
THERMAL COMFORT ASSESSMENT OF ENGINEERING WORKSHOP: A CASE STUDY OF UNIVERSITY OF MAIDUGURI

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ABSTRACT

Thermal comfort has a great influence on the productivity and satisfaction of indoor building occupants. The exposure to excessive heat or cold during work may cause discomfort and contributed to low productivity among workers. Maiduguri, Borno State is known with its hot and cold condition during summer and hammattan weather respectively. Unimaid Engineering workshop had exposed to excessive temperature during summer and excessive cold during hammattan while working. The study investigates the thermal comfort level experienced by students at Unimaid Engineering workshop during hammattan season. The study had been conducted at the machining section, the foundry unit, fabrication section and engine section. The environmental factors examined were the relative humidity (%), air temperature and air velocity of the workshop area. The environmental factors were measured using Luton apparatus, which is capable of measuring simultaneously those mentioned environmental factors. Then thermal comfort of the workers was assessed using ASHRAE thermal sensation scale by using Predicted Mean Vote (PMV). Further, Predicted Percentage Dissatisfied (PPD) was used to estimate the thermal comfort satisfaction of the occupant. Finally the PPD versus PMV were plotted to present the thermal comfort scenario of students involved in the workshop. The trend of relative humidity curve from the graph also indicated the increasing level of discomfort. The air temperature observed seems slight variation during the study. The study revealed that the PPD value of 34% of the students' population at the workshop is likely to be satisfied with thermal comfort. In conclusion, the empirical study from the PPD and PMV index indicated that students working at this were influenced by the cold. The less of PPD value from 80% of the population satisfied with the thermal comfort showed the environment were not good for the students while the PMV index showed the area of work is very cold.

Key words: Thermal comfort, temperature, predicted percentage dissatisfied, predicted mean vote.

INTRODUCTION

"Thermal comfort can be defined as that condition of mind which expresses satisfaction with the thermal environment" as it was being defined by the

association of heating, refrigeration and air conditioning engineers (ASHRAE, 2005). The reference to "mind" indicates that it is essentially a subjective term; however, there has been an extensive research in this area and a number of indices has been developed which

can be used to assess environments for thermal comfort, (Parsons, 2000).

Though it is difficult to satisfy everyone in a space due to physiological and psychological variation from person to person, thermal comfort is still one of the most significant factors affecting environmental satisfaction (Noe" l, Rene, & Donatien, 2010). Furthermore, the 'feeling comfortable' was very subjective in nature and cannot be defined objectively.

Thermal comfort has a great influence on the productivity and satisfaction of indoor building occupants (Roberto, Oliveira, & Mendes, 2008). Thermal comfort is very difficult to define, this is because we need to take into account a range of environmental and personal factors when deciding on the temperatures and ventilation that will make feel comfortable. The best way we can realistically hope to achieve is a thermal environment which satisfies the majority of people in the workplace, or put more simply, "reasonable comfort" (Noe" l, et al., 2010).

There are five primary factors that may be addressed when defining conditions for thermal comfort. A number of secondary factors affect comfort in some circumstances. These may be independent to each other but they have collectively a great impact. The primary

factors (Environmental Factors) are: Air temperature, Air speed and Humidity. The Personal Factors are: Clothing/ insulation and metabolic rate

The primary concern during this development should be to make sure that the people in the building are happy and comfortable. In part, this means that they are not too hot or too cold. Though knowledge of thermal comfort conditions are for people and energy use of buildings, the best strategy can be adopted.

Based on the studies of Fanger (1986) and subsequent sampling studies (Alfano, Ianniello, & Palella, 2013; Gorgnati, Ansaldi, & Fillipi, 2009; Ogbonna & Harris, 2008; Singh, 2015), ASHRAE has defined a thermal sensation scale, which considers the air temperature, humidity, sex of the occupants and length of exposure. The scale is based on empirical equations relating the above comfort factors. The scale varies from +3 (hot) to -3 (cold) with 0 being the neutral condition. Then a Predicted Mean Vote (PMV) that predicts the mean response of a large number of occupants is defined based on the thermal sensation scale.

The PMV is defined by Fanger as:

$$PMV = [0.303 \exp(-0.036M) + 0.028]L \quad (1)$$

Where M is the metabolic rate and L is the thermal load on the body that is, the difference between the internal heat generation and heat loss to the actual environment of a person experiencing thermal comfort.

The thermal load has to be obtained by solving the heat balance equation for the human body.

Fanger related the PMV to Percent of People Dissatisfied (PPD) by the following equation:

$$PPD = 100 - 95 \exp[-(0.03353 PMV^4 + 0.2179PMV^2)] \quad (2)$$

Where dissatisfied refers to anybody not voting for -1, 0 or +1. It can be seen from the above equation that even when the PMV is zero (i.e., no thermal load on

body) 5% of the people are dissatisfied! When PMV is within ± 0.5 , then PPD is less than 10 %. Maiduguri is located within the latitude $11^{\circ} 50' N$ $13^{\circ} 09' E$ and longitude

11.83° N 13.50° E respectively of which the temperature is usually high around 36°C-46°C during the summer and around 24 – 28°C during the hammattan with relative humidity very low and air velocity between 0.6 - 4m/s. With such scenario it makes the occupant living in the zone thermally uncomfortable.

METHODOLOGY

Description of the Site (Study Area)

To determine the thermal comfort requirements, the study was carried out in university of Maiduguri engineering laboratory workshop as the selected case study. Maiduguri being for its location on the subtropical region of the north eastern Nigeria, receive an amount of radiation from the atmosphere. The laboratory was primarily used for the practical by the engineering students which are made up of different sections. The sections are machining section, the foundry unit, fabrication section and engine section.

In view of this, the paper will be concern with the means of providing acceptable thermal comfort conditions, improvement of occupants required ventilation in university of Maiduguri engineering laboratory workshop. Also, the study is for hammattan weather condition because of the extreme cold experience during the hammattan.

The present study took place at the various sections of the laboratory. Also, the students are seen in different groups during the practical exams at the workshop performing different task assigned to each of the various groups. Each group consist of five (5) students of which a metal work piece is being given to them to produce objects of varying shapes as seen in Figure 1.



Figure 1: Students producing a shape from work piece

The students are given various tasks to perform using the design procedure given to them. These tasks ranges from mounting of work piece on G-clamp, cutting of work piece, filling and drilling of the work piece. The measuring equipment for this study was

set up opposite to student close to Lathe machine which almost located to the centre of the workshop main area. The measurements start at about 10:00 am. As we have started the measurements, it was accomplished together with students filled in the questionnaire. Figure

2 illustrate the view of the laboratory workshop with the

students filling the questionnaire.



Figure 2: shows the students filling the questionnaire

MATERIALS/EQUIPMENT

The device for the measurement was the ABH-4224 model a multi inquisition is shown in Figure 3. This instrument is used to obtain values for air temperature, relative humidity, and air velocity. Also, for the subjective measurements questionnaire survey was given out.

Objective Measurements

The three environmental variables were measured using a comfort measurement system instrument (ABH-4224 Model). Measurements were taken at a height of 1.1 m above the floor, which represent the height of an occupant when seated. The parameters measured are air temperature, relative humidity, and air velocity. These Parameters were recorded at 1 (one) minute intervals. The Figure 3 shows the apparatus employed.



Figure 3: ABH- 4224 Model

Subjective Measurements

To evaluate the occupants vote on the thermal condition of engineering laboratory workshop, a questionnaire survey was given out. A total of 50 questionnaires have been issued to the students (occupants) to be filled. Having measured the environmental, the two personal parameters, metabolic rate and clothing insulation were estimated in accordance with ISO 7730 (2005) and ASHRAE standard-55(2013).

This subjective thermal comfort data were recorded using a questionnaire adapted from ASHRAE standard-55 (2013) questionnaire survey that is simple and designed to seek occupant input for the level, the frequency and the time of the thermal comfort problem as well as the general conditions of the thermal environment can greatly help in defining the pattern of complaints and distribution in terms of time and space.

In this study, the metabolic rate was set to be 1.996 which correspond to medium light activity (machine tool), whereas the Clo-value (thermal resistance of clothing) was set to be 0.8 where males wear t-shirts with short sleeve or long sleeve and some women wore native and others native with hijab.

RESULTS AND DISCUSSION

Figure 4, 5 and 6 show the variation of Air temperature, relative humidity and Air velocity with respect to the time of the day: from 10:00am to 4:00pm.

Assessment of thermal comfort in the workshop was based on the responses to a questionnaire survey, which was administered simultaneously with the physical measurements under both ventilations conditions.

The questionnaire developed for this survey is divided into five main sections: Demographic information, Seasons, Metabolic rate, Thermal sensation and Current clothing garments.

A total of 50 respondents participated in the survey and all of them are undergraduate students. The respondents in total consisted of 4 females and 46 males. Greater majority of the respondents (28) were between the ages of 21-26, while 12 were under 20 years, 10 participants were between 27 - 35 years. The total response rate was 100%. Prior to the survey, the subjects would have been seated at their chairs for some few minutes (Jung, Song, Ahn, & Im, 2011; Mishra & Ramgopal, 2014), undertaking mostly medium activities. Sufficient time needed to be allowed for body pre-conditioning in each survey to maintain respondent metabolic rate (M) at the same level throughout the study: as noted above this was estimated to be equal to 1.996. Also, it should be noted that the study was carried out during Hammattan period.

During the day the variation of the air temperature was between 25.0 to 27.0°C and relative humidity between 35 to 47% and air velocity between 0.6 to 1.0 m/s.

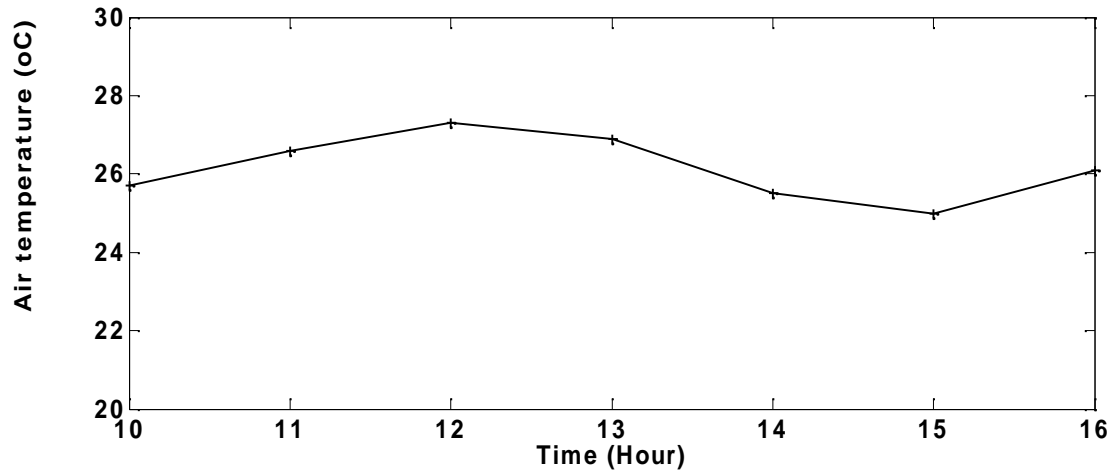


Figure 4: Variation of air temperature with time of the day

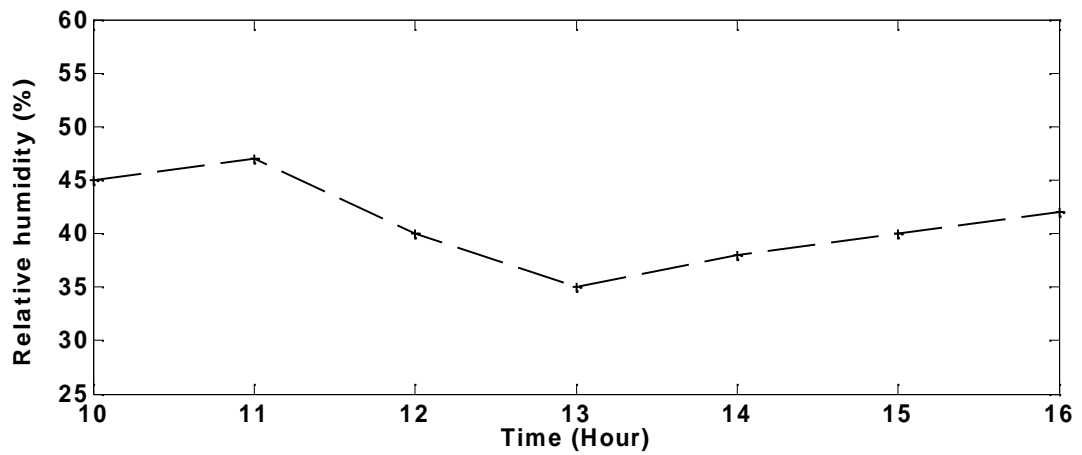


Figure 5: Variation of relative humidity with time of the day

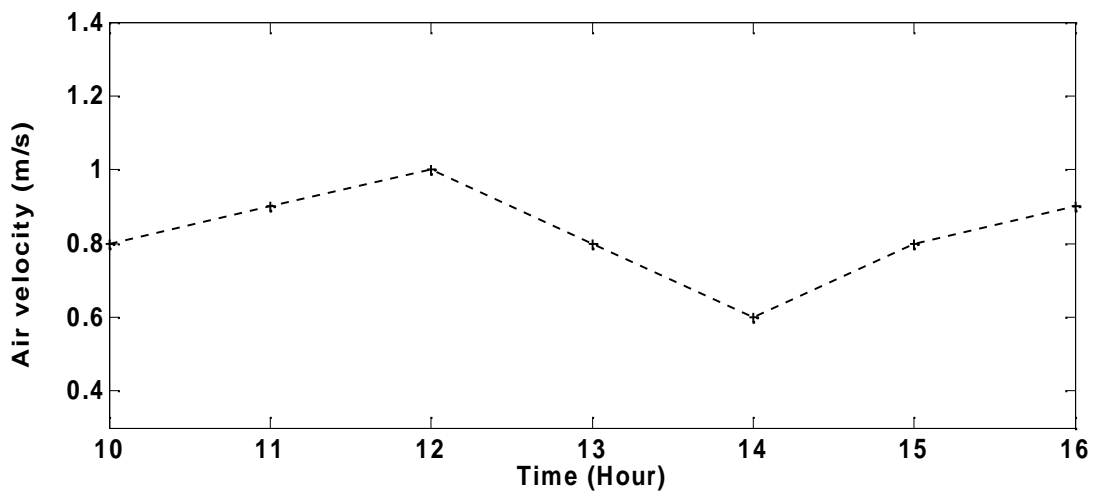


Figure 6: Variation of air velocity with time of the day.

Fig. 7 shows a summary of the PMV and PPD as one of thermal comfort index at Unimaid Engineering workshop. It measures the heat loss by radiation from the person. The value according to the clothes used was 0.8 Clo for short sleeves and light working trousers. The activity was moderate, rated with 1.996 met. The highest temperature measured was about 27.5°C. The humidity, which is due to the sub-sahara climatic condition during hammattan always very low, dropped to values below 40%. When the relative humidity reaches 35% the surrounding air take up more water which makes the air to be very dry. Clothing strongly modifies the comfort feeling in the workshop. In this study the management of the Engineering workshop had been advised to suggest a

Predicted Mean Vote (PMV) is one way to quantify the comfort achieved in a space. The PPD diagrams (Figure 7) clearly show a high ratio of people that are dissatisfied. The thermal comfort of students depends on their being an average skin temperature (resulting from the combination of climate, clothing and metabolic heat production).

relevant clothing index for their students to wear in order to avoid excessive cold among the students during hammattan. A spontaneous heating of the skin by shivering under these conditions that could overcome this cold is very difficult. The large heat pumps are very important for the students to ensure the heat exchange from the surrounding to their body by heat convection. The heat exchange would be very good with a relative humidity of 40% and below because there is not much water in the surrounding. However, the measured values of the relative humidity were low because the recommended relative humidity according to ASHRAE is 50-60%. The conditions were for sure uncomfortable for the students.

The thermal comfort assessment of the PMV index and PPD was not in the comfort zone. The PPD value is between 34 - 100%. That means the highest PPD in this workshop is 100%, and 44% are likely to be satisfied. These values of PPD are according to the clothes used was 0.8 clo for short sleeves and light working trousers. The activity was moderate, rated with 1.996 met.

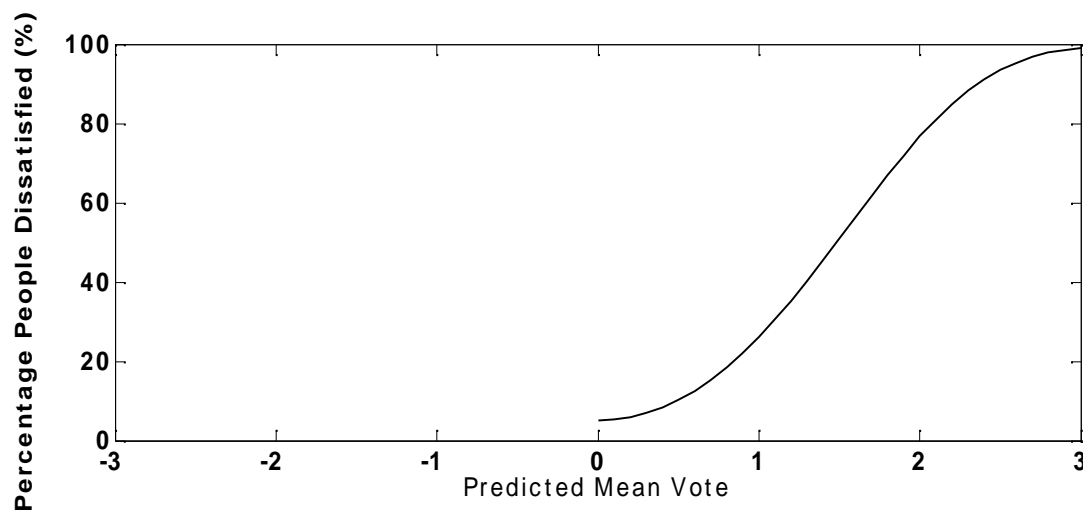


Figure 7: PPD as a function of PMV

CONCLUSION

From the results we can conclude that there exist, the strong interdependence among environmental comfort factors. Furthermore the previous survey study results that had been conducted prior than this study showed the in line finding from the PPD and PMV index. The PMV at the Engineering laboratory workshop is very cold. 34% are likely to be satisfied with thermal comfort at this workshop. The findings were also in-line with the theory of relative humidity, that is, ratio of the partial pressure of water vapor in the mixture to the saturated vapor pressure of water at a prescribed temperature.

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