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The open cycle simulation of the earth air heat exchanger using computational fluid dynamic

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Abstract. The purpose of this study is to simulate the fluid flow in a heat exchanger finned ground-air using computational fluid dynamics. The simulation carried out under the velocity of 1 m/s, 2 m/s, and 3 m/s; and the condition of the pipe was restricted to a depth of 2 m from the ground. The simulation was also used for flow, transient, incompressible, turbulent, and three dimensions. The materials that used for the Earth-Air Heat Exchanger (EAHE) is an iron pipe, which has dimension of 3 inches, 2 mm thick pipe, pipe length of 1.2 m and arranged directly with radial fin 17 with each distance of 2 cm and has a thickness of 2 mm, then the pipe was connected with PVC pipe with a length of 2.5 m. The temperature average of the outlet air of the 3D simulation result, using ANSYS, and was obtained 14.52°C inlet air velocity of 1 m/s, at 25.81°C is 2 m/s, and at 25.65°C is 3 m/s. The experimental result show that 26.37°C for the velocity of 1 m/s, at 25.92°C is 2 m/s, and at 25.72 °C is 3 m/s. The average COP value of 0.492, the simulation result for the velocity is 1 m/s, at 0.921 is 2 m/s, and at 0.377 is 3 m/s. Meanwhile, for the experimental result of 0.496 is 1 m/s, at 0.887 is 2 m/s, and the velocity of 3 m/s is 0.372.

1. Introduction

At this time, the air-conditioning system in the room has become a standard requirement for the human. Indonesian residents who live in urban areas using air conditioning system, such as fan, air conditioner, etc [1,2]. It is triggered by the presence of global warming and resulting in increased temperature in the tropic during the dry season will increase rapidly. Human is always working to make life better and live more comfortably with the development of technology, mindset, and necessity [3,4,5]. People always want the new thing, for efficiency and more practical life-packed. It can be done in a variety of ways, among others, by the method of a heat transfer system with a soil layer or Earth-Air Heat Exchanger (EAHE). Heat transfer system with soil utilization as heat absorption, land use (earth) as a passive cooling source, and the phenomenon that occurs quite easily and depending on the soil temperature with the surrounding air [6,7]. The environmental air is streamed into the pipe that has planted underground by using a blower and heat transfer with soil [8, 9]. The development of heat transfer method in this soil layer as well as low-cost refrigeration space 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, such as air conditioner [10, 11, 12].

The purpose of this study is to compare the experimental result of the reduction of the outlet temperature and the simulation, and to calculate and compare the coefficients of performance (COP). Limitation of this research is the heat transfer system in the soil layer using the open loop, the outside



air is forcibly pumped into the pipe by the blower and the analysis of air velocity of 1 m/s, 2 m/s, and 3 m/s.

2. Preparation of the simulation

An EAHE designed with 3-dimensional CAD 3 (3D) software. It is based on the result of the design of iron-finned of EAHE. The fin pipe was designed with exterior walls of x, y, z and x-y, and the outer wall of the pipe is in direct contact with the ground. The pipe had a 3-inch dimension with a 2 mm thick pipe and planted at a depth of 2 m which is connected to the vertical PVC pipe using the elbow. The length of the steel pipe is 1.2 m directly arranged with 17 fins with each focal distance of 2 cm and has a thickness of 2 mm.



Figure 1. 3D Geometry display of an EAHE

Boundary meshing condition in Ansys software 14.5. At this stage, the boundary conditions given to the EAHE is PVC and radial-finned iron pipes where the outer diameter of the 3-inch tube and the thickness of the pipe 2 mm. The coldest temperature of the soil material is within 2 m. The soil was assumed not to carry conduction with the outlet surface of the heat exchanger plant, assumed to be because it is solid ground and within 2m of which is used to cover the EAHE, so conduction is very small and negligible. Then the external pipe wall delivers heat into the inner diameter of the pipe conduction. The heat on the surface of the pipe is convection with the airflow that flowing in the air pipe with the velocity varying in the magnitude of 3ms, 2ms, and 1ms, respectively. The blower attached to the end of the pipe was assumed as the inlet velocity boundary condition and the other side pipe as output outlet. After the boundary condition is given, the next level of meshing arrangement on the EAHE according to the initial conditions. Meshing on the EAHE produces 42448 nodes and 60066 elements.

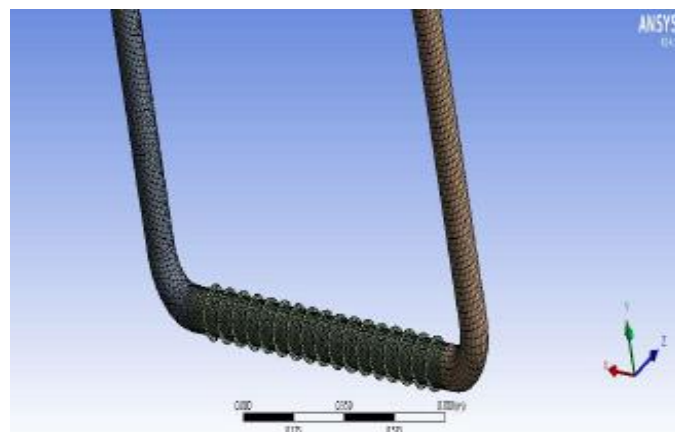


Figure 2. The result of the meshing using an Ansys software

Table 1. The value of air composition

Vair (m/s)	Time	T _{in} (C)	Cp (KJ/Kg.K)	P (Kg/m ³)	Kx10 ³ W/mK
1	10.00	26.85	1007	1.18	26.29
	11.00	27.62	1007	1.17	26.35
	12.00	28.84	1007	1.17	26.44
	13.00	34.23	1007	1.15	26.84
	14.30	30	1007	1.16	26.52
	15.00	28.76	1007	1.17	26.43
	16.00	28.42	1007	1.17	26.40
2	10.00	28.03	1007	1.17	26.38
	11.00	28.38	1007	1.17	26.40
	12.00	29.14	1007	1.17	26.46
	13.00	31.20	1007	1.16	26.61
	14.00	29.8	1007	1.17	26.40
	15.00	28.29	1007	1.17	26.40
	16.00	27.58	1007	1.17	26.34
3	10.00	26.29	1006	1.18	25.60
	11.00	27.93	1006	1.18	25.67
	12.00	29.13	1007	1.16	25.90
	13.00	30.36	1007	1.16	25.90
	14.00	32.18	1008	1.16	26.04
	15.00	29.19	1007	1.17	25.82
	16.00	28.4	1007	1.17	25.76

The parameters in table 1 are used for simulating different inlet temperature.

3. Simulation calculation

The contour temperature outlet pipe tool for simulating the EAHE to determine the average temperature of the outlet.

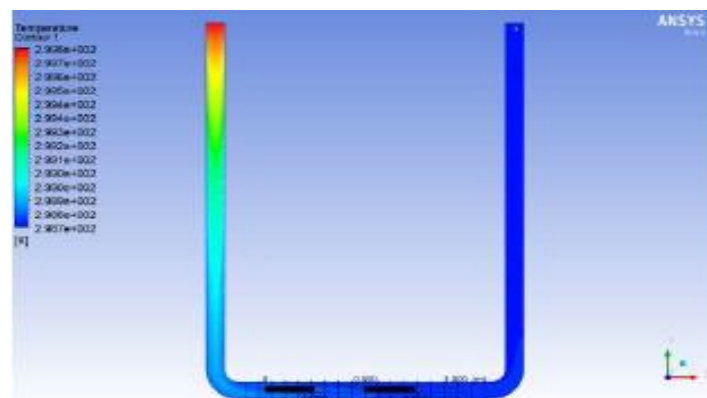


Figure 3. The result of fluid temperature contour in an EAHE tool at 1 m/s

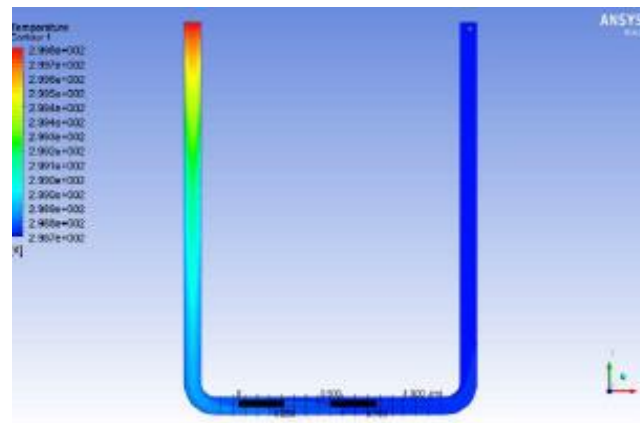


Figure 4. The result of fluid temperature contour in an EAHE tool at 2 m/s

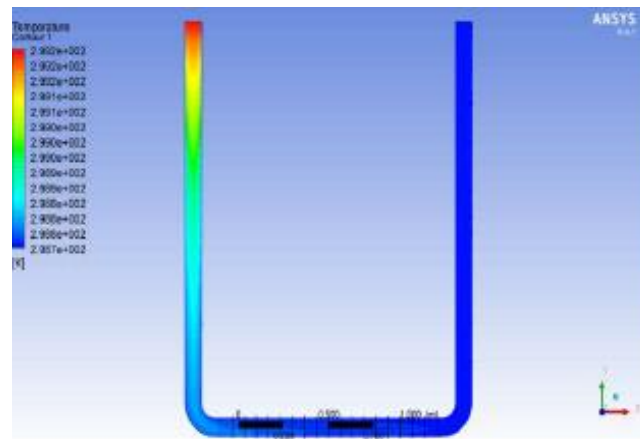


Figure 5. The result of fluid temperature contour in an EAHE tool at 3 m/s

4. The Comparison of The Experimental T_{out} and The Simulation

After the inlet and outlet experimental was obtained the results are used once again for testing the outlet simulation, then the data compared using the graph.

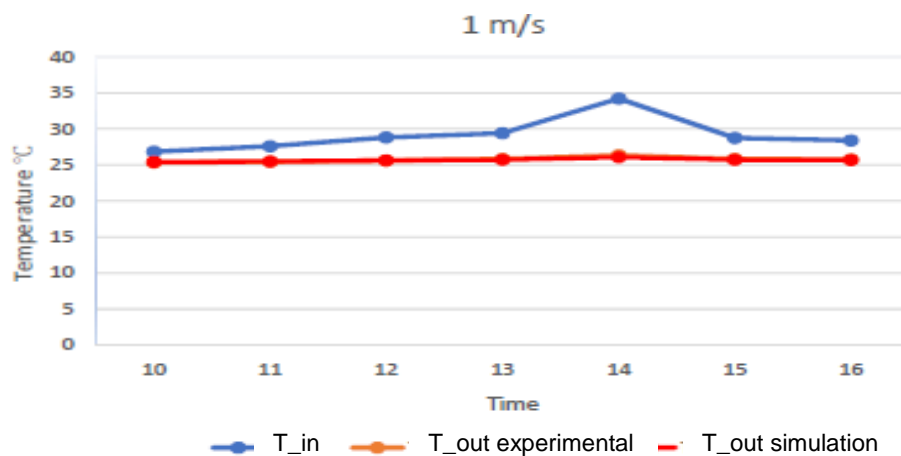


Figure 6. The comparison of T_{out} experimental and the simulation ($V_{air} = 1$ m/s)

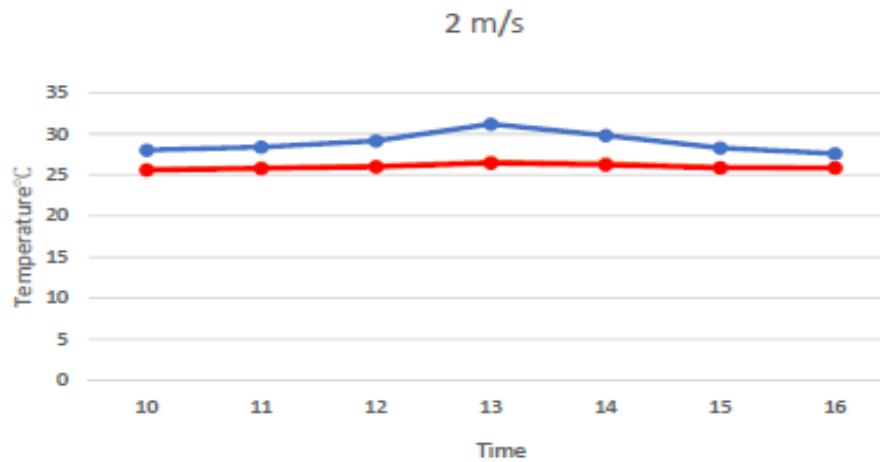


Figure 7. The comparison of T_{out} experimental and the simulation ($V_{air} = 2$ m/s)

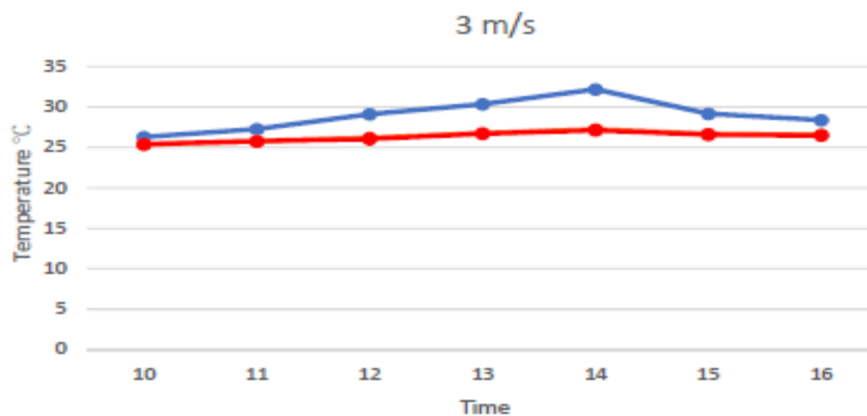


Figure 8. The comparison of T_{out} experimental and the simulation ($V_{air} = 3$ m/s)

The critical point at the velocity of 1 m/s is at time of 13.55 at the temperature of 34.23 °C, and the experimental heat exchanger pipe can reduce the temperature by 26.37°C, and the simulated heat exchanger pipe can reduce the temperature by 25.09°C. The critical point at the velocity of 2 m/s is at 13.26 at the temperature of 31.20°C and the experimental heat exchanger pipe can reduce to decrease the temperature of 26.56°C, and the simulated heat exchanger pipe can reduce the temperature by 25.43°C. The critical point at the velocity of 3 m/s is at 14.11 at the temperature of 32.18°C, and the experimental heat exchanger pipe can reduce the temperature of 27.23°C, and the simulated heat exchange pipe can reduce the temperature by 27.13°C.

5. Conclusions

The average outlet air temperature of 3D simulation was obtained 25.67°C for the velocity of the inlet air of 1 m/s, at 25.81°C is 2 m/s, and at 25.65°C is 3 m/s. The result of the experimental was obtained 26.37°C for the velocity of 1 m/s, at 25.92°C is 2 m/s, and at 25.72 °C is 3 m/s. The temperature drop for the experimental result average for the velocity of 1 m/s is 3.48°C, at 2 m/s is 2.97°C, and 3 m/s is 2.61°C. To reduce the average air temperature outlet from the simulation result for the velocity of 1 m/s is 3.14 °C, at 2 m/s is 2.87 °C, and at 3 m/s is 2.67 °C. The velocity effect on the pressure of the EAHE in the air with a mean velocity of

1 m/s is 0.475 Pa, at 2 m/s is -1.70231 Pa, and at 3 m/s is - 4.632521 Pa. The average of COP value of the simulation result was 0.492 for the velocity of 1 m/s, at 0.921 is 2 m/s, and at 0.377 is 3 m/s. While the experimental result, for the velocity of 1 m/s is 0.496011 Pa, at 2 m/s is 0.887, and at 0.372 is 3 m/s. To obtain the maximum result and the EAHE works effectively, it is a suggestion to conducted the future research in the summer. The simulation with other turbulent variable needs to be done to compare the value and accuracy of the simulation.

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