Experimental investigation of Dirt Deposition Effects on Temperatures across Automobile Radiator

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ABSTRACT: An automobile radiator is used to cool the engine to avoid engine damage. However, depending on the types of road types, such as gravel and earth roads, the efficiency of a radiator system can be questioned. Since radiator is covered by dirty element, the air from the outside could not pass through the radiator fin, and the process of heat exchange becomes less efficient. This cause the high temperature of engine block from fuel combustion cannot be reduced and if the temperature is keep increasing, the engine will fail. Therefore, it is essential to investigate temperature of radiator with deposition to further understand the performance of engine cooling system in this condition. The effects of dirt deposition (mud and silt) on the automobile radiator were investigated at difference percentage areas. The study used an in-house manufactured test rig equipped with several thermocouples at the inlet and outlet of the radiator to measure the temperatures. Results show that the temperatures at the inlet and outlet of the radiator increases with increase area covered by dirt on the surface of the radiator. However, the covering material like mud shows a higher temperature rise as compared to another covering material; the silt. With 75 % of deposition covered the radiator surface area, it was found that the difference temperature at the water outlet is about 6 % when comparing those two covering materials, attributed to their different physical properties. The strong adhesion of the mud and its tighter structure compared to silt cause less air flow through the radiator fins, which increased the water temperature.

Keywords: *Radiator; dirt; engine cooling system*

1. INTRODUCTION

Radiator is a vital part in the engines. It acts as a reservoir that stores water or a mixture of water and ethylene glycol as coolant for the engine cooling system. The radiator plays an important role to maintain the engine operating temperature, as high engine temperature may cause an increase in fuel consumption and fuel evaporation which can damage the engine components and cause sudden engine breakdowns [1]. Therefore, it is necessary to study on temperature of radiator, under different condition to enhance heat transfer efficiency in the engine cooling system.

Many studies have been done to improve the performance of automobile radiators [2][3][4][5][6]. Recently, a new intelligent diagnosis system has been developed for six types of cooling radiator faults such as radiator tubes blockage, radiator fins blockage, loose connection between fins and tubes, radiator door failure, coolant leakage, and normal conditions by using Infrared (IR) thermal images [2]. Meanwhile, there was also study which focused more on the coolant properties, such as using nanofluids to replace the conventional engine coolant. Hwang et al. [3] improved stability and thermal conductivity characteristics of nanofluid by suspended multi-walled several nanoparticles such as multi-wall carbon nanotubes (MWCNT), fullerene, copper oxide, and silicon dioxide in based fluid. Elias et al. [4] reported that Al_2O_3 nanoparticles can be used to increase thermal conductivity, and the properties increased with the coolant temperature. By considering the operating condition, Vithayasai et al. [5] concluded that, a significant improvement in the heat transfer process could be achieved once frontal velocity was above 1.6 m/s. Meanwhile, Oliet et al. [6] reported that overall heat transfer coefficient does not depend on the air side inlet temperature but is shown to be affected by coolant flow regime.

Most of the previous studies focused on the thermal conductivity and heat transfer performance under no-fouled condition [4][5][6]. However, there are still limited studies in investigating performance of the radiator under extreme condition; dusty environment because of the use of gravel and earthen roads. In this condition, severe dirt would deposit on the radiator fins. These dirt accumulation narrows heat dissipation through the fins and reduces heat removal. Subsequently, the engine could be overheated, which may influence the performance. Therefore, objective of this study is to investigate the effects of dirt accumulation on radiator coolant inlet and outlet temperatures.

METHODOLOGY

For the experimental setup, a test rig was fitted with K-type thermocouple at the radiator to measure the inlet and outlet temperature of coolant that go through the radiator. Figure 1 shows the test rig for the experiment. The test rig consists of radiator, reservoir, water pump, valve, pressure gauge and flow meter. This experiment used Perodua Kancil 850cc car radiator with dimension of 40 cm height, 35 cm width and 26 mm thickness. In

this study, a mixture of 50 % of water and 50 % of ethylene glycol is used as a coolant. The radiator outer surface area was divided into four parts; each part represents 25 % of the surfaced area covered by dirt. Mud and silt were chosen for the experiment since these are the common dirt that stick to the radiator surface area.

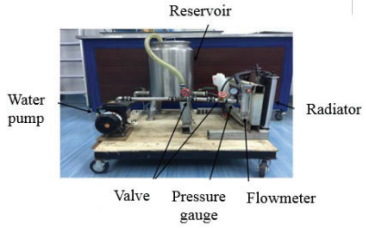

Figure 1. Test rig

Thermocouples were installedon radiator to measure the inlet and outlet temperature. Water pump (model CHL12-30) with 2.2 kW of power and 2900 rpm of speed is used to pump the water to the radiator. Reservoir is used to store the water before flowing to the radiator by the water pump.

2. RESULTS AND DISCUSSION

This section shows the experimental results when mud and silt was used as the covering material at radiator. The blue color is used as baseline when there is not dirt covered at radiator. Generally it can be seen in Figure 3 and 4, the pattern are similar where temperature of coolant inlet and outlet from radiator increased when the area of covered is increased.

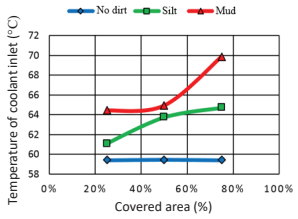

Figure 3. Temperature of coolant inlet to the radiator with difference percentage area covered.

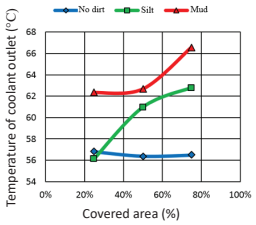

Figure 4. Temperature of coolant outlet from the radiator with difference percentage area covered.

It is also shown in Figure 3 that the coolant temperature into the radiator was higher when mud was used as the cover material compared to silt. When the area of covered is increased from 25 % to 50 %, the graph show mud is high than silt. Temperature for mud is 64.94 °C and 63.74 °C for silt and it increase near to 70 °C and 65 °C when 75 % is covered. For clean radiator show no change in temperature. When 25 % of dirt was used the temperature of mud is higher than silt which is 61.1 °C for mud and 59.41 °C for silt. The highest temperature gained when it comes to 75 % of area covered by both dirt. The temperature of mud is 68.89 °C higher than the silt which is 64.7 °C. Figure 4 also shows the mud was always have the higher temperatures compared to the silt at all the percentage area of dirt covered the radiator. This could be clarified by the way that mud stuck strongly on the radiator surface compared the silt. Because silt is loose, pocket of air space was observed on the covered radiator surface. This brought about some amount of air going through the air spaces to help in the cooling of the coolant to a lower temperature than when mud was used.

3. CONCLUSIONS

Two different types of dirt were used as covering material to cover the surface of the radiator namely silt and mud. It was observed that the temperature at the inlet and outlet of the radiator increased when the percentage of the covered area was increased. The highest temperature gained in both cases when 75% of dirt was used to cover the surface of the radiator. At 75 % of covered area shows difference temperature water outlet around 6 % difference between mud and silt. This is because the effective surface transfer area of the radiator is reduced which cause less heat omitted from the system and no significant effects on the coolant temperature from the inlet condition

It also found that the temperature at inlet and outlet of the radiator were high when the mud was used as covering material compared to the silt. From the analysis, it can be concluded that the dirt that accumulates on the surface of the radiator will decrease the performance of the radiator. If this problem persists, overheating will occur and indirectly will damage the engine.

REFERENCES

[1] A.M. Elsaid, “Experimental study on the heat transfer performance and friction factor characteristics of Co_3O_4 and Al_2O_3 based H_2O /(CH_2OH)$_2$ nanofluids in a vehicle engine radiator,” Int. Commun. Heat Mass Transf., 108, 2019, 104263.

[2] A. Taheri-garavand, H. Ahmadi, M. Omid, S. Saeid, K. Mollazade, A. John, R. Smith, and G. Maria, “An intelligent approach for cooling radiator fault diagnosis based on infrared thermal image processing technique,” Appl. Therm. Eng. 87 , 2015, pp 434–443.

[3] Y. Hwang, J.K. Lee, C.H. Lee, Y.M. Jung, S.I. Cheong, C.G. Lee, B.C. Ku, and S.P. Jang, “Stability and thermal conductivity characteristics of nanofluids,” 455, 2007, pp. 70–74.

[4] M.M. Elias, I.M. Mahbubul, R. Saidur, M.R. Sohel, I.M. Shahrul, S.S. Khaleduzzaman, and S. Sadeghipour, “Experimental investigation on the thermo-physical properties of Al_2O_3 nanoparticles suspended in car radiator coolant,” Int. Commun. Heat Mass Transf. 54, 2014, pp. 48–53.

[5] S. Vithayasai, T. Kiatsiriroat, and A. Nuntaphan, “Effect of electric field on heat transfer performance of automobile radiator at low frontal air velocity,” 26, 2006, pp. 2073–2078.

[6] C. Oliet, A. Oliva, J. Castro, and C.D. Pe, “Parametric studies on automotive radiators,” 27, 2007, pp. 2033–2043.