

PAPER • OPEN ACCESS

The experimental study and numerical of pipe finned as a earth-air heat exchangers

To cite this article: A Pintoro *et al* 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **505** 012059

View the [article online](#) for updates and enhancements.



IOP | ebooks™

Bringing you innovative digital publishing with leading voices to create your essential collection of books in STEM research.

Start exploring the [collection](#) - download the first chapter of every title for free.

The experimental study and numerical of pipe finned as a earth-air heat exchangers

A Pintoro¹, T U H S G Manik^{1*}, T B Sitorus¹ and E A Sihombing¹

¹Mechanical Engineering, Universitas Sumatera Utara, Medan - Indonesia

Email: dayatginting10@gmail.com*

Abstract. Earth-Air Heat Exchanger (EAHE) is cooling hot air by utilizing cold soil temperatures. This research was conducted to determine the out temperature (T_{out}) on the pipe for each variation of the inlet temperature (T_{in}) and variety of the inlet fluid velocity. In this research, the comparison between the experimental results and the results of theoretical calculations. In this study the air velocity of entry was adjusted using blowers and for measurement of temperature in pipes using thermocouples. From the experimental results of out temperature (T_{out}) at the tube with air velocity of 1 m/s is relatively the same as the result of theoretical calculation, the temperature decrease reaches temperature of ± 25 C, while for out temperature (T_{out}) experimental result using air velocity of 3 m/s tends to be higher than the exit temperature (T_{out}) on the theoretical calculation, ie only reaches a temperature drop at a point of ± 26 °C. The decrease in temperature of the underground culverts affects the length of pipe used in the research because the more air passes the pipe surface air, the faster the heat transfer between the air and the pipe wall occurs.

1. Introduction

At this time, the air conditioning system in the room has become a standard requirement for humans. Indonesia's population is living in urban areas using air conditioning system such as fan, AC, etc. This is triggered by global warming and the resulting rise in temperature in the tropic during the dry season will increase rapidly [1, 2, 3]. Human is always trying to make life better and more comfortable with the development of technology, mindset, and necessity [4, 5]. People still want the new thing, for more practical and life-packed. It can be done in a variety way, such as by the method of heat transfer systems with a layer of soil layer or Earth-Air Heat Exchanger [6, 7].

Heat transfer systems with land utilization as a medium heat absorbing, land use (earth) as a source of passive cooling and the phenomenon that occur quite simple and depend on soil temperature with environmental air [8, 9]. The atmosphere of the environment is streamed into the pipe that has been planted underground by using a blower and undergoing heat transfer with the soil. The development of heat transfer method in this soil layer in addition to low-cost space cooling is also expected to improve the environment by reducing the level of CFC (Chloro-Fluoro-Carbon) in the air which is widely used air conditioning machines such as Air Conditioner [10, 11, 12].

The purposes of this study are to find out the outlet temperature (T_{out}) of the exchanger, which occurs in experimentally and analysis calculation, to determine the effect of fluid velocity on the temperature drop at the outlet temperature (T_{out}), and to find out and compare the value of COP (*Coefficient of Performance*) in the experimental and theoretical air exchange device. Meanwhile, The



limitation of this research are the heat transfer system in the soil layer uses open cycles or open loop, the external air was forced through the pipe using a blower, and the inlet air velocity of 1 m/s, 2 m/s, 3 m/s. The benefit of this research is to find out the extent of the temperature reduction obtained by using the heat transfer system in the soil layer, the air conditioner that using natural energy without additional energy, and provide the researcher's experience on heat exchanger from the beginning to the calculation to its application.

2. Methodology

2.1. The preparation of experimental

The design of EAHE's pipe and fins are made from mild steel and the outer wall direct connection to the ground. The pipeline had a 3-inch dimension for outer diameter with a 2 mm thick tube and planted at 2 m, then connected with PVC with 3 inches outside diameter, 2 mm thick and 2 meters vertical with an elbow. While the length is 1.2 m and was arranged directly with 17 fins with each focal distance of 2 cm and the plate thickness is 2 mm.

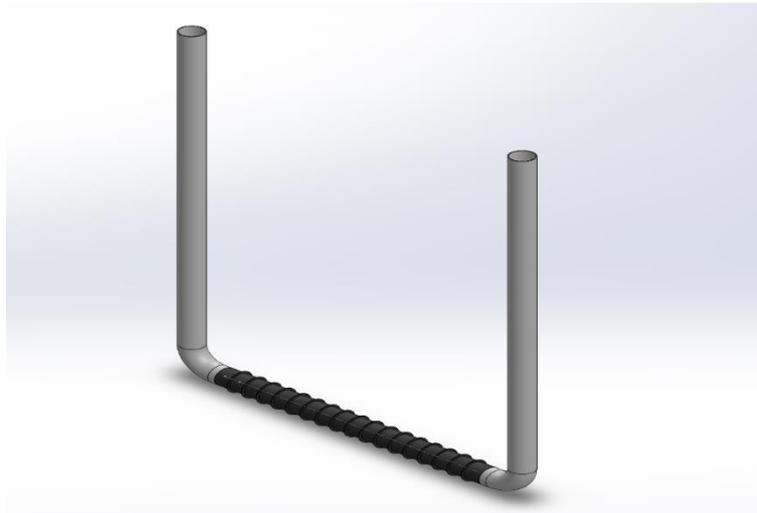


Figure 1. An EAHE with solid work application



Figure 2. An EAHE in the ground

At the phase of series, the Mild Steel with a length of 1.2 m is put together using welding citizen to connect the pipe with the Mild Steel fins, then attached to the elbows and the PVC using next one glue. At the experimental phase, the air flowed into the pipe using a blower with a velocity of the inlet airflow of 1 m/s, 2 m/s, and 3 m/s. The blower was connected to the inverter so that it can set the frequency of the blower rotation to produce the desired airflow rate. To ensure air velocity is generated according to anemometer usage. The thermocouple was placed at four temperature measurement along the pipe and connected to the computer using the Cole-Palmer 18200-40 acquisition of 8 channels. Zone 1 was positioned at the side of the inlet pipe, zone 2 at the outlet side, zone 3 is the thermometer was placed at the soil depth of 2 m, and zone 4 at 0.5 m above the ground level to measure the ambient temperature, then the thermocouple already connected to the Pole 1800-40 8. The channel is connected to a computer that has installed the Tracer-Daq software. The results of the acquisition were shown in the form of data and graphs in software Tracer-Daq. The acquired data is then stored as a .txt file.

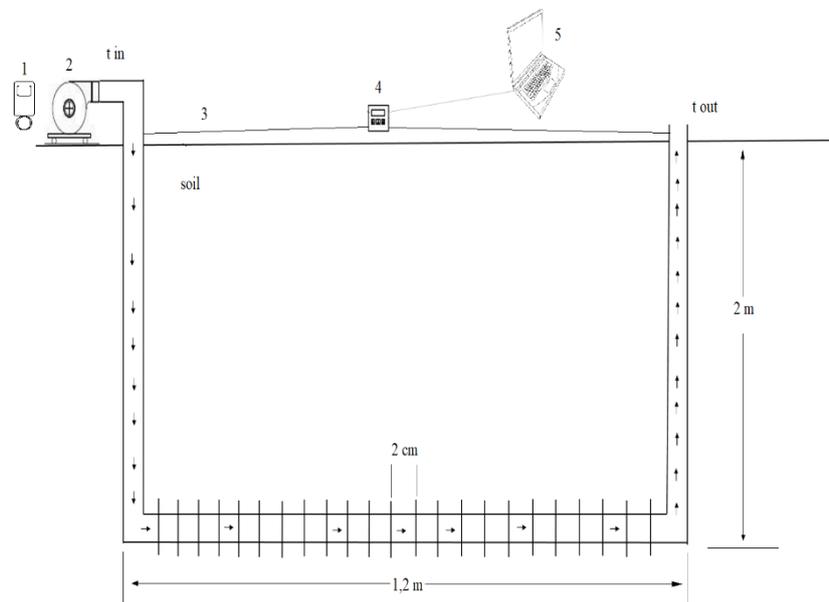


Figure 3. Set-up experimental

3. Results and Discussions

3.1. The calculation of experimental

Once the data of the air temperature entered into the system (T_{in}), the temperature of the air out of the system (T_{out}), ambient air temperature, and the temperature inside the soil surface (T_{soil}) obtained by testing in accordance with the variation of air velocity into the system that is velocity of 1 m/s, 2 m/s and 3 m/s, then calculated specific heat value (C_p), the density (ρ), and the thermal conductivity (k) for all air temperature that entered into EAHE device, and then calculate the mass flow rate using formula [13, 14]

$$\dot{m} = \frac{\pi D^2 \rho v_a}{4 N_p} \quad (1)$$

After that we analyze the heat transfer that occurs in the system:

First, we calculate the cross-sectional area (A) using the formula: $A = \pi DL$

Then we calculate the Reynolds numeral:

$$\text{Re} = \frac{V_{\text{air}} \times D_i}{\nu} \quad (2)$$

Prandtl number: $\text{Pr} = \frac{v \times c_p \times \rho}{k}$, the results of these calculations we can determine the flow of air in the pipe is turbulent.

After that we find the coefficient of friction on the pipe $f = (1.82 \log \text{Re} - 1.64)^{-2}$ and then the Nusselt number with the following formula:

$$\text{Nu} = \frac{f/8(\text{Re}-1000)\text{Pr}}{1+12.7\sqrt{f/8}(\text{Pr}^{2/3}-1)} \quad (3)$$

The coefficient of the convection heat transfer

$$h = \frac{\text{Nu} \times K}{D} \quad (4)$$

To calculate the outlet of air temperature $\text{COP} = \frac{Q_c}{P_f}$ using the formula $Q_c = \dot{m} \cdot C_p (T_{\text{in}} - T_{\text{out}})$, which to find out

$$\text{NTU} = \frac{hA}{\dot{m}C_p} \quad (5)$$

To find the effectiveness of EAHE

$$\varepsilon = \frac{T_{\text{in}} - T_{\text{out}}}{T_{\text{in}} - T_{\text{soil}}} \quad (6)$$

And the coefficient of performance is

$$\text{COP} = \frac{Q_c}{P_f} \quad (7)$$

Where $Q_c = \dot{m} \cdot C_p (T_{\text{in}} - T_{\text{out}})$ and P_f is the power consumption of the blower.

Table 1. The values of heat transfer calculation

Date	V_{air} (m/s)	T_{in} (oC)	\dot{m} (kg/s)	Re	c_p (J/kg.K)	ρ	$k \times 10^3$	Pr
10/11/17	1	34.23	0.004976	4465.210	1007.28	1.14	26,83	0.716
16/11/17	2	31.2	0.010022	9097.307	1007.16	1.15	26,61	0.715
13/11/17	3	32.18	0.014984	13563.983	1007.87	1.15	26,04	0.715

Table 2. The values of COP calculation

Date	V_{air} (m/s)	T_{in} (oC)	f	Nu	h_{conv} (W/K)	R_{konv}	COP	T_{out} Teoritis (°C)
10/11/17	1	34.23	0.039	15.09	5.46	0.39	1.16	24.99
16/11/17	2	31,2	0.032	27.88	10	0.42	0.72	25.35
13/11/17	3	32.18	0.028	38.85	13.63	0.31	0.73	25.81

3.2. The comparison of T_{out} experimental and simulation

After inlet and outlet experiment have been obtained, then the inlet result was used to get the outlet simulation testing, then the data compared using the graph.

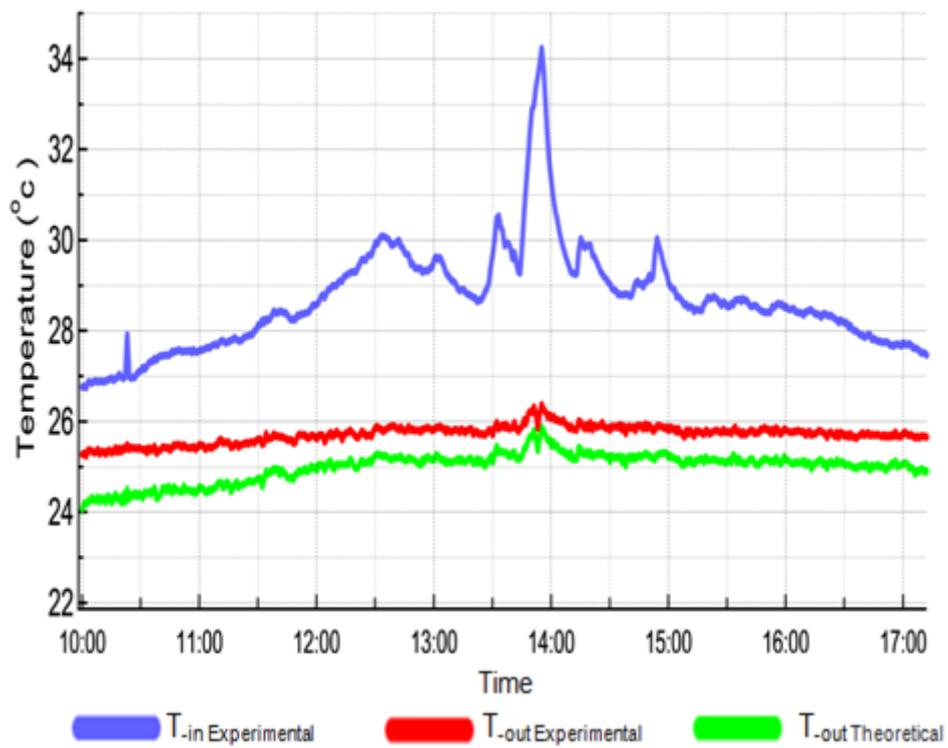


Figure 4. The comparison of T_{out} experimental and simulation ($V_{air} = 1$ m/s)

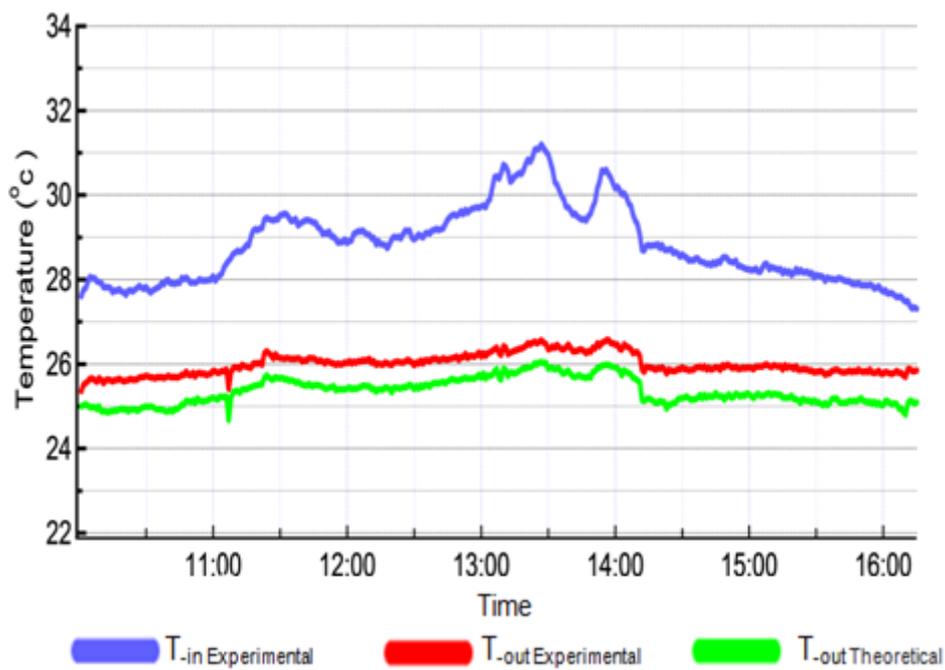


Figure 5. The comparison of T_{out} experimental and simulation ($V_{air} = 2$ m/s)

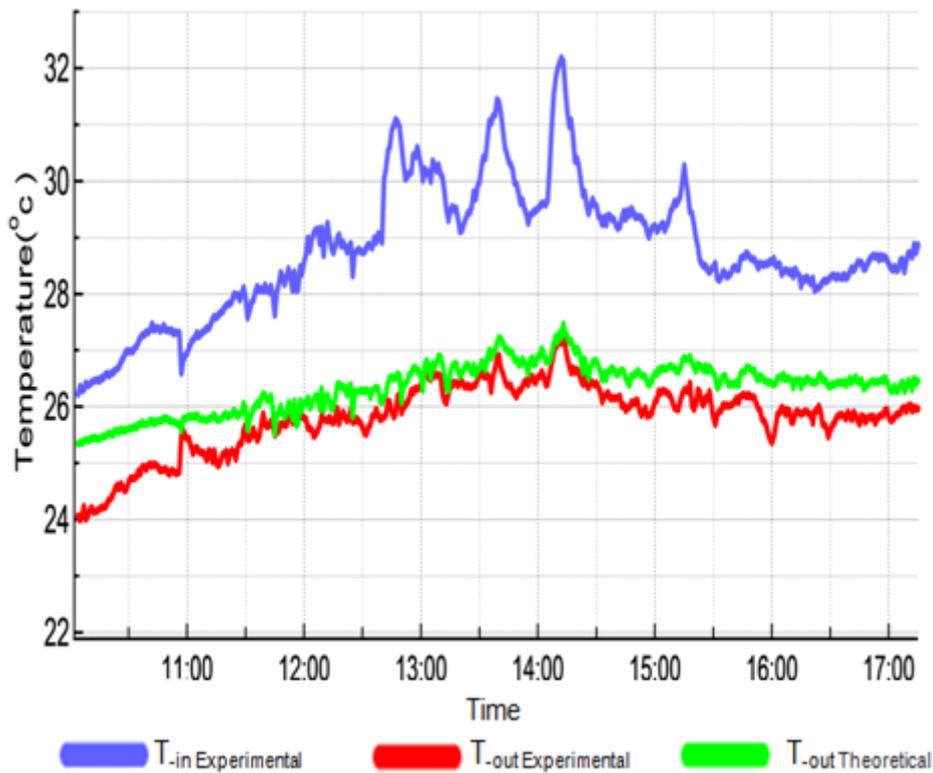


Figure 6. The comparison of T_{out} experimental and simulation ($V_{air} = 3 \text{ m/s}$)

Table 3. The comparison of the outlet temperature between experimental and theoretical

V_{air}	Statistic	$T_{in}(C)$	$T_{out}(^{\circ}C)$		Error
			Experimental	Theoretical	
1	Average	28.67	25.71	24.99	2.88%
2	Average	28.81	25.99	25.35	2.52%
3	Average	28.77	26.34	25.81	2.05%

Table 3 show that the average outlet of the temperature error (T_{out}), the average gave for the experimental model of the theoretical differ from 2.05% to 2.88%. The air temperature of the outlet average of an EAHE increases along with the velocity of the inlet. The average of the outlet temperature experimentally is higher than the channel one. It is due to the theoretical convection coefficient value is higher than the actual.

4. Conclusions

The temperature of the outlet air experimentally is higher than the theoretical, with an error for the velocity of the inlet air of 1 m/s is 2.9%, 2 m/s is 2.51%, and 3 m/s is 2.09%. Higher the air velocity, then the outlet temperature of an EAHE will be higher too. At the velocity of the inlet air of 1 m/s, the outlet temperature of 25.71°C increases to 26.01°C at 2 m/s, and 26,34°C at 3 m/s. The coefficient of performance (COP) for an EAHE decreases when the air velocity rises from 1 m/s to 2 m/s from the initial COP value of 1.16 to 0.721. However, at the velocity of 4 m/s rose to 0.736.

To prevent the occurrence of the considerable fluctuation of the inlet temperature, then we should use an open cycle system. The daily variation of the air temperature has a significant effect on calculating

the effectiveness (ϵ) and the value of the coefficient of performance. To enlarging the diameter of the pipe to increase the actual convection of the heat transfer coefficient. The analytical model that used in this study is good enough to predict the output air temperature and heat transfer. For further research, it is recommended to use the analysis model of a three-dimensional heat transfer.

References

- [1] Bulut H et al. 2014 *Experimental analysis of an earth tube ventilation system under hot and dry climatic conditions*. Google Scholar.
- [2] Sitorus T B et al. 2016 TAE - Proceedings of 6th International Conference on Trends in Agricultural Engineering 2016.
- [3] Sitorus T B et al. 2018 IOP Conf. Ser.: Mater. Sci. Eng. 309 012089
- [4] Irvan et al. 2017 IOP Conf. Ser.: Mater. Sci. Eng. 206 012028
- [5] Ariani F et al. 2017 IOP Conf. Ser.: Mater. Sci. Eng. 277 012045
- [6] Arjuna J et al. 2018 IOP Conf. Ser.: Mater. Sci. Eng. 309 012088
- [7] Incropera F and Dewitt D P 2011 *Introduction to Heat Transfer*. 7th Edition. New York: John Wiley & Sons.
- [8] Sitorus T B et al. 2017 *Journal of Engineering and Technological Sciences*, Vol. 49, No. 5, 657-670.
- [9] Belatrache D et al. 2015 *Numerical analysis of earth air heat exchanger at the operating conditions in Arid Climates*. Geothermal Energy.
- [10] Ben J and Kanoun O 2010 *Investigation of the ground thermal potential in Tunisia focused towards heating and cooling applications*. Applied Thermal Engineering.
- [11] Pfafferott J 2003 *Evaluation of earth-to-air heat exchanger with a standardized method to calculate energy efficiency*. Energy and Buildings.
- [12] Sitorus T B 2016 *International Journal of Technology* 5: 910-922, ISSN 2086-9614.
- [13] Cengel Y A 2003 *Heat Transfer: A Practical Approach*, 2nd ed. New York: McGraw-Hill.
- [14] Kreith Frank 2004 *Principles of Heat Transfer*, 9th ed. New York: Harper and Row.