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Development of an Integrated Thermal Comfort Assessment System (ITCAS)

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ABSTRACT: This paper presents the development of a computing system to determine the level of thermal comfort and productivity of employee in assembly industry automotive component. The PMV's index (Predicted Mean Vote) and PPD (Predicted Percentage Dissatisfied) was counted by using the Thermal Comfort Model created by using the Matlab software which is GUI (Graphic User Interface) based on ISO standard 7730. This calculation could only be implemented when all six of comfort factors namely relative humidity, air temperature, average radiant temperature, air velocity, metabolic rate and clothing. Data measurement was obtained through environment measurement in workstation which was chosen using EFM (Environmental Factors Multistation). The collected data was analyzed using Thermal Comfort Model created to determine value of PMV's index and PPD. The study found that, the environment is slightly hot, and their comfort is decrease with time working. The result shows, when PMV's index values increasingly distance from zero, so the productivity will decrease. From an equation model, the productivity for any workstation are able to predict based on PMV's value and PPD calculated by using Thermal Comfort Model.

KEYWORDS: PMV, PPD, ISO 7730, Environmental Factors, Thermal Comfort.

I. INTRODUCTION

Environmental conditions and heat balance in the human body plays an important role in the sensitivity to predict accurately the environmental factors that influence productivity in the work station such as humidity, intensity of sound, lighting, air temperature, thermal radiation, wind speed and the personal factors such as clothing and activities (Brager and Dear, 2001). Design the workplace environment is one of the factors influencing the development employee health and productivity rates (Olesen and Brager, 2004). In the discussion of the study, two basic categories to promote the productivity of workers, each of them have small differences in the design of the desktop environment of productivity ITP (Individual Task Performance), and productivity CTW (Collaborative and Teamwork) (R. Aynsley, 2007). From the study, 6% to 12% of workers in the central communication organization, increase of performance are faster when they have been exposed to the external environment, such as views from the windows and views over the area filled with the green plants. While the office staff by 10% and 25% had good improvement in mental state and memory, more memory than the limited view of the work environment (R. Aynsley, 2007). Therefore, the environmental factors in the workplace are very important in influencing an individual's comfort and health at work within an organization (A.R. Ismail et al., 2009). Thus ensuring the performance of employees and increase productivity that is expected by an organization to their employees (A.R. Ismail et al., 2009). The aim of the present paper is to develop Thermal Comfort Model based on ISO 7730 using GUI. A model perceived comfort when using EFM and relate to productivity at the workplace.

II. METHODOLOGY

Subject Selection

This study is at an automotive assembly industry sector which the company called Metal Industries Sdn Bhd, located in an industrial area Beranang, Semenyih. A component product called Body Switch was selected as workstations. The tools were used to measure called TCM (Environmental Factors Multistation). It was used to measure various parameters such as relative humidity, air temperature, mean radiation temperature, air velocity and environmental factors such as light intensity, noise and stress of the work environment studied.

Scope of Study

The measurements of the environmental factors are to determine the parameters by using equipment EFM (Environmental Factors Multistation). TCM tool is equipment used to make measurements of various parameters for determining the thermal comfort such as air temperature, mean radiation temperature, relative humidity, air velocity, pressure, sound and lighting rates. The value of PMV and PPD can be obtained through the Thermal Comfort Model parameters were determined according to the 10 minutes for each reading of data.

Method of Thermal Comfort Modelling

Figure 1 show the method of how the thermal model of produced to make the computation system of the value of PMV's index and PPD to determine the level of thermal comfort.

Data Analysis

The study will be conducted at the workstation at 9 am to 5 pm. During the study done, the measurement tools will be placed near the work station so that the data get are more accurate and does not interfere or obstruct the work done by the employees. Measurement readings are taken every 10 minutes for each reading. Data has been compiled to facilitate the reading of the PMV and PPD values obtained by using model parameters derived in this study. This data is compared with seven terms of the scale of sense from -3 to +3. The value obtained from the measurement and will be depicted inthe graph of the function of PMV and PPD. This can be determining the comfort level of employees.

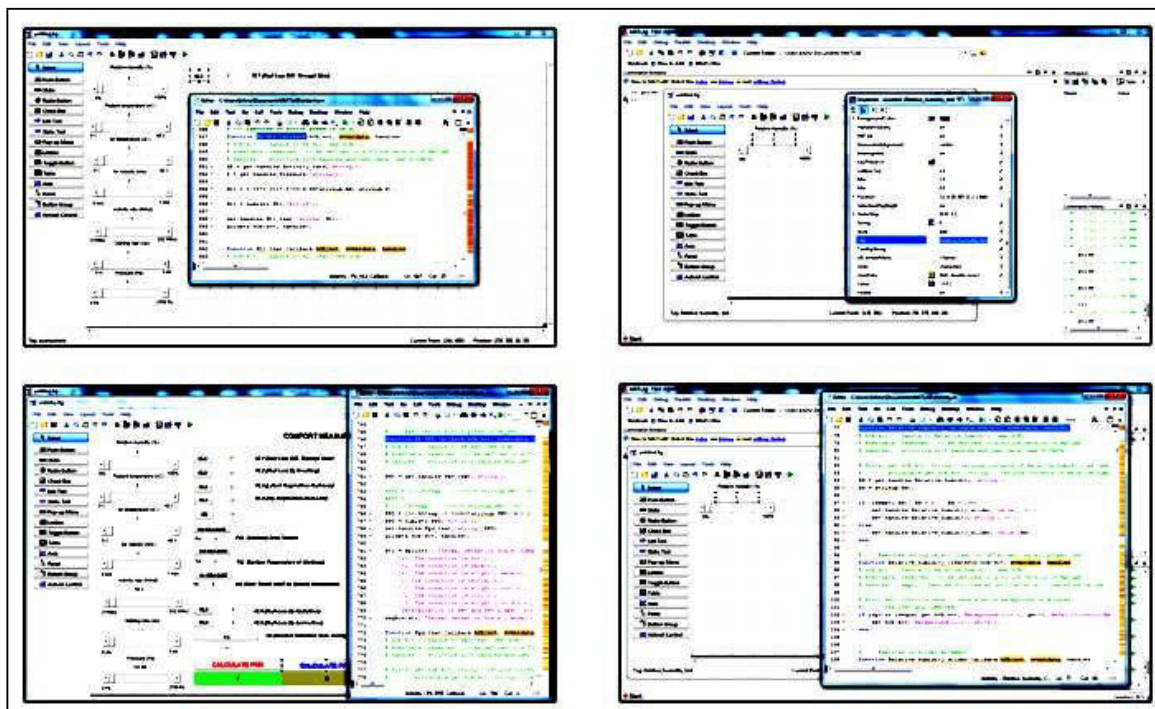


Figure 1: Thermal Comfort Model

III. RESULTS AND DISCUSSION

Measurements were done at a workstation called Body Switch. In the measurement of four environmental factors were recorded for each 10 minutes of relative humidity, air velocity, air temperature and average radiation temperature. In addition, the production rate for each work station for 10 minutes is taken and recorded in order to

get the rate of productivity for every 10 minutes. As for the measurement of personal factors was obtained through observations of employee activities and clothing worn by them. To determine the metabolic and clothing for workers who perform work on workstations should refer to the table in ISO 7730. The measurement is made is to test how the computation system do the calculation to obtain the PMV and PPD by using Thermal Comfort Model as showed in the Figure 2.

Analysis is carried out by using Thermal Comfort Model to calculate the value of PMV and PPD to determine the level of comfort working. The PMV and PPD values are refer to the standards in ISO 7730. The using of the index of PMV is between -2 and 2, while the six parameters are located in the following intervals in according with the standards of ISO 7730:

1. $M = 46 \text{ W/m}^2 - 232 \text{ W/m}^2$ (0.8 Met – 4.0 Met)
2. $I_{cl} = 0 \text{ m}^2 \cdot \text{°C/W} - 0.3 \text{ m}^2 \cdot \text{°C/W}$ (0 clo – 2clo)
3. $T_a = 10 \text{ °C} - 30 \text{ °C}$
4. $T_r = 10 \text{ °C} - 40 \text{ °C}$
5. $V_{ar} = 0 \text{ m/s} - 1 \text{ m/s}$
6. $P_a = 0 \text{ Pa} - 2700 \text{ Pa}$ Rh = 30% - 70%

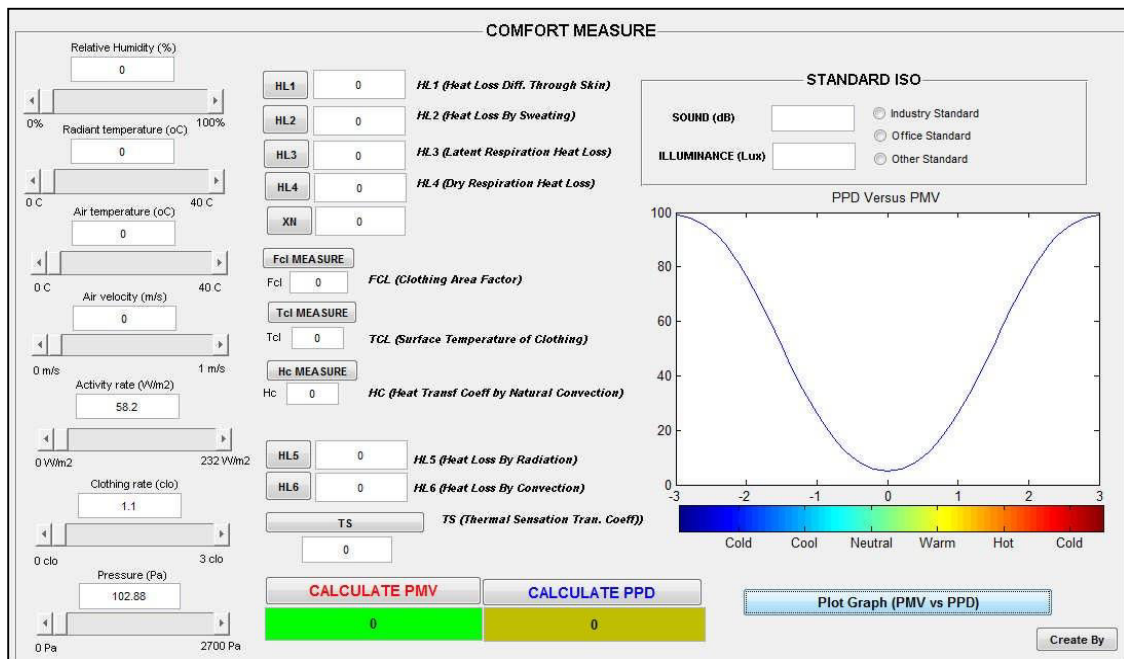


Figure 2: Thermal Comfort Model

Thermal Comfort Model is made by using the Matlab Graphic User Interface (GUI) for the model equation to allow the value of PMV and PPD values obtained. Selected activities are established, with the light activity metabolic rate is 58.2 Wm^{-2} or 1.0 Met and the clothing is 1.10 Clo or $0.170 \text{ m}^2 \cdot \text{k} / \text{W}$ consisting of trousers in long shorts, t- shirts shirt, socks and shoes. The data measurement and also graph relation between PMV and PPD showed in Figure 3.

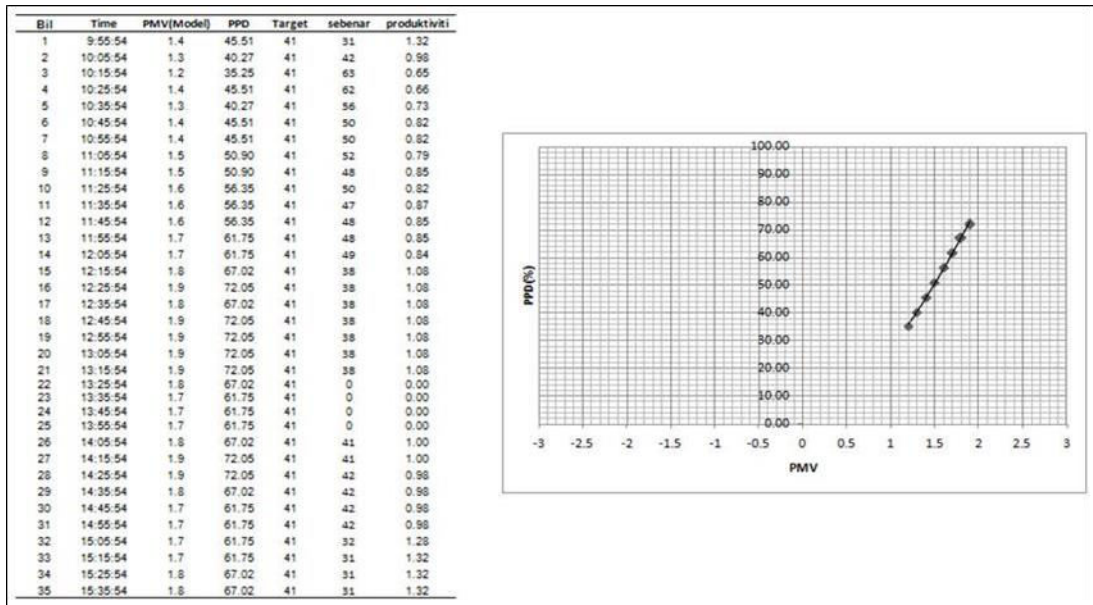


Figure 3: Data measurement and graph against PMV PPD

Figure 3 shows the PMV index for workstations Body Switch is from 1.2 to 1.9 and the percent for PPD is between 35.25% to 72.05%. The measurement data as shown in Figure 2 to perform calculations to obtain the PMV and PPD as well as for productivity in research to show the relationship between the PMV with productivity

Figure 4 shows the PMV and PPD index against time. It shows workers at the beginning of the work they feel comfortable because the temperature is moderately warm in the morning and eventually feel comfortable with the environment due to the increase of medium-hot environment of the hot conditions. PPD is a graph showing the same graph as the increase in the value of PMV PMV, the percentage of votes will also increase the discomfort. At the start of data reading is taken at 47.39% which is between the hours of 9:55 am to 11:45 am. While the figure is shown the highest percentage of PPD is between 72.05% of the 12:25 noon until 1:15 pm. While the air velocity also indicates which start with 0 m/s-1 until 0.07 m/s-1 at the end of the measurement. Moisture conditions in the morning showed 73.36% and then decreased to 72.75% while the moisture conditions at middle of day increased to 77.65% until the end of the measurement at 3.35 pm. The humidity condition is in the range 72% - 79%. This shows the work station is located in a warm environment to heat and discomfort to the worker. The data analysis is done to test how the computation system does the calculation to obtain the PMV and PPD by using Thermal Comfort Model.

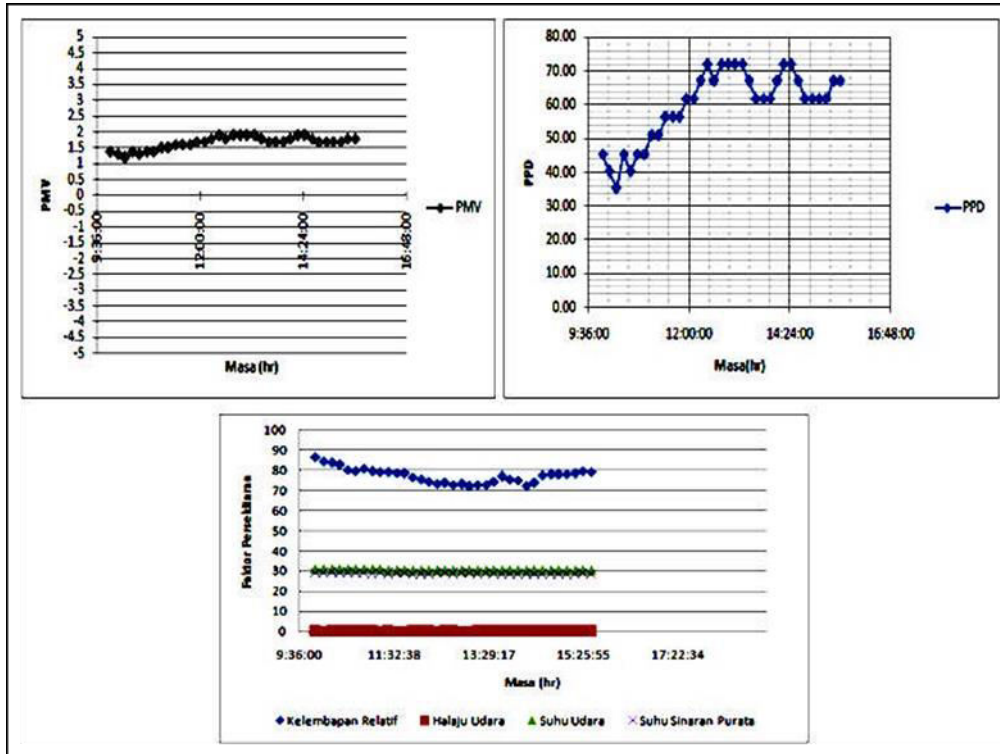


Figure 4: PMV, PPD and Environment Factors against Time

IV. CONCLUSION

The findings of this study showed that the PMV index and PPD can be computed by using Thermal Comfort Model which this value is important in providing the level of comfort in terms of actual production of automotive components industry. PMV is the value range between 1.2 to 1.9 are classified as warm conditions while PPD is the value is between 35.25% to 72.05%. With the range of PMV can be inferred that the working conditions studied were in the warm conditions, according to the terms of the scale of seven in the hot, neutral and cold. Besides that, the graph in the Figure 4 showed the relationship between Environmental factors, PMV and PPD of the index parameter mathematical model by using Thermal Comfort Model.

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