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The experimental study of the coolant flow rate of an ethylene glycol-mixed water to the heat transfer rate on the radiator

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Abstract. This study was conducted to determine the rate of the heat transfer in the radiator. There are two types of hot fluid, namely water and an ethylene glycol-mixed water of 50%. The water entry into the radiator at the temperature of 80°C. The inlet water varied by 0.00000067 m³/s, 0.00013 m³/s, 0.0002 m³/s, and 0.00027 m³/s, and the air release is 1.489 m³/s. The results indicate that the higher the flow of water flowing on the radiator pipe causes a radiator heat transfer rate increase. The best water releases for the radiator test is 0.0002 m³/s. The enhancement of q_h increases of 655.26 W or up to 13.06%, q_c increases of 402.04 W or 7.57%, U_h increases of 41.3 W/m²K or 11%, U_c increases of 4 W/m²K or 5.67%, and effectivity increases 2.35%.

1. Introduction

The need of vehicle in Indonesia is remarkably increased. According to data from GAIKINDO (Indonesian Motor Vehicle Industry Association) from January to October 2017 has recorded that domestic vehicle sales are reaching more than 800.000 unit [1]. The need of it, which is driving the development of vehicle efficient engine technology [2,3]. The process of combustion occurs repeatedly. To ensure that the engine condition usually works, it requires a cooling system. It requires a water-cooled fluid. A heat releases process occurs through a heat exchanger which is often called a radiator [4,5,6]. There are several studies, for example used regular water as a radiator fluid that is indicating the influence of water release variation come into the radiator that can affect the overall displacement of the radiator [7]. Subhedar [8] studied the potential of heat transfer using water and ethylene glycol that mixed with aluminum at 50:50. The results show that the radiator heat transfer performance increases by using nanofluid compared to conventional coolers. Nanofluid with the lowest volume fraction of 0.2% of 30% in heat transfer observed. The reduction estimation in the front area of the radiator if the base fluid is replaced by Nanofluid is done which will make the cooling system lighter, resulting in fewer obstacle and save fuel cost [9]. Kuppan examined the heat transfer in the car radiator by using ethylene glycol water with copper as a coolant with 4-8 LPM water flow and inlet temperature of 35.44 and 54°C and it was increased the heat transfer of 55% which compared to conventional fluid [10,11]. Sandhya [12], said that nanofluid that using 40% ethylene glycol and 60% water with a mixture volume of 0.1%, 0.3%, and 0.5% TiO₂, resulting an increase of heat transfer depending on the quantity of nano particles added to the base fluid. At the concentration of 0.5%, an increase in heat transfer of 35% compared to the base fluid observed. Zakaria [13], focused on the low



concentration of Al_2O_3 dispersed in the mixture of Water - Ethylene Glycol as a cooler in the cooling plate of PEM carbon polymer fuel cells with using coolant Al_2O_3 Nano particles used are concentrations of 0.1 and 0.5 vol% which are then dispersed in a 50:50 mixture (water: Ethylene Glycol). The result of the heat transfer can be increased up to 13.87% for 0.5 vol% Al_2O_3 that compared to the basic fluid. But the pressure drop also increases which results in an increase pumping power of up to 0.02W. Positive thermal results imply that Al_2O_3 nano fluid are the potential candidate for future application in thermal power management of PEM fuel. They were tried to research by comparing the use of water and mixed water-ethylene glycol and variation of discharge for both types of fluid to determine the effectiveness of heat transfer and maximum discharge for both types of fluid. The purpose of this research is to determine the rate of the heat transfer and the effectiveness of the radiator.

2. Methodology

The boiling point of ethylene glycol is capable of reaching the temperature of 197°C and the freezing point of -13.4°C [14]. The use of ethylene glycol mixed in a vehicle cooling system can reach 60000 km [15]. The Manufacturers recommend 50% water and 50% ethylene glycol for regular use and at cold temperatures use 30% water and 70% ethylene glycol to protect from freezing [16]. The materials that were used in this study consisted of water and mixed with 50% of the ethylene glycol, while the cold fluid was air. The air is cooling the hot fluid using a cross-flow heat exchanger method. The research tool to test the radiator is an airway equipped with a venturi meter. It also has a pump system, heating, and cooling system.

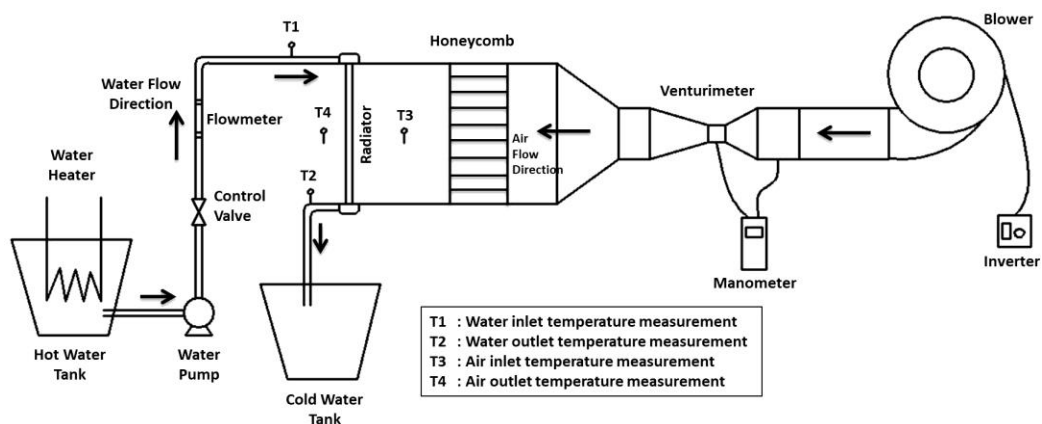


Figure 1. Experimental scheme



Figure 2. Photograph of experimental scheme

**Figure 3.**The radiator**Table 1.**Dimension of the radiator

Parameter	Symbol	Dimension
Radiator high	H	0.405 m
Radiator wide	L	0.318 m
Radiator thick	D	0.016 m
Number of pipe lines	-	1
Number of pipes	Nt	36
Number of fin lines	-	37
Number of fins	-	270
Total number of fins	Nf	9990
Pipe outside diameter	Dm,o	0.0015 m
Pipe insidediameter	Dm,i	0.0007 m
Pipe outside wide	Td,o	0.0166 m
Pipe inside wide	Td, i	0.0158 m
Thick pipe	Tt	0.0004 m
Pitch pipe	Tp	0.008 m
Longfin	Fi	0.0065 m
Wide fin	Fd	0.0166 m
Thick fins	Ft	0.0001 m
Louver angle	θ	25 degree

The experimental procedure can be explained as follows. First, turn on the pump to distribute the water in the tank through the radiator. Prepare the valve to the water passing through the radiator always continually moving at the release of $0.000067 \text{ m}^3/\text{s}$. Then the pump is switched off. Turn on the blower and set the inverter to get the release air of $0.1489 \text{ m}^3/\text{s}$, then the blower is switched off. The water inside the tank heated at 80°C , then the pump re-ignited. At the time the pump is switched on, simultaneously the air-controlled blower is also switched on. The inlet and outlet temperature of both fluids recorded using the thermocouple that connected to the data acquisition. The step before is carried out again at conditions of the water flow of $0.00013 \text{ m}^3/\text{s}$, $0.0002 \text{ m}^3/\text{s}$, and $0.00027 \text{ m}^3/\text{s}$.

3. Results and Discussions

From the analysis, the data that obtained in the form of pre-and post-hot fluid temperature, pre-and post-cold fluid, the different of the manometer height, and known the radiator specification. The data analysis could be done as follows [17, 18]:

1. Air release

$$Q = \sqrt{\frac{2 \cdot \Delta P}{\rho \left[\left(\frac{A_1}{A_2} \right)^2 - 1 \right]}} \cdot A_1 \quad (1)$$

2. The wide range of the total heat transfer on the air side

$$A_c = A_{t,o} + A_f \quad (2)$$

3. The wide range of the heat transfer on the side of the outer side wall pipe without the fin.

$$A_{t,o} = 2 \cdot (D_{m,o} + T_{d,o}) \cdot H \cdot N_t \quad (3)$$

4. The wide range of the heat transfer on the fin side.
- $A_f = 2 \cdot (F_d + F_t) \cdot F_l \cdot N_f$

$$(4)$$

5. The wide range of the total heat transfer on the water side .
- $A_h = 2 \cdot (D_{m,i} + T_{d,i}) \cdot H \cdot N_t$

$$(5)$$

6. The rate of the heat transfer of the hot and cold fluid flow

$$q_c = \dot{m}_c \cdot c_{p,c} \cdot (T_{c,o} - T_{c,i}) \quad (6)$$

$$q_h = \dot{m}_h \cdot c_{p,h} \cdot (T_{h,i} - T_{h,o}) \quad (7)$$

7. The effectivity of the heat transfer
- $\varepsilon = \frac{q}{q_{\max}}$

8. The equation for
- q_{\max}
- .
- $q_{\max} = C_{\min} (T_{h,i} - T_{c,i})$

$$(8)$$

9. The equation for
- C_{\min}
- .
- $C_h = \dot{m}_h c_{p,h}$

$$C_c = \dot{m}_c c_{p,c} \quad (9)$$

10. The heat effectivity if the fluid is hot or cold

$$\varepsilon = \frac{C_h (T_{h,i} - T_{h,o})}{C_{\min} (T_{h,i} - T_{c,i})}$$

$$\varepsilon = \frac{C_c (T_{c,o} - T_{c,i})}{C_{\min} (T_{h,i} - T_{c,i})} \quad (10)$$

Table 2. The calculation result on each variation of water release

Q(m ³ /s)	Q _h (W)	Q _c (W)	U _h (/)	U _c (/)	ε
0,000067	3723.49	4024.72	258.72	49.89	0.47
0,00013	4695.55	5011.54	340.86	64.91	0.58
0,0002	5018.19	5312.76	373.33	70.52	0.62
0,00027	4813.97	5244.97	346.39	67.33	0.61

Table 3. The calculation result on each variation of water release+ ethilane glycol

Q(m ³ /s)	Q _h (W)	Q _c (W)	U _h (/)	U _c (/)	ε
0,000067	4747.78	4771.89	380.17	68.18	0.53
0,00013	5533.97	5391.62	409.33	71.13	0.60
0,0002	5673.45	5714.80	414.63	74.52	0.64
0,00027	5170.15	5489.35	361.14	68.14	0.62

The amount of water release variation into the radiator pipe can affect the total heat transfer coefficient (U_h and U_c), the heat transfer rate in the radiator (q_h and q_c) and the effectivity of the radiator. From the

data processing above, and incorporated in the graph shows an increase in the rate of heat transfer for each release and water fluid mixed of ethylene glycol 50% better than normal water.

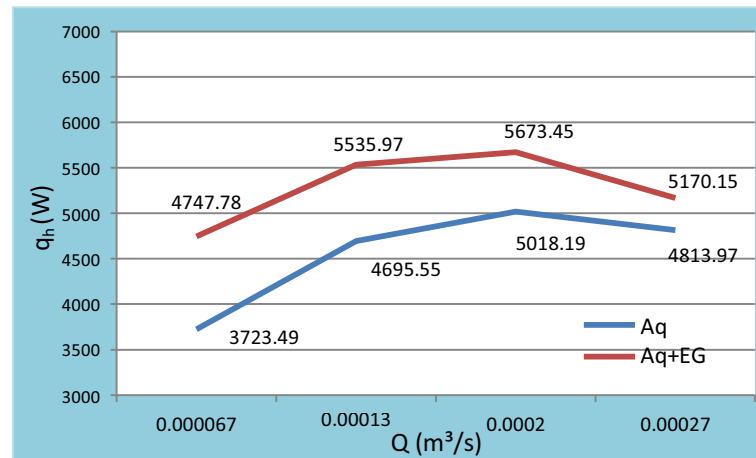


Figure 4. The relationship of the inlet water flow rate to the heat transfer rate

Figure 4, indicates the water discharge affects the rate of heat transfer of the water side. In the water line and the mixed water line of ethylene glycol has increased at the discharge of $0.00067 \text{ m}^3/\text{s}$, $0.00013 \text{ m}^3/\text{s}$ and $0.0002 \text{ m}^3/\text{s}$. However, there was a decrease in the discharge of $0.00027 \text{ m}^3/\text{s}$. It can be seen in the graph that at a discharge of $0.0002 \text{ m}^3/\text{s}$ for both fluid, has a high displacement rate. The water fluid have a water-side heat transfer rate of 5018.19 W and a mixture of ethylene glycol has a water-side heat transfer rate of 5673.45 W . It shows an increase of 655.26 W or an increase of 13.06% .

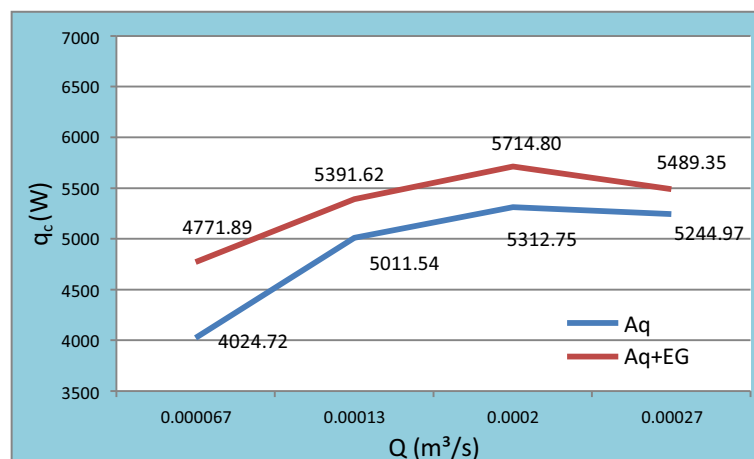


Figure 5. The relationship of the inlet water flow rate to the heat transfer rate

From figure 5, it can be seen that the water discharge affect the rate of air side heat transfer. In the water line and mixed water of ethylene glycol have increased at a discharge of $0.00067 \text{ m}^3/\text{s}$, $0.00013 \text{ m}^3/\text{s}$ and $0.0002 \text{ m}^3/\text{s}$. However, there was a decrease in the discharge of $0.00027 \text{ m}^3/\text{s}$. The discharge of $0.0002 \text{ m}^3/\text{s}$ for both fluid has a high displacement rate. The water fluid has a rate of air side heat transfer of 5312.76 W and a mixture of ethylene glycol water fluid have an air side heat transfer rate of 5714.80 W . It shows an increase of 402.04 W or an increase of 7.57% .

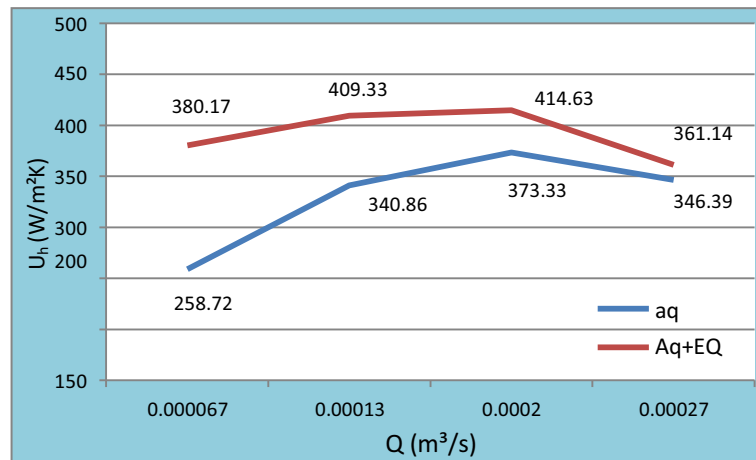


Figure 6. The relationship of the inlet water flow rate to the total heat transfer coefficient

Figure 6 shows that the overall heat transfer coefficient of the water side for the water line and mixed water of ethylene glycol have increased at a discharge of $0.00067 \text{ m}^3/\text{s}$, $0.00013 \text{ m}^3/\text{s}$ and $0.0002 \text{ m}^3/\text{s}$. There was a decreased in the discharge of $0.00027 \text{ m}^3/\text{s}$. At the discharge of $0.0002 \text{ m}^3/\text{s}$ for both fluid have a high water-side heat transfer coefficient. For a mixture of ethylene glycol water have a coefficient of $414.63 \text{ (W) / (m}^2 \text{ K)}$, and for water of $373.33 \text{ (W) / (m}^2 \text{ K)}$. It shows an increase of $41.3 \text{ (W) / (m}^2 \text{ K)}$ or an increase of 11%.

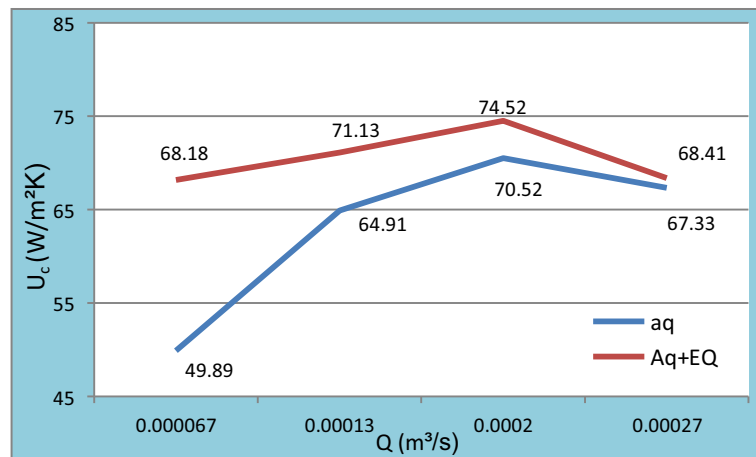


Figure 7. The relationship of the inlet water flow rate to the total heat transfer coefficient

Figure 7 shows that the overall heat transfer coefficient of the air side for the water line and mixed water of ethylene glycol have increased at $0.00067 \text{ m}^3/\text{s}$, $0.00013 \text{ m}^3/\text{s}$ and $0.0002 \text{ m}^3/\text{s}$. There was a decrease in the discharge of $0.00027 \text{ m}^3/\text{s}$. The graph shows that at a discharge of $0.0002 \text{ m}^3/\text{s}$ for both fluid has a high water-side heat transfer coefficient. For a mixture of ethylene glycol water have a coefficient of $74.52 \text{ (W) / (m}^2 \text{ K)}$ and for water of $70.52 \text{ (W) / (m}^2 \text{ K)}$. It shows a increase of $4 \text{ (W) / (m}^2 \text{ K)}$ or an increase of 5.67%.

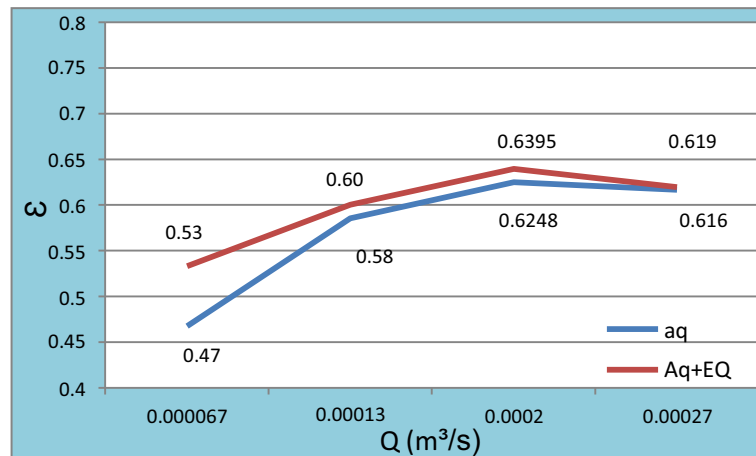


Figure 8. The relationship of the airflow rate of the radiator inlet water to the effectivity

Figure 8 shows the difference in the effectiveness of 2 types of cooling fluid. For the water and ethylene water lines, it increased at $0.00067 \text{ m}^3/\text{s}$, $0.00013 \text{ m}^3/\text{s}$ and $0.0002 \text{ m}^3/\text{s}$. There was a decrease in the discharge of $0.00027 \text{ m}^3/\text{s}$. Both line are at the highest point at a discharge of $0.0002 \text{ m}^3/\text{s}$. For water mixture of ethylene glycol have an effectiveness of 0.6395 and for water of 0.6248. The graph shows the effectiveness of ethylene mixed water is better than water with a difference of 0.0147 or up 2.35%.

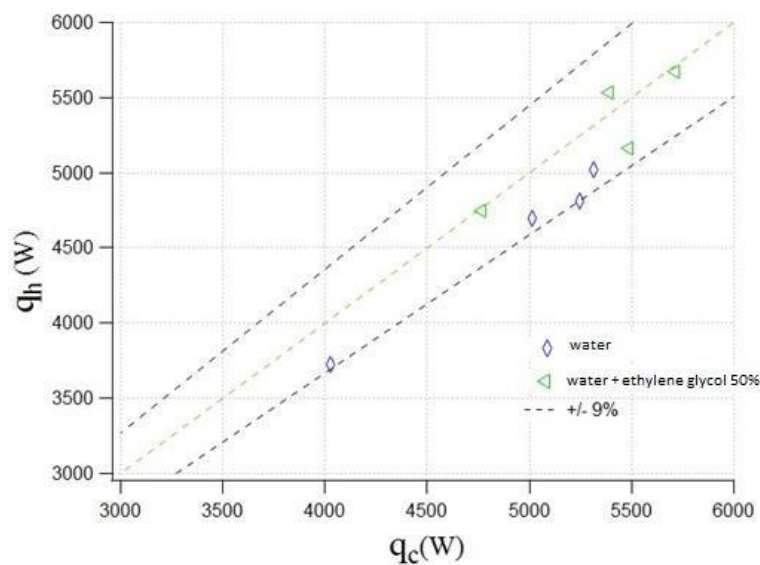


Figure 9. Testing of Energy Balance

Figure 9 shows the test for energy balance has an error of $\pm 9\%$. It indicates that the test falls into the excellent category. The price of ethylene glycol per liter is Rp. 100.000. The water radiator for the vehicle is usually sold in a 4 liter with the ratio of 2 liters of water and 2 liters of ethylene glycol. For the price of 2 liters of ethylene glycol is Rp. 200.000. For the replacement of radiator water made by the manufacturer recommended every 60000 km. It is worthwhile to use on the vehicle due to the very long replacement periods of water. The use of mixed ethylene glycol water also increases the boiling point to make the water radiator not volatile. It could be seen that the boiling point of ethylene glycol reaches 197°C . Data experimental show that there is an increase on the rate of heat transfer of the water side, the heat transfer rate of airside, the total transfer coefficient of the air side and the radiator

effectivity, then the use of an ethylene glycol-mixed water is more proper than the use with water as coolant radiator.

4. Conclusions

There is an increase of the effectivity for ethylene glycol-mixed water fluid. at of 2.35% concerning the water. The heat transfer rate of waterside increases of 655.26 W or up to 13.06%, and for the air side transfer increases of 402.04 W or up to 7.57%. The total transfer of the waterside increases of 41.3 W/m²K, or increases of 11%, and for the total transfer of the air side have an increase of 4 W/m²K or up to 5.67%. The best radiator performance occurs at water release of 0.0002 m²/s. It was shown on the test graph where the value for the water release is 0.0002 m²/s and it is higher than the others.

References

- [1] Gaikindo 2017 Gaikindo Wholesales Data Jan Okt 2017. Jakarta, Gaikindo.
- [2] Kristanto P 2015 Motor Bakar Torak Teori dan Aplikasinya. Yogyakarta : Andi.
- [3] Irvan et al 2017 IOP Conf. Ser.: Mater. Sci. Eng. 206 012028.
- [4] Ariani F et al 2017 IOP Conf. Ser.: Mater. Sci. Eng. 277 012045.
- [5] Arjuna J et al 2018 IOP Conf. Ser.: Mater. Sci. Eng. 309 012088.
- [6] Sitorus T B et al. 2017 Journal of Engineering and Technological Sciences, Vol. 49, No. 5, 657-670.
- [7] Sitorus T B et al 2018 IOP Conf. Ser.: Mater. Sci. Eng. 309 012089
- [8] Subhedar et al. 2016 Experimental investigation of heat transfer potensial of /water- mono ethylene glycol nanofluids as a car radiator coolant. India : Elsevier.
- [9] Sitorus T B 2016 Proceeding of 6th International Conference on Trends in Agricultural Engineering 7 - 9 September, Prague, Czech Republic.
- [10] Siahaan I J 2011 Uji eksperimental optimasi laju perpindahan kalor dan penurunan tekanan akibat pengaruh laju aliran air pada alat penukar kalor jenis radiator flat tube. Medan, Universitas Sumatra Utara.
- [11] Heris S et al. 2013 Experimental study of heat transfer of a car radiator with CuO/ethylene glycol-water as a coolant. Iran : Taylor & Francis Group, LLC.
- [12] Sandhy D et al. 2016 Improving the Cooling Performance of Automobile Radiator with Ethylene Glycol Water Based TiO₂ Nanofluids. India : Elsevier.
- [13] Zakaria I 2015 Experimental Investigation of Al₂O₃-Water Ethylene Glycol Mixture Nanofluid Thermal Behavior In a single Cooling Plate for PEM Fuel Cell Application. Malaysia : Elsevier.
- [14] Matar S 2001 Chemistry of petrochemical process, second edition. Saudi Arabia : Gulf professional publishing.
- [15] PT Astra Daihatsu Motor 2012 Owners's Manual Ayla. Jakarta : PT Astra Daihatsu motor.
- [16] Hull W et al. 2008 Analysis of ethylene glycol-based engine coolant as a vehicle fire fuel. International Symposium on Fire Investigation Science and Technology. USA: Wendell Hull & Associates, Inc.
- [17] Incropera F 2011 Fundamentals of Heat and Mass Transfer, Seventh Edition. United States of America: John Wiley & Sons, Inc.
- [18] Cengel Y A 2003 Heat Transfer A Practical Approach. 2nd edition. New York : McGraw-Hill.