



Simulation Of Combined Air-Ground And Solar Heat Exchange System In The Test Room Using CFD

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ABSTRACT

In terms of increasing comfort in a room, a lot of research done to create a system that can make the room feel comfortable without having to waste a lot of energy. The energy savings of today are the main priorities due to the limited availability of energy and the unlimited need for energy. The use of air conditioning in terms of increasing comfort in the room, besides wasting much energy, the other side effects of using air conditioning is also create a greenhouse effect for the earth. This research was done to create a couple system between earth air heat exchanger to cool the air in the room and solar chimney which has the role of generating room air ventilation. The main purpose of this research is to create a system that can be used to create a comfortable room without using energy. The simulation of this research using Ansys 19.0 : student version, simulation is done separately with transient method and active radiation function in models. The size of the test room 2 mx 2m x 2m, high solar chimney 5 m, diameter 0.3 m, and 1mm thick, the size of earth air heat exchanger along 26.5 m, diameter 4" and with thickness 3mm. In the simulation result, the system succeeded in decreasing the room temperature up to 27.883oC at simulation and 25.2653 oC on the experimental result whereas in the earth air heat exchanger the outlet temperature was 26.33 oC at simulation, and 27.3507 oC on the experimental results. diameter 4" and with thickness 3mm. In the simulation result, the system succeeded in decreasing the room temperature up to 27.883oC at simulation and 25.2653 oC on the experimental result whereas in the earth air heat exchanger the outlet temperature was 26.33 oC at simulation, and 27.3507 oC on the experimental results. diameter 4" and with thickness 3mm. In the simulation result, the system succeeded in decreasing the room temperature up to 27.883oC at simulation and 25.2653 oC on the experimental result whereas in the earth air heat exchanger the outlet temperature was 26.33 oC at simulation, and 27.3507 oC on the experimental results.

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1. INTRODUCTION

The enormous energy demand is a major problem facing humans today. The more developed the times and the more people, the greater the need for energy. One of the old ways to address this energy need is to convert fossil fuels into energy. However, these fossil fuels produce negative effects for the earth, and also these fossil fuels are limited in availability. In general, fossil fuels will cause environmental pollution because in addition to producing fossil fuel energy, they also release gases in the form of Carbon Dioxide (CO₂), Nitrogen Oxide (NO₂), and Sulfur Oxide (SO₂) which can cause acid rain, and global warming.

Therefore, many researchers are looking for alternative energy sources whose availability is not limited and also does not cause environmental pollution. Some of these inventions are in the form of wind power plants, and solar power plants, both of which require wind and sunlight to generate electricity. As we already know, wind and sunlight are something that we can get for free, their availability is unlimited, and also does not cause environmental pollution. Solar chimney is one solution to become an alternative energy where solar chimney relies on the sun's heat to heat the chimney which because of the pressure difference that occurs will make the air flow upwards.

Solar chimney generally used to turn a turbine that will produce electrical energy. However, this solar chimney can also be used to cool a room. As is known, to cool a room, an Air Conditioner (AC) will be needed and this Air Conditioner produces Chloro FluoroCarbon (CFC) substances which will make the earth's ozone layer become perforated so that UV-B radiation will directly penetrate the earth where this radiation can penetrate the earth. make skin cancer.

The use of solar chimney as air conditioner will be combined with air-ground APK. The combination of these two systems will be able to create a comfortable and not hot room without having to use electrical energy and without having to produce harmful substances such as CFCs. In general, when solar chimney is used as an air conditioner, the system can be called passive cooling.

At this time, the Computational Fluid Dynamic (Computational Fluid Dynamic) method or commonly abbreviated as CFD is one of the best ways to be able to prove that a system can work optimally without having to create it first. CFD is a set of methodologies that use computer equipment to simulate fluid flow, heat transfer, chemical reactions, and others by solving the Navier-Stokes equations numerically. With the help of CFD, it can be seen how the temperature distribution, pressure distribution, and air flow direction in the combined solar chimney and air-ground APK system can be seen.

2. RESEARCH METHOD

The details of the flow chart above are explained in the following points:

- a. Problem Identification and Research Objectives
In this section, the main problem is how to influence the performance of Solar Chimney and air-ground APK as air conditioning components. The research focused on how much temperature reduction can be achieved indoors in the simulation after Solar Chimney and air-ground APK work according to the concept and purpose.
- b. First study
Prior to conducting research, an initial study was conducted to study various concepts and disciplines from the topic of the problem. Sources of knowledge that are used come from books, writings, electronic books and existing journals.
- c. Data collection
The data collection was carried out by measuring the dimensions of the PVC pipe used, measuring the temperature on the Solar Chimney and environmental data such as soil temperature; ambient air temperature; air humidity. This data collection is carried out to support research in conducting simulations and adjusting the conditions generated during testing with the resulting conditions after testing.
- d. Simulation Preparation
In the preparation of this simulation, 3D geometry is made, boundary conditions such as ambient temperature, soil temperature, intake air temperature, solar radiation are made. In the preparation of this simulation, meshing will also be made, where this meshing is very influential for the accuracy of the results.
- e. Simulation Calculation

In this simulation calculation, iterations will be carried out. Iteration is a process of repeated calculations aimed at getting more specific results. In Ansys simulation, it is recommended to get convergent results in iterations.

f. Simulation Analysis

After the simulation calculations have been completed and the iteration results have reached convergence, the results obtained will be obtained. In the results obtained, it is seen whether the results are in accordance with the conditions at the time of testing. If the simulation results are close to the state at the time of testing, then the simulation has been successful, but if the results are not appropriate, it is necessary to re-simulate.

g. Conclusion

After the data is obtained and analyzed, conclusions can be drawn to answer the research objectives that have been determined.

3. RESULTS AND DISCUSSIONS

3.1 Boundary and Meshing Conditions on Ansys Software 19.0

The boundary conditions used in this system are pipes in the air APK –The ground is a PVC pipe with a pipe diameter of 4 inches. The air-ground APK pipe will be in direct contact with the ground, so that conduction heat transfer will occur between the soil and the outer surface of the pipe. Heat on the inner surface of the PVC pipe undergoes convection heat transfer with the air fluid flowing in the PVC pipe naturally. The boundary conditions used in the test room are a room made of bricks with a room size of 2m x 2m x 2m, and the simulation boundary conditions are solar chimney, the solar chimney material is zinc, with a solar chimney height of 5m and 0.3m.

After the boundary conditions are entered, the next step is setting the meshing on the air-soil APK, test chamber, and solar chimney. In this meshing, the smaller the size, the more accurate the results obtained. In this study, Ansys 19.0: Student Version was used to perform the simulation. In Ansys 19.0: Student Version, the largest meshing condition is 512000 nodes and 1024690 elements. For the air-ground APK the node is 235632, the node test room is 151989 and for the solar chimney node it is 75281.

3.2 Tables and Graphs of Test Results

In this section, tables and graphs of test results from solar chimney, test chamber, and air-ground APK will be presented for the data in the simulation. The temperature obtained from the test results using the Cole Parmer and Omega tools. In this test using 10 channels, namely:

- a. Inlet Air-ground APK (Ch01)
- b. Soil temperature (Ch02)
- c. Outlet Air-ground APK (Ch03)
- d. Inlet test chamber (Ch04)
- e. Middle of the test room (Ch05)
- f. Outlet test chamber (Ch06)
- g. Inlet solar chimney(Ch07)
- h. Front of solar chimney (Ch08)
- i. Back of solar chimney (Ch09)
- j. chimney solar outlets(Ch10)

Table 1. Air-ground APK Test Result Data

Time	Soil	In	out	Time	Soil	In	out	Time	Soil	In	out
12.00	27.47	30.80	27.59	13.40	27.54	30.80	27.71	15.20	27.47	31.56	27.76
12.05	27.57	30.77	27.65	13.45	27.62	30.80	27.74	15.25	27.49	31.52	27.75
12.10	27.56	30.83	27.68	13.50	27.44	31.09	27.75	15.30	27.56	31.55	27.90
12.15	27.54	30.77	27.71	13.55	27.42	31.21	27.82	15.35	27.61	31.63	28.13
12.20	27.57	30.55	27.66	14.00	27.41	31.18	27.80	15.40	27.63	31.42	27.95
12.25	27.67	30.58	27.72	14.05	27.39	31.52	27.80	15.45	27.56	31.31	27.80
12.30	27.56	30.38	27.64	14.10	27.35	31.81	27.79	15.50	27.53	31.19	27.77
12.35	27.57	29.91	27.62	14.15	27.31	31.91	27.78	15.55	27.56	31.10	27.76
12.40	27.56	29.55	27.54	14.20	27.29	32.14	27.90	16.00	27.58	31.08	27.82

12.45	27.53	29.49	27.46	14.25	27.19	32.04	27.75	16.05	27.54	30.98	27.77
12.50	27.53	29.48	27.43	14.30	27.20	32.12	27.81				
12.55	27.57	29.79	27.52	14.35	27.38	32.04	27.98				
13.00	27.49	30.00	27.49	14.40	27.39	32.09	28.21				
13.05	27.52	30.30	27.57	14.45	27.17	32.12	27.77				
13.10	27.46	31.80	27.76	14.50	27.03	32.29	27.61				
13.15	27.47	31.21	27.74	14.55	26.96	31.95	27.35				
13.20	27.46	31.18	27.68	15.00	27.46	31.80	27.75				
13.25	27.49	31.38	27.82	15.05	27.38	32.02	27.81				
13.30	27.54	31.08	27.92	15.10	27.51	31.85	27.89				
13.35	27.50	30.86	27.73	15.15	27.51	31.58	27.82				

Table 2. Room Test Results Data

Time	RAT	SAT	RH	Time	RAT	SAT	RH	Time	RAT	SAT	RH
10:01	26.09	25.59	79	12:06	25.94	24.81	83	14:06	26.48	25.36	81
10:06	26.09	25.58	78	12:11	25.98	24.78	82	14:11	26.47	25.29	80
10:11	26.09	25.49	78	12:16	25.95	24.79	82	14:16	26.44	25.21	79
10:16	26.01	25.39	79	12:21	25.98	24.83	81	14:21	26.45	25.23	79
10:21	25.93	25.28	80	12:26	26.15	24.88	81	14:26	26.38	25.30	79
10:26	25.90	25.28	81	12:31	26.09	24.92	81	14:31	26.51	25.32	80
10:31	25.82	25.18	80	12:36	26.30	24.97	80	14:36	26.52	25.43	79
10:36	25.75	25.08	81	12:41	26.33	25.07	80	14:41	26.51	25.32	79
10:41	25.40	24.59	82	12:46	26.32	25.01	81	14:46	26.56	25.46	78
10:46	25.35	24.59	81	12:51	26.34	25.07	81	14:51	26.50	25.33	78
10:51	25.31	24.59	80	12:56	26.47	25.11	80	14:56	26.59	25.36	79
10:56	25.27	24.61	80	13:01	26.48	26.19	80	15:01	26.42	25.35	79
11:01	25.29	24.80	79	13:06	26.58	25.28	81	15:06	26.42	25.35	80
11:06	25.36	25.18	78	13:11	26.78	25.88	80	15:11	26.41	25.34	80
11:11	25.35	24.97	78	13:16	26.71	25.33	80	15:16	26.40	25.34	81
11:16	25.36	24.66	78	13:21	26.70	25.83	79	15:21	26.40	25.33	80
11:21	25.30	24.63	79	13:26	26.60	25.32	79	15:26	26.39	25.32	81
11:26	25.50	24.65	79	13:31	26.54	25.35	80	15:31	26.38	25.32	82
11:31	25.79	24.70	79	13:36	26.45	25.31	80	15:36	26.38	25.49	82
11:36	25.82	24.73	80	13:41	26.52	25.32	80	15:41	26.37	25.47	82
11:41	25.83	24.87	80	13:46	26.56	25.29	81	15:46	26.37	25.43	81
11:46	25.72	24.72	81	13:51	26.54	25.34	81	15:51	26.32	25.42	82
11:51	25.91	24.95	82	13:56	26.53	25.37	82	15:56	26.31	25.41	82
11:56	25.92	24.77	82	14:01	26.52	25.63	82	16:01	26.30	25.41	82
12:01	25.85	24.75	82								

3.3 Simulation Calculation Results

The following will display the results of the analysis in the form of temperature, air flow, and mass flow rate. In this simulation, the simulation is carried out using the SteadyState method where the parameters to be input are temperature, speed, longitude, latitude, and object material.

a. Simulation on Solar Chimney

Simulation on Solar Chimney will be carried out by entering several parameters obtained from experimental test data, the data are inlet temperature, plate temperature, and also latitude and longitude positions. The value of these parameters can be seen in the table below.

Table 3. Solar Chimney Test Result Data

	T _{Inlet} (°C)	T _{Outlet} (°C)	T _{East Platt} (°C)	T _{Western} (°C)	Flow Rate Mass(kg/s)
Maximum	40.0391	49.0296	60	79.5907	0.0192
Minimum	27	26	29	30	0.0059
Average	33.3977	36.2246	36,7114	41.7119	0.0123

Based on the table above, the simulation results will be divided into 3 parts, namely at the time of the minimum value, maximum value, and at the time of the average value.

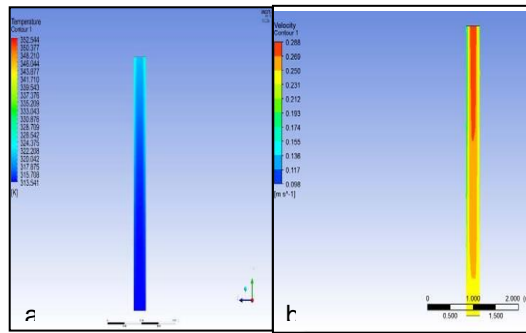


Figure 1. Maximum Temperature Contour on Solar Chimney

b. Contour Maximum Speed on Solar Chimney

First, a simulation of the maximum value obtained will be carried out. From the simulation results in Figure 4.8a, namely the temperature contour on the solar chimney, it can be seen that there is an increase in the temperature of the fluid inside the solar chimney. In Figure 4.8b is the velocity contour inside the solar chimney, which can be seen that the speed at a certain height will increase faster due to the difference in density, where the density of hot air is lower than that of cold air.

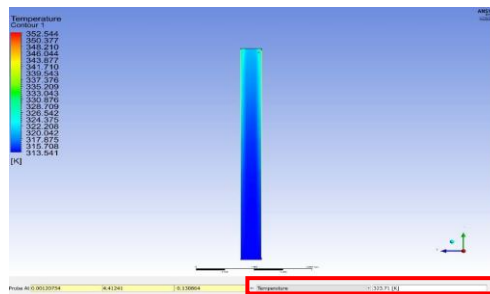


Figure 2.. Solar Chimney Maximum Temperature Contour

In figure 2. above, it can be seen that the temperature at the exit of the solar chimney is 323.71 K or 50.71oC. To get the temperature at the exit of the solar chimney, the probe feature is used to get a more specific temperature.

Scaled Residuals							ANSYS Fluent Release 16.0 (3d, c	
63	1.4034e-03	9.4644e-07	1.1842e-05	9.8189e-07	5.0405e-12	0:00:03		
64	1.2787e-03	8.5845e-07	1.0437e-05	9.0782e-07	4.5686e-12	0:00:02		
65	1.1641e-03	7.7782e-07	9.1828e-06	8.3613e-07	4.1264e-12	0:00:02		
66	1.0589e-03	7.0245e-07	8.0615e-06	7.6941e-07	3.7106e-12	0:00:01		
iter continuity x-velocity y-velocity z-velocity energy time/i								
! 67 solution is converged								
67	9.6389e-04	6.3211e-07	7.0569e-06	7.0083e-07	3.3326e-12	0:00:01		

Mass Flow Rate (kg/s)								

	in						0.02066923	
	Net						0.02066923	

Figure 3 . mass flow rate

In the picture above we can see the mass flow rate or mass flow rate which is marked with a red circle of 0.020669 kg/s. After the simulation at the maximum state is carried out, then the next simulation will be carried out at the minimum state by changing the existing parameters.

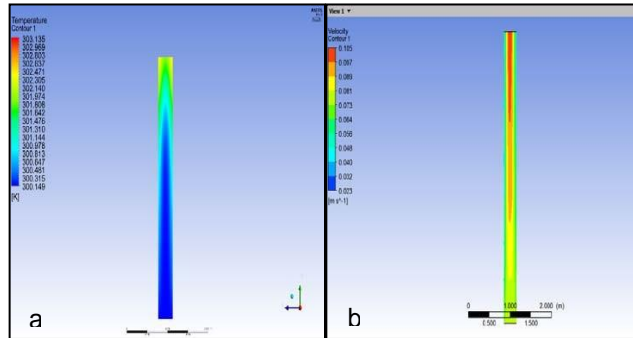


Figure 4. Minimum Temperature Contour on Solar Chimney

c. Minimum Speed Contour on Solar Chimney

In Figure 4 above, it can be seen that the temperature and speed contours of the solar chimney are at a minimum. It can be seen in Figure 4.11a that cold air with a temperature of 300.139K or 27.139oC flows upwards out of the solar chimney, and at the exit of the solar chimney the air changes temperature to around 302.471K or 29.471oC. In Figure 4.11b, the speed contour image on the solar chimney can be seen that the speed increases at a certain height.

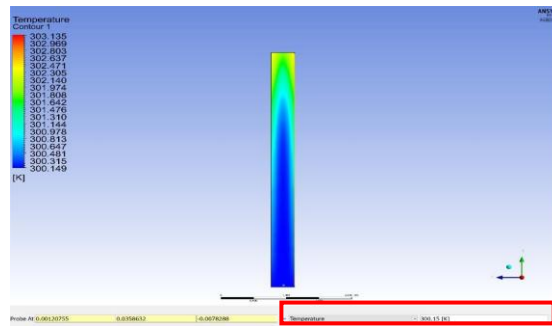


Figure 5. Solar Chimney Minimum Temperature Contour

In figure 5. above, it can be seen that the temperature at the exit of the solar chimney is 300.15 K or 27.15oC.

Scaled Residuals							ANSYS Fluent Release		
65	1.5643e-03	1.2199e-06	1.0433e-05	5.5171e-07	2.3814e-13	0:			
66	1.4101e-03	1.1165e-06	9.1010e-06	4.7626e-07	2.1149e-13	0:			
iter	continuity	x-velocity	y-velocity	z-velocity	energy				
67	1.2591e-03	1.0185e-06	7.9418e-06	4.0983e-07	1.8844e-13	0:			
68	1.1154e-03	9.2940e-07	6.9395e-06	3.5035e-07	1.6805e-13	0:			
69	solution is converged								
69	9.9561e-04	8.4499e-07	6.0714e-06	3.0144e-07	1.5088e-13	0:			
Mass Flow Rate							(kg/s)		
in							0.0062347926		
Net							0.0062347926		

Figure 6. Mass Flow Rate

In figure 6. above we can see the mass flow rate or mass flow rate of 0.00623479 kg/s. After the simulation on the maximum and minimum conditions has been carried out, then the simulation will be carried out in the average state by changing the existing parameters.

d. Contour Average Speed on Solar Chimney

Figure 7 above is a picture of the temperature contour and velocity contour on the solar chimney which is simulated at an average state.

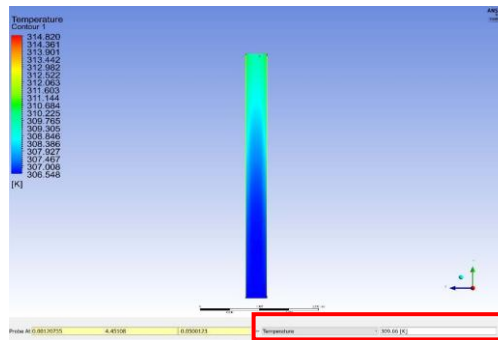


Figure 7. Chimney Solar Solar Temperature Contour

In figure 7. above, it can be seen that the temperature at the exit of the solar chimney is 309.66 K or 36.66oC.

Scaled Residuals						ANSYS Fluent F
65	1.4639e-03	8.8318e-07	1.0918e-05	8.4258e-07	1.2791e-	
66	1.3043e-03	7.8093e-07	9.4936e-06	7.7876e-07	1.1404e-	
iter	continuity	x-velocity	y-velocity	z-velocity	ener	
67	1.1583e-03	6.8817e-07	8.2403e-06	7.2142e-07	1.0156e-	
68	1.0284e-03	6.0521e-07	7.1367e-06	6.6752e-07	9.0378e-	
69	solution is converged					
69	9.1599e-04	5.3095e-07	6.1797e-06	6.1494e-07	8.0228e-	
Mass Flow Rate						(kg/s)

in						0.012758784

Net						0.012758784

Figure 8. Mass Flow Rate

In figure 8 above we can see the mass flow rate or mass flow rate of 0.012758 kg/s.

Table 4. Chimney Solar Simulation Data

	Experimental		Simulation		Percent Error(%)	
	T _{Outlet} (oC)	Mass Flow Rate (kg/s)	T _{Outlet} (°C)	Mass Flow Rate (kg/s)	T _{Outlet} (oC)	Mass Flow Rate
Maximum	49.0296	0.01922	50.71	0.0206	3.4273	7.19911
Minimum	26	0.00591	27.15	0.0062	4,4230	4.85536
Average	36.2246	0.0123	36.66	0.0127	1,2019	3.25111

3.4 Simulation on APK

After simulating the solar chimney, the next step is to simulate the APK. Similar to the simulation on Solar Chimney, the APK simulation will be carried out by entering several parameters obtained from experimental test data, the data are inlet temperature, soil temperature, and air velocity. The value of these parameters can be seen in the table below. In this APK simulation, the pipe temperature or soil temperature is considered uniform.

Table 5. APK Test Results Data

	T _{Inlet} (°C)	T _{Outlet} (°C)	T _{Land} (°C)
Maximum	32.29	28.21	27,6700
Minimum	29,4841	27.3507	26.9584
Average	31.17	27.74	27.46



Figure 9. Maximum Temperature at Outlet

In figure 9 above, it can be seen that the outlet temperature in the simulation results is 301.026 K or 28.026°C.

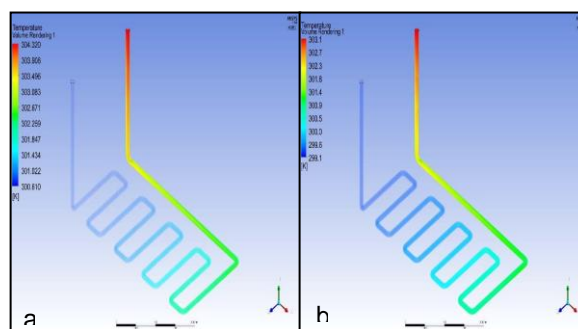


Figure 10. Average Temperature Rendering Volume APK

In Figures 9 and 10, above are the Volume Rendering Temperature of the APK. 9 is the average temperature of the APK and 10 is the minimum temperature of the APK. At first glance the temperature distribution in the picture above looks the same. To be able to know the difference can be seen in the legend in the image above. For example, for Figure 9 the red color indicates a temperature of 304.320 K and for Figure 10 the red color indicates a temperature of 302.1 K.



Figure 11. Average Temperature at Outlet

In figure 11. above, it can be seen that the outlet temperature in the simulation results is 300.91 K or 27.91oC

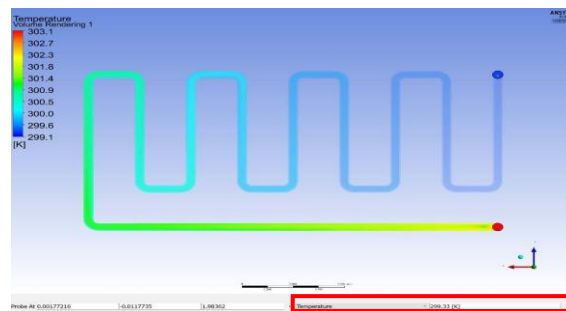


Figure 12. Minimum Temperature at Outlet

In figure 12. above, it can be seen that the outlet temperature in the simulation results is 299.33 K or 26.33oC.

Table 6. APK Simulation Data

	$T_{Inlet} (^{\circ}C)$	$T_{Outlet} (^{\circ}C)$ Experimental	Simulation	Percent Error (%)
Maximum	32.29	28.21	28.026	0.6522
Minimum	29,4841	27.3507	26.33	3.7318
Average	31.17	27.74	27.91	0.6128

a. Room Simulation

Simulations on the solar chimney and on the air-ground APK have been carried out, then the next is the simulation in the room. Similar to solar chimney and air-ground APK, simulation in the room will also be carried out by entering several parameters, namely the intake air temperature, intake air velocity, and room temperature before the system runs. Intake air velocity is considered constant at 0.3 m/s and room temperature is assumed to be 29 oC.

Table7. Room Test Results Data

	$T_{Inlet} (^{\circ}C)$	$T_{Room} (oC)$	$T_0 (oC)$
Maximum	34.7153	31.6475	29
Minimum	24.4623	25.2653	29
Average	27.14874	28,2949	29

Before showing the temperature contours in the room at maximum, minimum, and average, the two pictures below will show how the air flow in the room and the temperature contour in the room before the system runs.

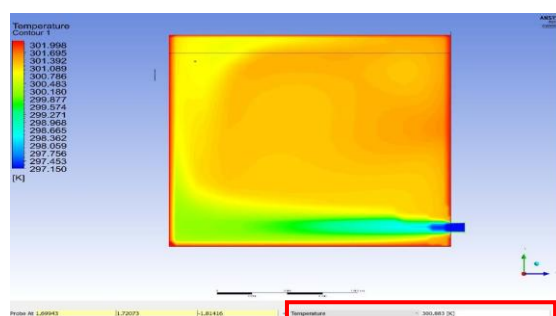


Figure 13. Minimum Temperature Contour in the Room

In figure 13. above, it can be seen that the room temperature in the simulation results is 300.883 K or 27.883oC. Contour in figure 12. And 13 looks very different.

Table 8. Room Simulation Result Data

	$T_{Inlet} (^{\circ}C)$	$T_{Room} (^{\circ}C)$		Percent Error (%)
		Experimental	Simulation	
Maximum	34.7153	31.6475	30.595	3.3256
Minimum	24.4623	25.2653	27,883	10.3609
Average	27.14874	28,2949	28,634	1.1984

4. CONCLUSION

After doing the simulation using Ansys 19.0, the maximum room temperature is 30.595oC, the minimum room temperature is 27.883oC and the average room temperature is 28.634oC. The largest percent error is in the simulation at a minimum room temperature of 10.3609%.

After simulating the solar chimney to find out how much mass flow occurs, the mass flow rate is 0.0206kg/s, the minimum is 0.0062kg/s, and the average is 0.0127kg. /s. The largest percent error is in the average condition, which is 7.1%.

By using the fluid dynamics calculation method, the maximum exit temperature is 28.026oC, the minimum exit temperature is 26.33oC, and the average exit temperature is 27.91oC. The largest percent error is in the minimum condition, which is 3.7318%

In chapter IV in Figure 4.17. we can see how the pressure changes in the solar chimney. In the contour in the figure, the greatest pressure is at the bottom of the solar chimney so that the air can move up and cause the air to circulate.

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