Penerbit Akademia Baru

Journal of Advanced Research in Fluid Mechanics and Thermal Sciences

Journal homepage: www.akademiabaru.com/arfmts.html
ISSN: 2289-7879

Saving Energy Costs by Combining Air-Conditioning and Air-Circulation using CFD to Achieve Thermal Comfort in the Building

Open Access

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ARTICLE INFO

Article history:
Received 20 August 2018
Received in revised form 23 November 2018
Accepted 4 January 2019
Available online 6 June 2019

ABSTRACT

In developed countries, a significant increase in energy consumption was seen in these several years due to the growing demand of HVAC system to achieve thermal comfort in the building environment. High energy consumption of HVAC system has been a major issue for buildings around us. ISO 7730 and ASHRAE Standard 55 stated that greater air flow is able to offset the increase of air temperature by lowering the chilled water temperature. Appropriate air speed and air temperature should be determined without affecting the thermal comfort of building occupants. The aim of the study is to investigate possible energy saving and cost savings in building with higher air temperature and greater air flow using CFD simulation without affecting the thermal comfort of building occupants. Different case studies were carried out to determine the ideal air speed and air temperature in different room models. PMV and PPD index were used as thermal satisfaction indicators to determine the thermal comfort of occupants in different indoor conditions. Experimental and numerical results were analyzed and ideal conditions were proposed based on the results. Potential energy savings up to 47.27% and annual saving of RM 4116.36 were obtained through the studies.

Keywords:
Air-conditioning; CFD; Thermal comfort; Energy saving

1. Introduction

In developed countries, building sector has the highest energy consumption compared to transportation and industry. According to Yang *et al.,* [1], around 42.5 % of the energy use worldwide consumed and over 30 % of carbon dioxide emissions were contributed by building sector to the environment. Studies from Yang *et al.,* [1], Muhieldeen *et al.,* [2] and Zhang *et al.,* [3] found that HVAC system is the major power consumption in a building. Chen *et al.,* [4] and Kampelis [5] found out that a significant increase in energy consumption was seen in these several years due to the growing demand of HVAC system to achieve thermal comfort in the building environment. Yun [6]

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reviewed that the increasing demand of comfort increases the energy consumption, carbon dioxide emission and time-series electricity demand of the buildings.

High energy consumption of HVAC system has been a major issue for buildings around us. This concern has led to the improvement and enhancement of building energy efficiency through numerous of studies from researchers such as Baoyumi [7], Prakash [8], Raftery [9] and Zhao [10]. International standards such as ASHRAE Standard-55 [11] and ISO 7730 [12] stated that greater air flow is able to offset the increase of air temperature by lowering the chilled water temperature. Potential cost and energy saving are able generated from chiller's compressor and pumps by reducing the chilled water temperature difference from the chilled water supply and return. Stefano *et al.,* [13] found out that increasing of air temperature with greater air flow is able to generate extensive energy savings in building with desired thermal comfort and air quality. However, increase of air flow might lead to discomfort cause by increase of relative humidity level, cold draft and temperature fluctuation in the building. Cold draft could be prevented by finding the appropriate air temperature and speed of air flow accepted by the occupants according to the study of Ahmed [14].

The objective of this paper is to investigate possible energy saving and cost savings in building with higher air temperature and greater air flow using CFD simulation with the combination of air-conditioner and fan without affecting the thermal comfort of building occupants. The study was conducted in two different lecture halls with different indoor parameters, characterised by a warm and humid climate. Predicted Mean Vote (PMV) and Predicted Percentage of Dissatisfied (PPD) index act as thermal comfort indicator was used to determine the thermal satisfaction of building occupants in different room conditions. Experimentation studies were conducted to justify the results of CFD simulation.

2. Experimental Work

2.1 Test Building

Two lecture halls (Lecture Hall A & Lecture Hall B) (Figure 1) in the fourth floor of a five story building (Block C) where fifth floor is one hall room located in one of Malaysian institution were selected for experimental venues. Each of the lecture hall is able to occupy 60 students and were mainly used for educational purposes. Lecture Hall A (13 m x 9m x 4m height) is located at South East, SE area of the building Hall A has an external wall with big proportion of glass windows facing the S 150 E direction. The wall is exposed to sun in the morning session from 7 a.m. to 12 p.m. which substantially increases the external heat gain in the lecture hall. Lecture Hall B (12m x 10m x 4m height) is located at the Centre South of the building which does not exposed to any sun throughout the day. Both of the lecture halls are occupied with plastic chairs and table, and equipment such as projectors, fluorescent lights and air-conditioners.

(a)

(b)

Fig. 1. Room Layouts. (a) Lecture Hall A. (b) Lecture Hall B

2.2 Case Studies

Total of 32 different case studies were designed for Lecture Hall A and Lecture Hall B. Three table fans were used to generate different air flow in the lecture halls. Different indoor parameters such as air temperature and fan speed were set to obtain the thermal satisfaction responses from the building occupants. Three portable table fans were positioned in front of both lecture halls to generate greater air flow inside the lecture halls and to improve the overall temperature distribution. Three different fan speeds were tested to determine the effect of difference air flows on the thermal comfort level of the building occupants with the increase of supply air temperature from the air-conditioners. Multiple case studies aimed to obtain a more accurate results for thermal comfort optimization in the lecture halls with the lower energy consumption of the HVAC system. The case study was started with air temperature of 24°C, which is the optimal building comfort temperature adapted by ISO 7730 [12]. The experiments were repeated with increase of supply air temperature from the air-conditioners to determine the effect on thermal satisfaction level of building occupants with different speed of air flows offsetting the increase in air temperature. The experiments were limited at 27°C of air temperature due to the discomfort caused by the increase of relative humidity level in the lecture hall. The amount of water vapour in the air is primarily depending on the temperature of the surrounding air. Warmer air holds more moisture than cold air, as the air temperature increases, the relative humidity level in the air will also increase. High relative humidity in the surrounding air will cause the building occupants to feel hot and sticky which reduces the overall thermal comfort in the lecture hall.

2.3 Data Collection

Experiments were conducted (Table 1) during March 2018 from 12 p.m. to 5 p.m. and was participated by 12 respondents with age between 19 to 24 years old. Thermal satisfaction survey form was completed based on their own perceptions of thermal sensation level through a scale from -3 (Cold) to +3 (Warm) according to Fanger's [15] comfort equation of heat exchange for human body in each of the case studies. Furthermore, data measurements of air velocity produced by portable fan and outdoor air temperature for Lecture Hall A and Lecture Hall B were also collected. Stopwatch was used to record the time interval of 15 minutes between each of the case studies in order to achieve results which close to steady-state conditions. Air velocity and air temperature were measured by using an anemometer–UT 363 Digital Anemometer. The air velocity produced by different fan speeds were 4.40 m/s for low fan speed, 5.05 m/s for medium fan speed and 5.65 m/s for high fan speed. The highest outdoor air temperature obtained was 33°C.

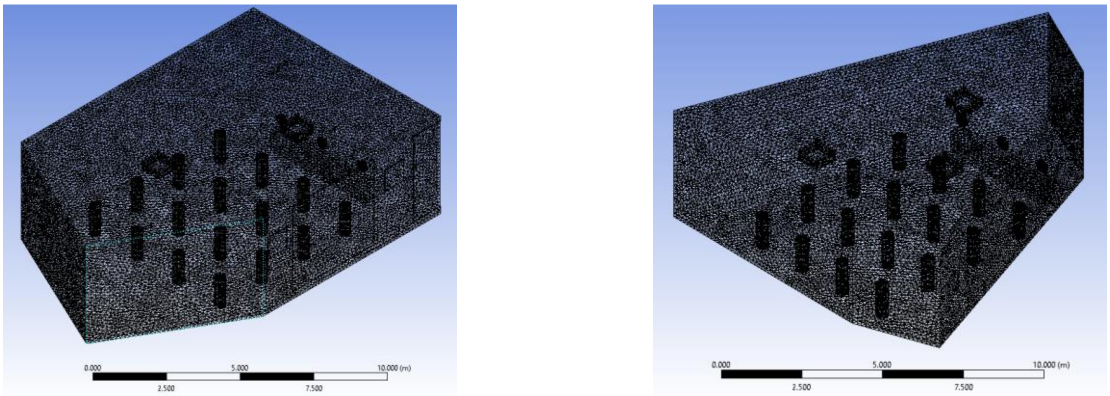
Table 1
Tools and devices

Item	Quantity	Function
UT 363 Digital Anemometer	1	To measure air temperature and air velocity inside the hall.
F-MN404 Compact Table Fan	3	To generate different speed of air flows.
MWM-015-CR York Air Conditioner Remote Controller	1	To control the set air temperature from the air-conditioner.
Stopwatch	1	To record the time interval.
Computer	1	For ANSYS Fluent software.
Digital camera	1	For taking photograph.

3. Numerical Simulation

3.1 Geometry Modelling

A CFD software, ANSYS Fluent v19.1 was used to conduct all the simulations. Two different lecture halls were sketched using Space-Claim software. Each of the room models were measured during the experimentation and modelled based on actual dimension of the lecture halls. Figure 2 shows the room model for Lecture Hall A and Lecture Hall B. However, 16 occupants were added and each of them was separated with a 2 x 2 m gap which aimed to model the results of air temperature and air velocity in different seating positions. Equipment such as air-conditioners and table fans were designed and positioned based on actual arrangement in both of the lecture halls. After describing the boundary conditions, the geometries were input into ANSYS software for geometry meshing.

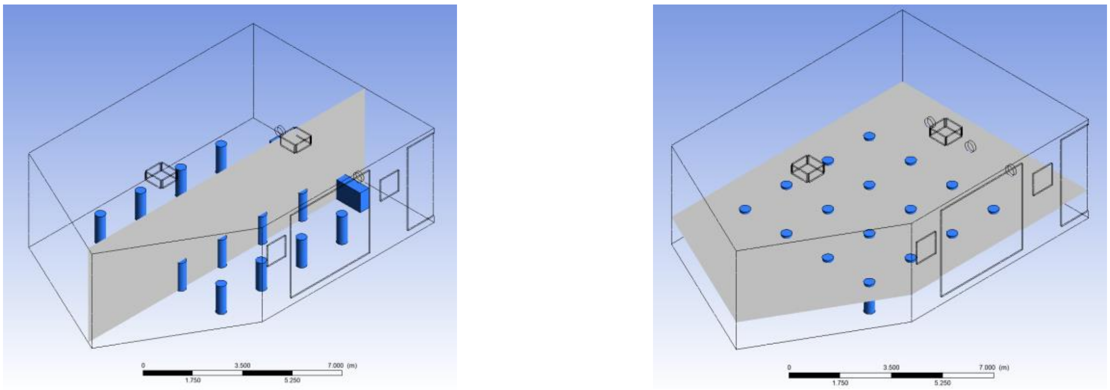


(a) (b)

Fig. 2. Mesh Model. (a) Lecture Hall A. (b) Lecture Hall B

3.2 Simulation Setup

Each of the case studies were simulated in a steady state condition and using the application of *k-ε* turbulence standard model for fluid flow equations followed the procedure of Nada *et al.,* [15], Muhieldeen *et al.,* [16] and Cheong *et al.,* [17]. Gravitational acceleration of -9.81 m/s in the direction of y-axis was set for the room model, where the negative sign is showing the direction of the flow. Constant velocity magnitude of 2.2 m/s for each AC velocity inlet and 0 m/s, 4.40 m/s, 5.05 m/s and 5.65 m/s which representing initial condition and three different fan speeds were used. Absolute backflow reference frame was set for pressure outlet. Mixed thermal condition of convection and radiation were added to the window and wall. Heat transfer coefficient of 0.512 (W/m$^{2\circ}$C) was set to the windows and 6.07 (W/m$^{2\circ}$C) was set to the wall. External free stream temperature was set to 33^{o}C according to the experimental measurement. Emissivity of window was set to 0.93 and 0.85 for wall. After all the conditions had been completely defined, hybrid initialization was initialized and 10 iterations of case set-up was produced. Before running the solver, the meshing of models, boundaries and cell zones were checked to prevent any errors or floating points occurred during the calculation. 250 number of iterations were solved for each of the case studies. Two planes named as Plane A and Plane B were added in the room models for side and plan view of the CFD simulation results (Figure 3). Plane A was positioned vertically at the third column occupants while Plane B was positioned horizontally is 1.2 m from the floor which is the seats level of standard sitting position. Temperature and velocity contours were generated on both planes and contour lines were added.



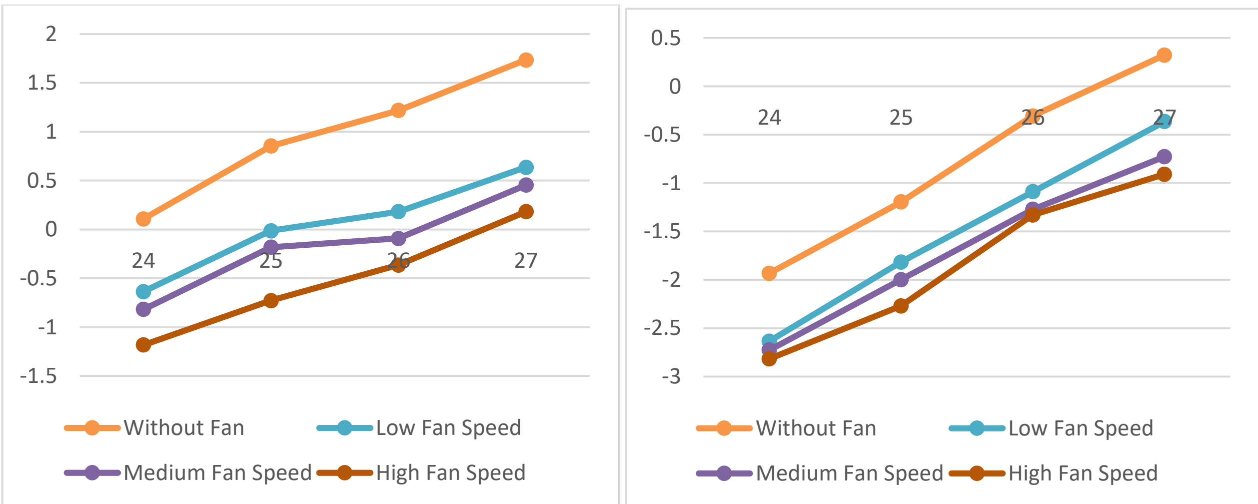
(a) (b)

Fig. 3. CFD-Post Model of Lecture Hall A. (a) Plane A. (b) Plane B

4. Results and Discussion

4.1 Experimental Results

Figure 4 shows that the PMV values increased when the AC set temperature increased. Increased of PMV index indicates that the occupants are feeling hotter when the AC set temperature was rise in the lecture hall. The air-conditioner maintained the surrounding temperature in a higher temperature causing the occupants to feel hotter and uncomfortable when the AC set temperature was increased. Furthermore, PMV index in the condition without external air flow showed higher values compared to those condition with greater air flow in both of the lecture halls. The results showed that the occupants are feeling cooler in the condition with greater air flow. This was due to the greater air flow promotes air circulation and temperature distribution in the lecture halls, cooler air was able to be transfer to a further distance more rapidly. In addition, greater air flow promotes the heat exchange between human skin and the environment. Heat generated by human body is able to be carries away or exchange with the air more efficiently, causing the occupants to feel cooler in those conditions. The experimental results proved that greater air flow generated by table fan in the lecture halls were able to offset the increase of AC set temperature without affecting the thermal comfort of the occupants.



(a) (b)

Fig. 4. Comparison of PMV Index with Different AC Set Temperature under Different Fan Speeds of Experimental Results. (a) Lecture Hall A. (b) Lecture Hall B

Furthermore, Figure 4 also shows that the average PMV values in Lecture Hall A is higher than Lecture Hall B due to the difference in heat load in both of the lecture halls. Heat load in Lecture Hall A is higher compared to Lecture Hall B because of their position in the building. Lecture Hall A is located at the South East of the building, it has an external wall with big proportion of glass windows facing the S 150 E direction. The wall is exposed to sun in the morning session from 7 a.m. to 12 p.m. which substantially increases the external heat load in the lecture hall. On the contrary, Lecture Hall B is located at the Centre South of the building which doesn't exposed to any sun throughout the day, causing it to have lower external heat load compared to Lecture Hall A. Therefore, higher cooling load is required for Lecture Hall A in order to reduce the heat gain from the glass windows in the afternoon for the occupants to feel comfortably in the lecture hall.

Figure 5 showed that PPD has the highest value in 27°C air temperature in the initial condition (without fan). Highest percentage of PPD indicates that there are highest number of occupants feeling dissatisfied or uncomfortable in the room condition. The occupants are feeling uncomfortable due to the warm temperature caused by solar radiation through the windows of Lecture Hall A. The AC was unable to provide sufficient cooling to the occupants at 27°C.

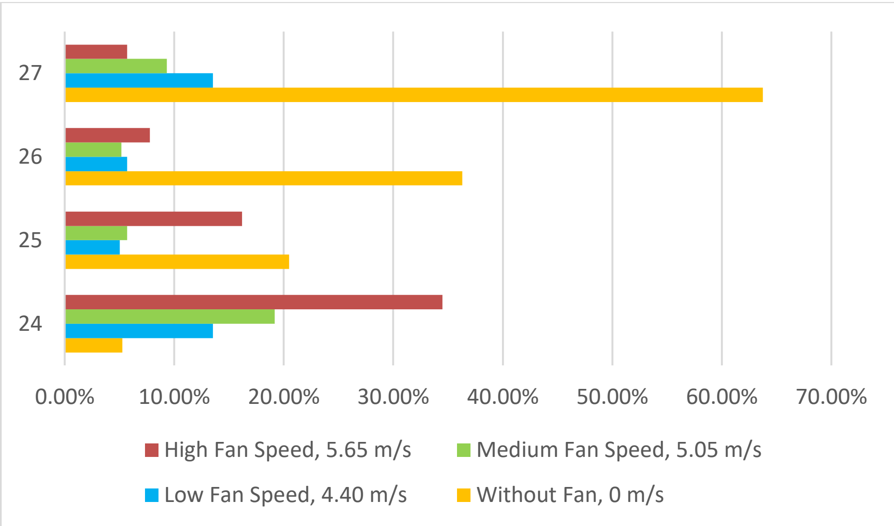


Fig. 5. Comparison of PPD Index with Different AC Set Temperature under Different Fan Speeds of Experimental Results in Lecture Hall A

In Figure 6, PPD values reaches the highest level when the AC set temperature is 24°C with the highest air speed in Lecture Hall B. The highest PPD is caused by the coolness felt by the occupants. Occupants feel cold due to the increases of heat exchange rate between human skins with the surrounding air caused by the higher air speed.

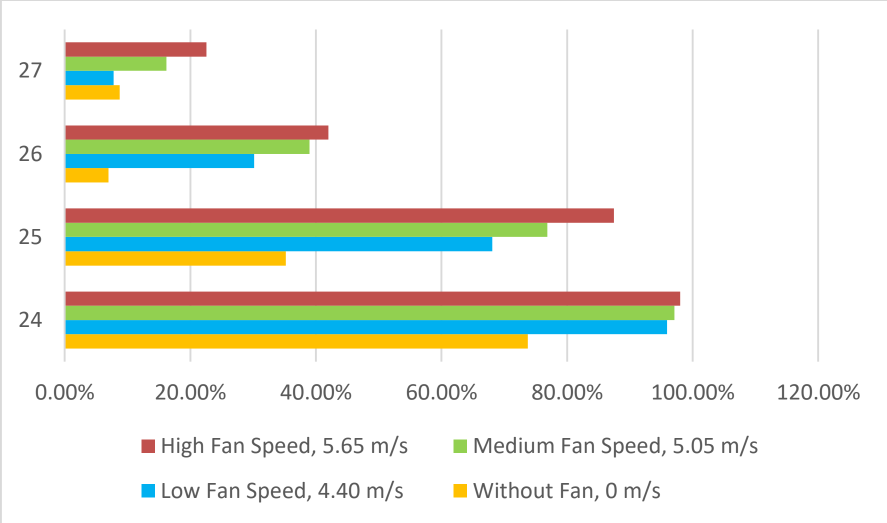
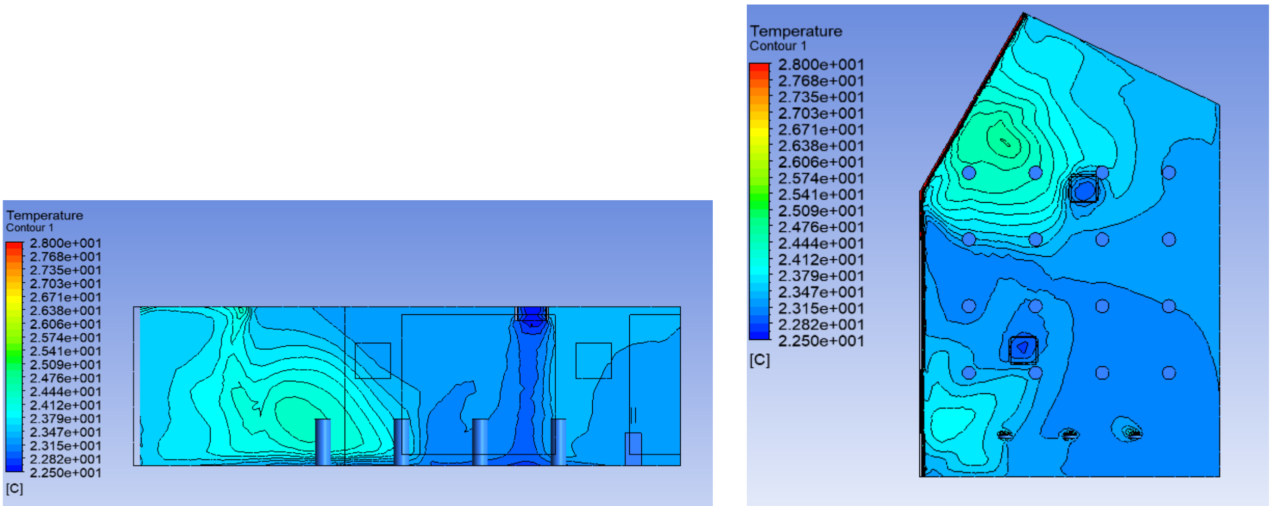


Fig. 6. Comparison of PPD Index with Different AC Set Temperature under Different Fan Speeds of Experimental Results in Lecture Hall B.

4.2 CFD Simulation Results

32 case studies with different indoor parameters were simulated using ANSYS Fluent v19.1 software. Results of CFD were presented with AC set temperature of 25°C as input parameter. Initial condition (without fan) and high fan speed condition of CFD simulation results were discussed.

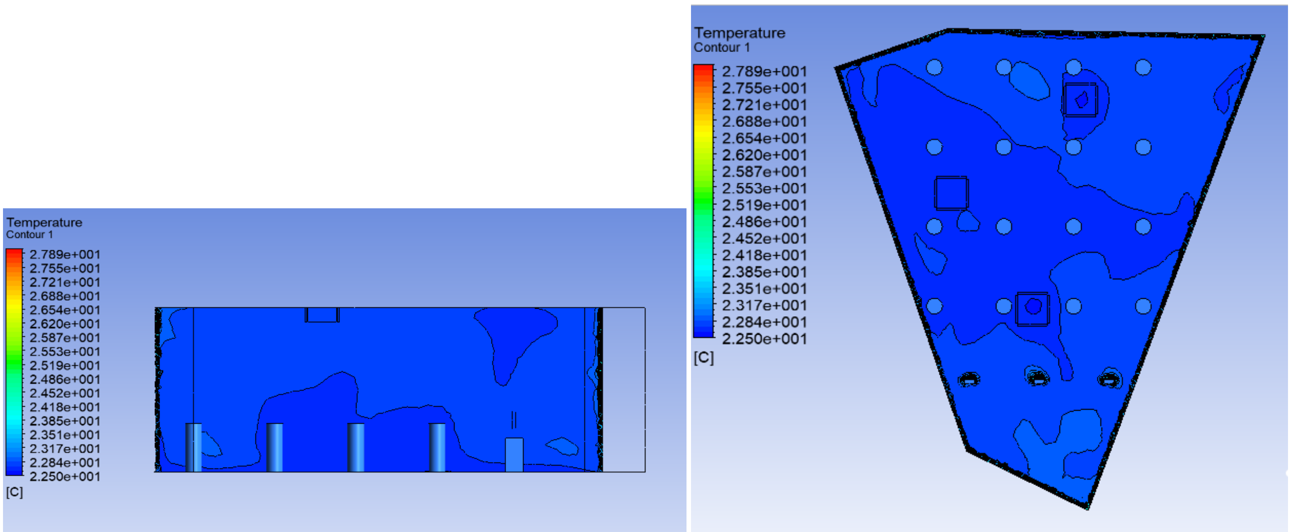
Figure 7 showed the temperature distribution in Lecture Hall A under initial condition. The overall room temperature is in the range between 23.15°C to 24.45°C. Occupants sitting under the air-conditioners are lower feeling of air temperature compared to the occupants which siting near to the windows and walls. It was due to external radiation and convection parameters added to simulate the highest external heat gain in the lecture hall throughout the day. Occupants sitting at the first to third row positions are having an average feeling temperature of 23.5°C while occupant sitting at the fourth row position has a higher feeling temperature of 24.26°C.



(a) (b)

Fig. 7. Temperature Contours of Lecture Hall A under Initial Condition (Without Fan). (a) Plane A. (b) Plane B

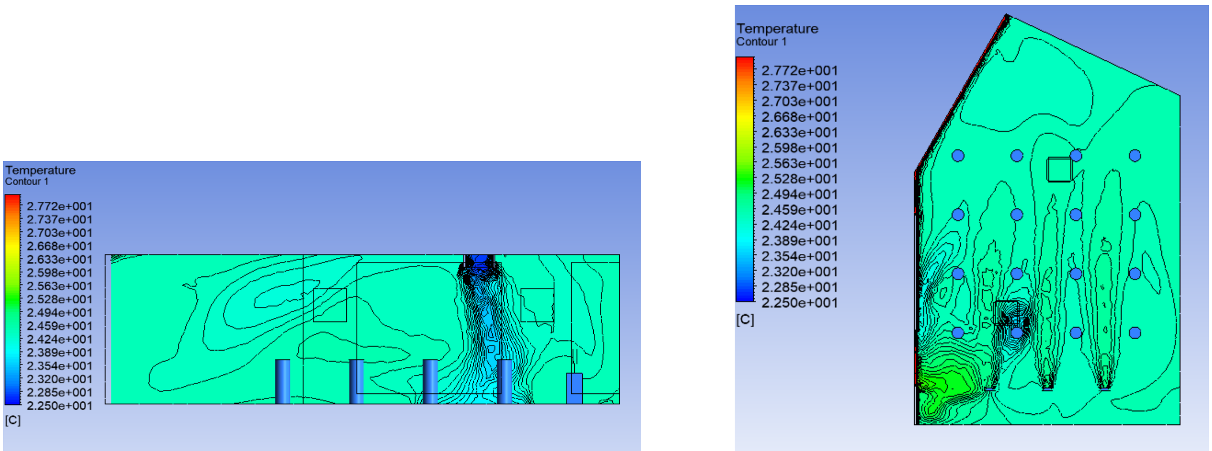
In Figure 8, the overall room temperature in Lecture Hall B is 22.27°C. Occupants sitting at the first and second row have a feeling air temperature of 21.51°C and 21.53°C while occupants sitting at third and fourth row are having a feeling air temperature of 21.53°C and 21.54°C. Lecture Hall B was not exposed to external heat load, allowing it able to provide lower room temperature for the occupants. Occupants are feeling cooler in Lecture Hall B compared to Lecture Hall A. The temperature were distributed uniformly in Lecture Hall B.



(a) (b)

Fig. 8. Temperature Contours of Lecture Hall B under Initial Condition (Without Fan). (a) Plane A. (b) Plane B

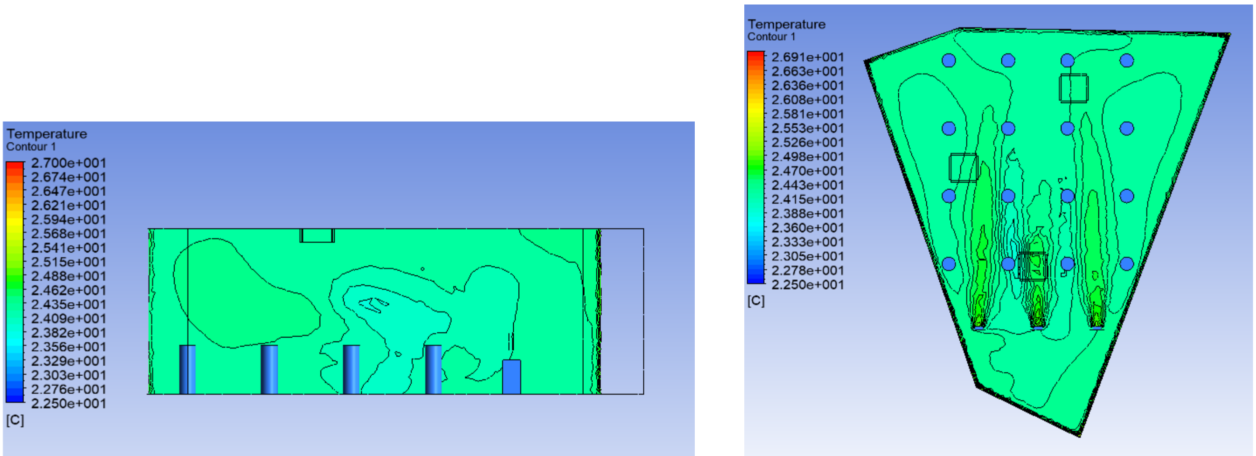
Figure 9 showed the temperature distribution in Lecture Hall A with greater air flow generated by using three table fans. The overall temperature in this condition falls between the ranges of 24°C to 25°C. Occupant sitting at the first row has a feeling temperature of 24.2°C while the occupant sitting at the fourth row has a feeling temperature of 24.6°C. Occupants who sit nearer to the table are feeling colder compared to those who sit far from the table fan. In Figure 10b, a pressure inlet of a table fan which located near to the windows is withdrawing warmer air compared to the others. It was due to greater air flow also promotes the air circulation and heat exchange between external heat source and the air in the lecture hall, causing the overall room temperature with greater air flow is higher than the room temperature at initial condition.



(a) (b)

Fig. 9. Temperature Contours of Lecture Hall A under High Fan Speed, 5.65m/s. (a) Plane A. (b) Plane B

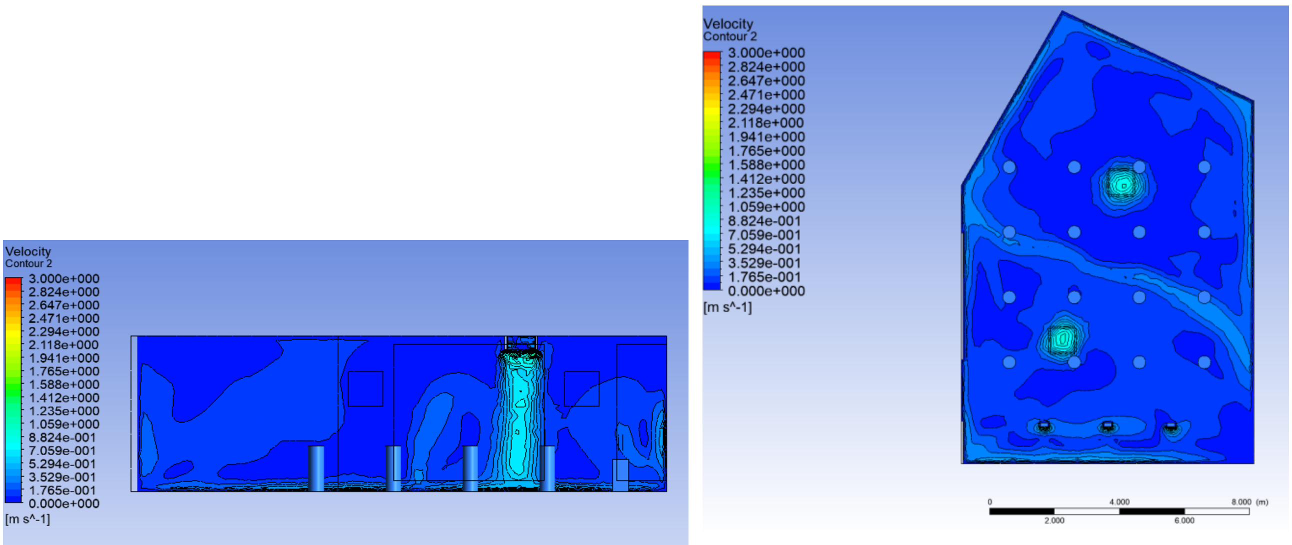
In Figure 10, the overall temperature in this condition falls between the ranges of 23.8°C to 24.5°C. Occupants sitting at the first and second row have a feeling air temperature of 24.15°C and 24.14°C while occupants sitting at third and fourth row are having a feeling air temperature of 24.30°C and 24.3°C. Occupants in Lecture Hall B have lower feeling temperature compared to Lecture Hall B despite of sitting at the similar positions due to the heat load difference in both of the lecture halls. Other than that, Lecture Hall B has a smaller room area which causing it to have better temperature distribution within the lecture hall.



(a) (b)

Fig. 10. Temperature Contours of Lecture Hall A under High Fan Speed, 5.65m/s. (a) Plane A. (b) Plane B

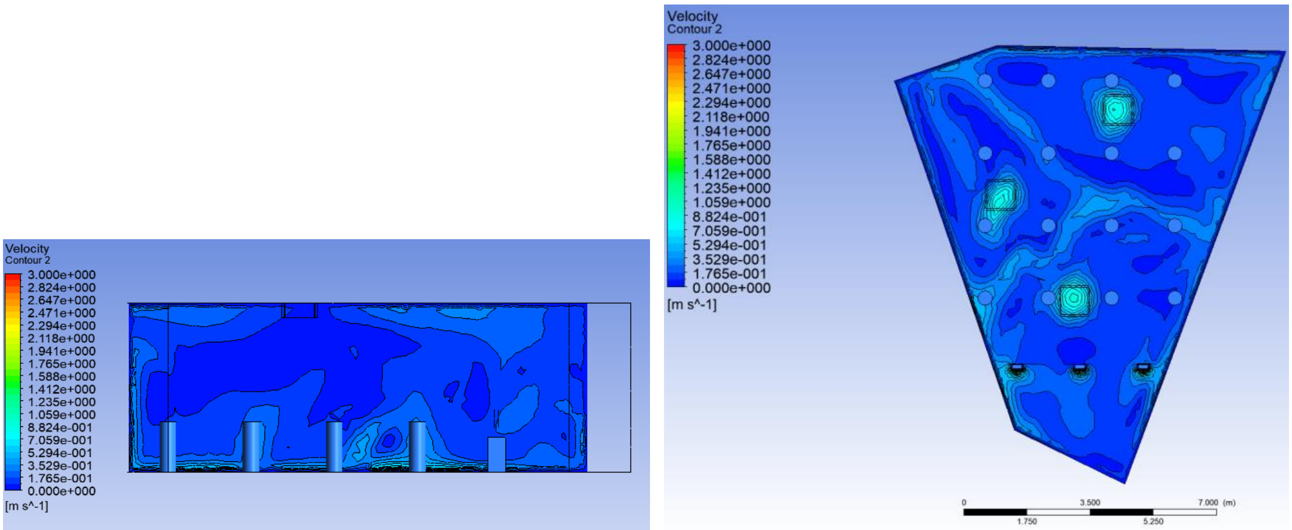
Figure 11 showed the air velocity inside Lecture Hall A through cross-section view of the interior air in two dimensions (2D). The overall occupants feeling air velocity was in the range of 0.039 m/s to 0.65 m/s. Occupants sitting at the first and second row have a feeling air velocity of 0.101 m/s and 0.087 m/s while occupants sitting at third and fourth row are having an feeling air velocity of 0.039 m/s and 0.082 m/s. Occupants sitting under the air conditioners are able to feel the gentle air blown from the AC outlet. Low air velocity reduces the temperature distribution and provides poor air circulation in the lecture halls. However, low air velocity prevents cold draft that will cause major discomfort to the occupants.



(a) (b)

Fig. 11. Velocity Contours of Lecture Hall A under Initial Condition (Without Fan). (a) Plane A. (b) Plane B

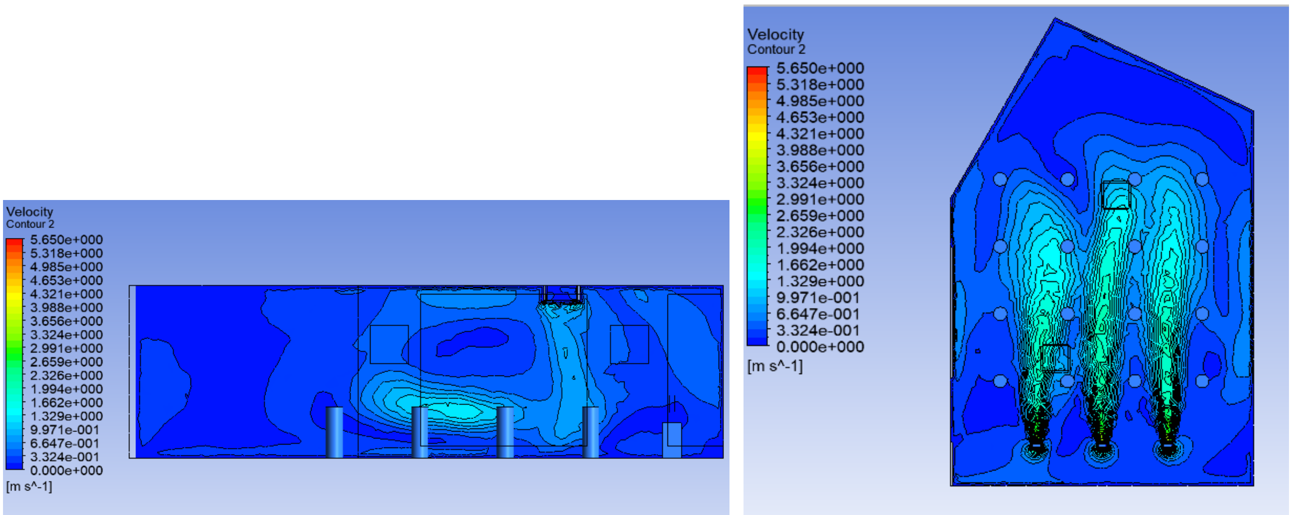
In Figure 12, the overall occupants feeling air velocity was in the range of 0.080 m/s to 0.85 m/s. Occupants sitting at the first and second row have a feeling air velocity of 0.254 m/s and 0.083 m/s while occupants sitting at third and fourth row are having an feeling air velocity of 0.262 m/s and 0.097 m/s. First and third row occupants are feeling slightly higher air velocity because of the positioning of air-conditioners were close to the occupants. Lecture Hall B has a higher occupants feeling air velocity compared to Lecture Hall A due to an extra air-conditioner which enhance the air circulation in the lecture hall.



(a) (b)

Fig. 12. Velocity Contours of Lecture Hall B under Initial Condition (Without Fan). (a) Plane A. (b) Plane B

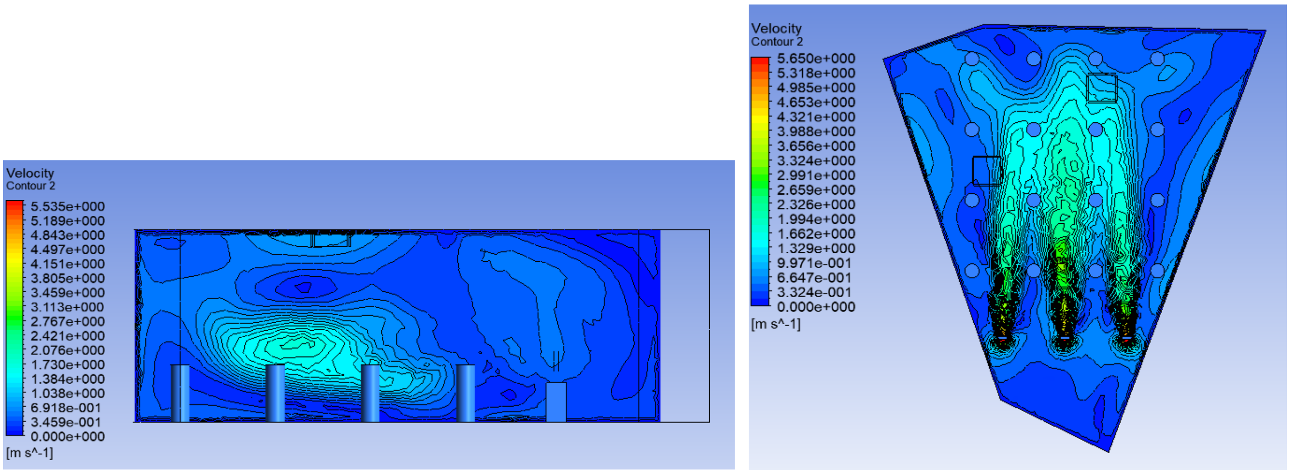
Figure 13 showed the air velocity inside Lecture Hall A through cross-section view of the interior air in two dimensions (2D). The overall occupants feeling air velocity was in the range of 0.235 m/s to 3.294 m/s. Occupants sitting at the first row have a feeling air velocity of 0.456 m/s while occupants sitting at second and third row are having an feeling air velocity of 0.757 m/s and 1.56 m/s. Fourth row occupants experienced to the lowest air velocity of 0.381m/s. Third row occupants experienced to the highest air velocity due to the strongest air flow overlapping at the third row positions. Occupants sitting in fourth row experience the least air velocity because of generated air velocity of 5.65 m/s unable to reach to the sitting position of the occupants.



(a) (b)

Fig. 13. Velocity Contours of Lecture Hall A under High Fan Speed, 5.65m/s (a) Plane A. (b) Plane B

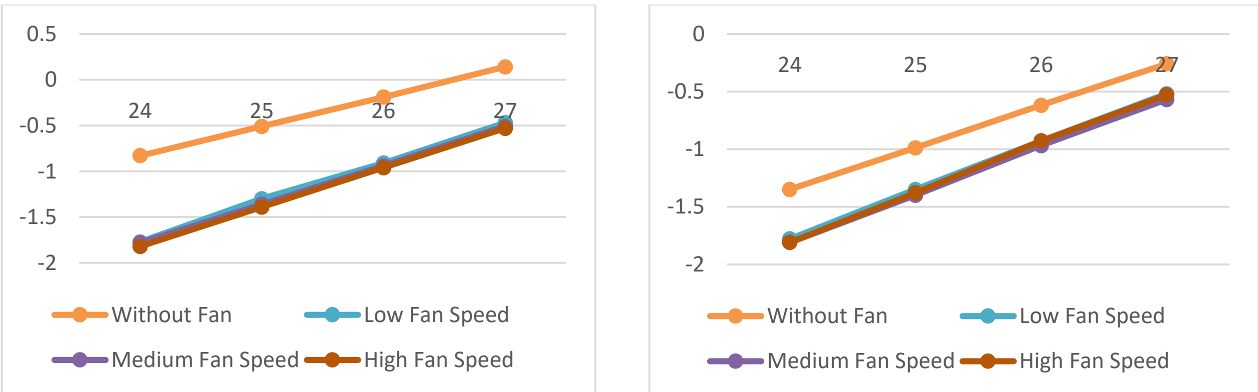
In Figure 14, the overall occupants feeling air velocity was in the range of 0.235 m/s to 3.059 m/s. Occupants sitting at the first and second row have a feeling air velocity of 0.277 m/s and 1.074 m/s while occupants sitting at third and fourth row are having an feeling air velocity of 1.475 m/s and 0.252 m/s. Second and third row occupants experienced high air velocity due to the air flow overlapping at the middle section of the lecture hall. Occupants sitting at the first and fourth row experienced the lower air velocity due to the positioning and power of the table fan. A wider and more powerful fan are able to tackle the problems of air flow distance and uneven air flow distribution. A stratum outlet can be used for uniform air flow distribution.



(a) (b)

Fig. 14. Velocity Contours of Lecture Hall A under High Fan Speed, 5.65m/s. (a) Plane A. (b)Plane B

Figure 15 shows a similar graph pattern with the experimental result, indicates that greater air flow is able to reduce the PMV index in both of the lecture. Occupants are feeling cooler with the increase of air flow in the lecture halls. The CFD simulation results proved that greater air flow generated by table fan in the lecture halls were able to offset the increase of AC set temperature without affecting the thermal comfort of the occupants.



(a) (b)

Fig. 15. Comparison of PMV Index with Different AC Set Temperature under Different Fan Speeds of CFD Simulation. (a) Lecture Hall A. (b) Lecture Hall B

Figure 16 and Figure 17 show the predicted percentage of dissatisfied (PPD) of the occupants in Lecture Hall A and Lecture Hall B. It was showed that PPD has the highest value in 24°C and high fan speed mode. Highest percentage of PPD indicates that there are highest number of occupants feeling dissatisfied or uncomfortable in the room condition. The occupants feel cold due to the increase of heat exchange rate between human skins with the surrounding air. When the heat is carried away, cooler air replaced the air above the skin causing the occupants to feel cold.

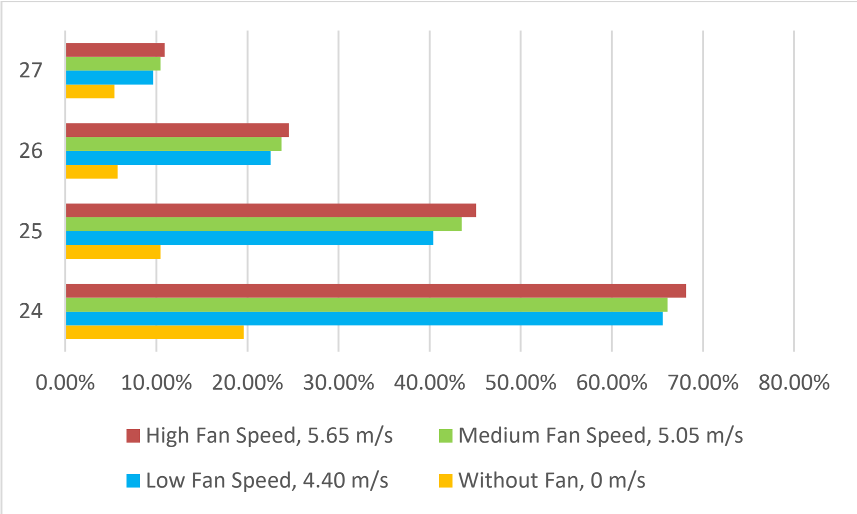


Fig. 16. Comparison of PPD Index with Different AC Set Temperature under Different Fan Speeds of CFD Simulation in Lecture Hall A

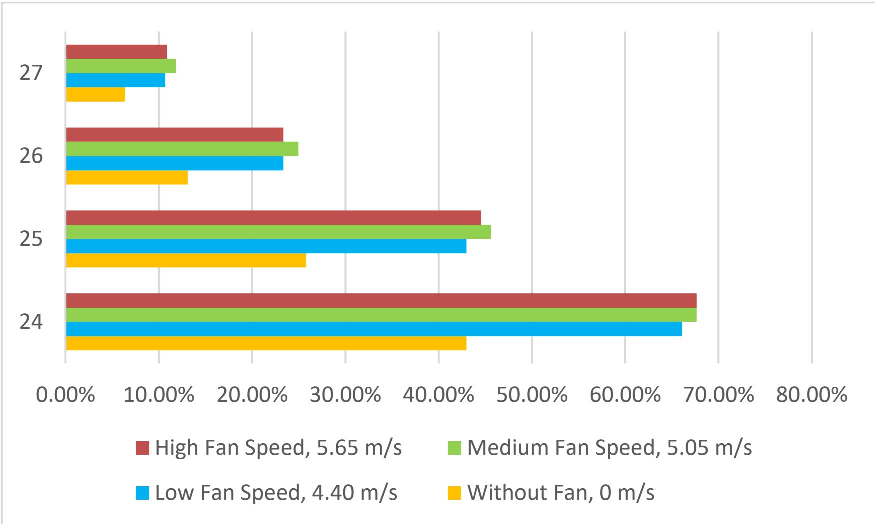
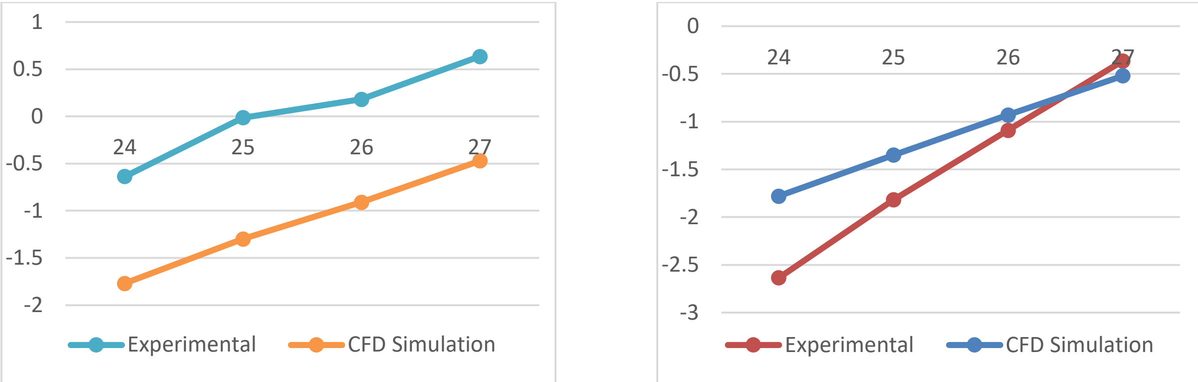


Fig. 17. Comparison of PPD Index with Different AC Set Temperature under Different Fan Speeds of CFD Simulation in Lecture Hall B

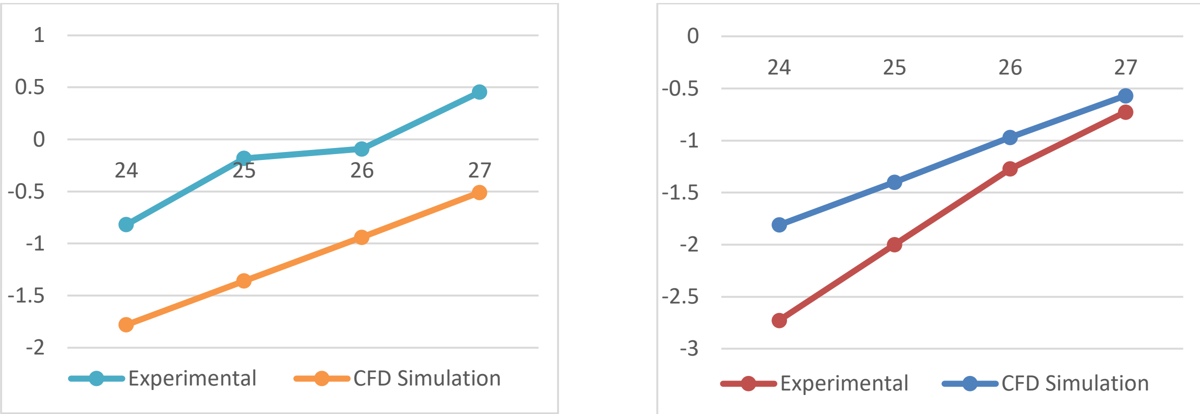
4.3 Comparison Between Experimental and CFD Results

Figure 18, Figure 19 and Figure 20 showed the comparison between experimental and CFD simulation results with different air flow generated in Lecture A and Lecture B. The figures presented that CFD simulation and experimental results have the identical graph patterns in both of the lecture halls. This confirms that the CFD simulations can be used to achieve the results of the study. The graphs also show a linear pattern, indicating that when the air temperature increased, the PMV values of the occupants were also increased. The differences of PMV range were caused by excluded heat load from equipment, lighting and infiltration in CFD simulation. The graph pattern of CFD simulation in Lecture Hall B shows a slight difference with experimental results. Respondents in Lecture Hall B is having a higher difference of thermal satisfaction perception due to the greater cooling distribution from an additional unit of air-conditioner compared to Lecture Hall A. Other than that, each of the respondents are having different metabolic rate, clothing insulation and perception of thermal satisfaction which cause the experimental results slightly differ from the CFD simulation results.



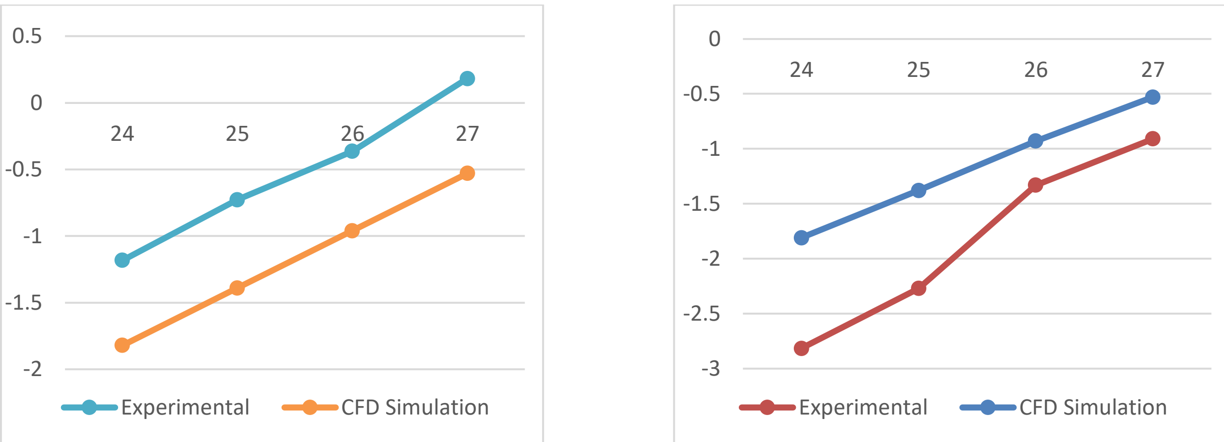
(a) (b)

Fig. 18. Comparison Between Experimental and CFD Results under Low Fan Speed, 4.25 m/s. (a) Lecture Hall A. (b) Lecture Hall B



(a) (b)

Fig. 19. Comparison Between Experimental and CFD Results under Medium Fan Speed, 505 m/s. (a) Lecture Hall A. (b) Lecture Hall B



(a) (b)

Fig. 20. Comparison Between Experimental and CFD Results under High Fan Speed, 5.65 m/s. (a) Lecture Hall A. (b) Lecture Hall B

4.4 Ideal Conditions of Air Temperature and Air Velocity

After analysing the results, the ideal fan speeds and AC set temperature based on PMV and PPD index nearest to thermal comfort condition in both lecture halls with greater air flow were summarized in Table 2. Each conditions have the similar preferred air velocity of 4.40 m/s. It is due to has air velocity will cause cold draft to the occupants, causing the occupants to feel cold and uncomfortable with the strong air flow. Draught rating of 21.08% was obtained with 4.40 m/s of air velocity which is acceptable according ASHRAE Standard-55 [10]. The ideal air temperature with preferred air velocity is 25°C for experimental and 27°C for CFD simulation in Lecture Hall A. However, due to the excluded heat gain from equipment, infiltration and lighting in CFD simulation, the proposed ideal AC set temperature was reduced to 25°C which is similar to the experimental studies to offset the increase of heat load in Lecture Hall A. On the other hand, experimental and CFD simulation results showed the similar ideal AC set temperature with 4.40 m/s air velocity which proven accuracy of the results of the study (Table 2).

Table 2
Ideal Conditions of Experimental and CFD Simulation

	Lecture Hall A		Lecture Hall B	
	AC Set Temperature	Fan Speed	AC Set Temperature	Fan Speed
Experimental	25°C	Low Fan Speed, 4.40 m/s	27°C	Low Fan Speed, 4.40 m/s
CFD	27°C	Low Fan Speed, 4.40 m/s	27°C	Low Fan Speed, 4.40 m/s
Proposed	26 °C	Low Fan Speed, 4.40 m/s	27°C	Low Fan Speed, 4.40 m/s

4.5 Potential Energy Saving

Figure 21 shows the comparison studies of average percentage of energy saving able to be achieved by the increased of air temperature with greater air flow. In the study of Stefano *et al.,* [13], an average cooling energy saving of 32.50% was able to achieve while an average cooling energy saving of 41.82% were obtained in the current study. The study has been proven a success in energy cost reduction.

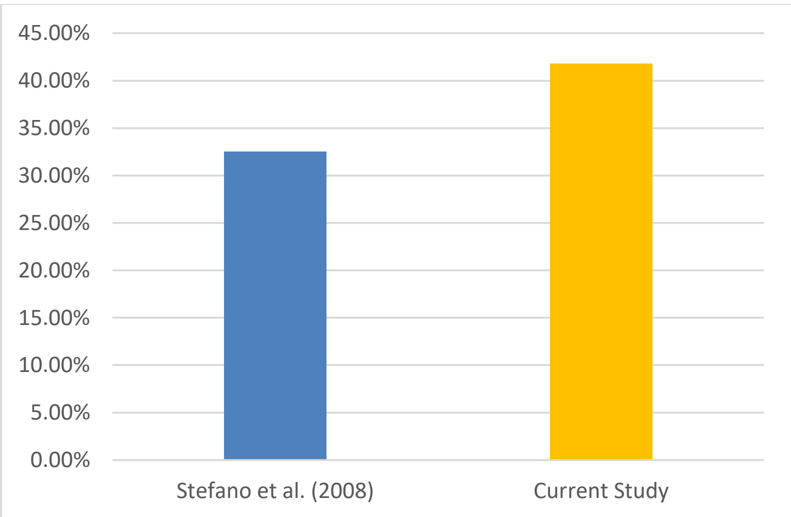


Fig. 21. Comparison of Average Percentage of Energy Saving

Possible energy costs saving were determined based on the ideal fan speeds and AC set temperature for Lecture Hall A and Lecture Hall B. Possible energy cost savings were calculated separately due to the different cooling capacity of air-conditioner used in both of the lecture halls. The initial and improved electricity cost were shown in Figure 22. With a greater air flow and increase of AC set temperature from 23°C to 26°C, a total of RM 147.16 electricity cost is able to save per month in Lecture Hall A and the percentage of energy saving is up to 36.36%. On the other hand, with AC set temperature increase from 23°C to 27°C, a total of RM 195.87 electricity cost is able to save per month in Lecture Hall B and has a percentage of energy saving up to 47.27%. A total annual saving of RM 4116.36 was able to achieve in Lecture Hall A and Lecture Hall B by increasing air temperature with greater air flow.

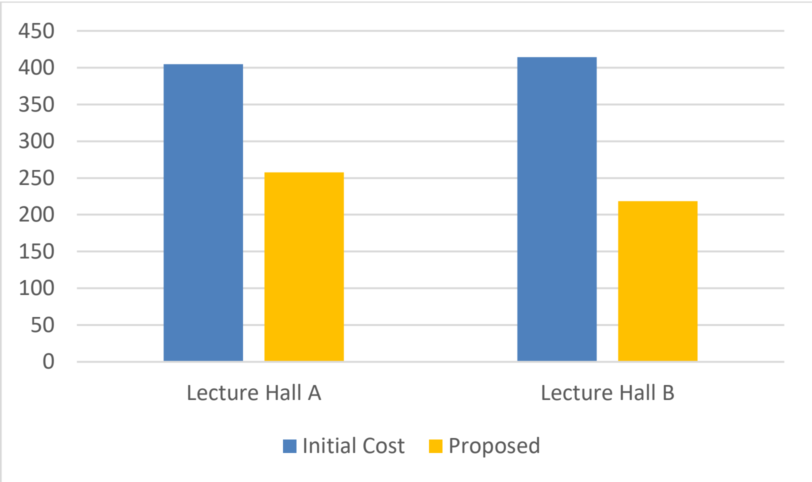


Fig. 22. Monthly Electricity Cost of Air-conditioners in Lecture Hall A and Lecture Hall B

5. Conclusions

From this study, it was found that increase air flow in the building is able to decrease the PMV values of building occupants. Decreases in PMV values are able to offset the increase of air temperature while maintaining the thermal comfort level in the building with the least predicted percentage of dissatisfied (PPD). With the help of greater air flow, the AC set temperature in Lecture Hall A is able to increase for 3°C while the AC set temperature in Lecture Hall B is able to increase for 4°C. The percentage of energy saving reaches 36.36% for Lecture Hall A and 47.27% for Lecture Hall B. Possible monthly electricity cost savings is up to RM 147.16 for Lecture Hall A and RM 195.87 for Lecture Hall B. The objective of the study has been clearly achieved. Future studies can be done to determine the effect of draught rating and turbulence intensity of air flow on thermal comfort in the building. Positioning of air outlet and design of diffuser can be study.

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