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Simulation and Analysis of Airflow in ACMV System at G3 Building UTHM

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Abstract: Feeling sleepy and cannot pay full attention during class is one of the problems faced by student when studies inside lecture or classroom. That are one of the reasons students says when cannot performing well in their studies. The symptoms that shown by the student indicate there are sick building syndromes inside the buildings. To confirming the symptoms related to sick buildings syndromes, an analysis is made based of the air flow inside a lecture room. A model is created based on the actual lecture room in one of the main buildings in UTHM. The model was created using the computer aided design software SolidWorks. To stimulate the model and analyze the data a computational fluid dynamics (CFD) simulation was use by using software ANSYS FLUENT. The CFD simulation was focus on the three main parameters which is temperature, air velocity and the relative humidity. From the simulation, the results are for the temperature is 27 oC, as for the air velocity is 0.55 ms-1 and for the relative humidity is 75%. Then the results we compared to authorities' bodies. The requirement is from Malaysia Standard (ICOP-2010) and ASHRAE Standard 55-2013. The comparison is to check whether the air flow inside the lecture room following the requirement from the authority's bodies. From the comparison a percentage of error for temperature, air velocity and relative humidity is calculated. The percentage were 3.85%, 10% and 7%.

Keywords: CFD, ASHRAE Standard 55-2013, Malaysia Standard (ICOP-2010), ACMV, ANSYS

1. Introduction

Humans always try to live in a comfortable environment. They always try to live in an environment that is hot when outside is cold, and they also try to live in an environment that is cold when it is hot outside. They can stay for a long period in a place where the temperature is suitable and comfortable for them. The suitable temperature and comfort zone for our body also known as thermal comfort. Thermal comfort is "that condition of mind that expresses satisfaction with the thermal environment and is assessed by subjective evaluation" [1]. As Malaysia's temperature is a tropical climate that is hot and humid with an average temperature between 23.7ºC to 31.3ºC during the day and relative humidity between 67% to 95%, this may impact occupant thermal comfort [2] Thus, the Air Condition

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Mechanical Ventilation (ACMV) system becomes vital and important for occupants in buildings to achieve thermal comfort.

This study aims to stimulate and analyze the airflow inside the G3 building to compare with the authority standard. As different type of building requires a different type of ACMV system and different type of building will have different airflow. For example, the equipment needed to install the ACMV system is different in the specification as the different buildings have different sizes and specifications. Other than that, the building's function is also vital to be concerned about as the ACMV system's design is also affected by the building's function. In this study, we focus on the lecture room of G3 building in Universiti Tun Hussien Onn Malaysia (UTHM). The type of room in this study is the lecture room.

Airflow is one of the critical aspects that need emphasis in the ACMV system. The problem related to the airflow inside the building usually came from improper mechanical ventilation inside the ACMV system. Several sicknesses are related to lack of air flow inside the building such as Sick Building Syndrome (SBS) and Building Related Illness (BRI). From this disease, we know that bad airflow inside the building will harm the occupant, especially the student that using the lecture room. A bad airflow inside the lecture room may affect the student's performance in their study as they cannot focus on their lecturer because of bad airflow.

Other than that, there are standards for specification for ACMV system. The standard is made to ensure the reliability of the system whether the system can function properly or not. If the designer of ACMV system did not follow the standards by the authority bodies, the system may fail and the people who using it may harm their own health. As the system relating to the air that flow on the living area of people, if may endangered their health by not supplying suitable air flow and increasing carbon dioxide concentration [3].

The main objective of the study to be achieved in the simulation and analysis of airflow in ACMV system at lecture room of G3 building are:

i. To analyze the airflow inside lecture room of G3 buildings.
ii. To compare the current ACMV system in lecture room of G3 buildings with the authority's standards.

2. Materials and Methods

This study aims to analyze the airflow inside lecture room of G3 building buildings. The software involved in analyzing the airflow is DuctSizer and ANSYS software. The DuctSizer software is used to determine the parameter of the air inside the ducting for the building while ANSYS software will do a simulation of the airflow to compare the airflow data from the simulation with the requirement of the airflow. The other vital part that will focus on this study is the airflow requirement for the building. The authority requirement that will follow are the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Standard[4] and Malaysia Standard (ICOP-2010)[5].

The model of lecture room are from one of the main Building in Universiti Tun Hussein Onn Malaysia (UTHM) which is G3 building. The location of the library are located 20 km from the city of Batu Pahat at 1 ° 51 '32.0 "N and 103 ° 05' 13.9 "E. The buildings consist of several main lecture theatres, lecture rooms, and tutorials room. The building can accommodate around two thousand people as twenty-six rooms are used for learning and lecture purposes. The building also consists of one cafeteria and one mosque and several toilets for the utilities that the students can use during their lecture and rest. In this study, one of the rooms selected in this building is because all the learning and lecture rooms inside the buildings use air-conditioners as their primary system, the HVAC system.

The standards can be achieved by referring to that guideline that can be found from the handbook developed by ASHRAE standard and Malaysia Standard (ICOP-2010). With a full understanding of the standards, the objective of this study can be satisfied. Table 1 shows the requirement for the physical parameters of ACMV system in Malaysia Standard (ICOP-2010) and ASHRAE standard 55-2013.

Table 1: Physical requirement from the authorities

	Malaysia Standard (ICOP-2010)	AHRAE Standard 55-2013
Air Temperature	24 °C - 26 °C	22.5 °C- 26°C
Air Velocity	0.15 m/s - 0.50 m/s	15 m/s - 0.50 m/s
Relative Humidity	40 % - 70 %	30 % - 60 %

The design of the model is required before undergo simulation on ANSYS software. The model is design using computer aided design software called SolidWorks. SolidWorks is a desktop CAD solution that was the first to support 3D mechanical design. The software purpose for creating 3D models on Windows created by the SolidWorks business. It offers automated design tools at the product level (Zhang et al., 2009). The model is draw based on the actual lecture room at G3 building in UTHM. The size of the lecture room is based on the real size of the lecture room at G3 building. The is 10 m x 10 m x 2m (Length x Width x Height) (Sies et al., 2020). Figure 1 show the model use for the analysis. The design of the model are almost the same as the lecture room as there are some limitation on the data regarding the lecture room. There is parallel duct that have been draw on the top of the lecture room. The size of the duct is 9 mm x 14 mm (Height x Width). There are six windows at the left and the right of the lecture room. Figure 2 show the ducting at the top of lecture room.

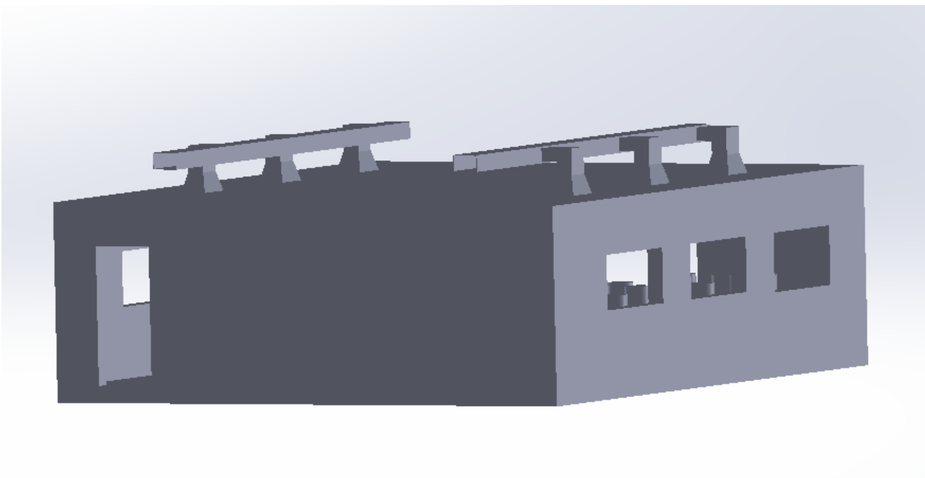

Figure 1: The model of lecture room

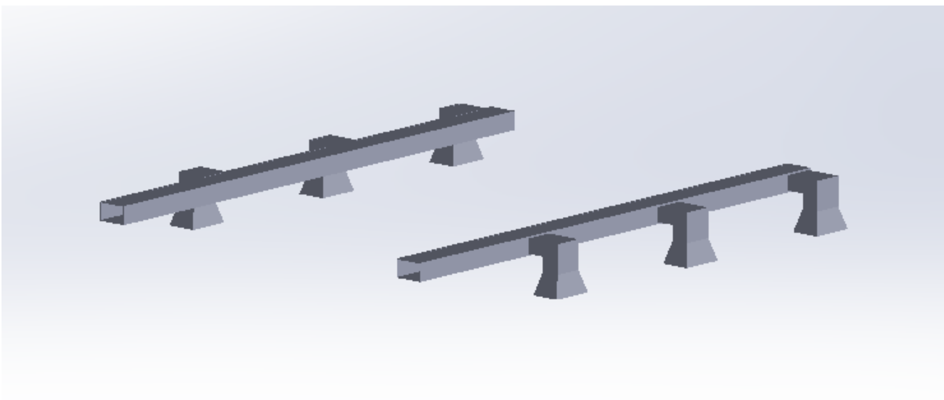

Figure 2: The ducting at the top of lecture room

Ansys Fluent can provide a computational fluid dynamic (CFD) tool for accurate results across the widest range of CFD applications. It was very suitable for our study which is the simulation of airflow inside the lecture room of G3 building. To undergo the simulation in the ANSYS software, a prototype of a model of lecture room is needed. The model will be created using an actual lecture room from G3 Building. he assumptions made for simulation are given as follows:

(a) The air conditioning system in selected lecture rooms is fully functioning and running well.

(b) The rooms are fully sealed and enclosed without any holes or gaps (excluding doors, window, and exhaust vent).

(c) The outside temperature on the surface of the room is constant

(d) Internal heat source emitted from the digital devices and lights will be neglected due to minimal effect on the temperature.

(e) The furniture (chairs and tables) are included in the simulation.

There are three main parameter that being observed and compared in this study. The parameter that involve in this study are temperature, air velocity and relative humidity. These three parameters are selected because of these are the main physical parameter that stated in the requirement by the authorize bodies. After the results for each parameters are obtained, there will be a calculation in the term of percentage of error to see the difference between the results and the requirement from the authorities bodies. The formula for the calculation are stated as the following:

$$E = \frac{|X_{simulation} - X_{requirement}|}{X_{requirement}} \times 100\% \qquad (1)$$

Where,

E	= Percentage of error
$X_{simulation}$	= Data obtained from the simulation
$X_{requirement}$	= Parameter data from the authority's

3. Results and Discussion

One of the main parameters in this study is temperature. One of the main functions of installing ACMV inside a room or our house is to control the temperature. The data obtained from the simulation of ANSYS software shows that the temperature range inside the room is from 300 K to 300.1 K, indicating that the temperature is not very varied. Therefore, the temperature is almost the same inside the room, which is 27 oC. Figure 3 shows the temperature under the inlet of the air, which is the duct and at the middle plane. The figure shows that in every inlet, the temperature is the lowest while the temperature is the highest at the position between the inlet. Nevertheless, the air temperature distribution in the whole room is stratified.

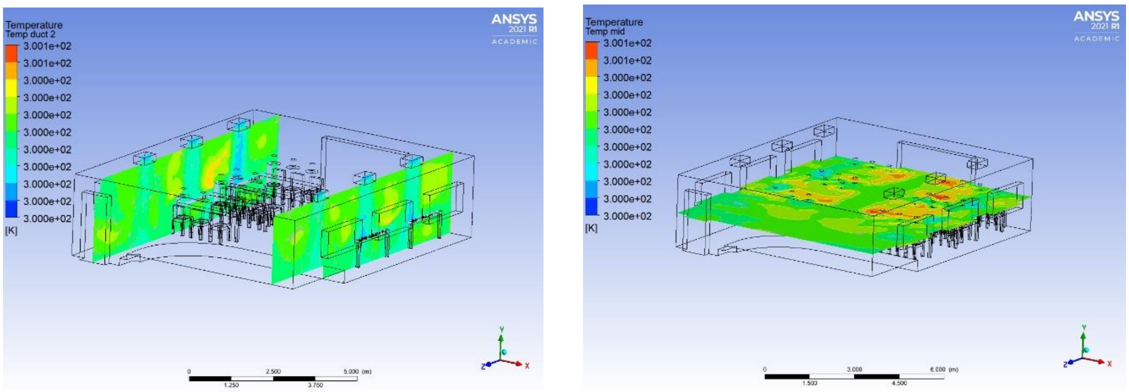

Figure 3: The temperature distribution under the inlet and middle plane

Next, to investigate the relationship between the air velocity and the temperature, a line graph is plotted to know the relationship between the temperature and the velocity. For example, from Figure 4, we can see that the higher the air velocity, the lower the temperature. The reason is that the heat transfers occur during the movement of air. So the velocity of the air can affect the temperature of the surrounding. In addition, there are natural convection occurs during the process.

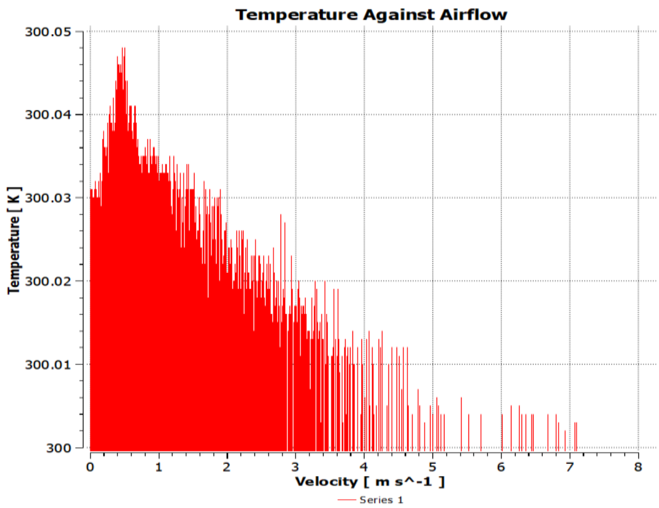

Figure 4: Temperature against air velocity

From all the data obtained above, compare the result above with the requirement from ASHRAE 55 and Malaysia Standard (ICOP-2010). The need for ASHRAE 55 22.5 ºC to 26 ºC, while Malaysia Standard (ICOP-2010) is around 23ºC to 26 ºC. The result obtains from the simulation shows that the temperature is about 300 K inside the room, which is 27 ºC. The difference between the results and the requirement is slightly different, which is 1 ºC.the difference between the results may cause by the equipment and the things that have inside the lecture room. For example, the chair and the table inside the room may radiate some heat that may influence the resuls of the simulation. The difference between the result is acceptable as the differences are minor. The percentage of error shows that 3.85 %. Table 2 shows the result obtain and the comparison between the data and the requirement.

Table 2: The comparision of air temperature

	ASHRAE 55	MS 2010	Difference	Percentage Error
Temperature	22.5 ºC to 26 ºC	23ºC to 26 ºC.	1 ºC	3.85 %.

The following parameter to be discussed is air velocity. The unit used by this parameter is ms^{-1}. According to the result of the simulation in the software of ANSYS, the analysis was successfully performed. The study managed to obtain the development of the air velocity or the movement of air or airflow in the form of the air stream and air vector. Figure 5 shows the velocity of the air in the shape of the air stream and air vector. From the figure, the air velocity is seen at the maximum velocity at 6.5 ms^{-1} while the lowest at the value of 0.4 ms^{-1}. The reason is that the majority of the air stream that travels inside the room maintained at a value between 0.4 ms^{-1} to 0.8 ms^{-1}. The highest value of the air velocity is shown below the inlet of air. The maximum value can be achieved because the energy contained inside the air is not dissipated yet, while travel inside the room makes the velocity decrease.

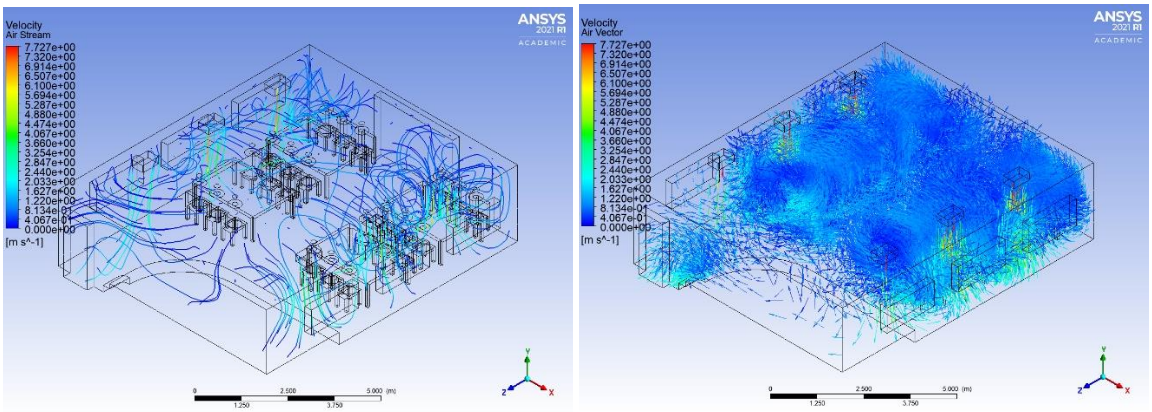

Figure 5: The air velocity in analysis of air stream and air vector

The data obtained from both the air vector and air stream analysis compared to ASHRAE 55 and MS 2010. The requirement for air velocity for ASHRAE 55 is 0.15 ms^{-1} to 0.50 ms^{-1}, while the value for the condition set by the Malaysian authority is also the same value 0.15 ms^{-1} to 0.50 ms^{-1}. So the average for the air velocity shown on the analysis is 0.55 ms^{-1}. So the percentage of error between the requirement and the results is 10%. Table 3 shows the comparison of the air velocity.

Table 3: The comparison of air velocity

	ASHRAE 55	MS 2010	Difference	Percentage Error
Air Velocity	0.15 ms^{-1} to 0.50 ms^{-1}	0.15 ms^{-1} to 0.50 ms^{-1}	0.05 ms^{-1}	10 %.

Air humidity is the number of water droplets contained in the air. If the humidity is high, so the person in the area will feel a wetter atmosphere. The analysis on the ANSYS software shows that the humidity in the room in the form of a mass fraction of water. The results show the humidity in the form of a dotted mark. Figure 6 shows the relative humidity inside the room. Most of the figure indicates that the relative humidity inside the room is around 75% to 8.0%. There are several reasons why the relative humidity can be higher than average. One of the reasons is the effect of outside weather on that time, whether there is rain or after the rain so the humidity will be high. Other than that, the flawed HVAC system can contribute to insufficient dehumidification and lead to the increase of humidity.

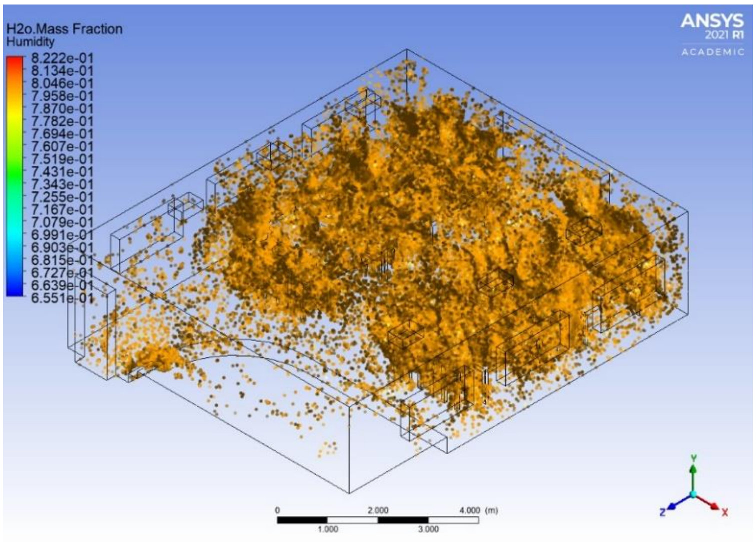

Figure 6: The relative humidity inside lecture room

According to ASHRAE 55, the allowable and the requirement for the relative humidity is around 30% to 60%. The authority of Malaysia, which is Malaysian standard 2010, stated that the relative humidity is approximately about 40% to 70%. There is a different value between these two requirements. One reason the requirement for humidity in Malaysia is higher than the international body is that Malaysia's climate needs higher humidity than the other region. From the result of the analysis, the average range of the humidity is around 75%. There is a difference of about 5% compared to the Malaysian standard. The reason may lie in some errors that occurred during the analysis of the software. Table 4.4 shows the comparison of the relative humidity.

Table 4: The comparison of relative humidity

	ASHRAE 55	MS 2010	Difference	Percentage Error
Relative Humidity	30% to 60%	40% to 70%	5%	7 %.

Another analysis can be made from the flow inside the duct. Several parameters can be obtained from the flow inside the duct. The software that will be used is called DuctSizer software. The software can be called an automated calculator for ducting. We can get information regarding the flow inside the duct by entering a two-parameter and choosing the right room temperature, relative humidity, and atmospheric pressure. The parameter can be obtained from the software are the Reynold number, the friction factor and heat loss inside the duct. Figure 6 shows the ductsizer software with the parameter mentioned above. The figure shows that the Reynold number obtained is 2 107 507, indicating the flow is turbulent. The head loss inside the duct is 4.424 with other parameters such as a friction factor of 0.04.

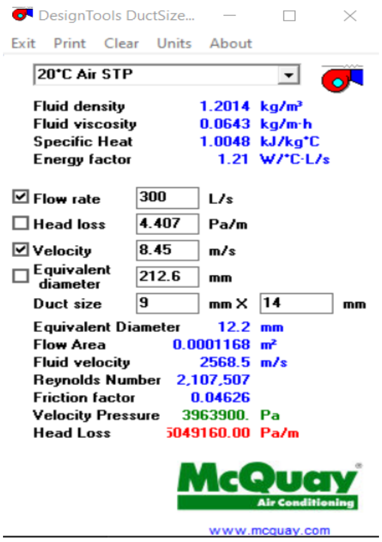

Figure 5: Ductsizer software analysis

4. Conclusion

In conclusion, both objective of this study has been achieved by the researcher at the end of this study. From the analysis, the data obtain for the temperature is 27 ^{o}C inside the room. The requirement from the authority are 22.5 ^{o}C to 26 ^{o}C. the percentage of error for temperature are 3.85%. For the result of air velocity, the analysis obtains the results of 0.4 ms^{-1} to 0.8 ms^{-1} while the requirement of the air velocity is 0.15 ms^{-1} to 0.50 ms^{-1}. So, the percentage of error for the air velocity is 10%. For the relative humidity obtained from the analysis is around 75% different around 5% with the requirement which is 70%. The percentage of error of 7%. Hence it can conclude that the lecture room of G3 building follows the requirements from the authority's body based on the analysis of this study even though there are small error of percentage between the results obtained.

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