Investigation the Advisable Position of Split Air Conditioning Unit on Classroom Using Computational Fluid Dynamics (CFD)

OPEN ACCESS

Volume: 3

Issue: 3

Month: July

Year: 2024

ISSN: 2583-7117

Published: 01.08.2024

Citation:

Rampravesh Yadav[1], Shivendra Singh[2], Dr. B. Suresh[3] “Investigation the Advisable Position of Split Air Conditioning Unit on Classroom Using Computational Fluid Dynamics (CFD)” International Journal of Innovations In Science Engineering And Management, vol. 3, no. 3, 2024, pp. 32–43.

Rampravesh Yadav[1], Shivendra Singh[2], Dr. B. Suresh[3]
[1]Research Scholar, Department of Mechanical Engineering, Corporate Institute of Science & Technology, Bhopal
[2]Asst Prof., Department of Mechanical Engineering, Corporate Institute of Science & Technology, Bhopal
[3]Prof. & HOD, Department of Mechanical Engineering, Corporate Institute of Science & Technology, Bhopal.

Abstract
If control the humidity, temperature, and air circulation in a space, need an air conditioning (AC) system. When an air conditioner successfully maintains a pleasant temperature in a room, say that it is doing well. One setting where instruction and study take happen is in university lecture halls. Typically, a classroom may accommodate from twenty to fifty students. It is recommended that classrooms be constructed as enclosed spaces in order to minimize outside noise. Unequal distribution of air circulation and temperature is a common issue in classrooms. The course model at Yogyakarta's Sekolah Tinggi Teknologi Nasional (STTNAS) is used to conduct numerical simulations in this study. The classroom's air conditioning system is equipped with two or three split-type units. This investigation of the classroom's velocity and temperature distribution involves relocating the air conditioner. The four scenarios include different locations for the air conditioner. To study the distribution of air velocity, pressure, and temperature, the classroom model is numerically simulated using ANSYS Fluent software using a transient pressure-based solver. For 10 minutes, the room is modelled with the inlet temperature of 16 ºC and an intake velocity of 0.5 m/s. The mean temperature of the classroom was unaffected by relocating the air conditioner, according to computer calculations. A temperature of 27.9 ºC is recorded in cases 1 and 2, while 27 ºC is recorded in cases 3 and 4.

Keyword: Air conditioning, Classroom, Computational fluid dynamics, thermal comfort, indoor air quality.

INTRODUCTION

“Heating”, “Ventilation”, and “Air Conditioning” is an abbreviation for such systems. Enterprise data centers require HVAC systems to be planned for and managed alongside the other data center components like servers, storage, networking, security, and power. These systems regulate the "data center's ambient environment", which includes humidity, temperature, air flow, and air filtration [1], [2]. Almost all pieces of IT gear have certain temperature & humidity requirements. Product specifications and physical planning guidelines often detail these needs. The all air handling unit and component which include in the HVAC system [3][4]. The safety, security, fire, and environmental issues of all of the equipment in the data center must be taken into consideration while designing HVAC system. This is why proper forethought, installation, and upkeep of an HVAC system are essential. In addition, emergency planning has to be included. A data center may, for instance, use HVAC redundancy, stockpile replacement parts, and store portable cooling units as backups [5]–[8].

To provide and remove air from a confined environment, natural ventilation makes use of forces that are already present in nature. It has been shown that rooms with inadequate ventilation tend to have a stronger moldy odor in some areas, particularly in the corners [9], [10]. Natural ventilation in buildings may be categorized into three main types: stack ventilation, pressure-driven fluxes, and wind-driven ventilation. 'The stack effect' relies in the buoyancy of heating or rising air to produce pressures. The principle of wind-driven ventilation is to use the wind's energy to move air through a building's interior and any openings in its outside [11]–[13].

Most old structures relied on natural ventilation systems. In the late 20th century, as air conditioning become more commonplace, the method was mostly abandoned in bigger US buildings. Natural ventilation was once considered obsolete in commercial buildings worldwide and in the United States, but it has recently seen a comeback thanks to advancements in software for Building Performance Simulation (BPS), BAS, LEED design requirements, and window manufacturing techniques [14], [15].

The “heating”, “ventilation”, and “air conditioning systems” in hospitals are performing a crucial function by keeping the buildings at a healthy temperature and humidity level and by keeping the air clean and free of germs. Due to these variables, particular consideration must be given in design of the hospital air conditioning systems to a number of criteria that are also relevant in other industries[16]. In a healthcare setting, air conditioning does much more than just keep people comfortable. The effective functioning of medical equipment utilized in hospitals and other healthcare facilities is contingent upon its sensitivity to temperature and humidity levels. However, the design of such structures is made more complicated by the fact that hospitals must have rooms with quite distinct uses [17], [18].

It's important to have a well-defined plan for how each area will be used. Some patients in a hospital could be exposed to the "infectious-contagious diseases", necessitating a degree of isolation; similarly, patients with suppressed or the weak immune systems (in intensive care units, neonatal wards, operating theaters, etc.) need to be protected from the plethora of pathogens that thrive in hospitals. Because of the high concentration of the pathogens in hospitals, and because most of these chemicals travel in air currents, the air conditioning devices in hospitals is particularly vulnerable to the accumulation of large quantities of the pathogens and can even serve as areas for their cultivation, posing a risk to health of those who use it. All of this may be prevented if the buildings are planned properly to prevent patients, staff, and visitors from being exposed to harmful bacteria and viruses [19], [20].

Objectives

- To study the effect of install AC unit in sidewall and front wall.
- The purpose of putting three air conditioners in the classroom is to examine the impact on students' thermal comfort.
- To study the effect of installing the AC unit in front wall and both sidewall.
- To study the effect of installing the AC unit in Front wall and back wall.
- The objective is to move the air conditioner about the room and see how the distribution of pressure, temperature, and velocity changes.

RESEARCH AND METHODOLOGY

Governing equation

Motivated by both velocity and buoyancy, the airflow inside the building is turbulent. It was anticipated that the flow would be incompressible due to the moderate air velocity and modest pressure gradient. It was thought that all thermophysical parameters, with the exception of density, would be constant or at least change linearly with temperature. The buoyancy effect was taken into account using the Bossiness approximation since the temperature changes inside the room are quite minor. The fundamental equations pertaining to mass, momentum, and energy are expressed as:

$$\nabla \cdot \vec{v} = 0$$

$$\rho_0(\vec{v} \cdot \nabla)\vec{v} = -\nabla(p + \rho_0 g z) + \rho_0 g \beta (T - T_0)\nabla z + \nabla \cdot \tilde{\tau}_{eff}$$

$$\nabla \cdot \big(\vec{v}(\rho e + p)\big) = \nabla \cdot \left[(k + k_t)\nabla T + \tilde{\tau}_{eff} \cdot \vec{v}\,\right]$$

In this case, β represents the air temperature expansion coefficient, and $\tilde{\tau}ef\ f$ represents the stress-effective tensor defined as $\tilde{\tau}ef\ f = \tilde{\tau} + \tilde{\tau}t$. In the Bossiness approximation, $\tilde{\tau} = (\nabla \vec{v} + \nabla \vec{v})$ and $\tilde{\tau}t = (\nabla \vec{v} + \nabla \vec{v}T)$. The turbulent model is used to calculate the turbulent dynamic viscosity (μt) and turbulent thermal conductivity (kt). It is also possible to express e, the energy per mass, as follows:

$$e = h - \frac{p}{\rho} + \frac{v^2}{2}$$

where h is the specific enthalpy.

Design

At Yogyakarta's Sekolah Tinggi Teknologi Nasional (STTNAS), researchers examine the classroom model. This classroom has split-type air conditioning units already installed and specification of classroom is 10.2 m in length, 7.6 m in width, and 3 m in height. In this study consider the various location of AC unit with two and three AC unit. In the base design, 2 split-type AC unit are considered. Dimension of the AC unit and inlet and outlet present in the AC unit are show in the figure 1, which is constant for all consider cases. Both AC unit install in the sidewall is Assume as case 1 and location of AC unit are show in the figure 2. In case 2, both AC unit are install in front wall and location of Ac unit are show in figure 3. In case 3, and case 4, increase one AC unit. In case 3, one AC unit in front wall, and one AC unit are install in each side wall. Location of AC unit in case 3 are illustrate in figure 4. Case 4 has a single AC unit installed in the rear wall and two units in the front wall. Figure 5 shows the locations of the air conditioning units. The efficiency of the air conditioning system is ascertained using numerical simulations run on the classroom model. Figures 2-5 depict the research paradigm, where a classroom devoid of any students serves as the object of investigation.

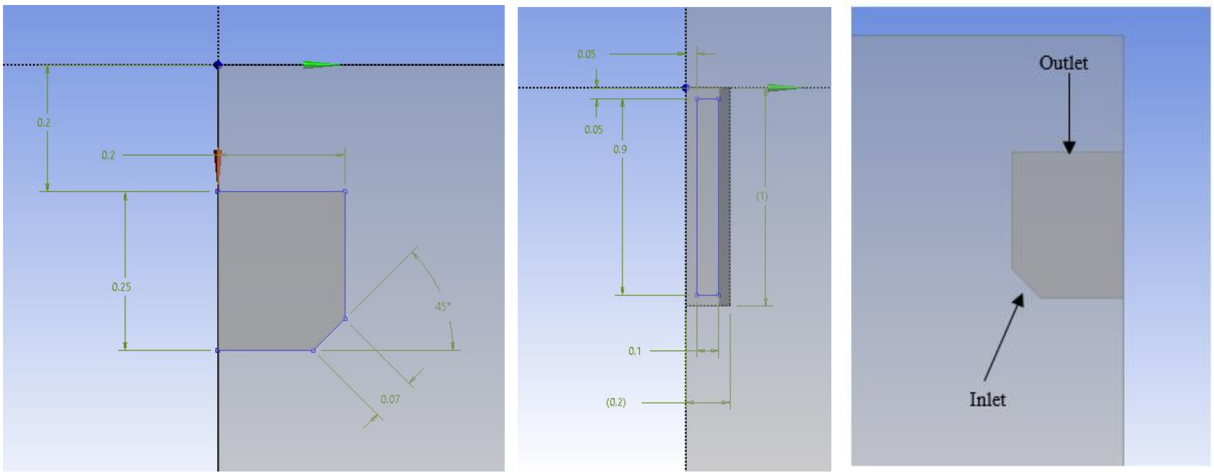


Figure 1 Inlet and outlet in AC unit with dimension

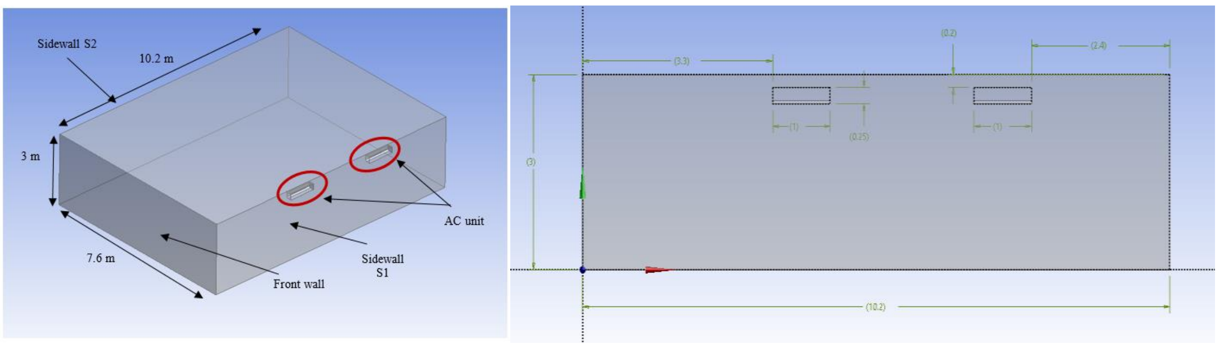


Figure 2 Computational model of Case 1 – Sidewall with Dimension

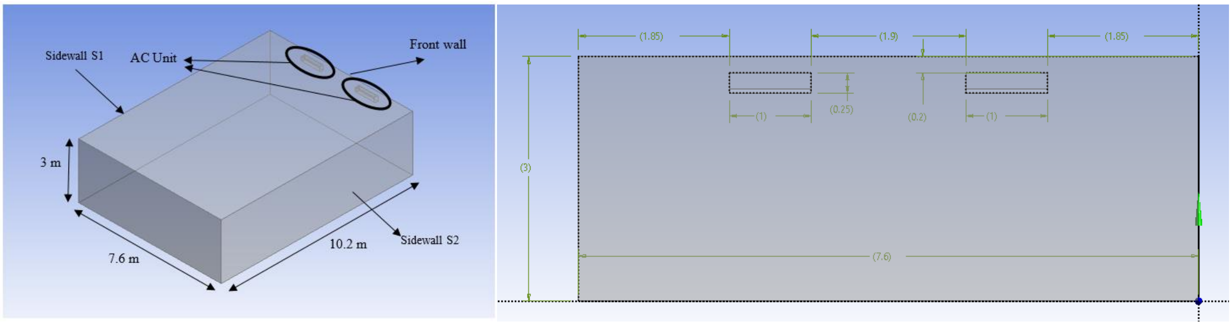


Figure 3 Computational model of Case 2 – Front wall with Dimension

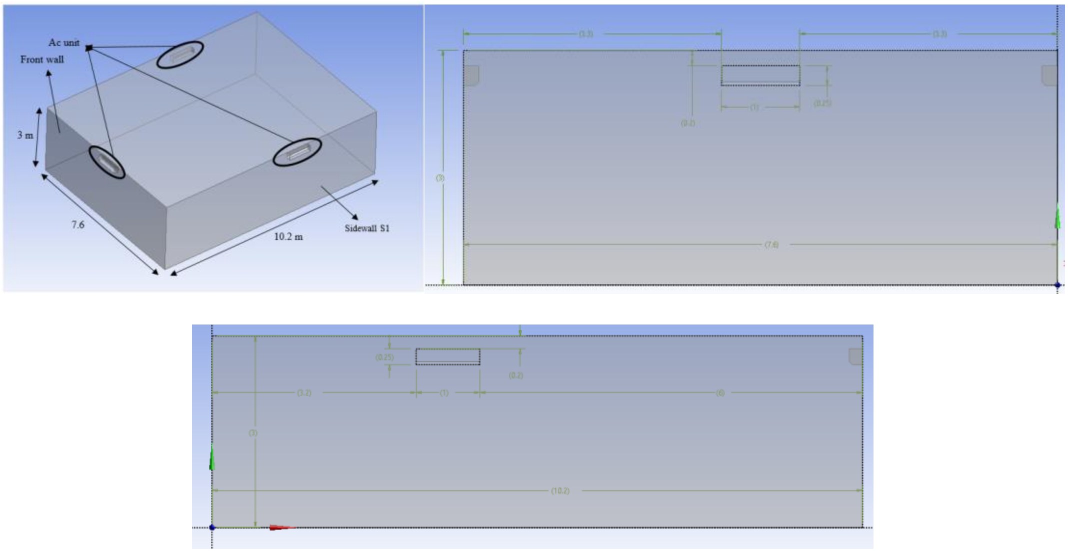


Figure 4 Computational model of Case 3 – Front and side wall with Dimension

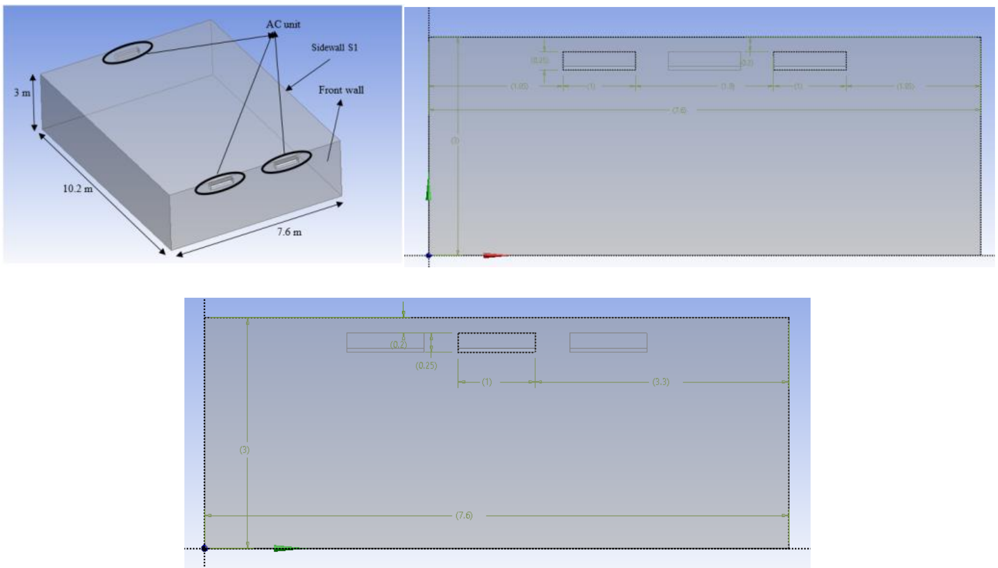


Figure 5 Computational model of Case 4 – Front and back wall with Dimension

Mesh generation

Partitioning large computational domains into smaller ones for calculation is called meshing. Here, the ANSYS Meshing program is used for meshing. The use of automatic meshing has resulted in a tetrahedral mesh. See Figure 6 for further information on how the mesh is formed and how it is arranged. Choose an element size of 0.02 m for the face mesh and 0.4 m for the volume mesh to generate the mesh. The table 1 contains mesh details. Therefore, the mesh is considered to be in excellent shape and ready for simulation.

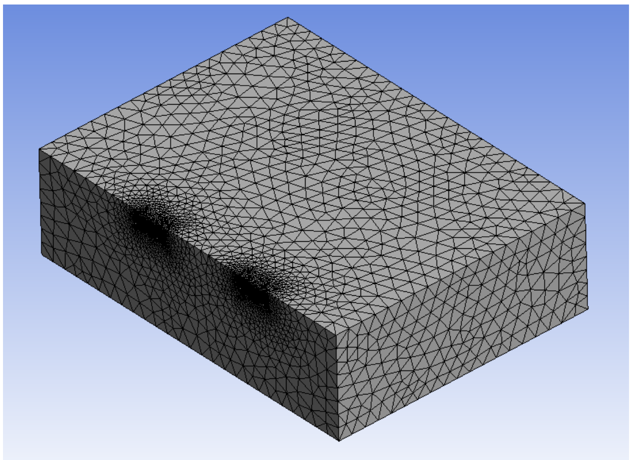


Figure 6 Mesh generation of computational model

Table 1 Mesh generated detail

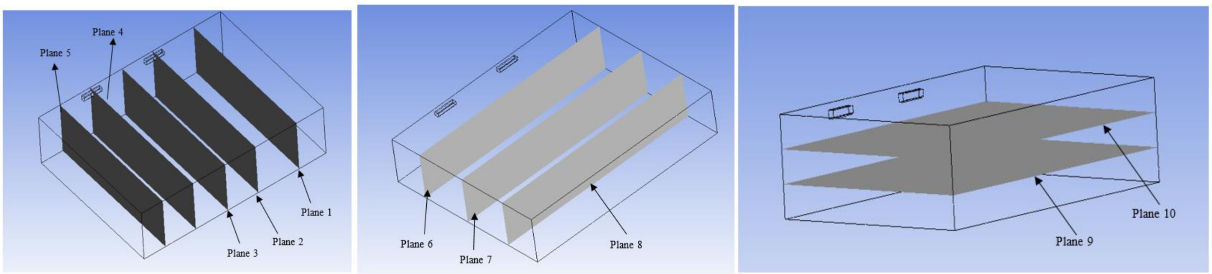
Cases	Element	Node
Case 1 - side wall	119474	22773
Case 2- front wall	117905	22486
Case 3 – front and side wall	166119	31512
Case 4- front and back wall	165198	31316

Numerical approach and boundary condition

To better understand the air conditioning system's impact on classroom temperature and air velocity, this research will use numerical simulations at Yogyakarta's Sekolah Tinggi Teknologi Nasional (STTNAS). To carry out these simulations, the commercial program known as ANSYS Fluent can be used. Commercial programs such as CATIA V5 & ANSYS Meshing Using to create our models and meshes. The findings will be shown using a commercial ANSYS CFD-Post program. Iteratively computing answers until a convergent approximation is achieved is what this technique is all about. The transient pressure-based solver in ANSYS Fluent is used to do the calculations. A realizable k-epsilon model incorporating a conventional wall function is used for flow prediction in turbulence models. The activation of the energy equation is also necessary since the simulation represented the distribution of temperatures. The solution approach included the following components: PRESTO for pressure, SIMPLE-Scheme on pressure-velocity coupling, and second-order upwind with momentum and energy. The values for the pressure, momentum, turbulence kinetic energy, turbulence dissipating rate, and energy in the solution control are 0.3, 0.7, 0.8, 0.8, and 1, respectively. The continuity, momentum, and turbulence equations have a convergence criterion of 1e-04, whereas the energy equation has a criterion of 1e-06. An entrance for velocity, an exit for pressure, and the wall make up a boundary condition. With a temperature of 16ºC and an assumed intake speed of 0.5 m/s, the evaporator part of the indoors AC unit is subjected to the inlet velocity. At the same time, as shown in the picture, a pressure outlet is often located on top of the indoors AC unit in split-type AC designs that are available. The simulation starts with a room temperature of 30ºC. There are a total of 600 seconds of time used to replicate the room during its 10-minute duration, with each step lasting 1 second.

Data Analysis Method

In order to map out the pattern of air pressure, temperature, and velocity, the data is processed with the help of ANSYS CFD-post. The distribution of velocity, pressure, and temperature may be seen using three distinct observation planes. In a space with five vertical planes running its length, three vertical planes along the room's front wall, and two horizontal planes running its height make up the three main planes. The vertical plane along the length name as plane 1, plane 2, plane 3, plane 4, and plane 5 is locate as 1.5 m, 3.8 m, 5.5 m, 7.3 m, and 9 m from the front wall respectively. The vertical plane along the front wall name as Plane 6, Plane 7, and Plane 8 is locate as 1.5 m, 3.8 m, and 6 m, from the side wall S1 respectively. The horizontal plane along the height name as Plane 9, and Plane 10 is locate as 1 m, and 2 m respectively. Figure 8 show the horizontal planes and vertical planes formed.



Planes Along the length of the room | Planes along the front wall | Planes along the height

Figure 7 All considered plane presentation

Numerical Validation

For validate the current result a comparison was made between current result and result get from (Abdulkadir, 2018)[21] from CFD analysis for same configuration and boundary conditions. There were many numerical data to compare, so just picked average temperature in plane 1-5. For validation of classroom, turbulent flow (k - e realizable) model in ANSYS fluent were use. The boundary condition is mention in upper section, which is use for simulate the model. Figure 9 illustrate the comparison of average temperature in plane 1-5 of both simulated model. The graph show that the difference between both results is about 1.73%, which is generally acceptable.

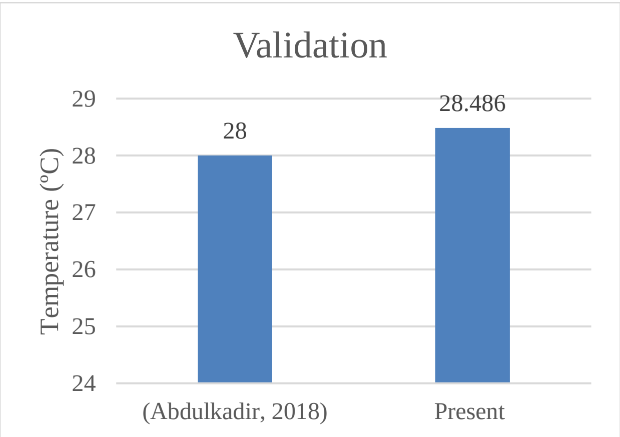
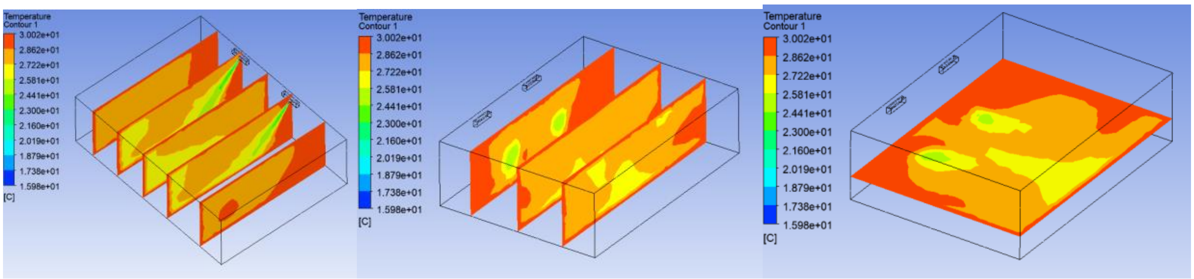


Figure 8 Temperature validation in plane 1

RESULT AND DISCUSSION

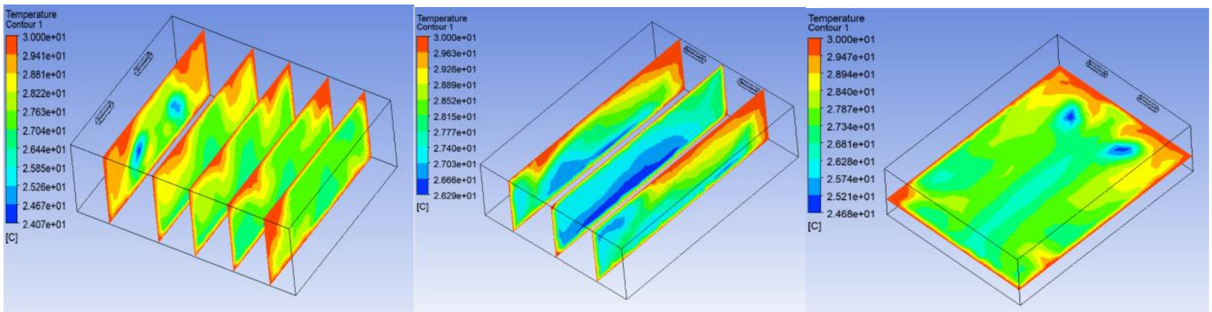
Temperature distribution

Figure 10-13 shows the temperature distribution on considered all planes in the classroom after 10 minutes of cooling system use. In case 1, there is area near to sidewall where AC unit install is still uncooled in plane 1-5. In the plane 2, and 4 illustrate the cooled air near the AC unit. In the vertical plane 6-8 illustrate that near the AC unit maximum area is uncooled but as far as from AC unit cooled air expand it means in last portion of opposite side wall (opposite of the wall where AC unit install) having less temperature. In case 2, AC unit install in front wall, therefor it illustrate that in vertical plane 1-5 maximum temperature is near to the all wall. Due to relocate the AC unit in front wall distribution of cooled air is in middle portion of the classroom. Uncooled air is near to the top wall and AC unit. Plane 9 which is located as 1 m above from the floor illustrate that cooled air distribute accurately from stating to end wall air temperature vary 26 ºC to 27 ºC. In case 3, three AC unit use to cool the classroom in which one AC unit is locate in front wall, and other two AC unit is locate in both side wall. Temperature distribution illustrate that uncooled air is present near to the front wall and other portion is cool. Temperature range at cooled portion of classroom is 24 ºC - 27 ºC. In case 4, three AC unit use to cool the classroom in which two AC unit are install in front wall and another one is in back wall. In this case temperature distribution illustrate that uncool air is near to the back wall. Temperature range vary at cooled portion of the classroom is 24 ºC - 27 ºC.



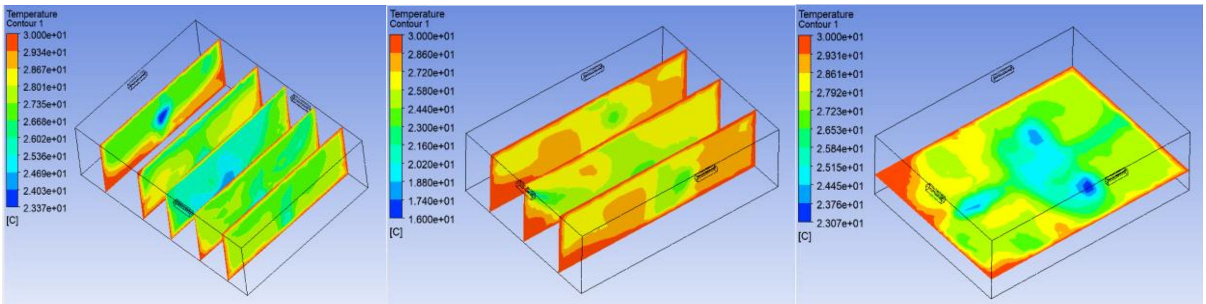
Plane 1 – 5 Plane 6-8 Plane 9

Figure 9 Temperature distribution contour in Case 1 – Side wall



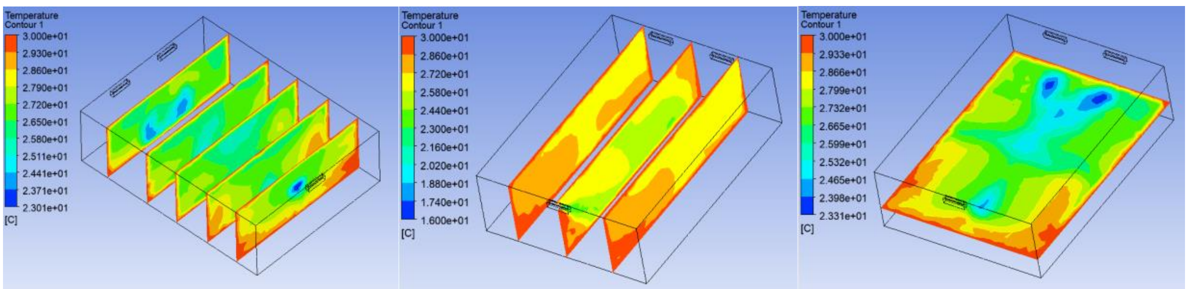
Plane 1 – 5 Plane 6-8 Plane 9

Figure 10 Temperature distribution contour in Case 2 – Front wall



Plane 1 – 5 Plane 6-8 Plane 9

Figure 11 Temperature distribution contour in Case 3 – Front and side wall

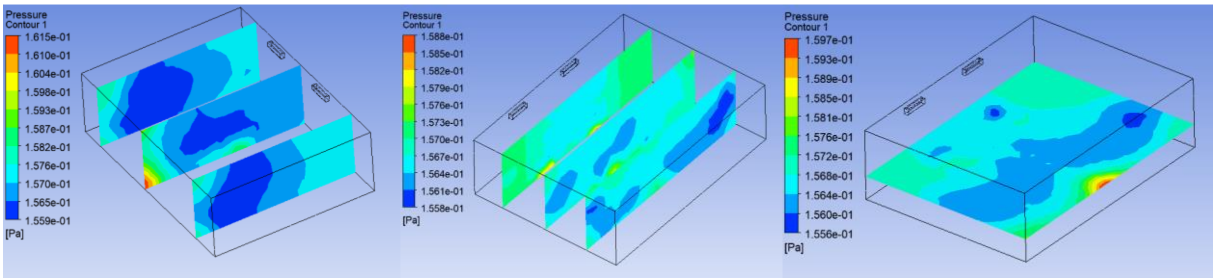


Plane 1 – 5 Plane 6-8 Plane 9

Figure 12 Temperature distribution contour in Case 4 – Front and back wall

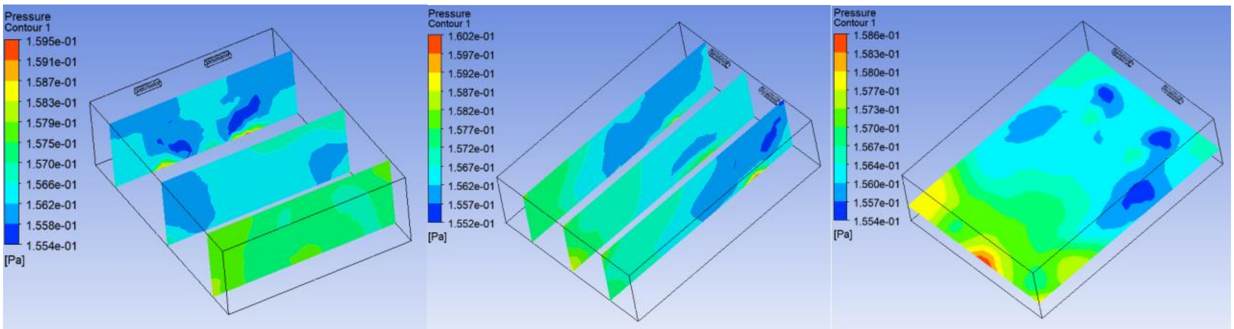
Pressure distribution

Figure 14-17 illustrate the pressure distribution on considered all planes in the classroom after 10 minutes of cooling system use. In case 1, AC unit install in side wall from vertical and horizontal plane pressure maximum at near to the wall, and minimum in the middle of the classroom. In this case pressure vary in middle of the classroom is 0.157 Pa – 0.159 Pa. In case 2, AC unit Install in front wall from vertical planes illustrate that Plane 1, Plane 3, having low pressure and plane 5 having pressure more than plane 1 and 2. It means in the back side of the classroom pressure is high as compare to front side. Case 3, having a three AC unit one in front wall, and other two are in each side wall. From pressure distribution of various plane illustrate that the pressure is high near to the wall and low at the middle of the classroom. Case 4, having three AC unit where two unit are in front wall and one in back wall. Vertical and horizontal plane illustrate that the pressure is high near to the wall and low at middle of the classroom. Pressure distribution illustrate that where temperature is high, pressure is high and where temperature is low pressure is also low, it means pressure is directly proposal to the temperature.



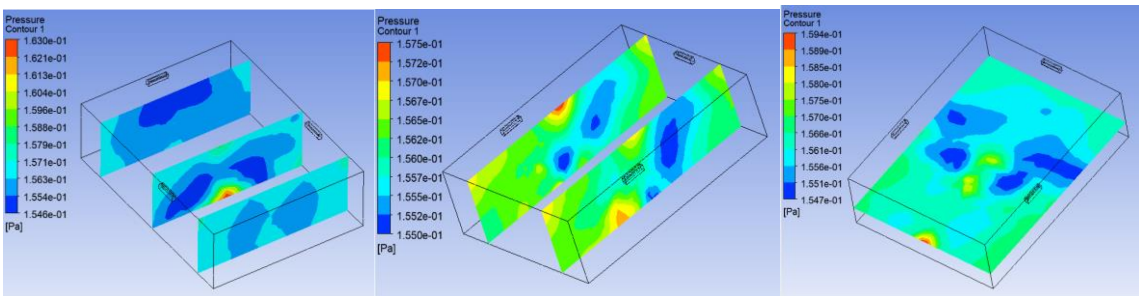
Plane 1 – 5 Plane 6-8 Plane 9

Figure 13 Pressure distribution contour in Case 1 – Side wall



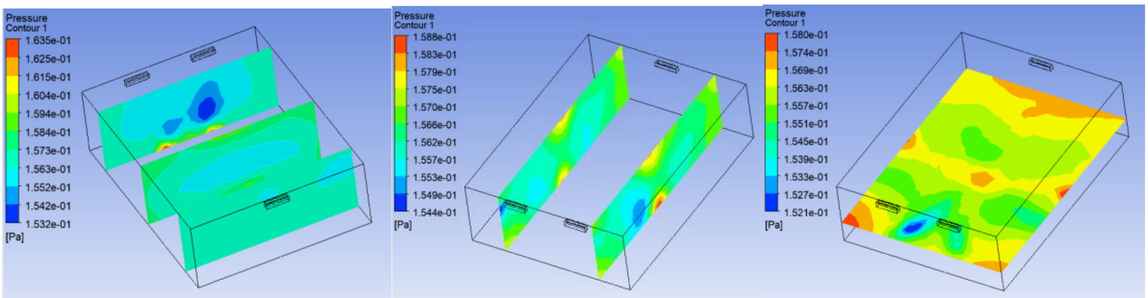
Plane 1 – 5 Plane 6-8 Plane 9

Figure 14 Pressure distribution contour in Case 2 – Front wall



Plane 1 – 5 Plane 6-8 Plane 9

Figure 15 Pressure distribution contour in Case 3 – Front and side wall

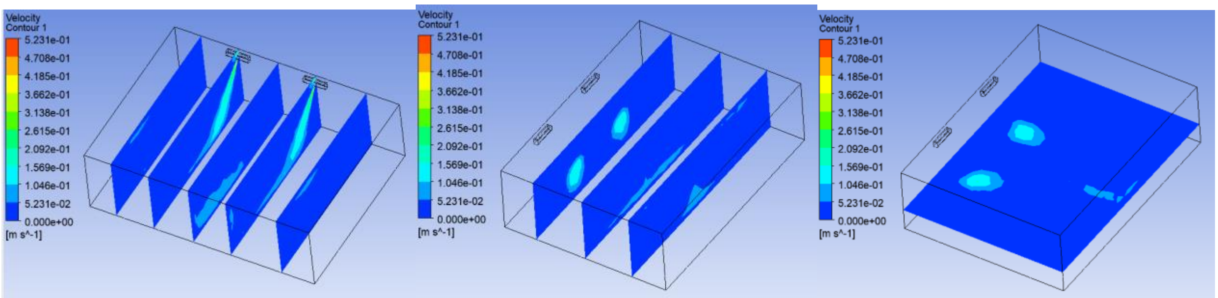


Plane 1 – 5   Plane 6-8   Plane 9

Figure 16 Pressure distribution contour in Case 4 – Front and back wall

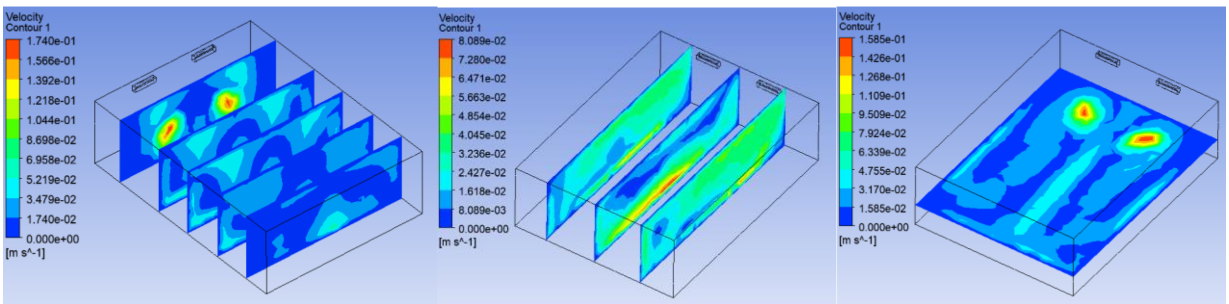
Velocity Distribution

After using the cooling system for 10 minutes, Figures 18-21 show the distribution of pressure on every planes in the classroom. Inside the room, the initial velocity is zero. In the first scenario, two air conditioners are situated along the side wall. The frigid air is moving at a speed of 0.5 m/s. Observing. The air's velocities out of the interior AC units along plane 2 and 4, which are the vertical ones just ahead of them, reveals that the flow direction is same. Consequently, regions far from the AC units will undoubtedly have greater air velocity. The air velocity is lower just underneath the interior air conditioning units since that region is not subjected to the cold blasts that the AC units produce. In case 2, the front wall is equipped with two air conditioning units. The cold air is most concentrated in the room's center, and its direct interaction with the air in plane 1 causes its highest velocity, as shown in the vertical and horizontal planes. case 3: there are three air conditioning units, one on each side of the room, with the third one in the front wall. The cool air from the air conditioner mounted on the front wall is visible in the vertical and horizontal planes, enveloping the whole classroom from the very beginning to the very end. The speed is greatest in the center of the room and slows down as one gets closer to the walls. In Case 4, there are three air conditioners: two on the outside wall and one on the rear wall. The proper distribution of air is seen by the arrangement of the vertical and horizontal planes. At or near the rear wall, speed is at a minimum.



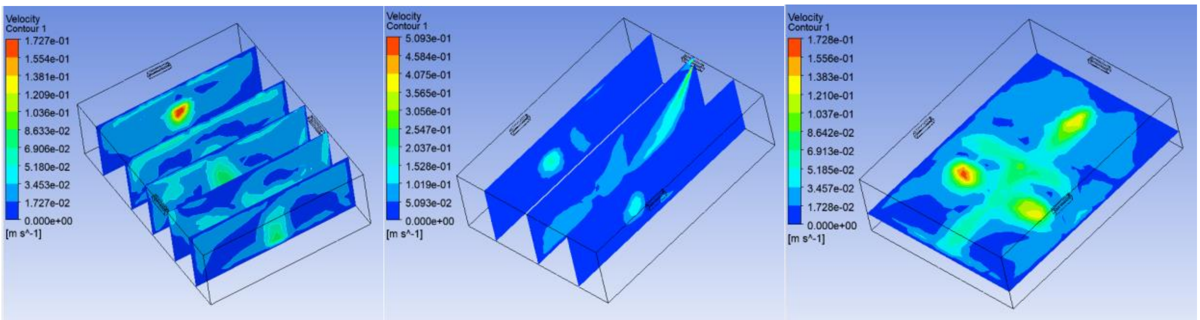
Plane 1 – 5   Plane 6-8   Plane 9

Figure 17 Velocity distribution contour in Case 1 – Side wall



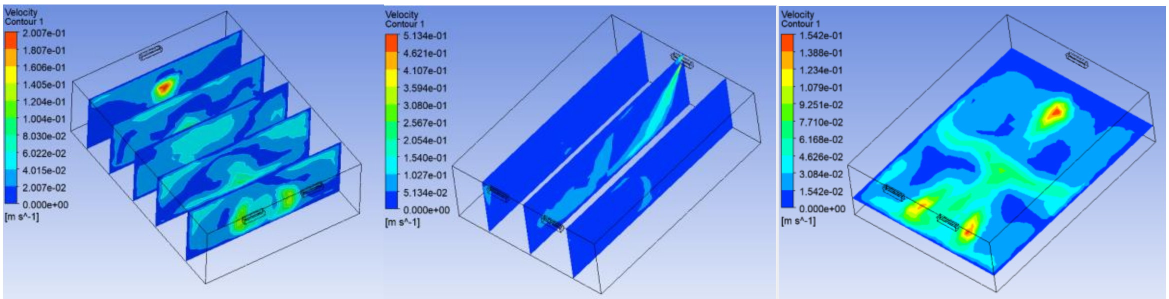
Plane 1 – 5 Plane 6-8 Plane 9

Figure 18 Velocity distribution contour in Case 2 – Front wall



Plane 1 – 5 Plane 6-8 Plane 9

Figure 19 Velocity distribution contour in Case 3 – Front and side wall



Plane 1 – 5 Plane 6-8 Plane 9

Figure 20 Velocity distribution contour in Case 4 – Front and back wall

Discussion

Figure 22 illustrate that the case I and case 2 having same temperature in classroom, which is approx. 27.9 ºC. In both case (case 1 and case 2) there is two AC unit install with different location of AC unit. Hence it is illustrate that the change of location did not change the average temperature of classroom. But Figure 23 illustrate that the change in average temperature and velocity in plane which is consider. Average temperature of the classroom is same for case 3, and case 4, which is 27 ºC. In both case (case 3 and case 4), there is three AC unit install with different location of AC unit. Average temperature of the plane 1 are different but in plane 8, 9, and 10 it is same in case 3, and case 4. Average temperature in plane 1 and plane 2 is low in case 4 as compare to case 3. Average temperature of the case 3, case 4 is low as compare to case 1, and case 2.

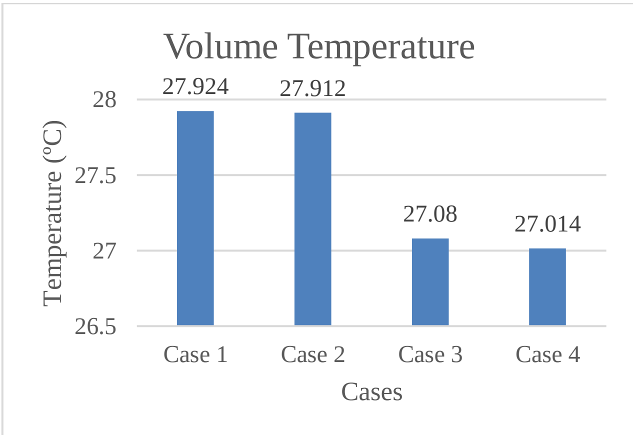


Figure 21 Average temperature in classroom in all cases

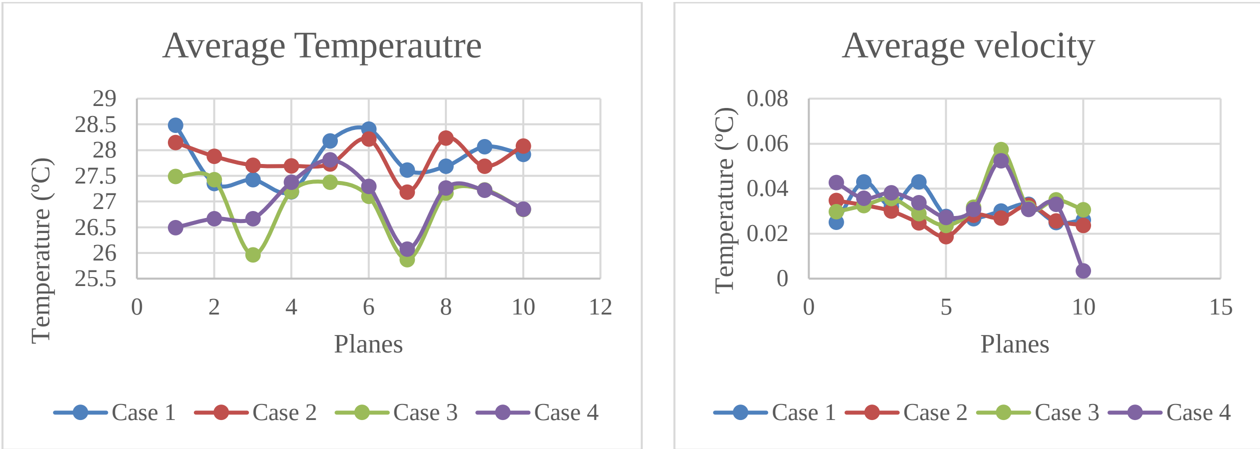


Figure 22 Average temperature and velocity in all plane for all cases

CONCLUSION

Control the humidity, temperature, and air circulation in a space, need an air conditioning (AC) system. When an air conditioner successfully maintains a pleasant temperature in a room, say that it is doing well. One setting where instruction and study take happen is in university lecture halls. Typically, a classroom may accommodate from twenty to fifty students. It is recommended that classrooms be constructed as enclosed spaces in order to minimize outside noise. Uneven allocation of air circulation and temperature is a common issue in classroom. The course model at Yogyakarta's Sekolah Tinggi Teknologi Nasional (STTNAS) is used to conduct numerical simulations in this study. The classroom's air conditioning system is equipped with two or three split-type units. This investigation of the classroom's velocity and temperature distribution involves relocating the air conditioner. The four scenarios include different locations for the air conditioner. Here are the key takeaways from the current investigation:

- The average classroom temperature in both cases one and two is 27.9 ºC.
- The average classroom temperature in cases 3 and 4 is 27 ºC.
- Compared to cases 1 and 2, the average classroom temperature in cases 3 and 4 is lower.

Average temperature of plane 1 and average temperature of horizontal plane 9, and 10 is low in case 4 as compare to remaining cases.

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