Jurnal Nasional Teknik Mesin
CYCLOID

Jurnal Nasional Teknik Mesin CYCLOID, Vol. 1, No. 1, Maret 2023; 1-10

eISSN xxxx – yyyy – zzzz
pISSN xxxx – yyyy - zzzz

The effect of airspeed over the evaporator coil on the outlet evaporator air temperature at start-up condition

[1]Jeri Tangalajuk Siang, [2]Bartolomeus Rante Allo, [3]Yohanes Karyawan
jeritsiang@gmail.com
[1,2,3] Universitas Atma Jaya Makassar

Abstract- This study was conducted experimentally to analyze the effect of airspeed over the evaporator coil on the outlet air temperature of the evaporator. This research was conducted with three different airspeeds of 2.0 m/s, 2.18 m/s, and 2.45 m/s. The result shows that at the entire operating time of the air conditioning system, the outlet air temperature is lower when the airspeed flow over the evaporator coil is low compared to the outlet temperature of the outlet air temperature. The temperature difference at the first 200s operating time for 2.0 m/s, 2.18 m/s, and 2.45 m/s are 2.0°C, 1.3°C and 0.9°C, respectively. At the operational time above 200s, the temperature difference for 2.0 m/s, 2.18 m/s and 2.45 m/s are 0.8°C, 0.9°C, and 0.9°C, respectively. The speed of temperature decreases at the first 200s operational time are 0.01°C/s, 0.007°C/s, 0.005°C/s. The speed of temperature decrease at an operational time above 200s is different at an operational time above 200s. The speed of temperature decreases at above 200s operational time are 0.0018°C/s, 0.0021°C/s, 0.0021°C/s. The volume flow rate of the cooled air increases with an increase in airspeed over the evaporator. At the airspeed of 2.0 m/s, 2.18 m/s, and 2.45 m/s the volume flow rates of cooled air are 0.118 m^3/s, 0.129 m^3/s, and 0.145 m^3/s.

***Keywords* : outlet air temperature; airspeed; volume flow rate**

I. BACKGROUND OF THE RESEARCH

Air conditioning system is an equipment that is commonly used today [1]. This equipment is often found in modern buildings. In Indonesia, air conditioning systems are commonly found in urban areas. That is due to the average surounding temperature in the cities being higher than that in village. The role of number of buildings in a particular area affects the surounding temperature. As released by the BMKG, Indonesia's average air temperature has increased by around 0.3°C every decade in the last four decades [2]. The most increase in average air temperature is in the cities compared to the average air temperature in the village. In cities that have high air temperatures, air conditioning systems are very important. Not only in buildings, whether offices, businesses, or other types of buildings, already have air conditioning systems [3].

Household air conditioning systems are produced in various types and capacities. This is intended to propose the air conditioning systems to the needs of the room and its aesthetics [4]. The indoor unit (cold air distributor) can be placed on the wall, on the ceiling of the room, or placed standing in front of the wall of the room [5]. The type of air conditioning system that is placed on the ceiling of the room is known as a cassette type air conditioning system. The indoor unit which is installed on the wall is known as a split wall type room air conditioning system. Meanwhile, the indoor unit of the air conditioning system that is installed standing in front of the wall is known as a floor-standing type of air conditioning system.

The size of the room in one house or building varies. There are small, medium, and large room volumes. This is a problem when the size and cooling capacity of the air conditioning system is designed for only one size. To provide air conditioning systems in various sizes of the room to be conditioned, air conditioning systems are manufactured based on their cooling capacity. For household air conditioning systems, there are capacities of 0.5 PK, 0.75 PK, 1 PK, and 1.5 PK [6]. On a large scale, a central-type air conditioning system can be larger than 10 PK [7].

The cooling capacity of an air conditioning system besides being analysed in its specifications, there are several factors that can affect an air conditioning system operates at optimum conditions. External and internal factors of the air conditioning system affect the cooling capacity [8, 9].

External factors that affect the performance of air conditioning systems are the ambient air temperature and room air temperature [10]. When the ambient air temperature changes, it affects the cooling capacity of the air conditioning system [8].

The internal factor is the mass of the refrigerant contained in the system [11]. The manufacturer of the air conditioning system has provided how much refrigerant mass must be charged into the system to produce optimum cooling capacity. When the mass of the refrigerant does not meet that specified by the manufacturer, it results in a degradation of cooling capacity or an increase in the use of electrical energy [9].

Another internal factor is the air fan and blower. In outdoor units, usually, the airspeed flows over the condenser coil is kept constant. However, when condenser fan is problematic, then the heat release process in the condenser will be reduced and the resulting heat absorption from the cooled room will also be reduced. It's the same with the blower of the evaporator. When the fan speed of the outdoor unit is unchangeable, the blower on the evaporator can be changed as needed.

In common air conditioning systems, the speed of air across the evaporator is set at several speed levels. For household air conditioning systems, generally, the air speed across the evaporator has three-speed levels [12]. The evaporator air speed is varied to suit the cooling needs of the room.

The cooling capacity of the air conditioning system is measured when the air conditioning system is in a steady state. So measurements can be made using variables air velocity, mass flow rate, and temperature difference.

In this study, the conditions to be discussed are at the start-up of the air conditioning engine. At start-up, the air temperature will decrease to the point where the temperature cannot be lowered again. The final temperature of the air from the evaporator will be measured at three levels of airspeed according to those in the system.

eISSN xxxx – yyyy – zzzz
pISSN xxxx – yyyy - zzzz

II. THEORETICAL BASIS

A. Heat transfer process at the evaporator coil

The primary function of an air conditioning system is to absorb heat from the conditioned room. The heat transfer process occurs by convection between air particles in a chamber. The heat is brought to the evaporator coil. In the evaporator coil, the heat carried by air is absorbed by the evaporator coil. The evaporator coil is generally made of copper, while the coil fins are generally made of aluminum [13]. In the evaporator coil, heat from the air passes into the evaporator pipe by conduction, and then the refrigerant absorbs the heat by the convection heat transfer process.

1) Convective heat transfer

Heat absorption from a room occurs by convection, where low-temperature air is blown from the evaporator coil. This cold air will absorb heat from the high-temperature air. The amount of heat absorbed from air molecules at high temperatures by air molecules at low temperatures is the same. This process continues until the maximum cooling capacity of the air conditioning system is reached. This process occurs in a way air in the room flows across the low-temperature evaporator coil, where the heat from the air passed is absorbed by the evaporator coil. A similar heat transfer process also occurs in the condenser. The outlet air temperature across the condenser coil is higher than the ambient air temperature.

2) Convective – conductive heat transfer

In the evaporator coil, there is a boundary between the fluid and the metal material. Heat will move from the air to the metal material in the evaporator or from the metal material to the air in the condenser. The same thing also happens to the metal material of the pipe with the refrigerant. In the evaporator, heat will move from the pipe to the refrigerant and in the condenser, heat will move from the refrigerant to the evaporator coil metal material.

3) Conductive heat transfer

Conduction heat transfer in the operation of air conditioning systems occurs in the pipes and fins of the evaporator coil. The outer temperature of the evaporator coil pipe which is higher than the inner temperature of the evaporator coil pipe causes heat to flow from the outer surface of the coil pipe to the inner surface of the evaporator coil pipe. This process will continue until the outside temperature and the inside temperature of the cooling coil pipe are the same. The conduction process also occurs in the condenser with the reverse process, where the inside temperature of the coil pipe is greater than the outside temperature of the condenser coil pipe.

4) Thermal conductivity

The material property that determines the rate of heat transfer is thermal conductivity which is expressed in Watts/m K. Thermal conductivity is expressed by the ability of a material to conduct heat. The greater the value of thermal conductivity, the better the heat conductivity. Materials with high thermal conductivity are generally metal materials, and can be used as heat exchangers. While materials with low thermal conductivity are used as insulators.

5) Convective heat transfer coefficient

In the convection heat transfer process, the rate of heat transfer can be seen from the convection heat transfer coefficient (h) with units of W/m^2 K. The convection heat transfer coefficient depends on the properties of the fluid such as thermal conductivity, viscosity, and density. In addition, the convection heat transfer coefficient also depends on the fluid velocity.

III. RESEARCH METHOD

This research was carried out experimentally using a split wall type air conditioning system with a cooling capacity of ¾ PK.

A. Measurement devices

In this study, the research variables used were wind speed and air temperature.

1) Fan anemometer

Wind speed is measured using a fan anemometer

2) DHT 22 temperature sensor

The air temperature entering and leaving across the evaporator is measured using a DHT22 temperature sensor which is recorded on a computer using an Arduino Uno microcontroller.
The research focus is only on the evaporator section, so that temperature and wind speed data on the condenser section are not measured.

IV. RESULTS AND DISCUSSION

A. Outlet temperature of the evaporator at three different airspeed

Figure 1 shows the outlet temperature changes at the evaporator at various airspeeds. The outlet temperature at the start-up of the air conditioning system was measured for 627 seconds. In the first 200 seconds of the operations, the profiles of the outlet temperatures at three different airspeeds were different. Figure 2 shows the detail of the temperature changes at three different airspeeds. After 200 s of the start-up operation of the air conditioning system, the outlet temperature slopes of three different wind speeds are nearly similar. The slope outlet temperature slopes at three different airspeeds can be observed in Figure 3.

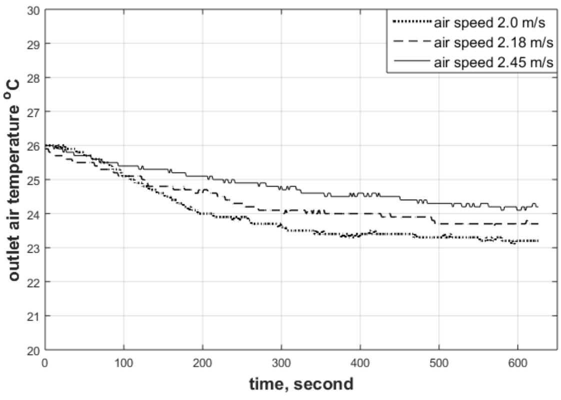

Figure 1 Outlet temperature change at various airspeed over the evaporator

eISSN xxxx – yyyy – zzzz
pISSN xxxx – yyyy - zzzz

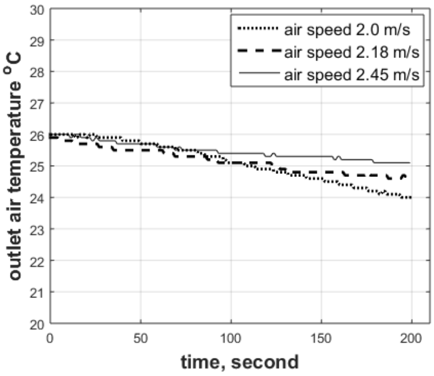

Figure 2 Outlet emperature slopes at first 200 s operation

TABLE 1
Outlet temperature difference after 200s and 627 s operation

No	air speed (m/s)	*Tin* (°C)	*Tout* at 200 s (°C)	ΔT at 200 s (°C)	Speed at 200 s (°C/s)
1.	2,0	26.0	24.0	2.0	0.01
2.	2,18	25.9	24,6	1.3	0.007
3.	2,45	26.0	25.1	0.9	0.005

Figure 2 shows the outlet temperature changes from three different airspeed. At the 2.0 m/s airspeed, the outlet temperature changes from 26°C to 24°C. At 200 s, outlet temperature decreases as 2°C. At the 2.18 m/s airspeed, the outlet temperature decreases from 25.9°C to 24.6°C which decreases as 1.3°C in 200 s. The change in outlet temperature of the evaporator is shown at least at 2.45 m/s airspeed. At this airspeed, the outlet temperature decreases from 26°C to 25.1°C or the outlet temperature only reduces as 0.9°C. The decrease in temperature of air flow over the evaporator can be observed in Table 1. The speed of temperature decreases at airspeed of 2.0 m/s is 0.01°C/s, at airspeed of 2.18 m/s and 2.45 m/s are 0.007°C/s and 0.005°C/s, respectively.

TABLE 2
Volumetric capacity and volume of cooled air at 0 - 200s

No	air speed (m/s)	*Tin* (°C)	*Tout* at 200 s (°C)	Q (m^3/s)	vol (m^3)
1.	2,0	26.0	24.0	0.118	23.6
2.	2,18	25.9	24,6	0.129	25.7
3.	2,45	26.0	25.1	0.145	28.9

B. Speed of temperature decrease

Table 2 shows the speed of the air conditioning system in absorbing the heat from the flowing air over the evaporator coil. The evaporator outlet channel area is 0.059 m^2. At speed of air of 2.0 m/s, the volume flow rates of cooled air over the evaporator is 0.118 m^3/s, at 2.18 m/s and 2.45 m/s airspeed, the volume flow rate of air to be cooled are 0.129 m^3/s and 0.145 m^3/s. Table 2 also shows the total volume of air-cooled at the 200 s beginning of the operation of the air conditioning system. The volume of the air-cooled flows over the evaporator at 200 s 0f the beginning operation of the air conditioner are 23.6 m^3, 25.7 m^3, and 28.9 m^3 at the airspeed of 2.0 m/s, 2.18 m/s, and 2.45 m/s, respectively.

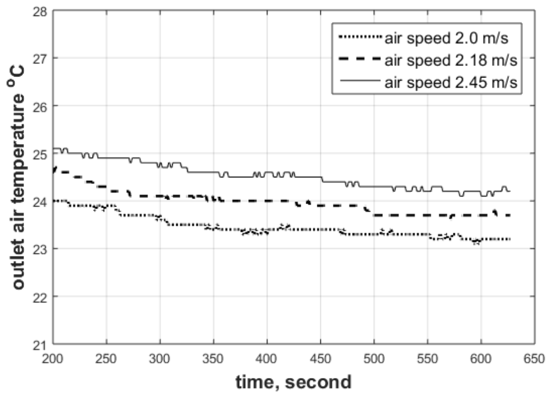

Figure 3 Outlet temperature slopes after 200s operation

Figure 3 shows the outlet temperature change during the operation time from 200 s operation to 628 s time operation at three different airspeed. Figure 3 shows nearly similar trend of outlet temperature change of the three different airspeed. At 2.0 m/s airspeed, the outlet temperature changes from 24.0°C to 23.2°C which means the temperature decreases as 0.8°C. The temperature change at 2.18 m/s airspeed is from 24.6°C to 23.7°C or the temperature drop as 0.9°C. At 2.45 m/s airspeed, the temperature changes as 0.9°C. Table 3 shows the decrease in outlet temperature of air at three airspeed values. On the basis of temperature decreases in the range of 200 s – 628 s operation time, the speed of temperature decreases at 2.0 m/s, 2.18 m/s and 2.45 m/s winspeed are 0.0018°C/s, 0.0021°C/s and 0.0021°C/s, respectively.

TABLE 3
Speed of temperature change after 200s and 627s

No	air speed (m/s)	T_{in} (°C)	Tout at 627 s (°C)	ΔT at 627 s (°C)	Speed at 627 s (°C/s)
1.	2,0	24.0	23.2	0.8	0.0018
2.	2,18	24,6	23.7	0.9	0.0021
3.	2,45	25.1	24.2	0.9	0.0021

Similar to Table 1, Table 3 shows the decreases in outlet air temperature in the specific operation time of the air conditioning system. Table 3 shows the decrease in temperature and its speed at the time operation range of 200 s – 627 s. It can be seen that the level of decrease in outlet temperature is highest at an airspeed of 2.0 m/s and the lowest decrease in outlet temperature is at an airspeed of 2.45 m/s. Speed of air temperature at 2.0 m/s, 2.18 m/s and 2.45 m/s can be expressed as 0.0018°C/s, 0.0021°C/s and 0.0021°C/s, respectively.

eISSN xxxx – yyyy – zzzz
pISSN xxxx – yyyy - zzzz

TABLE 4
Volumetric capacity and volume of cooled air at 200s - 627s

No	air speed (m/s)	*Tin* (^oC)	*Tout* at 200 s (^oC)	Q (m^3/s)	vol (m^3)
1.	2,0	24.0	23.2	0.118	50.5
2.	2,18	24,6	23.7	0.129	55.1
3.	2,45	25.1	24.2	0.145	61.9

The volumetric flow rate and volume of the air-cooled flow over the evaporator are shown in Table 4. A volume flow rate of cooled air increases as the speed of air increases. The volume flow rate increases from 0.118 m^3/s to 0.145 m^3/s as the airspeed increases from 2.0 m/s to 2.45 m/s. The The volume of air flow over the evaporator increases from 50.5 m^3 to 61.9 m^3 when the airspeed increases from 2.0 m/s to 2.45 m/s.

The decrease in outlet temperature at lower airspeed at first 200s operational time is more than the decrease in outlet temperature at a higher speed of air due to the volume flow rate of the cooled airflow over the evaporator at low airspeed being lower than the volume flow rate at a higher speed of air. Therefore, at the same heat transfer rate, the final temperature of the air at the higher volume flow rate is lower.

V. CONCLUSION

The result and discussion show important results that can be concluded as follow.
At 200s at the beginning of the operation of the air conditioning system, the outlet temperature of the cooled air decreases with a decrease in airspeed over the evaporator. The decrease in outlet air temperature is inversely proportional to the airspeed over the evaporator. At the operational time above the 200s, the decrease in outlet temperature is directly proporsional to the increase in airspeed over the evaporator.

VI. REFERENCE

[1] Yu, B. F., Hu, Z. B., Liu, M., Yang, H. L., Kong, Q. X., & Liu, Y. H. (2009). Review of research on air-conditioning systems and indoor air quality control for human health. *International journal of refrigeration*, *32*(1), 3-20.

[2] BMKG (2022 Mei 18), Panas dan Sumuk di Sebagian Wilayah Indonesia Diamplifikasi oleh Tertahannya Udara Panas Akibat Pusaran Kembar di Samudra Hindia Barat Sumatera, online, available https://www.bmkg.go.id/berita/?p=bmkg-panas-dan-sumuk-di-sebagian-wilayah-indonesia-diamplifikasi-oleh-tertahannya-udara-panas-akibat-pusaran-kembar-di-samudera-hindia-barat-sumatera&lang=ID&tag=apps-info-bmkg

[3] Opoku, R., Edwin, I. A., & Agyarko, K. A. (2019). Energy efficiency and cost saving opportunities in public and commercial buildings in developing countries–The case of air-conditioners in Ghana. *Journal of Cleaner Production*, *230*, 937-944.

[4] Che, W. W., Tso, C. Y., Sun, L., Ip, D. Y., Lee, H., Chao, C. Y., & Lau, A. K. (2019). Energy consumption, indoor thermal comfort and air quality in a commercial office with retrofitted heat, ventilation and air conditioning (HVAC) system. *Energy and Buildings*, *201*, 202-215.

[5] Ray N. Welter (2014 August 12), The 5 different types of air conditioners, online, available https://welterheating.com/types-air-conditioners/

[6] Energy Saver (2023 February 16), Sizing and selecting a room air conditioner, online, available https://www.energy.gov/energysaver/room-air-conditioners#:~:text=The%20required%20cooling%20capacity%20for,is%2012%2C000%20Btu%20per%20hour.

[7] Carier (2023 February 16), What size do air conditioner I need?, online, available https://www.carrier.com/residential/en/us/products/air-conditioners/what-size-air-conditioner-do-i-need/#:~:text=Residential%20air%20conditioners%20usually%20range,typically%20expressed%20in%20increments%20of%20.

[8] Sharifian, A., & Siang, J. T. (2015). Impacts of room temperature on the performance of a portable propane air conditioner. *International journal of Air-Conditioning and Refrigeration*, *23*(02), 1550015.

[9] Siang, J. T., & Sharifian, A. (2017). Performance of a single-duct portable propane air conditioning system under different refrigerant charge levels. *Heat Transfer—Asian Research*, *46*(8), 1246-1261.

[10] Che, W. W., Tso, C. Y., Sun, L., Ip, D. Y., Lee, H., Chao, C. Y., & Lau, A. K. (2019). Energy consumption, indoor thermal comfort and air quality in a commercial office with retrofitted heat, ventilation and air conditioning (HVAC) system. *Energy and Buildings*, *201*, 202-215.

[11] Kim, W., & Braun, J. E. (2012). Evaluation of the impacts of refrigerant charge on air conditioner and heat pump performance. *International journal of refrigeration*, *35*(7), 1805-1814.

[12] Wongwises, S., Kamboon, A., & Orachon, B. (2006). Experimental investigation of hydrocarbon mixtures to replace HFC-134a in an automotive air conditioning system. *Energy Conversion and Management*, *47*(11-12), 1644-1659.

[13] Dhade, N., & Kumar, G. S. (2019). Improving The Heat Transfer Rate Of Ac Evaporator By Optimizing Material. *International Journal for Recent Development in science & Technology*, *3*(12).