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The Effect of Variations Temperature in Expansion Valve on The (COP) Coefficient of Performance from An Air Conditioning Engine Prototype Mini Water Chiller

This experiment aims was to determine the effect of variations temperature in expansion valve on the (COP) Coefficient Of Performance from an air conditioning engine prototype mini water chiller, the prototype mini water chiller was designed by students in the Mechanical Engineering Education, Undiksha. The method used in this research is experimental method. The testing process was carried out at the Refrigeration Engineering Laboratory in Mechanical Engineering Education, Undiksha. In this experiment, the variation of working temperature in expansion valve is determined from 8°C, 11°C, 14°C, 17°C and 20°C. The tool used to vary the temperature in expansion valve is a thermoelectric cooler. To calculate the (COP) Coefficient Of Performance from prototype mini water chiller, it is necessary to collect data temperature at every several measurement points at T_1 , T_2 , and T_4 . Then from the data acquisition, data processing is carried out to calculate the (COP) Coefficient Of Performance value. After testing, it was found an effect of variations working temperature in expansion valve on the (COP) Coefficient Of Performance from prototype mini water chiller. The lower working temperature in expansion valve, the (COP) Coefficient Of Performance from an air conditioning engine will increase.

Keywords: Coefficient of Performance (COP), Prototype Mini Water Chiller, Expansion Valve.

1. INTRODUCTION

The role of technology, especially in refrigeration and air conditioning, has been widely used in various sectors of human life [1]. In general, the use of air conditioning equipment in the room creates comfort for the users of the room [2]. A water chiller-type air conditioning unit is often used in buildings or places with a large room capacity. To facilitate learning and research related to air conditioning machines of water chiller type. So, Students of Cooling Concentration, Mechanical Engineering Education, Undiksha, made a mini water chiller prototype design using a modified 1 PK Split AC unit that resembles the working principle of a water chiller machine in general.

The expansion valve is a component of the air conditioning engine unit, playing an important role in the refrigeration cycle. The expansion valve serves to lower the pressure of the liquid refrigerant and then flows into the evaporator to absorb heat in the room [1]. Because after passing through the expansion valve, the refrigerant flows directly to the evaporator to absorb heat in the room. The working temperature of the expansion valve will affect the condition of the refrigerant in the heat absorption in the room. However, generally, the location of the expansion valve section is in the outdoor unit in air conditioning engine units. It is positioned close to each other in the unit. Heat radiation from several different components such as compressors, condensers, installation pipes, and heat from outside air will affect the working temperature of the expansion valve. So that if this is left unchecked, it can affect the performance, intake of electrical energy,

and impact the unit's lifetime.

According to Ekadewi [3], there was an increase in COP (Coefficient Of Performance) in the freezer due to the capillary tube wound on the suction line. Then, from a study conducted by [2] which examined the effect of the capillary tube's working temperature on the cooling machine's performance, the researcher found that the lower the temperature of the capillary tube, the refrigeration capacity (Q_e) will increase. Meanwhile, the value of COP (Coefficient Of Performance) obtained the optimal temperature at the lowest capillary tube temperature. So from this research, it can be concluded that the effect of the working temperature of the expansion valve affects the performance of a cooling machine.

It is necessary to carry out many testing processes to improve the mini water chiller prototype. Several tests have been carried out, among others, Dwikayana's research [5] on the effect of the water fluid flow rate in the AHU (air handling unit) pipeline on achieving the optimum temperature of the mini cooling machine. The water chiller from the research found that using a water fluid flow rate of 0.83 liters/second resulted in the most optimal temperature compared to a water fluid flow rate of 0.27 liters/second and 0.55 liters/second. Deva Supriana's research [6], which examines the effect of cooling fluid variations on optimal temperature achievement in the design of a mini water chiller cooling machine, from this study the results of the water + coolant mixture get the most optimal temperature compared to the use of water fluid and coolant fluid. In Abdi Pranata's research [7], the ratio of water and air as a condenser cooling medium to the optimal primary cycle temperature on the mini water chiller prototype. This research found that the cooling temperature of the mini water chiller prototype room when the condenser was cooled using water was better than when the water chiller was cooled. The condenser is cooled using air media. Kadek Andika Angga Diputra in 2019 who examined the effect of variations in diameter and length of the capillary tube on the maximum temperature achievement of the primary cycle in the design of the mini water chiller machine, from this study, it was found that using a capillary pipe with a diameter of 0.064 inches. A length of 1 meter resulted in an average of the lowest AHU temperature compared to other variations [8]. Ryan Pratama Putra's research [9] on the effect of variations in room cooling load on the performance of the mini water chiller prototype, from this research it was found that the lowest room cooling rate occurred at a loading temperature of 30°C. In contrast, the highest room cooling rate occurred at a loading temperature of 50°C. Then for COP (Coefficient Of Performance), the lowest was obtained at a loading temperature of 50°C. In contrast, the highest COP (Coefficient Of Performance) was obtained at a loading temperature of 30°C.

However, research related to the effect of variations in the working temperature of the expansion valve on the COP (Coefficient Of Performance) has not been carried out. This research on variations in the working temperature of the expansion valve on an air conditioning machine with a prototype mini water chiller has the aim to determine the effect of variations in the working temperature of the expansion valve on the value of the COP (Coefficient Of Performance) of an air conditioning machine unit of the prototype mini water chiller so that it can be used as a reference to improve the performance, efficiency, and life time of air conditioning machine unit of mini water chiller prototype.

2. MATERIALS AND METHODS

The method used in this research is the experimental method. Experimental research is the implementation of research by intentionally giving a treatment by researchers to know the consequences. Then according to Sugiyono [10], experimental research is a research method that aims to find a relationship or effect of specific treatments carried out by a researcher on the impacts resulting from the treatment.

As for in this study, the researchers made variations on the working temperature of the expansion valve to find a relationship between variations in the working temperature of the expansion valve and the value of COP (Coefficient Of Performance). The magnitude of the variation of the working temperature of the expansion valve is taken based on the standard working temperature of the air conditioning machine of 23°C, then varied with a temperature range based on relevant previous studies. So from it, the result will obtain a range of variations in the working temperature of the expansion valve of 8°C, 11°C, 14°C, 17°C, 20°C. Using the design of thermoelectric cooler to vary the working temperature of the expansion valve. The use of thermoelectric cooler design is to control the working temperature of the expansion valve according to the specified variation is positioned directly on the expansion valve part of the mini water chiller prototype. The thermoelectric cooler design uses two TEC1706 thermoelectric modules that lower the temperature when a 12 V DC electric current is applied. A digital thermostart component controls this tool so that the temperature at the expansion valve matches the specified temperature variation.

Parameters in calculating the COP (Coefficient Of Performance) value of the mini water chiller prototype required temperature data obtained by measuring the temperature at each measurement point, among

others, parameters in calculating the COP (Coefficient Of Performance) value of the mini water chiller prototype required temperature data obtained by measuring the temperature at each measurement point, including, T_1 (pressure pipe), T_2 (suction pipe), and T_4 (expansion valve outlet pipe). The obtained temperature data is then converted into the enthalpy value in the R-22 properties table to calculate the COP (Coefficient Of Performance) value.

Figure 1: Prototype *mini water chiller*

Figure 2: *Thermoelectric cooler* design.

Figure 3: Research Instrument Design

3. RESULTS

3.1 Data Acquisition Results

Table 1: Result of data acquisition at point T1 (suction pipe)

REPEATING TESTS	STANDARD 23°C (A ₀)	VARIATION 21°C (A ₁)	VARIATION 17°C (A ₂)	VARIATION 14°C (A ₃)	VARIATION 11°C (A ₄)	VARIATION 8°C (A ₅)
1	26,00	27,00	26,70	26,00	25,70	25,00
2	26,20	26,50	27,00	25,70	26,00	25,60
3	26,40	26,00	26,70	26,00	25,50	25,50
4	26,00	27,50	26,50	25,60	25,60	25,20
5	26,30	26,20	26,80	25,70	25,70	25,30
6	26,50	26,20	26,20	26,00	25,50	25,50
7	26,00	26,80	26,60	25,60	26,00	25,30

8	25,80	27,00	26,30	25,80	25,70	25,50
9	27,00	26,60	26,80	25,70	25,30	25,00
10	26,80	26,30	27,00	26,10	25,80	25,00
11	26,50	26,80	26,50	25,80	25,50	25,30
12	26,00	27,10	26,20	25,70	25,80	25,50
13	26,40	26,50	26,80	25,90	26,00	25,50
14	26,30	26,40	26,80	26,00	26,00	25,50
15	26,00	26,40	26,40	25,70	25,40	25,40
16	25,90	26,00	26,60	25,70	25,70	25,40
17	26,60	26,40	26,80	26,00	25,50	25,70
18	25,80	26,50	26,50	25,60	25,50	25,20
19	26,00	26,80	26,70	25,80	25,80	25,40
20	26,00	27,00	26,70	26,00	25,60	25,60

Table 2: Result of data acquisition at point T2 (pressure pipe)

REPEATING TESTS	STANDARD 23°C (A ₀)	VARIATION 21°C (A ₁)	VARIATION 17°C (A ₂)	VARIATION 14°C (A ₃)	VARIATION 11°C (A ₄)	VARIATION 8°C (A ₅)
1	56,80	48,00	44,00	40,00	37,00	35,00
2	56,20	47,40	44,50	39,40	37,50	35,80
3	56,00	47,30	44,30	40,00	37,50	35,60
4	57,00	47,00	43,80	39,60	37,20	35,50
5	56,80	48,00	44,00	39,40	37,00	35,40
6	56,50	48,00	43,50	39,50	37,00	35,80
7	57,00	48,00	43,30	39,70	37,80	35,50
8	56,20	47,60	43,70	40,00	37,60	35,60
9	56,20	47,20	44,00	39,40	37,00	35,00
10	56,00	48,00	44,20	39,90	37,70	35,00
11	57,00	48,20	43,50	39,70	37,20	35,40
12	56,80	47,80	43,80	39,80	37,50	35,70
13	56,60	47,60	43,80	39,50	38,00	35,50
14	57,00	47,30	44,00	39,80	38,00	35,50
15	57,00	48,00	44,00	39,40	37,20	35,40
16	56,40	48,20	44,30	40,00	37,60	35,80
17	56,30	47,70	43,50	40,30	37,20	35,80
18	56,50	47,50	43,60	39,60	37,00	35,40
19	57,00	48,00	44,00	39,70	37,50	35,70
20	56,80	48,00	44,20	40,00	37,40	35,70

Table 3: Result of data acquisition at point T4 (expansion valve outlet pipe)

REPEATING TEST	STANDARD 23°C (A ₀)	VARIATION 21°C (A ₁)	VARIATION 17°C (A ₂)	VARIATION 14°C (A ₃)	VARIATION 11°C (A ₄)	VARIATION 8°C (A ₅)
1	24,80	21,00	18,20	15,70	13,00	9,50
2	24,60	21,30	18,00	15,50	12,50	9,30
3	24,00	22,00	18,50	15,70	12,80	9,80
4	25,00	21,80	19,00	15,60	13,00	9,50
5	24,00	21,00	18,80	15,50	13,00	9,70
6	24,80	21,00	18,30	15,80	12,40	10,00

7	24,60	21,60	19,00	15,70	12,20	9,50
8	24,70	22,00	19,20	16,00	12,00	9,50
9	25,00	22,30	18,00	15,50	12,30	9,80
10	24,80	21,20	18,20	15,80	12,50	9,90
11	24,30	21,00	18,40	15,20	12,80	9,60
12	24,00	20,80	18,30	15,60	13,00	9,40
13	24,60	21,00	19,00	16,00	12,70	9,50
14	25,00	21,50	18,20	16,20	12,60	9,70
15	24,80	20,60	18,50	15,50	12,50	9,60
16	24,30	20,00	18,80	15,30	12,50	9,30
17	24,60	20,40	19,00	15,40	12,40	9,70
18	25,00	20,80	18,40	15,60	12,80	9,60
19	24,00	21,00	18,00	15,20	13,00	10,00
20	24,60	21,00	18,00	15,70	13,00	9,50

3.2 Calculation Of Cop (Coefficient Of Performance) Value

As for calculating the COP (Coefficient Of Performance) value of a refrigeration machine, it can be determined as in the following calculation :

With :

T_1 (temperature at point 1) = 27°C

T_2 (temperature at point 2) = 48°C

T_4 (temperature at point 4) = 21°C

Find :

COP (Coefficient Of Performance)

Answer :

To calculate the COP (Coefficient Of Performance) value, first look for the enthalpy values of T_1 , T_2 , and T_4 in the R-22 properties table. Based on the table, properties of R-22 can be obtained :

H_1 (enthalpy 27°) = 413.50 Kj/Kg (seen in the vapor column because the refrigerant state at that point is vapor).

H_2 (enthalpy 48°C) = 417.30 Kj/Kg (seen in the vapor column because the refrigerant state at that point is vapor)

H_4 (enthalpy 21°C) = 225.30 Kj/Kg (seen in the liquid column because the state of the refrigerant at that point is liquid)

Then the value of COP (Coefficient Of Performance) can be calculated by the following equation :

$$COP = \frac{Q_e}{P} = \frac{(H_1 - H_4)}{(H_2 - H_1)} \quad (1)$$

$$COP = \frac{(413,50 - 225,30) \text{ Kj/Kg}}{(417,30 - 413,50) \text{ Kj/Kg}}$$

$$COP = 49,53$$

The COP (Coefficient Of Performance) value is obtained from the above calculation, which is 49,53. With the exact count, the magnitude of the COP (Coefficient Of Performance) value in each variation of the working temperature of the expansion valve can be presented as shown in the following table.

Table 4: COP (Coefficient Of Performance) calculation results

REPEATING TESTS	STANDARD 23°C (A ₀)	VARIATION 21°C (A ₁)	VARIATION 17°C (A ₂)	VARIATION 14°C (A ₃)	VARIATION 11°C (A ₄)	VARIATION 8°C (A ₅)
1	41,65	49,53	57,02	67,09	79,40	87,70
2	42,10	48,89	56,44	66,45	79,36	88,65
3	42,68	47,53	55,92	67,09	74,68	88,76
4	41,59	49,25	56,39	65,29	77,22	86,22
5	42,48	47,48	57,16	66,45	79,40	87,25
6	42,64	47,48	56,12	65,43	77,79	87,12
7	41,71	48,81	57,59	65,03	77,64	87,35
8	41,11	49,73	55,88	65,59	76,21	88,92
9	43,62	49,19	57,44	66,45	76,03	87,54
10	43,26	47,67	57,38	67,28	76,28	87,49
11	42,79	48,75	57,11	66,59	76,41	87,30
12	41,89	49,85	55,63	65,52	77,24	88,20
13	42,50	48,73	57,43	67,42	77,41	89,71
14	42,18	48,70	57,37	67,43	77,45	89,60
15	41,65	48,10	55,90	66,45	75,66	88,46
16	41,51	47,06	55,48	65,20	75,98	86,35
17	42,91	48,53	57,95	65,85	76,59	89,63
18	41,02	48,92	56,94	65,29	77,60	86,17
19	41,89	49,00	57,10	66,59	77,24	86,73
20	41,71	49,53	56,42	67,09	76,03	89,33
<i>Rata-rata</i>	42,14	48,64	56,73	66,28	77,08	87,92

The following is a graph of the translation of the results table for the COP (Coefficient of Performance) data acquisition.

Figure 4: Comparison graph of COP (Coefficient of Performance) for all variations in the working temperature of the expansion valve.

The graph above shows that the average comparison of the COP (Coefficient Of Performance) values of the mini water chiller prototype before the expansion valve working temperature variation is 42,14. Then after the variation of the working temperature of the expansion valve of the mini water chiller prototype, the average value of COP (Coefficient Of Performance) is A₁ with an average value of 48,64. A₂ with an average score of 56,73. A₃ with an average score of 66,28. A₄ with an average score of 77,08 and A₅ with an average

score of 87,92.

The average increase in the value of COP (Coefficient Of Performance) after variations in the working temperature of the expansion valve are :

1. In variation A1, the average increase in the value of COP (Coefficient Of Performance) is 6,49 or 13% compared to standard conditions.
2. In variation A2, the average increase in the value of COP (Coefficient Of Performance) is 14,59 or 26% compared to standard conditions.
3. In the A3 variation, the average increase in the COP (Coefficient Of Performance) value is 24,14 or 36% compared to standard conditions.
4. In A4 variation, the average increase in the COP (Coefficient Of Performance) value is 34,94 or 45% compared to standard conditions.
5. In variation A5, the average increase in the value of COP (Coefficient Of Performance) is 45,78 or 52% compared to standard conditions.

Thus, it can be seen that the COP (Coefficient Of Performance) value is inversely proportional to the working temperature of the expansion valve. The lower the working temperature of the expansion valve, the COP (Coefficient Of Performance) value of the mini water chiller prototype unit will increase. This is because the lower the working temperature of the expansion valve, the lower the temperature of the refrigerant flowing into the evaporator. The low temperature of the refrigerant flowing into the evaporator or the enthalpy value at point H₄ results in an increase in the refrigeration effect (Q_e) and a decrease in the compressor work value (P).

The lower the working temperature of the expansion valve, the refrigeration effect resulting from the cooling engine will increase [4]. The mini water chiller of the air conditioning machine uses a combination cooling system between water and air. Where in this unit uses two cycles to decrease the temperature, including the primary and secondary cycles. There is a cooling process of water stored in the water tank in the primary cycle. In the secondary cycle, the water that has experienced decreased temperature has flowed into the room and cold air from the water. These are circulated using the AHU (Air Handling Unit) component. In some cases, the decrease in the refrigerant enthalpy value at point H₄ (outlet from the expansion valve) does not always positively impact the refrigeration effect (Q_e) on the refrigeration machine. The heat exchange that occurs in the evaporator causes the cold effect of the refrigeration machine not to be utilized optimally. The enthalpy value at point H₁ (suction pipe) has decreased.

In the research that has been carried out by Putu Bayu Prawira [11] on Split AC, it shows that the decrease in the refrigerant enthalpy value at point H₄ results in a decrease in the enthalpy value at point H₁ (suction pipe), which will result in a lower refrigeration effect (Q_e). However, in this study, the decrease in the refrigerant enthalpy value at point H₄ did not result in a reduction of the enthalpy value at point H₁ (suction pipe), so that the refrigeration effect (Q_e) would increase along with the decrease in the refrigerant enthalpy value at point H₄.

Recall that the mini water chiller prototype of a cooling machine uses a combination cooling system between water and air. The evaporator component in the mini water chiller prototype is used to lower the cooling water temperature. Then the cold water from the water will be used as a room cooler. The density of a substance will affect the cooling rate of a substance. When compared between the density of water and air, air density is 1.2 Kg/m³ less than the density of water, which is 1000 Kg/m³. So that if it is associated with the cooling rate of a substance, the magnitude of the cooling rate is directly proportional to the density; the greater the density of a substance, the greater the cooling rate [12]. Similarly, the amount of specific heat of a substance also affects the cooling rate. Specific heat is the amount of heat absorbed or required by 1 g of a substance to raise its temperature by 1°C. So the more significant the particular heat of a substance, the more heat absorbed by the substance. Air has a specific heat of 1000 J/Kg°C while water has a specific heat of 4200 J/Kg°C, so the absorption of heat in the water is better than air, so water cooling media will be better at absorbing heat when compared to air [13].

However, decreasing the working temperature of the expansion valve results in a decrease in the compressor working value (P). The lower the working temperature of the expansion valve results in a reduction in compressor work. A decrease in the enthalpy value at point H₄ results in faster heat absorption in the evaporator. The evaporator in this mini water chiller unit aims to cool the water and then cool the air. The water is then used to cool the room because the water medium is better at absorbing heat so that it allows a faster cooling process in the room along with a decrease in enthalpy at point H₄.

COP (Coefficient Of Performance) is a value that states the performance of a refrigeration engine which is the result of a comparison between the refrigeration effect (Q_e) and compressor work (P). The greater the value of the refrigeration effect (Q_e), the more heat is absorbed from a cooling machine in the cooling process, the greater the refrigeration effect, the higher the COP (Coefficient Of Performance) value of a cooling machine, and vice versa. Then the compressor work is the amount of energy used by the compressor during the cooling process; the lower the compressor work, the greater the COP (Coefficient Of Performance) value of a refrigeration machine will increase, and vice versa. This is in line with Khairil Anwar's research on the freezer unit [4], where the cooling effect on the capillary tube increased the refrigeration effect (Q_e). Wherein this study, the lower the working temperature of the expansion valve, the refrigeration effect (Q_e) has increased, resulting in the highest value of COP (Coefficient Of Performance) at the lowest working temperature of the expansion valve.

4. CONCLUSIONS

The highest increase in the value of COP (Coefficient Of Performance) was obtained at the variation of the working temperature of the expansion valve 8°C (A_5), which was 45,78 or 52% when compared to before the variation of the working temperature of the expansion valve (A_0). This is because the lower the working temperature of the expansion valve, the lower the temperature of the refrigerant flowing into the evaporator, allowing for faster heat absorption in the evaporator. Therefore the compressor work becomes lighter in the process of decreasing the temperature. The lower the compressor work, the higher the COP (Coefficient Of Performance).

On the other hand, if the working temperature of the expansion valve becomes more significant, the temperature of the refrigerant flowing into the evaporator also increases, which makes the absorption of heat in the evaporator slower. Therefore the compressor works harder in the process of decreasing the temperature. The higher the compressor work, the COP value. (Coefficient Of Performance) is decreasing.

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REFERENCES

- [1] A. PUDJANARSA., *Mesin Konfersi Energi*. Yogyakarta, ANDI, 2013.
- [2] W. STOECKER AND J. JONES., *Refrigeration and Air Conditioning*, 2nd ed, Newyork, McGraw-Hill.Inc, 1979.
- [3] E. ANGRAINI, "Analisis Pengaruh Pipa Kapiler yang Dililitkan pada Line Suction," *Jurnal Teknik Mesin*, vol. 4, no. 2, pp. 94–98, 2002.
- [4] K. ANWAR, E. ARIF, AND W. H. PIARAH, "Efek Temperatur Pipa Kapiler Terhadap Kinerja Mesin Pendingin," *Jurnal Mekanika.*, vol. 1, pp. 30–39, 2010.
- [5] M. D. KAYANA, "Analisa Pengaruh Laju Aliran Fluida Air Pada Saluran Pipa AHU (*Air Handling Unit*) Terhadap Capaian Suhu Optimum Mesin Pendingin *Mini Water Chiler*," *Jurnal Pendidikan Teknik Mesin*, vol. 6, no. 3, 2018.
- [6] P. D. SUPRIANA, K. R. DANTES, AND I. N. P. NUGRAHA, "Capaian Suhu Optimal Pada Rancangan Mesin Pendingin Mini Water Chiller," *Jurnal Pendidikan Teknik Mesin*, vol. 7, no. 1, pp. 35–41, 2019.
- [7] I. G. A. PRANATA, "Studi Komparasi Perbandingan Air Dan Udara Sebagai Media Pendingin Kondensor Terhadap Pencapaian Suhu Optimal Siklus Primer Pada *Prototype Water Chiller*," *Jurnal Pendidikan Teknik Mesin*, vol. 7, no. 1, pp. 18–21, 2019.
- [8] A. C. L. FUAD AND A. B. KHRISNA PUTRA, "Studi Eksperimen Pengaruh Panjang Pipa Kapiler dan Variasi Beban Pendinginan pada Sistem Refrigerasi *Cascade*," *Jurnal Teknik ITS*, vol. 5, no. 2, 2017.
- [9] R. P. PUTRA. *Analisis Pengaruh Variasi Beban Pendinginan Ruangan Terhadap Unjuk Kerja Prototype Mini Water Chiller*. Pendidikan Teknik Mesin. Undiksha, Singaraja, 2020.
- [10] SUGIYONO, *Metode Penelitian Kuantitatif Kualitatif dan R&D*. Alfabeta, 2008.
- [11] I. P. B. PRAWIRA, *Analisis Perbandingan Unjuk Kerja Mesin Pendingin Dengan Variasi Media Pendingin Pada Sisi Kondensor*. Pendidikan Teknik Mesin, Undiksha, Singaraja, 2020.

- [12] I. G. WIRATMAJA, K. R. DANTES, AND E. A. J. ARTHA, “Peningkatan Laju Pendinginan Ruangan Dengan Media Pendingin Kombinasi Udara Dan Air Disisi Kondensor Pada Mesin Pendingin Tipe *Split Air Conditioning*” *Jurnal Pendidikan Teknik Mesin*, vol. 9, no. 1, pp. 50–58, 2021.
- [13] FIRMAN AND M. ANSHAR, *Refrigerasi dan Pengkondisian Udara*, 1st ed. Makasar, Garis Putih Pratama, 2019.