MECOMARE, 10 (2) (2021) pp. 61-70

Published by: TRIGIN Publisher

International Journal of Mechanical Computational and Manufacturing Research

Journal homepage: www.trigin.pelnus.ac.id

Analysis of Solar Collector Adsorption Cooling Machine Using 3D Simulation

John Peter Simanjuntak

Faculty of Engineering, University of North Sumatra, Indonesia

ARTICLEINFO

Article history:

Received Jun 11, 2021
Revised July 10, 2021
Accepted August 28, 2021

Keywords:

Adsorption
Collector
Cooling Machine
Simulation
Solar Energy
3D

ABSTRACT

Solar Energy is the biggest energy on the earth, solar enegy in Indonesia can be utilized for variety of things. Based on solar radiation data collected from 18 locations in Indonesia, solar radiation for West Indonesia area has reached 4,5 kWh/m2/day with monthly variation about 10%, while East Indonesia area has reached about 5,1 kWh/m2/day with monthly variation about 9%. Therefore, the solar energy can be utilized as the main source of energy for the adsorption refrigeration cycle cooling machine to produce cooling effect. The simulation object of this research is collector, which simulated with Fluent Ansys 15.0 software and modeled with 3D CAD software. The surface area of this collector is about 1m2,covered with 2 glass covers and tilted at 0o The result from this simulation is the theoretical solar energy that adsorbed into collector about 10,472 MJ, average temperature at upper collector plate about 92,5℃, average temperature at lower collector plate about 89,95 ℃, and average temperature at upper glass cover about 82,92℃.

Corresponding Author:

John Peter Simanjuntak
Faculty of Engineering
University of North Sumatra
Jln. Dr. T. Mansur No.9, Medan City, North Sumatra, 20222, Indonesia
Email: jhonpeter@gmail.com

1. INTRODUCTION

Cooling applications cause very high energy consumption with damaging effects on the environment (Sudarwani, 2012). As a solution, international regulations are now oriented towards the use of renewable energy to meet the relative needs of humans during the summer period (Setiawan, 2012). Although solar energy can be utilized both by electrical and thermal pathways, thermal cooling technology is more suitable for use compared to PV (photovoltaic) based because thermal cooling can make better use of solar energy (Juarni, 2021). Therefore, in recent years, solar thermal processes, especially adsorption and absorption, have become the subject of significant commercial research and development (Nuryadin, 2020). As a country with a tropical climate, big cities in Indonesia generally need coolers for air conditioning. Electrical energy consumption for cooling and air conditioning in commercial buildings in big cities in Indonesia can reach 60% (Ambarita, n.d.). From the two facts above, the potential for solar energy is quite large and the need for cooling is quite large, which is the background of this research (Panjaitan, 2019). A major research theme is capturing solar radiation energy in thermal form and utilizing it to produce cooling (refrigeration) (Wailanduw et al., n.d.). Therefore, the equipment used requires a heat exchanger that is able to convert the thermal energy, and utilizes the thermodynamic cycle, namely the adsorption cycle (Abu, 2014).

The objectives of this simulation are: (1) Knowing the location of the greatest temperature concentration in the solar collector during heating (Pabi temperature distribution between the simulation results and the experimental results (Azzamudin & Marwan Effendy, 2017) ban et al., 2016). (2) Comparing the temperature distribution of the simulation results with the experimental results from the solar collector (Amrizal et al., 2021). (3) Analyzing the factors causing the difference in. (4) Calculate the theoretical collector efficiency and compare it with the collector efficiency obtained from previous experiments. The benefits of writing this thesis are: (1) Scientific and academic aspects. This research is related to Computational Fluid Dynamic (CFD) and Heat Transfer I and II courses, so that by doing this research is expected to provide broad insight for researchers and develop knowledge in the field adsorption cycle refrigeration machine. (2) Aspects of practice and implementation (Tarkono & Ali, 2016). Focusing on adsorption case modeling on CFD software which is then compared with experimental results (Ditia et al., 2021). (3) Analysis using software will save research costs when compared to using equipment that will cost more (Musilah et al., 2021).

2. RESEARCH METHOD

2.1 Simulation Flowchart

Broadly speaking, the implementation of this simulation is carried out sequentially and systematically as shown in Figure 1.

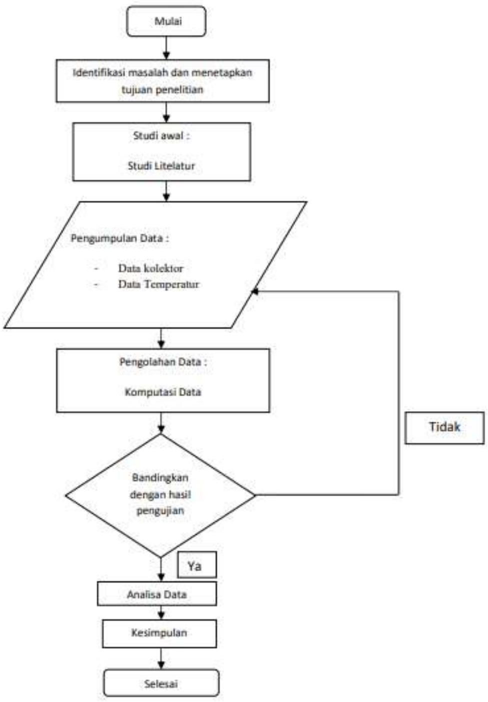

Figure 1. Simulation Flowchart

2.2 Test Scheme

The working principle of the test scheme, namely: (1) A thermocouple is used to measure the change in temperature of the collector during the day in the test and sends the data to a Cole-Palmer thermocouple. (2) The Cole-Palmer thermocouple will record the temperature every 5 seconds and the data will be sent to the laptop by USB. (3) The temperature change data is then displayed on the laptop so that it can then be used for analysis purposes.

Practical data used as input to the CFD program and the desired output from the simulation can be seen in table 3.1 below.

Table 1. Simulation Input and Output

Input	Output
Radiasi Matahari	Perubahan Temperatur Kolektor
Tekanan awal sistem	Tekanan akhir sistem
Dimensi Kolektor	Efisiensi Kolektor Teoritis

3. RESULTS AND DISCUSSIONS

3.1. Solar Collector 3D Design

The solar collector is designed with three-dimensional (3D) CAD software. The design is made based on data from the design of the solar collector. The solar collector is designed in three parts, namely the top and the middle in the form of a beam with a length of 1000mm, a width of 1000mm and a height of 20mm, the bottom is a beam with a length of 1000mm, a width of 1000mm, a height of 50mm and has a pipe with a length of 150mm with a diameter of in. Then it is imported into ansys geometry and changes the material into a fluid

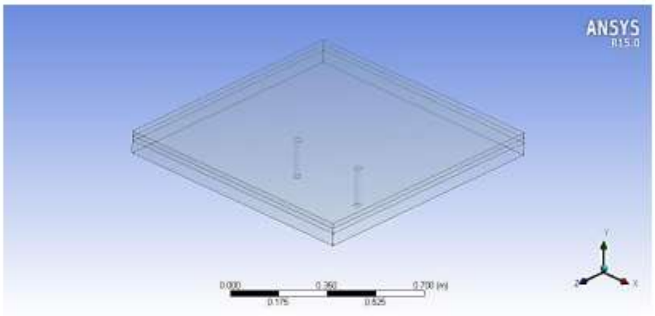

Figure 2. Collector Geometry 3D Model in Ansys 15.0 . Software

3.1.1. Boundary and Meshing Conditions in Ansys 15.0 Software Software

The boundary condition used in the solar collector is the collector wall made of stainless steel. Incoming radiation is limited by two mirrors with a distance of 2 cm between the glass and a distance of 2 cm from the collector. The sides of the glass are bounded by a frame, and the sides and bottom of the collector are insulated. The insulation used consists of plywood, black foam, styrofoam, and rockwool. One of the solar collector pipes is given a boundary condition in the form of a pressure inlet. While the rest are given a boundary condition in the form of a wall. After the boundary conditions are given, the mesh settings on the solar collector are adjusted according to the initial conditions. Meshing on this solar collector produces 6,330 points and 23,222 elements, which can clearly be seen in the following figure:

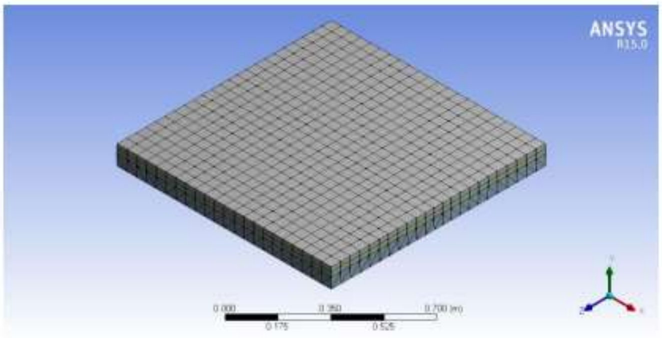

Figure 3. 3D Mesh Collector Model on Ansys Software 15.0

3.1.2. Fluent Analysis on Ansys 15.0 Software Software

After the design is completed and the boundary conditions are given to the Geometry software Ansys 15.0, the solar collector analysis is continued with Fluent analysis by entering the initial calculation data, both material properties and initial conditions of the system for further calculation and analysis. With assumptions such as heat comes from heat from solar radiation which is set on solar loading from 7.00 am to 17.00 pm on September 22. The thickness of the glass is 8mm, while the thickness of the insulation is 68.7mm, 15.5mm rockwool, 20mm Styrofoam, 20mm black foam, and 12mm plywood. The pressure is set at 7998 Pascal with a simulated initial temperature of 25□and gravity of 9.81 m/s^2.

3.2. Comparison Graph of Experimental Temperature and Simulation Results

3.2.1. Collector Top Plate

The plot of the upper plate temperature on the collector simulation results using the Ansys 15.0 software can be seen in Figure 4.11 below

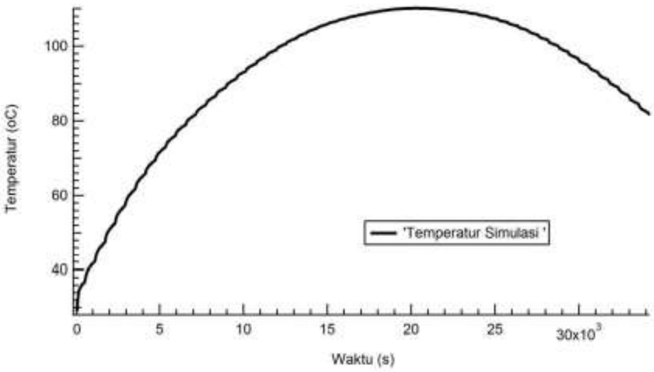

Figure 4. Plot of Collector Top Plate Temperature Result from Simulation

From the simulation results, the temperature at the top plate point of the collector compared to Channel 7 in the experiment can be seen in the graphic image below:

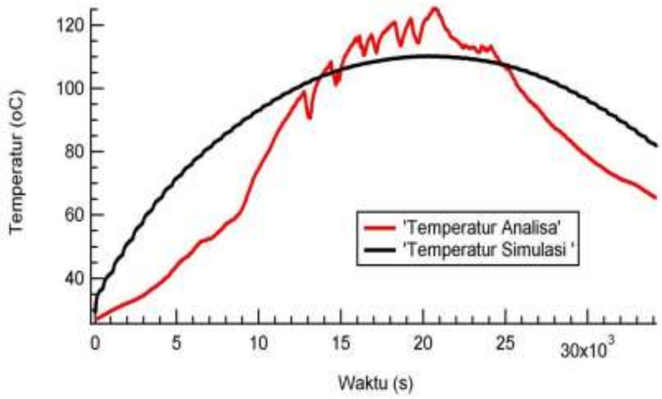

Figure 5. Top Plate Temperature Graph Simulation vs Analysis

Figure 4.12 is a comparison of the top plate temperature of the collector simulation results with the temperature of the test results using the Cole Palmer Thermocouple on channel 7 from 07.30 WIB to 17.00 WIB on September 22, 2016. From the graph it can be seen that the temperature data analyzed during the day exceeds the temperature data obtained. simulation. This is due to the settings in the simulation that still do not match the experimental data. The temperature data from the simulation and analysis of the top plate of the collector is attached in appendix 2. Where the temperature error above can be calculated by the formula:

$$R = \frac{T_{rata-rata\ simulasi} - T_{rata-rata\ analisa}}{T_{rata-rata\ analisa}} \times 100\% \quad (1)$$

$$R_{plat\ atas} = \frac{(92{,}502 - 82{,}754)°C}{82{,}754°C}$$

$Rplat\ atas$ = 11.78%

3.2.2. Collector's Bottom Plate

The plot of the bottom plate temperature on the collector simulation results using the Ansys 15.0 software can be seen in Figure 4.13 below

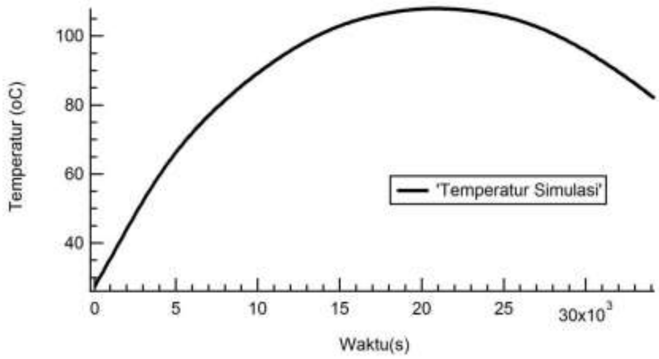

Figure 6. Plot of Collector Bottom Plate Temperature Result from Simulation

From the simulation results, the temperature at the bottom plate point of the collector compared to Channel 1 in the experiment can be seen in the graphic image below:

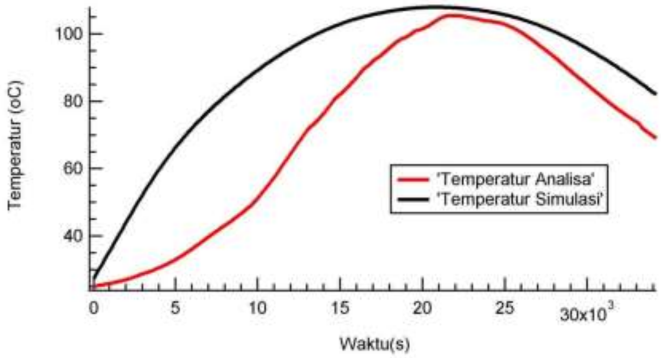

Figure 7. Bottom Plate Temperature Graph Simulation vs Analysis

Figure 4.14 is a comparison of the top plate temperature of the collector simulation results with the temperature of the test results using the Cole Palmer Thermocouple on channel 1 from 07.30 WIB to 17.00 WIB on September 22, 2016. The bottom plate temperature graph of the analysis results is below the simulation results because the insulation system used in experiments are still not good at inhibiting heat transfer from the environmental system. The temperature data from the simulation and analysis of the bottom plate of the collector is attached in Appendix 2. Where the temperature error above can be calculated by the formula:

$$R = \frac{T_{rata-rata\ simulasi} - T_{rata-rata\ analisa}}{T_{rata-rata\ analisa}} \times 100\% \quad (2)$$

$$R_{plat\ bawah} = \frac{(89{,}597 - 72{,}182)°C}{72{,}182°C}$$

$Rplat\ bawah$ = 24.13%

3.2.3. Collector Top Glass

The plot of the upper glass temperature on the collector simulation results using the Ansys 15.0 software can be seen in Figure 4.15 below

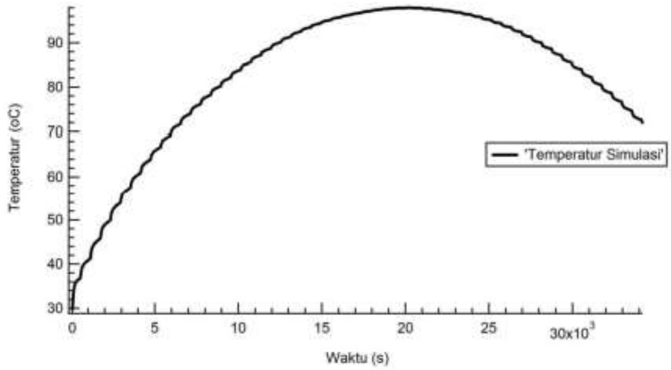

Figure 8. Plot of Collector Top Glass Temperature result from Simulation

From the simulation results, the temperature at the top glass point of the collector compared to Channel 3 in the experiment can be seen in the graphic image below:

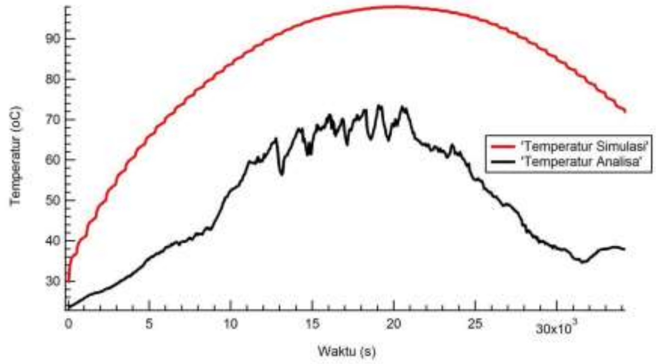

Figure 9. Top Glass Temperature Graph Simulation vs Analysis

Figure 4.16 is a comparison of the temperature of the glass on the collector of the simulation results with the temperature of the test results using the Cole Palmer Thermocouple on channel 3 from 07.30 WIB to 17.00 WIB on September 22, 2016. From the graph it can be seen that the difference between the analysis temperature and the simulation temperature is very large. This is because environmental factors, such as outside air temperature and wind speed, are not included in the simulation. The temperature data from the simulation and analysis of the top plate of the collector is attached in appendix 2. Where the temperature error above can be calculated by the formula:

$$R = \frac{T_{rata-rata\ simulasi} - T_{rata-rata\ analisa}}{T_{rata-rata\ analisa}} \times 100\% \qquad (3)$$

$$R_{kaca\ atas} = \frac{(82{,}921 - 50{,}002)°C}{50{,}002°C}$$

$Rkaca\ atas$ = 65.83%

The very large temperature error of the top glass of the collector is 65.83% due to the influence of the outside air temperature and wind that occurs during the experiment, causing the top glass temperature to be lower than the simulation temperature.

3.3. Solar Collector Analysis

3.3.1. Calculation of Total Solar Radiant Energy

The following is the data on the intensity of solar radiation on the first test of the 0o angle collector starting from 7.00 WIB - 18.00 WIB on November 22, 2016. Using equations 2.16, 2.14, 2.10 and 2.6, we get table 4.1

Table 2. Test Data I Collector Angle 0o on November 22, 2016

Waktu (jam)	ω (°)	$\cos\theta_z$	τ_b	G_b (W/m²)
7.00	-79,5325	0,1817	0,2111	52,0331
8.00	-64,5325	0,4300	0,4228	246,6277
9.00	-49,5325	0,6490	0,5297	466,3737
10.00	-34,5325	0,8238	0,5848	653,6354
11.00	-19,5325	0,9424	0,6131	783,9755
12.00	-4,5325	0,9969	0,6243	844,3685
13.00	10,4675	0,9834	0,6216	829,3401
14.00	25,4675	0,9028	0,6043	740,2275
15.00	40,4675	0,7608	0,5671	585,3249
16.00	55,4675	0,5669	0,4958	381,3354
17.00	70,4675	0,3343	0,3546	160,8418
18.00	85,4675	0,0790	0,1306	14,0018

From table 4.1, a graph of clear sky radiation can be made which is shown in Figure 4.17 below:

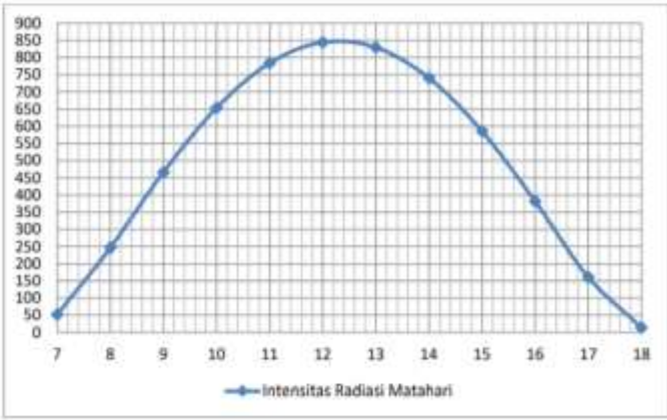

Figure 10. Clear Sky Radiation Chart

From the data in table 4.1 the amount of solar radiation energy received per unit area in 1 hour intervals can be calculated by integrating the intensity of solar radiation () by using equation 2.21, the following table is obtained:

Table 3. Total Solar Radiant Energy

Waktu	G_b (W/m²)	Jumlah Energi Radiasi Matahari / I (J/m²)
07.00-08.00	52,0331	537589,5059
08:00-09:00	246,6277	1283402,5131
09:00-10:00	466,3737	2016016,3832
10:00-11:00	653,6354	2587699,7588
11:00-12:00	783,9755	2931019,2896
12:00-13:00	844,3685	3012675,5277
13:00-14:00	829,3401	2825221,7330
14:00-15:00	740,2275	2385994,3388
15:00-16:00	585,3249	1739988,6135
16:00-17:00	381,3354	975919,0274
17:00-18:00	160,8418	314718,3834
total	14,0018	20610245,0744

From table 4.2 above, it can be obtained that the total solar radiation energy reaching the collector surface is $Ittot$ = 20610245.0744 J/m2

3.4. Collector Efficiency

3.4.1. Theoretical Collector Efficiency

The theoretical collector efficiency is calculated comparing the heat absorbed by the collector with the heat used to heat activated carbon and the heat lost in the collector. To calculate the efficiency of the collector used equation 2.45

$$\eta_{kolektor\ teoritis} = \frac{2{,}2316\ MJ}{10{,}4724\ MJ} = 0{,}2131 = 21{,}31\%$$

3.4.2. Experimental Collector Efficiency

The efficiency of the experimental collector is the efficiency of the experimental results carried out by Mr. Efsartua Butarbutar on September 22, 2016 which is calculated by comparing the actual heat energy that reaches the collector with the actual heat energy absorbed. Where in the test is obtained of 2523030.232 J and equal to 14713911 J. Can be calculated using the formula:
Then the efficiency obtained in the first test:

$$\eta = \frac{2523030{,}232}{14713911} x\ 100\%$$

= 17.14%

3.4.3. Comparison of Theoretical Collector Efficiency With Experimental Collector Efficiency

From the calculation of the collector efficiency theoretically and from the calculation of the collector experimentally, it can be calculated the magnitude of the error from the efficiency of the collector. Where is the error of the theoretical collector efficiency with the experimental collector efficiency is

$$Ralat = \left|\frac{0{,}2131 - 0{,}1714}{0{,}2131}\right| \times 100\% = 19.57\%$$

4. CONCLUSION

The conclusions obtained from this research are: (1) From the 3D simulation results using the ansys 15.0 software which is set on September 22, 2016 from 07.00 WIB to 17.00 WIB, the highest temperature concentration is found on the top plate of the solar collector with the highest temperature. is 396,748 K at a pressure of 7998 Pa. (2). From the comparison of the temperature of the simulation results with the temperature of the experimental results, the upper plate temperature error is 11.78%, the lower plate temperature error is 24.13%, and the upper glass temperature error is 65.85%. (3) The temperature distribution of the experimental results can be influenced by the insulation system used to inhibit heat transfer to the environment and weather influences such as wind can affect the temperature of the top glass so that the error obtained becomes large. (4) The theoretical collector efficiency is 21.31%, and has an error of 19.57% on the experimental solar collector efficiency of 17.14%.

The suggestions given for further research are: (1) To get more accurate analysis results, the meshing size can be reduced and refined. (2) In order for further research to use UDF on ansys 15.0 software. (3) In the next study, environmental factors, such as wind speed and outside air temperature, are included in the simulation so that the results obtained are close to the results from the experiment. (4) So that when performing a CFD simulation analysis, make sure the computer or laptop has high specifications and is in good condition. (5) Data collection in research is recommended to use tools that have better accuracy or are digital in order to minimize the occurrence of large errors.

ACKNOWLEDGEMENTS

We would like to thank all those who have contributed to this research, so that the research can be carried out properly.

REFERENCES

ABU, N. (2014). *RANCANG BANGUN MESIN PENDINGIN TENAGA PANAS DENGAN METODE PENYERAPAN (ADSORPTION REFRIGERATION CHILLER)*. Universitas Darma Persada.

Ambarita, H. (n.d.). *Kapasitas Adsorbsi Karbon Aktif dan Alumina Aktif sebagai adsorben terhadap beberapa Refrigeran pada Siklus Adsorpsi*.

Amrizal, A., Amrul, A., Wardono, H., Salsabillah, A. E., & Sasongko, A. D. (2021). Simulasi unjuk kerja kolektor surya PV/T berdasarkan bentuk penampang pipa absorber. *Journal of Science and Applicative Technology*, *5*(1), 245–252.

Antoni, D., Herdiansyah, M. I., Akbar, M., & Sumitro, A. (2021). Pengembangan Infrastruktur Jaringan Untuk Meningkatkan Pelayanan Publik di Kota Palembang. *Jurnal Media Informatika Budidarma*, *5*(4), 1652–1659.

Arif, M., Sitorus, T. B., Nasution, D. M., & Sembiring, P. G. (2019). SIMULASI PERFORMANSI EVAPORATOR SISTEM MESIN PENDINGIN SIKLUS ADSORPSI MENGGUNAKAN PERANGKAT LUNAK ANSYS 17.0. *Jurnal Dinamis*, *7*(2).

Arisukma, P., Purnomo, N. A., & Udyani, K. (2021). Studi Desain Absorber untuk Penyerapan CO2. *Prosiding Seminar Nasional Sains Dan Teknologi Terapan*, *9*(1), 327–337.

Azzamudin, R., & Marwan Effendy, S. T. (2017). *Analisis Distribusi Aliran Udara Pada Ruangan Dengan Variabel Temperatur dan Penempatan AC Menggunakan Metode Computational Fluid Dynamics (CFD)*. Universitas Muhammadiyah Surakarta.

Ditia, A., Bardant, T. B., Utami, A. R. I., Maryana, R., Irawan, Y., Muryanto, M., Triwahyuni, E., & Sudiyani, Y. (2021). Telaah Potensi Penerapan Teknologi Terkini pada Hidrolisis Selulosa dengan Sistem Pengendalian Terintegrasi dalam Proses Bioetanol G2. *Jurnal Selulosa*, *11*(01), 21–38.

Juarni, J. (2021). *PROTOTIPE SISTEM PENDINGIN (FREEZER) IKAN BERBASIS ENERGI SURYA (PHOTOVOLTAIC) PADA KAPAL NELAYAN*. UNIVERSITAS HASANUDDIN.

Kedang, Y. I. (2019). Membran Nanofiltrasi untuk Aplikasi Pemisah Zat. *Jurnal Saintek Lahan Kering*, *2*(1), 27–29.

Musilah, R. N., Putri, T. A., & Utami, A. D. (2021). Struktur Biaya Produksi Padi pada Program UPSUS Pajale di Kabupaten Demak. *Forum Agribisnis: Agribusiness Forum*, *11*(2), 153–166.

Nuryadin, B. W. (2020). *Pengantar Fisika Nanomaterial: Teori dan Aplikasi*.

Pabiban, D., Namas, M., & Sarifudin, K. (2016). Rancang Bangun Sistem Distilasi Surya Tipe Parabolic Untuk Menurunkan Kadar Salinitas Air Laut. *Jurnal Ilmiah Flash*, *2*(2), 131–141.

Panjaitan, J. (2019). *PENGARUH LAMA PENGERINGAN ASAM GELUGUR SECARA HYBRID DENGAN ENERGY SURYA TERHADAP KANDUNGAN ASAM SITRAT*.

Rubiyanto, D. (2017). *Metode Kromatografi: Prinsip Dasar, Praktikum dan Pendekatan Pembelajaran Kromatografi*. Deepublish.

Setiawan, S. (2012). Energi panas bumi dalam kerangka MP3EI: Analisis terhadap prospek, kendala, dan dukungan kebijakan. *Jurnal Ekonomi Dan Pembangunan*, *20*(1), 1–28.

Simbolon, H., Trimulyono, A., & Rindo, G. (2015). Analisa Nilai Maximum Thrust Propeller B-Series dan Kaplan Series pada Kapal Tugboat Ari 400 Hp dengan Variasi Diameter, Jumlah Daun, Sudut Rake Menggunakan CFD. *Jurnal Teknik Perkapalan*, *3*(4).

Sudarwani, M. M. (2012). Penerapan green architecture dan green building sebagai upaya pencapaian sustainable architecture. *Dinamika Sains*, *10*(24).

Tarkono, T., & Ali, H. (2016). *Pemanfaatan Limbah Pabrik Kelapa Sawit Sebagai Material Teknik*.

Wailanduw, A. G., Yuwono, T., & Widodo, W. A. (n.d.). SIMULASI NUMERIK DENGAN PENDEKATAN URANS PADA ALIRAN YANG MELINTASI SUSUNAN DUA SILINDER SIRKULAR SIDE BY SIDE DEKAT DINDING. *PROSIDING SEMINAR NASIONAL TEKNIK MESIN 8*, 46.