuszy.

Słowa kluczowe: komfort cieplny, metody pomiaru, PMV

1. INTRODUCTION

Nowadays, man spends most of his life and time in closed rooms. That is why it is so important to create such a microclimate that every person in a given room feels thermal comfort. The definition of thermal comfort is, above all, the pursuit of the best possible conditions to meet the constantly growing needs and thermal requirements of humans. Thermal comfort or its lack (discomfort) is responsible for well-being or bad mood, for increasing or decreasing concentration or work efficiency – these factors contribute to the use of appropriate heating and air conditioning devices at the stage of design works or in the modernization of existing buildings with the use of appropriate building materials. In research on the comfort of heat, parameters such as air temperature, air flow velocity, light intensity, humidity in the room, carbon dioxide (CO_2), temperature a black ball, resistance of heat flow through conduction via clothing (in 'clo') – what the subjects are wearing at the moment [1-3]. This is not the first time that research on thermal comfort has been conducted in educational buildings (including Kielce University of Technology). In 2019, 16 people took part in such a study. For 75% of respondents, the temperature in the room corresponded, for 18.75% the temperature was still acceptable, and for 6.25% of the respondents the temperature was definitely unacceptable. It was also concluded from the questionnaires that 13 people would not want to change the temperature, 2 people would like the temperature to be higher, and 1 person

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would prefer it to be cooler. The value of PMV calculated by means of the questionnaires was 0.13, and PMV calculated with a special calculator based on the PN EN ISO 7730 [4] standard, the value was -0.08. Both of these scores ranged from -0.5 to +0.5. Based on the research, it was found that the respondents felt thermal comfort [5]. In 2020, a total of 98 people, from three classrooms, aged 19-23 participated in the study. The research concluded that the PMV calculated on the basis of the questionnaires, and the PMV calculated from the formula, differ from each other, which confirmed the importance of using appropriate thermal conditions [6].

2. MEASUREMENT METHODS

Comfort measurement methods can be divided into direct and indirect. For the direct method questionnaires are used to determine the thermal sensations of people in a given room/building. Often three questions about thermal sensations are asked: is the temperature comfortable or unpleasant during the period; whether it was too hot or cold, and whether the test person would like it to be warmer, unchanged or cooler. Moreover, two questions regarding the air humidity in the room are provided: whether it was too humid, moderately or to dry and whether the respondent would like to change the air to be more humid, drier or whether to leave it unchanged. Other questions might deal with lighting of the room and others regarding for example physical activity of people who fill those questionnaires in (whether the examined person performer intense or moderate physical exertion, walked or was in a state of rest within given time before coming to the study room). A different set of questions dealt with air quality, about the person's well, clothing and etc. Based on this information the people can be assessed regarding their direct thermal responses. The indirect method uses the ISO 7730 standard. This standard provides the formula by which the PMV value is calculated. This value is responsible for the predicted average rating of the study group. To perform the necessary calculations to obtain the PMV you need to measure room temperatures, humidity, air velocity.

During the measurements the microclimate meter is located in the center of the room. It collects the data from the probes. Figure 1 presents the meter that records the parameters during an example test (probes described in the picture).

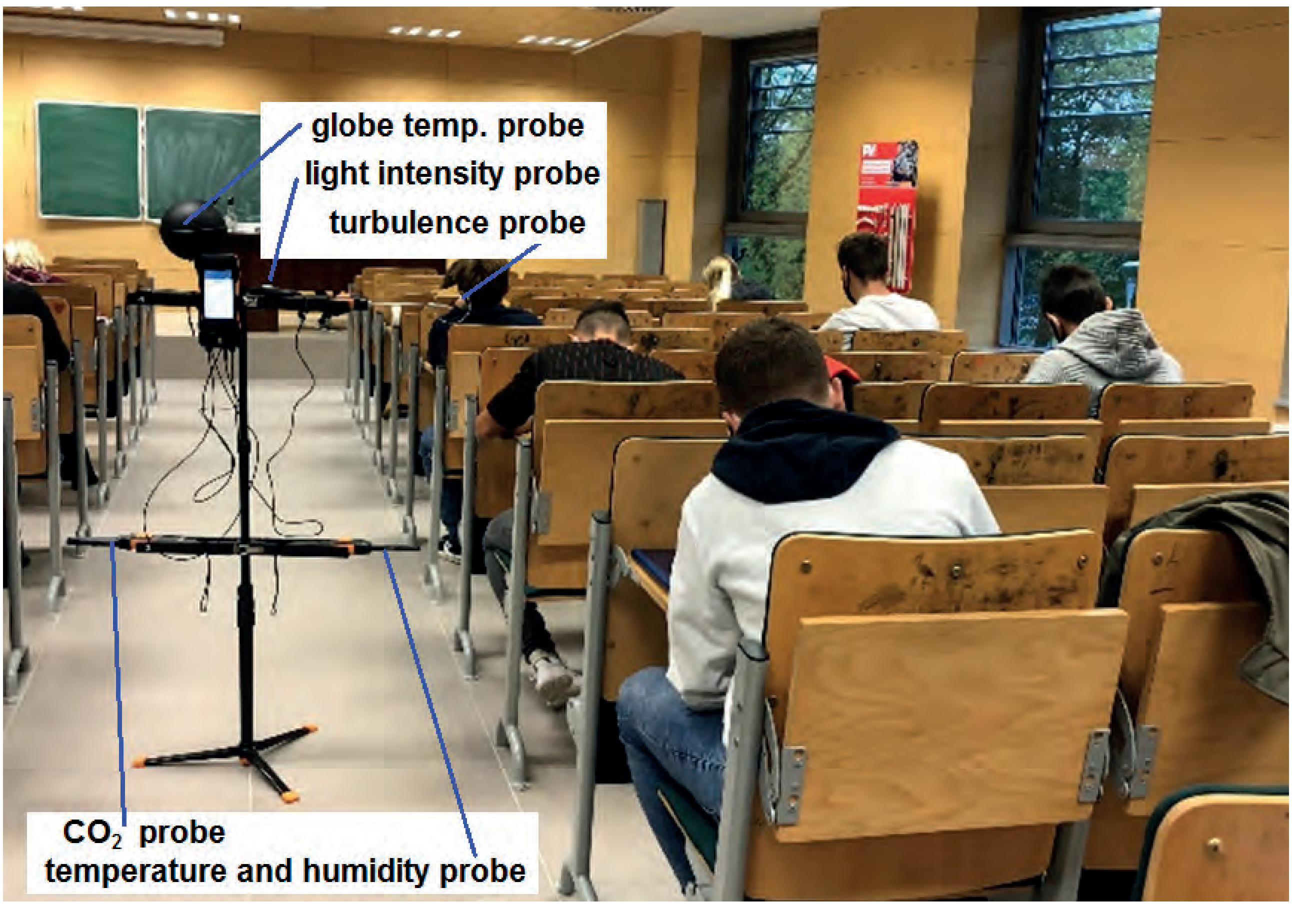

Fig. 1. The measuring station

environment

After switching on the microclimate meter all the measurements obtained had to stabilize within 15 minutes in order to show the accurate results of the parameters of the internal environment of the tested room climate. In the meantime, the surveyed persons complete the questionnaires. Figure 2 presents the view of the meter from Figure 1. Although the data are stored within the device, the current parameters (e.g. of temperature, pressure, light intensity, humidity, etc.) are visible on the screen as shown in Figure 2.

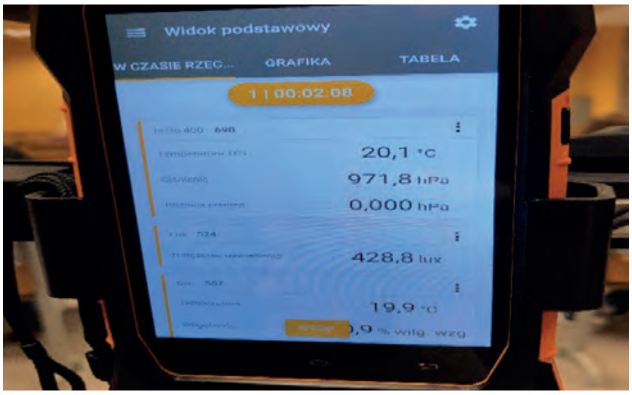

Fig. 2. The screen of the meter from Figure 1 with current data

3. TEST RESULTS OF THE QUESTIONNAIRE SURVEY IN THE SELECTED ROOM

The room selected for the test has a mechanical ventilation system with permanently programmed microclimate parameters. The touchscreen on the wall enables the programming of the air temperature and lighting level (which is usually conducted by a teacher). The values obtained by the meter during an example study of thermal comfort presented in this chapter are as follows:

- Air temperature – 29.40°C;
- Globe temperature – 28.97°C;
- Air velocity – 0.19 m/s;
- Relative humidity – 51.90%;
- Mean radiant temperature – 28.61°C.

14 people participated in the present study, aged from 19-26 years. They were asked to fill in the questionnaires containing a number of questions. Unfortunately, four questionnaires were rejected due to the lack of response to one questionnaire, not specifying their health condition, and practicing vigorous exercise prior to the study. It is quite important because the state of health e.g. a cold and performing intense exercise before the test, may disturb the actual perception of the prevailing conditions of the internal environment by the respondents. Consequently, the analysis included 10 correctly and fully completed questionnaire forms, which made it possible to learn about the preferences of the respondents regarding the conditions in the room under study. It needs to be mentioned that because of high temperature (the tests were carried out in the month of June) the respondents wore light summer clothes. The clothing thermal isolation (clo) for this group it was 0.62. Figure 3 shows the thermal sensations of the respondents as provided by them in the forms.

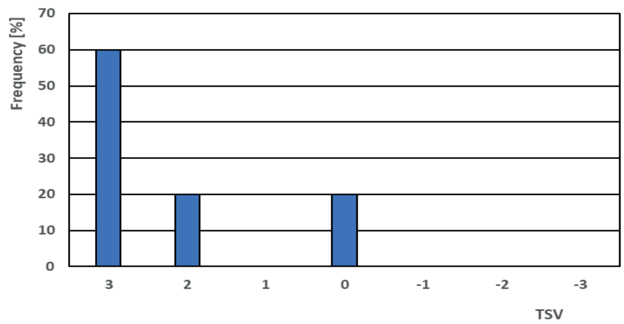

Fig. 3. Frequency of answers on thermal sensations (Thermal Sensation Vote): 3 – Too hot, 2 – Too warm, 1 – Pleasantly warm, 0 – Comfortable, -1 – Pleasantly cool, -2 – Too cool, -3 – Too cold

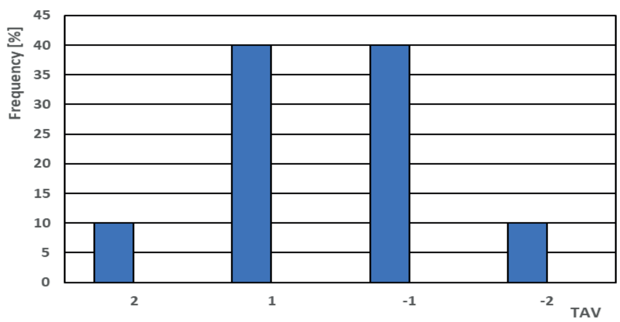

Fig. 4. Frequency of answers on temperatures felt by the respondents (Thermal Acceptability Vote): 2 – Comfortable, 1 – Acceptable, -1 – Unpleasant, -2 – Definitely unpleasant

As can be seen, for 60% of people, the room conditions are too hot, which is the result of high temperature (above the comfort level of most people). 20% of people think it is „too warm". Together, these people constitute 80% of the dissatisfied group regarding the microclimate of the considered room. Only 20% of people feel thermal comfort. Using a calculator to calculate the PMV according to the ISO 7730 standard, the PMV was calculated to be 0.96 [7]. For 6 people who answered "too hot" in questionnaires, the PMV was 2.20. There is a significant difference between the responses of the respondents and their PMVs and the PMVs calculated using the ISO 7730 standard. In Figure 4, the analysis of the respondents' opinion describing their feelings about the temperature in the room is presented.

Only 10% of people described the room temperature as comfortable, and 40% of people as still acceptable (this votes can be considered as positive responses). The temperature in the room was considered unfavorable by 40% of respondents, and absolutely unacceptable by 10% of the respondents. Such a high level of the unhappy people should be avoided (according to the standard PN EN ISO 7730). Figure 5 shows the thermal preferences of the study participants to the prevailing temperature in the considered room.

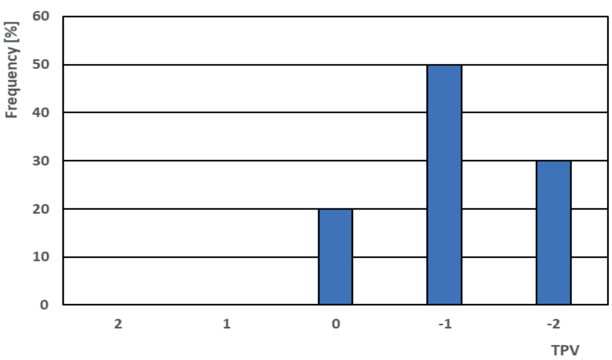

Fig. 5. Frequency of answers on thermal preferences vote: 2 – Definitely warmer, 1 – Warmer, 0 – No change, -1 – Cooler, -2 – Definitely cooler

20% of respondents would not like to change the air temperature (they seem to be satisfied with the indoor conditions in this room). Contrary to 50% of people who would like it to be cooler (this group is the largest, which is not surprising after the analysis of Figure 3). Only 30% of respondents would like it to be definitely cooler. The assessment of air humidity by the partcipants of the study has also been carried out with the application of the questionairres and is presented in Figure 6.

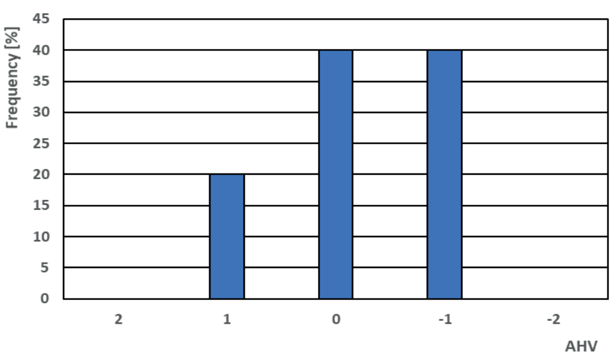

Fig. 6. Frequency of answers on assessment of air humidity vote: 2 – too humid, 1 – quite humid, 0 – pleasantly, -1 – quite dry, -2 – too dry

20% of people think that the room, in which they are located, is quite humid. 40% of respondents consider the air humidity in the room to be pleasant, which means that the conditions in the room suit these people. 40% of the group said it was quite dry in the classroom. Thus, it is difficult to make any conclusions about this parameter and its impact on thermal comfort within this group. Figure 7 shows the individual preferences of the surveyed people regarding the humidity in the room.

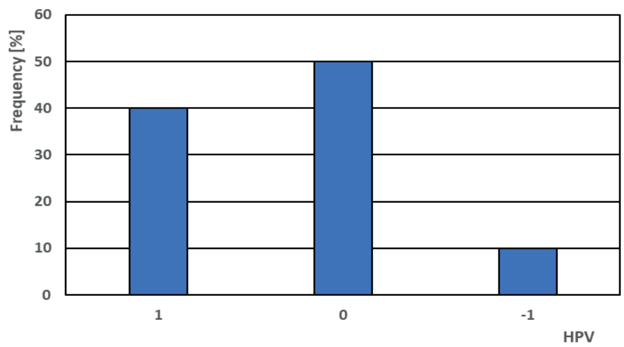

Fig. 7. Frequency of answers humidity preferences vote: 1 – more humid, 0 – no change, -1 – more dry

50% of the group would decide to change the air humidity (if they could, but the air management system does not allow such a modification of indoor air parameters). 40% express the view that it should be more humid and 10% of the respondents that it should be drier. The other half of the group would not change the humidity in the room. Maybe they could not make proper assessment of the humidity level and decided to leave it unchanged.

4. CONCLUSIONS

On the basis of the performed test of thermal comfort in the chosen room in which the air temperature was 29°C and where ten people expressed their anonymous opinions, it could be concluded that the temperature in the room did not suit the participants and that this parameter was by far the most important one in the assessment of thermal sensations. 80% of respondents considered that it was too hot or too warm there. This is the key information to conclude that the parameters set for the ventilation system's operation, without the possibility of changing these values easily, did not meet the thermal expectations of people staying in the studied room.

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