Performance analyses of engine radiator system with capacity 1000 cc

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Abstract. A radiator is a significant component of a vehicle engine that is used as a cooling system, specifically a radiator of a car engine that serves to cool the water that has absorbed heat from the engine and then transferred to the air that flowed by the radiator fan. The purpose of this study is to analyze the performance of a heat exchanger of the radiator of the engine 1000 cc. Based on the result of the analysis, it was concluded that the largest total of the heat transfer coefficient occurred at the air flow rate of 125.8x10⁻³ m³/s, the air (cold) Uc = 71,48 W/m²K, and the waterside (heat) Uh = 353,32 W/m²K. The optimum air flow rate occurs at 125.8x10⁻³ m³/s. Addition, the total heat transfer coefficient is quite significant, and the effectiveness obtained is 69%. Under all circumstances, the experimental temperature of the radiator outlet air is lower ± 3 oC than theoretically, while the temperature of the outlet air through the radiator lower ± 12oC.

1. Introduction

In the era of globalization, the technological advancement in the automotive sector is overgrowing to encourage people to learn science and technology continually [1, 2]. In the automotive world, especially in the motorcycle as known by various types of functional system. Where the system work is interconnected with one another, then if one of the systems is damaged, the engine will be ruined. The engine is described as a system consisting of multiple support systems that work simultaneously and integrated [3]. Several support systems function at once, the cooling system, lubrication system, fuel system, and electrical system. The above system works simultaneously to produce the machine work which is the output of the machine itself. In a cooling system, which is the support system of a machine-sustaining system and not the primary system in which the engine performs work and effort, but it has a critical function. The cooling system in the outline as the work of protection of itself, then, its performance could be maintained for an extended period [4]. Heat transfer between fluid occurs through the separator wall or in and out of the wall quickly. Most of the heat exchanger and fluid are separated by heat transfer surface and are ideally not inserted or leaked. Heat transfer in recovery wall separator usually occurs through conduction. Heat piping not only serves as a separating wall, but also facilitate heat transfer by condensation, evaporation, and diverting fluid in hot plumbing. The process of releasing heat to the surrounding the air occurs through direct contact between the air and a pipe that equipped with the fin tool after the tube receives heat from the water which previously brought heat from the combustion process that occurs in the combustion chamber [5, 6]. If the heat release process occurs through a heat exchanger which is often called a radiator.

The radiator is a vital component in a vehicle engine that used as a cooling system [7]. In an engine, generally, water is a heat transfer medium. For this cooling system, excessive heat will be released through the coolant circulating the device. The water around the device becomes hot and then pumped to the heat exchanger. The addition of fin is an approach to increase the cooling rate of the radiator. Also, it provides a larger heat transfer area and increases the heat transfer convection coefficient.

The purpose of their study to obtain the performance of the radiator of engine 1000 cc. This study is limited to the stationer rotation condition by recording the value of the engine rotation, the air of the temperature that carrying and leaving the radiator and the temperature of the inlet and outlet.

2. Effectiveness of The Radiator

The heat transfer depends on the radiator core features. The fluid (water) cooled into the radiator at ± 80°C will
release heat due to the lower temperature difference between the water and the wall of the inner radiator wall, which is transferred conventionally [8, 9]. Furthermore, the lower temperature difference between the internal wall and the outer of the pipe will trigger conduction heat conduction, and the heat transfer, in the same way, will be sent to the fin that is deliberately connected to the outer wall of the pipe. To obtain the desired hot water absorption with the help of a fan, the air is blown towards the radiator to the radiator, so that the temperature difference between the pipe fin and the external wall of the outer pipe against the air once again triggered the heat transfer by convection.

2.1. The Energy Balance
In this study, hot water flows inside the radiator pipe, transferring heat to the outer air flowing in the conduit. If the heat transfer rate on the hot part of the fluid, and on the cold fluid part can be calculated in successively as follows [10]:

For a hot fluid side:
\[ q_h = m_h c_p,h (T_{h,i} - T_{h,o}) \]  
(1)

For cold fluid side:
\[ q_h = m_c c_p,c (T_{c,o} - T_{c,i}) \]  
(2)

2.2. Effectiveness of heat exchanger
The effectiveness of heat exchanger is one of the most important things in designing heat exchanger. It is due to the effectiveness parameter is an illustration for heat exchanger work. The heat transferred to the cold fluid must be equal to the heat released from the hot fluid. Where the effectiveness of heat exchanger may also be defined as follows [11, 12]:

\[ \varepsilon = \frac{q_{\text{actual}}}{q_{\text{max}}} \]  
(3)

where:

- For water side:
  \[ \varepsilon = \frac{C_p(T_{h,i} - T_{h,o})}{C_{\text{min}}(T_{h,i} - T_{c,i})} \]  
  (4)

- For air side:
  \[ \varepsilon = \frac{C_p(T_{c,o} - T_{c,i})}{C_{\text{min}}(T_{h,i} - T_{c,i})} \]  
  (5)

Then, it could be calculated the NTU (number of transfer unit) or the number of heat transfer unit, as follows [13]:

\[ \text{NTU} = \frac{U A}{C_{\text{min}}} \]  
(6)

Holman also provides equations for the effectiveness of heat exchange devices with NTU relationship (number of transfer units), one of which is the effectiveness the heat exchanger of cross-flow one pass with both non-mixed fluids. The mathematical equation is as follows [14, 15].

\[ \varepsilon = 1 - \exp \left( \frac{1}{C_p} \right) (\text{NTU})^{0.22} \left( \exp \left[-C_r(\text{NTU})^{0.78}\right] - 1 \right) \]  
(7)

3. Methodology
This research uses radiator (No. part 16400-BZ480-001) of Daihatsu Ayla 1000 cc radiator as shown in figure 1.
Figure 1. The radiator of engine 1000 cc

Figure 2. The scheme of experimental
Table 1. The dimensional of engine radiator with capacity 1000 cc

| No. | Parameter                     | Symbol     | Dimension                        |
|-----|-------------------------------|------------|----------------------------------|
| 1   | Radiator Length               |            | 0,318 m                          |
| 2   | High Radiator / High Pipe     |            | 0,405 m                          |
| 3   | Width of Radiator / Width of Pipe |          | 0,0166 m                        |
| 4   | Thick Pipe                    |            | 0,0004 m                         |
| 5   | Side Section In Pipe          |            | 0,0007 x 0,0158 m                |
| 6   | External Pipeline Section     |            | 0,0015 x 0,0166 m                |
| 7   | Pipe Distance (Tube Pitch)    |            | 0,008 m                          |
| 8   | Number of Pipe                |            | 36                               |
| 9   | Long Fins                     |            | 0,0065 m                         |
| 10  | Wide Fins                     |            | 0,0166 m                         |
| 11  | Thick Fins                    |            | 0,0001 m                         |
| 12  | Number of Fins Lines          |            | 37                               |
| 13  | Peak / Line Number            |            | 135                              |
| 14  | Number of Fins Lines          |            | 270                              |
| 15  | Fin-pipe arrangement          |            | in line                          |

The radiator test scheme in figure 2 above illustrates that in this test, the heated water using the heater in the water tank up to 80°C will be pumped into the radiator, and before the hot water goes into the radiator, it first sets the flow rate of the water using the control valve in accordance with the water flow rate required in this case tester using a constant flow rate of 7 lpm (12x10⁻⁵ m³/s). It coincides with the arrangement of the rate of the airflow that flowing perpendicular to the radiator cross-section. The actual shape after the design as shown in figure 3.

Figure 3. Photograph of the experimental scheme
4. Results and Discussions

The results of the research that carried out by changing the flow rate of the airflow perpendicular to the radiator crosssection which affects the heat transfer coefficient (h), heat transfer (U), the effectivity of heat exchanger on both cold (air) and hot (water) fluids) at the radiator.

Figure 4 shows that the thermal heat transfer coefficient of the cold side (air) always increase along with the higher flow rate of air flowing perpendicular to the radiator cross section and for the highest thermal air-flow coefficient occurs at the highest airflow rate of $125.8 \times 10^{-3}$ m$^3$/s at 71.48 W/m$^2$K.

Figure 5 shows the relationship between the flow rate of the air flowing perpendicular to the radius of the radiator with heat transfer coefficient (water). Similarly, with through the air coolant, the highest heat transfer coefficient ($U_h$) could be seen at the highest airflow rate of $125.8 \times 10^{-3}$ m$^3$/s at 353.32 W/m$^2$K.

Figure 6 shows the relationship between the flow rate of the air flowing perpendicular to the radiator cross-section with the outlet temperature ($T_{h,o}$) through the radiator pipe. It could be seen that the higher airflow rate, the higher the water temperature decreases or in other words, the low of the temperature of the radiator outlet water, and the lowest drop in the outlet temperature occur at the highest airflow rate of $125.8 \times 10^{-3}$m$^3$/s at 70.87°C.

![Figure 4](image1.png)

Figure 4. The relationship of the airflow rate ($Q_c$) with heat exchanger of the air side ($U_c$)

![Figure 5](image2.png)

Figure 5. The relationship of the airflow rate ($Q_c$) with the total pf heat transfer ($U_h$)
Figure 6. The relationship of the airflow (Qc) with the temperature of the outlet water (T_{h,o}) through the radiator pipe.

Figure 7. The relationship of the airflow flows perpendicular to cross section radiator (Qc) with the effectiveness of the radiator.
Figure 8. The relationship between the heat transfer on the air side (qₐ) with the water side (qₜ).
In figure 7, we can see a graph of the relationship between the rate of the airflow flowing perpendicular to the cross section of the radiator with the effectiveness of the radiator. The higher airflow rate that flowing perpendicular to the radiator cross-section, the lower the effect of the radiator, so that the lowest effectiveness value occurs at the airflow rate of $125.8 \times 10^{-3} \text{m}^3/\text{s}$ at 69%.

In figure 8, we can see a graph of the relationship between heat transfer on the air side ($q_a$) with the water side ($q_h$), where the heat transfer value of each fluid, both air and water, could be known as a percentage of its heat balance or energy equilibrium. In this case, we obtain the energy equilibrium of five air variation is below 10%, i.e., $58.9 \times 10^{-3} \text{m}^3/\text{s}$, $64 \times 10^{-3} \text{m}^3/\text{s}$, $69.5 \times 10^{-3} \text{m}^3/\text{s}$, $82.7 \times 10^{-3} \text{m}^3/\text{s}$, and $112.7 \times 10^{-3} \text{m}^3/\text{s}$ and two variation of air is above 10%.

Figure 9. The airflow rate on the outlet water temperature of the radiator
Figure 10 shows the result of comparison of temperature of outlet air experimentally and theoretically is below +/- 15%. With four variations that is $58.9 \times 10^{-3} \text{m}^3/\text{s}$, $64.0 \times 10^{-3} \text{m}^3/\text{s}$, $69.5 \times 10^{-3} \text{m}^3/\text{s}$ and $82.7 \times 10^{-3} \text{m}^3/\text{s}$. And with three variations air in below +/-20% that is $93.7 \times 10^{-3} \text{m}^3/\text{s}$, $112.7 \times 10^{-3} \text{m}^3/\text{s}$, and $125.8 \times 10^{-3} \text{m}^3/\text{s}$.

5. Conclusions

Based on the result of the investigation and the analysis that has been done, it could be concluded that when observed from the most significant thermal transfer coefficient, experimentally occurred at the rate of airflow perpendicular to the radiator cross section $125.8 \times 10^{-3} \text{m}^3/\text{s}$, i.e., the air side $U_c = 71.48 \text{ W/m}^2\text{K}$, and waterside $U_h = 353.32 \text{ W/m}^2\text{K}$. Theoretically, the most significant thermal heat transfer coefficient occurs at the same airflow rate, i.e., the air side $U_c = 37.06 \text{ W/m}^2\text{K}$, and the waterside $U_h = 207.73 \text{ W/m}^2\text{K}$. For optimum airflow rate that flows perpendicular to the radiator section is occur at rate of $125.8 \times 10^{-3} \text{ m}^3/\text{s}$. In this case the thermal heat transfer coefficient is quite large and the effectiveness obtained is 69%. In all circumstances, experimentally, the air temperature of the outlet radiator is lower at $\pm 3^\circ\text{C}$ than theoretical, and the inlet radiator is also lower at $\pm 12^\circ\text{C}$.

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