Thermal comfort tests in the selected building in Poland

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Abstract. The article focuses on research on thermal sensations, thermal preferences and thermal sensations vote. The analysis was made on the basis of examining 6 lecture halls in the "Energis" didactic building of the Kielce University of Technology. Air temperature, relative humidity, black sphere temperature, carbon dioxide concentration and air velocity were measured in the tested rooms. There were also surveys concerning thermal impressions prevailing in the lecture halls. On the basis of the answers obtained by the respondents, charts were drawn up regarding thermal sensations, the assessment of air humidity and thermal preferences. It was found that most of the respondents did not feel well in the conditions in which they were staying. Providing users with the right thermal conditions has a significant impact on their health, productivity and well-being.

1 Introduction

Thermal comfort is a state in which a person is satisfied with the prevailing conditions. Nowadays, we spend most of our time indoors. When studying or working in closed rooms, we want to feel comfortable in them. The concept of thermal comfort is becoming more and more common. Thermal sensations are a biased concept. Adequate conditions should be provided for as many people as possible so as to guarantee a state of indifference in which it is neither too cold nor too warm. Inappropriate conditions in the room may lead to illness and fatigue, which in turn will result in lower work efficiency. When the room is too warm, the users do not feel thermal comfort. This means that energy is wasted. Therefore, it is important to ensure the comfort of users, because they are then more productive and at the same time we save energy. Well-being in the workplace allows you to increase the effectiveness of the tasks performed, improve the quality of services offered and reduce the risk of an accident at work.

Many scientists are involved in research on thermal comfort and factors influencing the change in thermal sensations, however the basis for current thermal comfort tests were laid by O. Fanger in 1970s, who also proposed his thermal comfort model [1, 2, 3]. Indraganti et al. [4] analysed the thermal comfort in office buildings and observed that the calculated PMV (Predicted Mean Vote, describing the thermal assessment of room occupants) indexes are much greater than the actual perceptions of room users. Jazizadeh et al. [5] on the basis

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of research carried out in office buildings, they concluded that air temperature has the greatest influence on thermal comfort. Studies by Luo et al. [6] postulate that thermal comfort is significantly influenced by an increase in the metabolic rate. On the other hand, the authors [7] indicate that air temperature and relative humidity have the greatest influence on thermal sensations. Aghniaey et al. [8,9] conducted a study on thermal comfort at a university campus in the United States. The research included parameters such as air temperature in the room, relative humidity, air velocity, carbon dioxide concentration and the average radiation temperature. Their research shows that the calculated PPD values are greater than the actual results from the surveys. In the article [10] the authors dealt with research on thermal comfort in 25 air-conditioned buildings. Their research shows that the ISO 7730 standard for calculating PMV does not assess the actual feelings of the respondents. Manu et al. [11] presented the Fanger model for office buildings and showed the differences between the survey results and the Fanger model. Mors et al. [12] indicated significant differences between the actual feelings from the questionnaires and the PMV determined by the standard. The authors [13] came to similar conclusions and indicated the discrepancy between the actual feelings and the results of the PMV index calculations. In Polish climatic conditions, studies on air quality and thermal comfort are carried out by the author [14] and co-workers [15-17].

The article presents a study of thermal sensations in the educational building “Energis” of the Kielce University of Technology. The aim of the study was to analyse the thermal comfort according to the respondents in this intelligent building. Such studies are not very common due to the very limited number of intelligent buildings. Moreover, the pandemic times and online work and education result in a limited number of tests throughout the world.

2 Material and method

The research on thermal comfort was carried out from May to June 2021 in the teaching building “Energis” of the Kielce University of Technology. The research was carried out in 6 lecture halls. Each of the tested rooms has access to an individual temperature setting. The building is equipped with a mechanical ventilation system and air conditioning. The outside temperature ranged from 22°C to 27°C. The study was conducted using two methods. The first was to measure air parameters. Specialized equipment for reading microclimate parameters was used for the tests. The Testo 400 meter collected information about the microclimate conditions in the room from probes mounted on a tripod. Parameters such as air temperature, air velocity, relative humidity, CO_2 concentration and average radiation temperature were recorded. The Testo 400 measuring instrument is shown below.

Fig. 1. Test stand with a Testo 400 microclimate measuring device.

The air velocity was measured using an anemometer marked as “1” in Fig. 1. Its accuracy of air movement measurements is +/- 0.03 m/s. The average radiation temperature was tested with a black sphere, marked as “2” in Fig. 1. The measurement error is +/- 0.3°C. Air temperature and relative humidity were measured using a hytherograph, in the figure the probe was marked as “4”. The air temperature was measured with an accuracy of +/- 0.3°C, and the accuracy with which the relative humidity is given is +/- 2%. The CO_2 concentration is measured by a special probe, marked “5” in Fig. 1, with an accuracy of +/- 50 ppm. All probes were placed on a special stand and then connected to a multifunction meter, marked “3” in Fig. 1. Values of the parameters tested were read after 15 minutes of stabilization of the parameters. At the same time, people staying in the examined room filled in an anonymous questionnaire. This is the second method that deals with the thermal sensations of the microclimate.

The study involved 75 people aged 19 to 28, including one man aged 41. The respondents were asked to provide answers about their feelings and expectations regarding the thermal conditions in the tested room. This study allowed for the assessment of thermal comfort. Additionally, the survey asked about the type of clothing they are currently wearing. On this basis, the level of clothing insulation was determined together with the thermal resistance of the office chair (0.1 clo). At the very end of the questionnaire, there was a record with information on the sex, age, height and weight of the respondents. The questionnaire also included a question about the health of the respondents. If someone answered “yes” and “I don't know”, the questionnaire was rejected due to the thermal feelings of the sick, which are not reliable.

3 Results and discussion

The research carried out in the “Energis” building of the Kielce University of Technology was carried out in 6 lecture halls. A total of 75 people took part in the research, including 26 women and 49 men. The chart below shows the frequency of responses to thermal sensations vote according to the respondents.

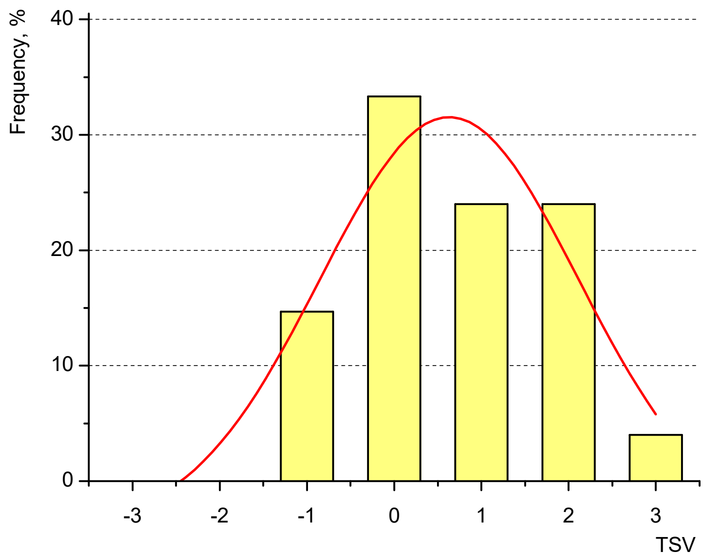

Fig. 2. Assessment of thermal sensations vote (TSV) based on questionnaires: “-3” - too cold, “-2” - too cool, “-1” - pleasantly cool, “0” - comfortable, “1” - pleasantly warm, “2” - too warm, “3” - too hot.

From the research on thermal sensation it was noted that the answer “comfortable” was the most frequently given answer. It amounted to 33.33% of all the answers provided. The students then answered “too warm” and “too hot”. Both of these responses were 24.00% each. The answer “pleasantly cool” was repeated 11 times, which is 14.67% of all respondents. The least chosen option was the answer “too hot” and it amounted to 4.00%, i.e. three respondents out of 75 were too hot. The Gauss curve was also marked on the presented graph. It represents the distribution of normal. Looking at all the answers provided, it can be concluded that the respondents did not feel well in the rooms studied. PPD “predicted percentage of dissatisfied” defines the percentage of people dissatisfied with the thermal conditions in a given room. For public buildings, the PPD is up to a maximum of 10.00%.The percentage of selecting “-3” - too cold, “-2” - too cool, “2” - too warm, and “3” - too hot was greater than 10.00%. The PPD for this study was 28.00%, this means that there was no thermal comfort in the examined rooms. As you can see in the chart above, it can be concluded that most people in the building feel excessive and pleasant warmth. It is probably caused by the season of high air temperatures ranging between 22°C-27°C. The next figure (Fig. 3) shows the percentage assessment of the temperature in the rooms tested.

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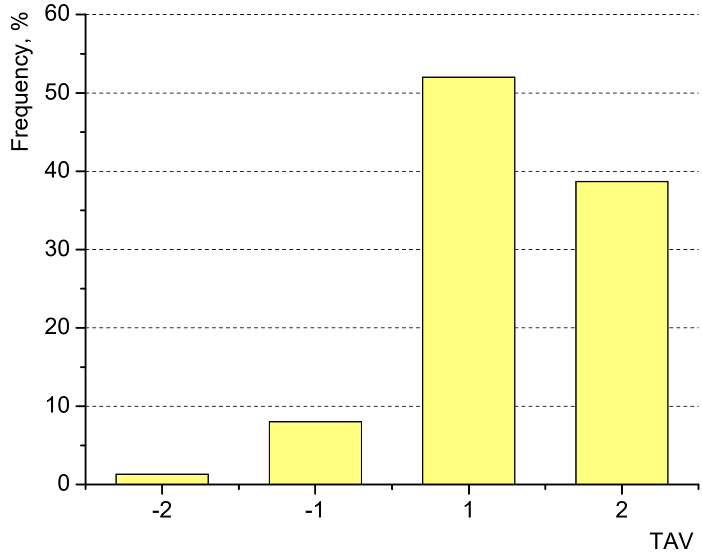

Fig. 3. Assessment of thermal acceptability vote (TAV) based on questionnaires: "-2" - definitely unpleasant, "-1" - unpleasant, "1" - acceptable, "2" - comfortable.

The vast majority of respondents chose the answer "acceptable" - 52.00%, that is 39 out of 75 respondents. The answer "comfortable" was assessed by 29 people, or 38.67% of the people participating in the study. 6 people marked "unpleasant", which is 8.00% of all respondents. Only one person chose the answer "definitely unpleasant", which is equal to 1.33% of the respondents. The temperature in the rooms ranged from 23°C to 25.2°C and the air velocity was from 0.05 m/s to 0.08 m/s, which reflects the respondents' assessment of the current temperature as comfortable and acceptable (Fig. 4). The next figure shows expectations for room temperatures.

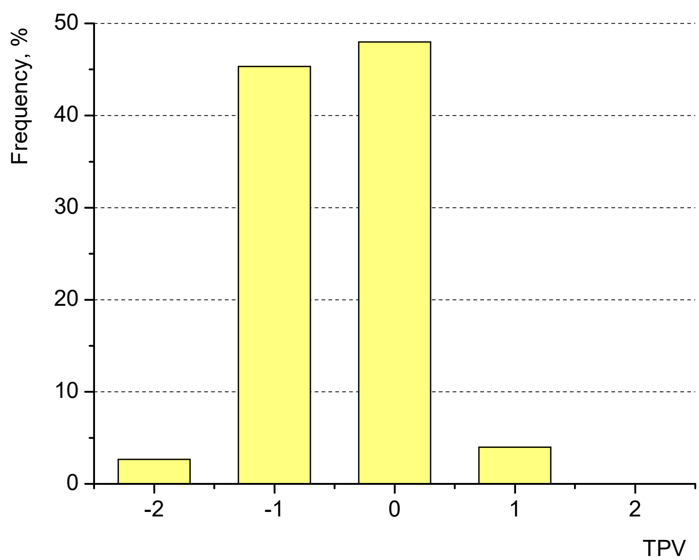

Fig. 4. Assessment of thermal preferences vote (TPV) based on questionnaires: "-2" - definitely cooler, "-1" - cooler, "0" - unchanged, "1" - warmer, "2" - definitely warmer.

When asked about the expected temperature conditions in the rooms surveyed, the majority of respondents, 36 out of 75 (48.00% of all respondents) admitted that they would like the room temperature to be “unchanged”. 34 out of 75 people, or 45.33%, said that the temperature in the rooms should be much lower. Three people from among the respondents considered that the temperature in the rooms should be “warmer”. On the other hand, 2 people said that the room should be “definitely cooler”. During the tests, air humidity was also determined. The diagram below (Fig. 5) summarizes the respondents' responses regarding the assessment of humidity in the tested rooms.

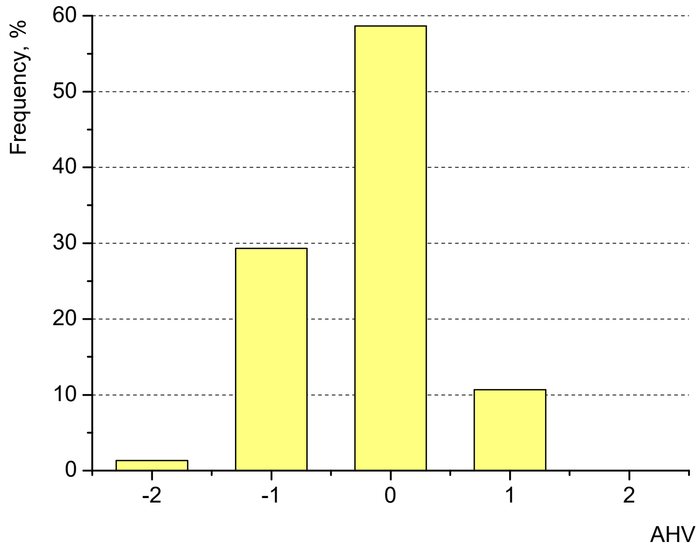

Fig. 5. Assessment of air humidity vote (AHV) based on questionnaires: “-2” - too dry, “-1” - fairly dry, “0” - pleasantly, “1” - quite damp, “2” - too humid.

When assessing indoor air humidity, more than half of the respondents (58.67%), i.e. 44 out of 75, considered the current conditions pleasantly. For 22 people, or 29.33% of the rooms, it was fairly dry. However, for 8 respondents it was “quite damp”, that is for 10.67% of all people. For one person, the prevailing conditions were “too dry”. From the chart above, it can be seen that the respondents were satisfied with the current air humidity, assessing it as pleasant. Relative humidity was measured at the level from 34.5% to 49.7%. The graph (Fig. 6) below shows the expectations of the respondents in terms of air humidity.

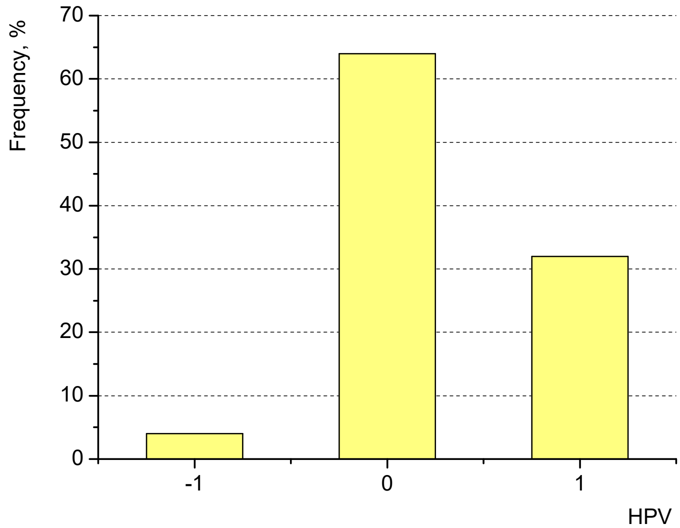

Fig. 6. Assessment of humidity preferences vote (HPV) based on questionnaires: “-1” - more dry, “0” - no change, “1” - more humid.

The chart above shows the expectations of the respondents in terms of air humidity. A preference for increasing indoor humidity was expressed by 24 people, i.e. 32.00% of all respondents. In turn, 3 people declared that there was less humidity in the rooms. On the other hand, more than half of the respondents, i.e. 48 respondents - 64.00% said that they would not like changes in humidity. When analysing the chart above, it can be seen that the respondents do not want changes to the air humidity in their rooms. The research conducted by Krakowiak and Krawczyk [19] presented the expectations of the respondents regarding air humidity. The vast majority of respondents prefer to have a higher relative humidity in the rooms, which was 53.15%. Figure 7 shows the dependence of TSV on the temperature preference for all rooms.

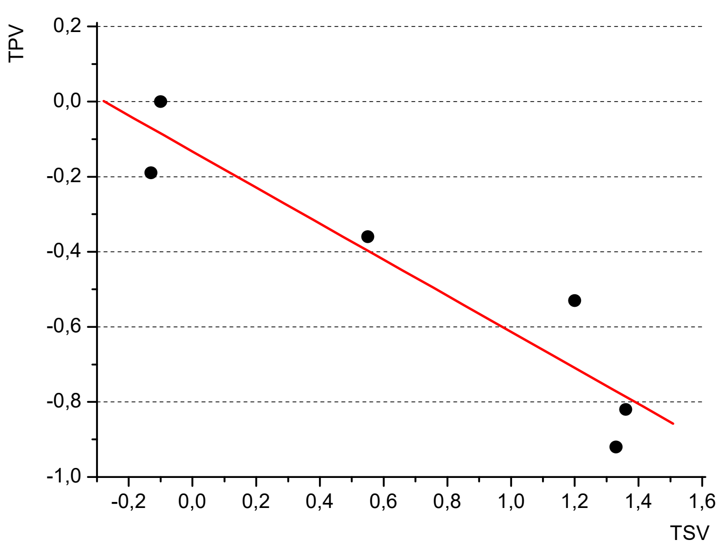

Fig. 7. Diagram of TSV dependence on temperature preferences for the tested rooms.

The graph above (Fig. 7) shows the dependence of the average assessment of thermal sensations vote on the temperature expected by the respondents. From the data contained therein, it can be concluded that the respondents definitely prefer a cooler room temperature. Comparing with the results published in the article [20], the respondents prefer a warmer environment and mostly found it comfortable in the temperature range from 19.3°C to 20°C. People who are comfortable would like the temperature in the room to be unchanged. The majority of respondents feel the prevailing indoor heat, at the same time respondents overwhelmingly expected lower air temperatures.

4 Conclusions

The presented research on thermal sensations shows that the majority of the respondents did not feel well in the conditions they lived in. The percentage of selecting “-3”, “-2”, “2”, and “3” was greater than 10.00% and was 28.00%. Another confirmation that the respondents were not satisfied with the prevailing conditions is the average rating of thermal sensations vote. From 6 studies, as many as 4 reported an average TSV above +0.5 and -0.5. Comparing the TSV results with the temperature preference, it can be seen that the temperature has an influence on the thermal sensation. The respondents preferred lower air temperature values. Such an analysis of thermal comfort made it possible to state that most of the respondents felt the prevailing heat in the rooms, while the vast majority of the respondents expected a lower air temperature. Too high room temperatures may reduce the effectiveness of work and learning. Therefore, in public buildings, such as schools and universities, microclimate parameters should be stabilized. Such facilities should be equipped with mechanical ventilation and air conditioning. Providing room users with appropriate conditions is crucial for their health, well-being and productivity.

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