CFD Analysis of Universitas Indonesia Psychrometric Chamber Air Loop System

Ananda Reno Andi Bahar
Mechanical Engineering Department, Universitas Indonesia

Ardiyansyah Saad Yatim
Mechanical Engineering Department, Universitas Indonesia

Elang Pramudya Wijaya
Mechanical Engineering Department, Universitas Indonesia

https://doi.org/10.5109/4794173

出版情報：Evergreen. 9 (2), pp.465-469, 2022-06. 九州大学グリーンテクノロジー研究教育センター
バージョン：

CFD Analysis of Universitas Indonesia Psychrometric Chamber Air Loop System

Ananda Reno Andi Bahar[1], Ardiyansyah Saad Yatim[1,*] Elang Pramudya Wijaya[1]
[1]Mechanical Engineering Department, Universitas Indonesia, Indonesia

*Author to whom correspondence should be addressed:
E-mail: ardiyansyah@eng.ui.ac.id

(Received February 11, 2022; Revised June 20, 2022; accepted June 20, 2022).

Abstract: Indonesia is a tropical country with relatively warm temperatures, so it is necessary to use air conditioning in daily activities. The use of the air conditioner causes the large use of electricity. This prompted the government to intervene by issuing the Minister of Energy and Mineral Resources Regulation No. 57 of 2017 regarding the provisions for labeling energy from air conditioning units that are marketed in general. To test the air conditioner unit requires a room called a psychrometric chamber which is an isolation room where the temperature and humidity can be controlled. Before use, the psychrometric chamber is needed to be tested first by analyzing the air loop using CFD, ensure the installation design is completed, and compare between the ideal condition (CFD) and actual condition (on the field). In this case, the object used is Universitas Indonesia's indoor side of the psychrometric chamber, air conditioner 18,000 Btu/h split type, and other supporting components. The method used is air enthalpy based on SNI ISO 5151 regulation by measuring, modeling, installing, simulating, and compare temperature and air velocity data between CFD as ideal condition and actual psychrometric chamber. The result shows that the temperature difference at the AHU inlet is 4.7 °C, the AC inlet is 2.9 °C, the air velocity difference at the AHU inlet is 2.8 m/s, AC inlet is 2.6 m/s, and indoor air loop systems side installation is completed.

Keywords: Air Conditioner, Air Handling Unit, Air Loop, Computational Fluid Dynamics, Psychrometric Chamber

1. Introduction

Indonesia is a tropical country because it is located on the equator of the world. This makes the temperature conditions in Indonesia quite warm, which is in the range of 24°C – 32°C with a humidity of 60% - 95%, resulting in many areas, especially in big cities, using air conditioning or air conditioning in the room to maintain the temperature and stay comfortable[1,2]. Comfortable environment has a great impact on people's productivity and health [3,4].The use of this massive air conditioner causes the use of electricity[2,5,6]. According to data from the Ministry of Energy and Mineral Resources in 2017, electricity usage reached 1,012 kWh per capita. Most of air conditioning are being used by commercial and residential area[7–9]. The amount on energy used for heating, ventilation, and air conditioning (HVAC in a commercial building is reported to be approximately almost 50% of their total energy consumption[10–12]. According to the trend in electricity consumption that continues to rise can have an impact on global warming[13,14]. Furthermore, the government issued a Minister of Energy and Mineral Resources Regulation No. 57 of 2017 through the Ministry of Energy and Mineral Resources, which adopted the international standard JATL and SNI ISO 5151[15,16]. The contents of this regulation that the Indonesian government explains the application of minimum energy performance standards and the inclusion of energy-saving labels for air conditioning devices. Because of the regulations, the existing air conditioning units are soon to be replaced by new and more efficient systems[17]. New and efficient systems would be an action to reduce the global warming potential.

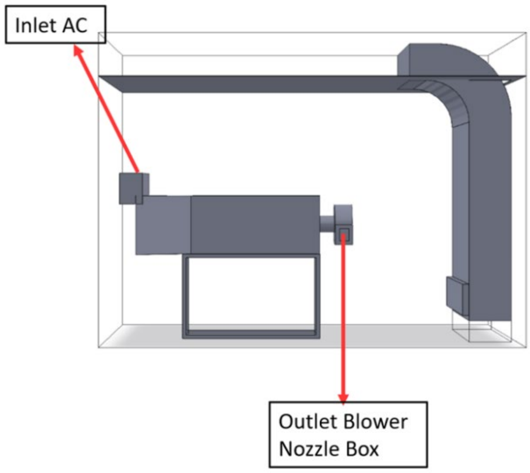
To support these regulations in implementing efficient and energy-efficient energy conversion in air conditioning devices. The psychrometric chamber itself is an AC testing tool to conform to predetermined standards. To support temperature and humidity conditioning, the installation of a psychrometric chamber requires several components including an air handling unit that works to regulate air and air temperatures, nozzles, and box nozzles as a place for air to flow to take its characteristics, and a perforated ceiling that circulates air evenly into the room[6,18,19]. In order to analyze the flow visualization inside the psychrometric chamber, Computational Fluid Dynamics (CFD) is usually used. Most of the current studies are based on CFD and based on Reynolds-averaged Navier-Stokes (RANS) equations with an eddy viscosity turbulence model [20–22] or large eddy simulation (LES) techniques[23,24]. It's a challenge to simulate the indoor environment. This study aims to obtain the analysis of air distribution from the actual conditions in the air circulation (air loop) psychrometric chamber simulation of ideal conditions using Computational Fluid Dynamics calculations.

2. Methodology

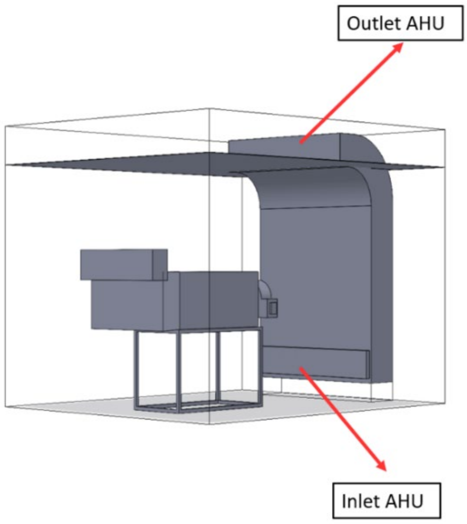
The study is based on Minister of Energy and Mineral Resources Regulation No. 57 of 2017 that using SNI ISO 5151 as standard in order how to make a psychrometric chamber, according to SNI ISO 5151 states that the indoor side of the chamber should be maintained at 27°C. The Air Enthalpy method is a way to test the dynamic performance of an air conditioner by calculating the enthalpy and circulating air volume on the inlet and outlet sides of the AC[25]. Enthalpy is measured by measuring the temperature of the dry-bulb and wet-bulb[26]. The room was set with the AHU outlet with a temperature of 27°C and the maximum AC outlet at 16°C and when the AC was not running at a maximum temperature of 25°C to see the performance of the AHU when maintaining the room temperature at 27°C according to the regulations of the SNI ISO 5151 test room conditions.

In order to analyze the air loop system in the chamber, it needed to make a CAD modeling that consists of an air handling unit, nozzle box, perforated ceiling, and other supporting parts. After everything got assembled it needed to be converted to a cavity feature so that the CFD can simulate only the air as the fluid part. After the model successfully opened in the CFD program the next step are doing name selection and mesh independence.

Mesh independence is needed to determine how many meshes is the best for the model, in this study there are 6 variation of mesh independency that variate the general sizing and mesh body sizing on the perforated ceiling model, the general mesh size of 0.07 and body size mesh of 0.007 with the total of mesh element of 945,748 is determined as the best mesh of this model because showing the most convergence result compare the other 5 variations. The Grid Convergence Index calculation was carried to define the best and efficient mesh size used in this simulation[27]. Porous zone mode should be turned on in the perforated ceiling model so CFD can simulate the airflow through the model, air velocity set on 2 m/s with 27°C temperature on the AHU outlet as ideal condition and 24.8°C as actual condition based on the real data, nozzle box outlet set with 18°C temperature, air velocity on 1 m/s as ideal condition and 2.5 m/s as an actual condition[28,29]. Data on the actual condition of the psychrometric chamber is being collected with 2 variations on the AC outlet, the first one is by setting the AC outlet at 16°C as maximum AC performance and 25°C in order to see how well the air handling unit maintained the air temperature at 27°C. On the models' tab set multiphase (volume of fluid), energy (on), viscous (k-epsilon, standard).



(a)



(b)

Fig. 1: (a) Indoor Room Model, Side View; (b) Indoor Room Model, Isometric View

In boundary conditions, the interior-perforated ceiling type was set from the wall to porous-jump so that ANSYS can simulate the impact of air when passing through the perforated ceiling. Porous-jump needs to be turned on when the model is in solid form without any holes, this is done to make CFD calculations easier [30]. Figure 1 shows the geometry of the indoor room of the psychrometric chamber.

3. Results and Discussion

After getting the simulation results with CFD calculations and experimental results to see differences in air velocity and temperature values in the psychrometric chamber, a comparison of data collection conditions (TABLE 1) and locations that can be compared; The AHU outlet as the variable that is regulated can be seen in TABLE 2 and the AHU inlet and indoor air unit inlet as the air sample taken can be seen in TABLE 3 and 4.

Table 1. Data comparison condition

Name	**Condition**	**Comparison**	
		Temperature	**Velocity**
CFD I	*Steady, Ideal Simulation*	✓	-
CFD II	*Steady, Actual Simulation*	-	✓
Actual I	*Average, Experimental*	✓	-
Actual II	*Average, Experimental*	-	✓

Table 2. AHU outlet data comparison

Outlet AHU					
Temperature (°C)			***Velocity (m/s)***		
CFD I	Actual I	Actual II	CFD II	Actual I	Actual II
27	24.8	26.0	3	3	3.0

Table 3. AC inlet data comparison

Inlet AC			
Temperature (°C)		**Velocity (m/s)**	
CFD I	Actual I	Actual II	CFD II
26.8	23.9	0.7	3.3

Table 4. Air Handling Unit data comparison

Inlet AC			
Temperature (°C)		**Velocity (m/s)**	
CFD I	Actual I	Actual II	CFD II
26.8	22.1	1.1	3.9

For comparing temperature use the “CFD I” and “Actual I” data and for air velocity use “CFD II” and “Actual II” data. As seen in the comparison data in table 1-4, the CFD simulation and actual data shows differences value at temperature and air velocity.

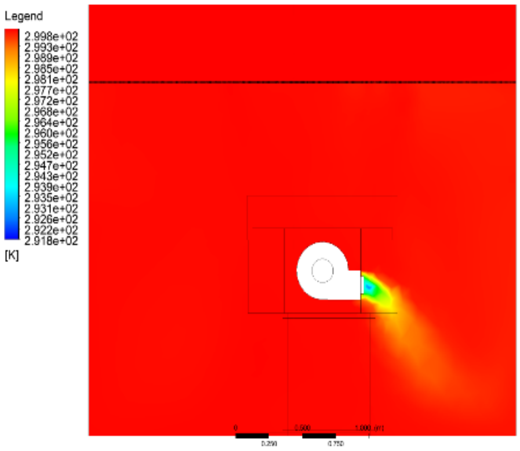


Fig. 2: Temperature contour

Figure 2 shows the temperature contour on the indoor side of the chamber, it shows that the temperature comes out from the nozzle box and goes directly to the room. Figure 3 shows that the porous zone on the ceiling area of the room was holding the air velocity in the room. Furthermore, the 0 Pa pressure at the inlet resulted in pressure differences between the room and the air handling unit, resulted in the air movement from the plenum and directly to the air handling unit inlet section.

Fig. 3: Velocity streamline

3. Conclusion

In this study, a psychrometric chamber is designed and developed to test energy performance of a split air conditioner. The air loop inside the chamber was analyzed using CFD before actual installation. The simulated model compares between the ideal condition (CFD) and actual condition on the field. The chamber uses air enthalpy method which is based on SNI ISO 5151. The study includes measurement, modeling and simulation, installation and comparison of temperature and air velocity data between CFD simulation as ideal condition and actual psychrometric chamber. The result shows that the temperature difference at the AHU inlet is 4.7 °C, the AC inlet is 2.9 °C, the air velocity difference at the AHU inlet is 2.8 m/s, AC inlet is 2.6 m/s, and the installation of indoor air loop systems side is completed.

Acknowledgements

This study work funded by PUTI 2020 Research Grant from Universitas Indonesia

Nomenclature

AC	Air conditioner (-)
AHU	Air handling unit (-)
CAD	Computer aided design (–)
CFD	Computational fluid dynamics (-)
COP	Coefficient of performance (–)
RANS	Reynolds-averaged Navier-Stokes (-)

References

1) M.H. Mahmood, M. Sultan, and T. Miyazaki, "Study on water-vapor adsorption onto polymer and carbon based adsorbents for air-conditioning applications," *Evergreen*, **6** (*3*) 215–224 (2019).
2) A.Q.A. Halim, B.T. Tee, and W.S.W.W.M. Zain, "Face bypass damper application to overcome air conditioning oversizing issue," *Evergreen*, **8** (*3*) 686–692 (2021).
3) X. Wang, S. Liu, L. Xiong, D. Wu, and Y. Zhang, "Research on intelligent regulation of air conditioning energy saving based on human thermal comfort," *J. Ambient Intell. Humaniz. Comput.*, 1–14 (2021).
4) I. Yaningsih, M.H. Mahmood, A.T. Wijayanta, T. Miyazaki, and S. Koyama, "Experimental study on dehumidification technology using honeycomb desiccant block," *Evergreen*, **5** (*2*) 11–18 (2018).
5) M.T. Kibria, M.A. Islam, B.B. Saha, T. Nakagawa, and S. Mizuno, "Assessment of environmental impact for air-conditioning systems in japan using hfc based refrigerants," *Evergreen*, **6** (*3*) 246–253 (2019).
6) E.P. Wijaya, and A.S. Yatim, "Numerical investigation of air movement on laboratory scale psychrometric chamber," *J. Adv. Res. Fluid Mech. Therm. Sci.*, **84** (*2*) 82–91 (2021).
7) T. Wu, B. Cao, and Y. Zhu, "A field study on thermal comfort and air-conditioning energy use in an office building in guangzhou," *Energy Build.*, **168** 428–437 (2018).
8) M.A. McNeil, and V.E. Letschert, "Future Air Conditioning Energy Consumption in Developing Countriesand what can be done about it: The Potential of Efficiency in theResidential Sector," Ernest Orlando Lawrence Berkeley NationalLaboratory, Berkeley, CA (US), 2007.
9) M.I. Alhamid, R.M. Miftah, and M.A. Rainanda, "Analysis of ozonation effect on performance and water quality in closed-system cooling tower," *Evergreen*, **8** (*4*) 896–903 (2021).
10) H. Han, M. Hatta, and H. Rahman, "Smart ventilation for energy conservation in buildings," *Evergreen*, **6** (*1*) 44–51 (2019).
11) L. Pérez-Lombard, J. Ortiz, and C. Pout, "A review on buildings energy consumption information," *Energy Build.*, **40** (*3*) 394–398 (2008).
12) P. Byrne, N. Putra, T. Maré, N. Abdallah, P. Lalanne, I. Alhamid, P. Estelle, A. Yatim, and A.-L. Tiffonnet, "Design of a solar ac system including a pcm storage for sustainable resorts in tropical region," *Evergreen*, **6** (*2*) 143–148 (2018).
13) L.W. Davis, and P.J. Gertler, "Contribution of air conditioning adoption to future energy use under global warming," *Proc. Natl. Acad. Sci.*, **112** (*19*) 5962–5967 (2015).
14) M.W. Gallagher, and I.K. McEwan, "Insights into grain entrainment using particle image velocimetry," in: Proc. 8th Int. Symp. Appl. Laser Tech. to Fluid Mech. Lisbon, 1996.
15) S.N. Indonesia, "Pengkondisi udara dan pompa kalor non-saluran - Pengujian dan penilaian kinerja. SNI ISO 5151:2015. p. 1-63.," 2015.
16) Kementerian ESDM, "Peraturan Mentri Energi dan Sumber Daya Mineral Republik Indonesia Nomor: 57 Tahun 2017," 2017.
17) R.D. De Kleine, G.A. Keoleian, and J.C. Kelly, "Optimal replacement of residential air conditioning equipment to minimize energy, greenhouse gas emissions, and consumer cost in the us," *Energy Policy*, **39** (*6*) 3144–3153 (2011).
18) A. Brantyopati, A. Yatim, M.I. Alhamid, and T. Widodo, "Design and construction of temperature measurement in psychrometric chamber for split air conditioner testing and energy labelling," in: AIP Conf. Proc., AIP Publishing LLC, 2020: p. 20028.
19) T. Widodo, A. Yatim, M. Alhamid, and A. Brantyopati, "Design and construction of air flow measurement device in psychrometric chamber for air conditioner energy labeling," in: AIP Conf. Proc., AIP Publishing LLC, 2020: p. 50005.
20) J. McNeill, J. Hertzberg, and Z.J. Zhai, "Experimental investigation of operating room air distribution in a full-scale laboratory chamber using particle image velocimetry and flow visualization," (2013).
21) S.B. Thool, and S.L. Sinha, "Simulation of room airflow using cfd and validation with experimental results," *Int. J. Eng. Sci. Technol.*, **6** (*5*) 192 (2014).
22) M.Z.I. Bangalee, J.J. Miau, S.Y. Lin, and J.H. Yang, "Flow visualization, piv measurement and cfd calculation for fluid-driven natural cross-ventilation in a scale model," *Energy Build.*, **66** 306–314 (2013).
23) Y. Jiang, M. Su, and Q. Chen, "Using large eddy simulation to study airflows in and around buildings," *ASHRAE Trans.*, **109** (*2*) 517–526 (2003).
24) M. Su, Q. Chen, and C.-M. Chiang, "Comparison of different subgrid-scale models of large eddy simulation for indoor airflow modeling," *J. Fluids Eng.*, **123** (*3*) 628–639 (2001).
25) S.O. Lifferth, "Design and construction of a new psychrometric chamber," (2009).
26) G. Du, S. Zhou, Y. Zhou, and X. Liu, "Design of performance testing system for hvac based on enthalpy difference method," *Procedia Eng.*, **205** 2156–2163 (2017).
27) T.S. Phillips, and C.J. Roy, "Richardson extrapolation-based discretization uncertainty estimation for computational fluid dynamics," *J. Fluids Eng.*, **136** (*12*) (2014).
28) C.A. Hviid, and S. Svendsen, "Experimental study of perforated suspended ceilings as diffuse ventilation air inlets," *Energy Build.*, **56** 160–168 (2013).
29) A. Nocente, T. Arslan, S. Grynning, and F. Goia, "CFD study of diffuse ceiling ventilation through

perforated ceiling panels," *Energies*, **13** (*8*) 1995 (2020).

30) I.N. Ibrahim, A. Yatim, and M.I. Alhamid, "Design and construction of indoor air handling unit of a psychrometric chamber for split air conditioner testing," in: AIP Conf. Proc., AIP Publishing LLC, 2020: p. 70020.