The Effect of Decontamination on Vehicle Cooling System

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ABSTRACT

This study analyzed the performance of the water pump and radiator under process of as-it-is condition, contamination, and decontamination among three types of radiator, namely used, new, and new coated radiators. Contamination process is completed by spraying the mixture of fine clay and water onto the radiator's surface for 30 layers Decontamination process is done by AirestecSdnBhd, a local company. Internal analysis covers replacing the cooling fluid with used radiator water, tap water and tap water with additive to run experiments. As result, water pump displays similar trends for each set of experiment and air flow velocity, and its highest efficiency is 8.20 %. For external treatment, the effectiveness after decontamination process for new coated radiator, new radiator and used radiator are 43.60%, 31.42% and 30.16% respectively. While for internal treatment, tap water with additive, tap water and used radiator water exhibits 31.79%, 31.42% and 28.98% of effectiveness. As a conclusion, decontaminants towards radiator are effective to increase the performance of the radiator, but no impact on the efficiency of the water pump.For internal treatment, cooling fluid with additive help enhance the radiator performance in cooling system.

Keywords

Vehicle cooling system,radiator, effectiveness, contamination, decontaminiation

1. INTRODUCTION

Judgment on the level of performance or capability of a vehicle cooling system was not entirely rely on the label of brands and tags of price, but it's ability to effectively remove the unwanted heat which probably leaded to damage of mechanical components [1]. Particularly for most of the tropical countries which surrounding temperature is relatively high, the vehicle cooling system carries important responsibility to work on heat transfer via radiator of an engine in order to make sure that engine could operate under optimal temperature[2].

As refer to the sales of new vehicle in 2014, the number of new vehicles purchasing was increasing throughout the year. Since every single vehicle needed to rely on the cooling system to eliminate the excess heat from the engine, the demands for better reliability and longer life of engine cooling system definitely increased too. Related to the research, the study of the characteristic of components of engine cooling system undeniably became significant measure for future improvement.

From previous research study, the characteristics of main components in engine cooling system such as water pump and radiator were analyzed under real engine operating situation. For both research, water was selected as the cooling fluid to circulate the system, the temperature of the coolant, the speed of the vehicle operating, and the air velocity flowing in the radiator were taken into consideration. The efficiency of water pump and effectiveness of radiator were studied.

Accumulation of dirt, dust, and other contaminants in cooling system might result in insufficient cooling effect, and even catastrophic overheating [3]. Prolonged damage over the time leaded to engine core's severe damage as it is hard to observe when liquid cooling system goes wrong [3]. Thus, treatment used such as coating method of radiator could be a measure to minimize the problems of contamination.

In this project, the experiment will be conducted to observe the efficiency of pump and effectiveness of radiator using different radiators at varying vehicle travelling velocity under different radiator's conditions namely original condition, contaminated condition and decontaminated condition. Besides, the study will involve different types of cooling fluid for instance used radiator water, tap water and tap water with additive to identify whether there is a difference in performance of cooling effect.

2.0 EXERIMENTAL RIG AND PROCEDURES

2.1 Experimental Test Rig

The simulator test rig used in the experiment work is displayed in Fig. 1. The simulator test rig consists of an electrical motor pump to circulate the water through the thermal storage, and direct the cooling fluid to reach flow meter. Cooling fluids flows through the radiator and back to the water pump. The water flow rate is controlled via controlling the valve. Bypass valve is installed for a more accurate flow control. Blower placed in front of the air box of the radiator and cooling fan mounted on the radiator are used to simulate the real air flow situation to allow heat transfer via medium of air.

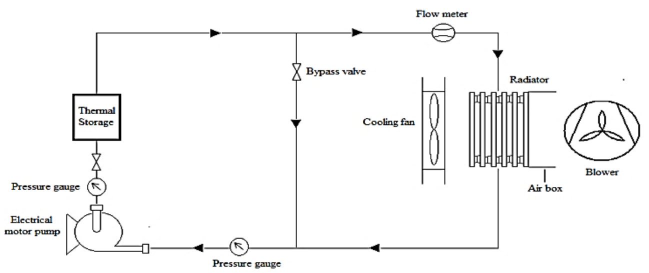

Figure 1: Schematic diagram of simulator test rig

2.2 Experimental Procedure

The experiment is mainly divided into two parts, external analysis which covers experimental works of investigating performance of water pump and different types of radiators at varying vehicle travelling velocity under different radiator's conditions, and internal analysis which includes experiments related to performance of radiators using different types of cooling fluid at varying vehicle travelling velocity. For external analysis, tap water is used as the cooling fluid to run all of the experiments, and three types of radiators involved are used radiator, new radiator and new coated radiator. During as-it-is condition, the simulator test rig is flushed and filled with tap water to ensure that pipes are full with tap water. The electrical motor pump is started and the heater is switched on. The temperature of tap water entering and leaving the radiator, and the temperature of air entering and leaving the fin of the radiator are recorded after the system reaches steady state.

The three radiators in as-it-is condition are then contaminated by using method of spraying the solution which is the mixture of water and clay onto the surface of the radiators. Decontamination process after completing the experiments of contaminated radiators involves releasing of multi-enzyme treatment cleaning for all three radiators and protective layer dip coating for used and new radiators. Experiments of contaminated radiators and decontaminated radiators are exactly the same with the procedure of experiments in as-it-is radiator condition.

The efficiency of the water pump can be calculated through the equation as shown in Equation 1:

$$\eta = \frac{\text{Outputpower}}{\text{Inputpower}} \text{x} 100 \quad (1)$$

where output power is referred to the power of the water pump [4]. The output power of the water pump can be obtained via the equation shown in Equation. 2:

$$\text{Power} = \left[\left(P_{\text{gauge at delivery}} + P_{\text{atm}}\right) - \left(P_{\text{vacuum at suction}} + P_{\text{atm}}\right)\right] \text{ x Flowrate} \quad (2)$$

The effectiveness of the radiator which displayed in Equation 3 can be defined as the ratio of the rate of actual amount of heat transfer to the rate maximum possible heat transfer in a radiator [5]. The actual rate of heat transfer in a radiator is equal to the rate of heat transfer of coolant is shown in Equation 4 while the rate of maximum possible heat transfer is equal to the rate of heat transfer of air is shown in Equation 5. The reason is due to the specific heat capacity of coolant is higher than the specific heat capacity of air.

$$\varepsilon = \frac{\dot{Q}}{\dot{Q}_{max}} \quad (3)$$

$$\dot{Q} = \dot{m}_{coolant}\left(h_{coolant,in} - h_{coolant,out}\right) \quad (4)$$

$$\dot{Q}_{max} = \dot{m}_{air}\left(h_{air,out} - h_{air,in}\right) \quad (5)$$

where $\dot{m}_{coolant}$ is the mass flow rate of coolant, $\dot{m}_{air}$ is the mass flow rate of air, $h_{coolant\ ,in}$ refers to enthalpy of coolant entering the radiator,$h_{coolant\ ,out}$ equals to enthalpy of coolant leaving the radiator, $h_{air\ ,in}$ is the enthalpy of air entering the radiator and $h_{air\ ,out}$ represents the enthalpy of air leaving the radiator.

All experiments and temperatures are carried out under similar environmental condition. It may be noted here that all the data required includes temperatures of coolant entering and leaving the radiators are recorded at steady state condition.

3. RESULTS AND DISCUSSIONS

3.1 Efficiency of Water Pump

Figure 2 displays the efficiency of the water pump against flow rate. The efficiency of the water pump follows the same trend for each type of the radiator namely used radiator, new radiator, and new coated radiator under each condition as as-it-is situation, contamination, and decontamination at each air flow velocity which are 40 km/h, 50 km/h, 60 km/h and 70 km/h. As observed from Figure 2, the efficiency of the pump increases as the water flow rate increases until it reaches maximum performance level, which is 8.20% at 13 *lpm*. The efficiency of the pump decreases with increasing water flow rate after the peak of the efficiency. In other words, the contaminants on the surface of the radiators and the decontamination treatment applied do not affect the performance of the water pump for each of the experiment.

3.2 Effectiveness of Radiator

The effectiveness of the used radiator shows the highest performance level at air flow velocity 40 km/h in condition of decontamination state. As compared, after the used radiator is decontaminated, the effectiveness of used radiator is higher than the performance of used radiator during as-it-is condition. The used radiator in contaminated condition shows the lowest percentage of radiator effectiveness. The performance of the used radiator at air flow velocity of 50 km/h, 60 km/h and 70 km/h are lower in sequence of decontaminated condition, as-it-is condition and contaminated condition compared to air flow velocity of 40 km/h.

As observed from Figure 3, the effectiveness of used radiator in decontaminated condition displays 30.16% at 40 km/h and water flow rate of 22 *lpm*. The value is higher than the effectiveness of used radiator at 22 *lpm* in as-it-is condition, 24.91% and at 22 *lpm* in contaminated condition, 21.74%.

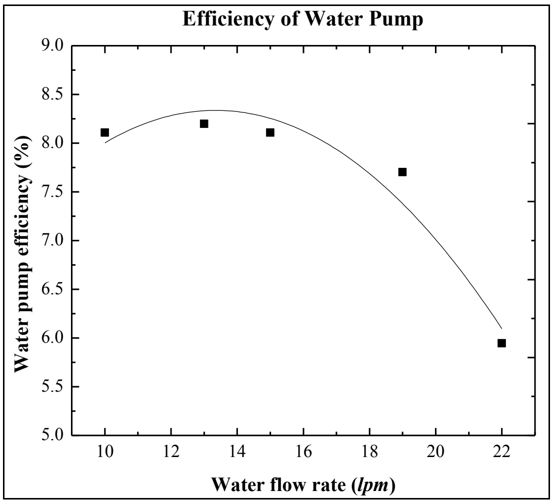

Figure 2: Water pump efficiency against water flow rate

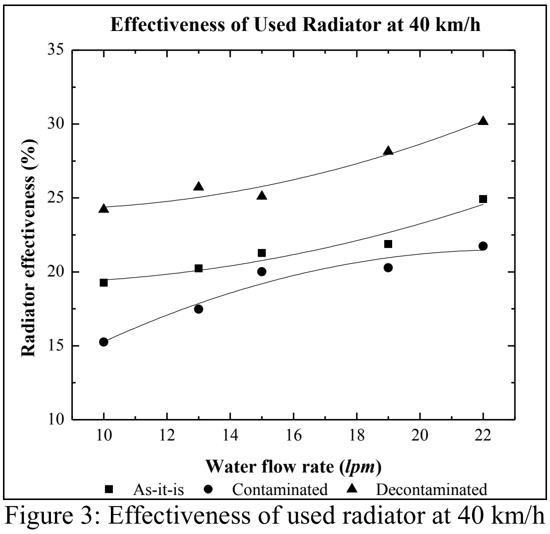

Figure 3: Effectiveness of used radiator at 40 km/h

The effectiveness of new radiator shows the highest performance level at air flow velocity 40 km/h in condition of decontamination state. As compared, after the new radiator is decontaminated, the effectiveness of new radiator is higher than the performance of new radiator during as-it-is condition. The new radiator in contaminated condition shows the lowest percentage of radiator effectiveness. The performance of the new radiator at air flow velocity of 50 km/h, 60 km/h and 70 km/h are lower in sequence of decontaminated condition, as-it-is condition and contaminated condition compared to air flow velocity of 40 km/h.

As observed from Figure 4, the effectiveness of new radiator in decontaminated condition displays 31.42% at 40 km/h and water flow rate of 22 *lpm*. The value is higher than the effectiveness of new radiator at 22 *lpm* in as-it-is condition, 29.79% and at 22 *lpm* in contaminated condition, 28.77%.

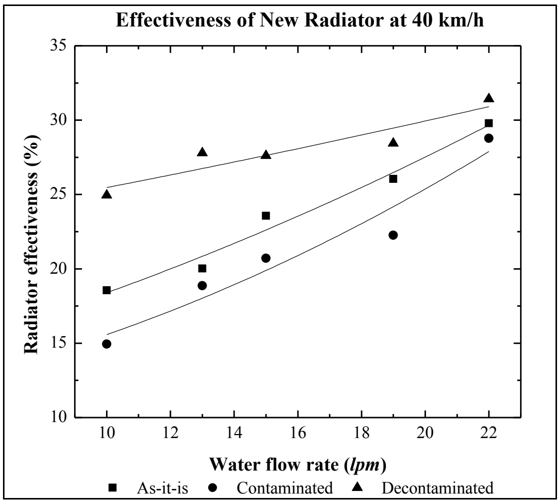

Figure 4: Effectiveness of new radiator at 40 km/h

The effectiveness of new coated radiator shows the highest performance level at air flow velocity 40 km/h in condition of decontamination state. As compared, after the new coated radiator is decontaminated, the effectiveness of new coated radiator is higher than the performance of new coated radiator during as-it-is condition. The new coated radiator in contaminated condition shows the lowest percentage of radiator effectiveness. The performance of the new coated radiator at air flow velocity of 50 km/h, 60 km/h and 70 km/h are lower in sequence of decontaminated condition, as-it-is condition and contaminated condition compared to air flow velocity of 40 km/h.

As observed from Figure 5, the effectiveness of new coated radiator in decontaminated condition displays 40.48 % at 40 km/h and water flow rate of 22 *lpm*. The value is higher than the effectiveness of new coated radiator at 22 *lpm*in as-it-is condition, 28.55 % and at 22 *lpm* in contaminated condition, 24.40 %.

Overall, it indicates that the treatment of applying multi-enzyme to decontaminate the three radiator and dip-coating layer applied for used radiator and new radiator is effective and practicable in raising the performance of the radiator to better the circulating of cooling system.

3.3 Effectiveness of Radiator Using Different Cooling Fluids

The comparisons between the effectiveness of new decontaminated radiator using different cooling fluids namely used radiator water, tap water and tap water with additive at each air flow velocity are analyzed. The effectiveness of new decontaminated radiator using different cooling fluids at air flow velocity of 40 km/h, 50 km/h, 60 km/h and 70 km/h are displayed in Figure 6, Figure 7, Figure 8 and Figure 9.

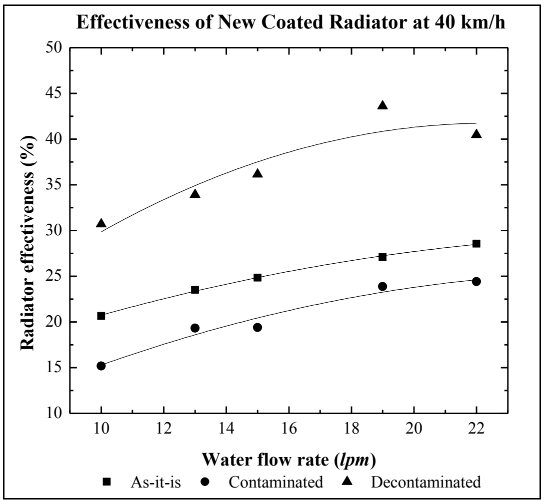

Figure 5: Effectiveness of new coated radiator at 40 km/h

As observed, the effectiveness of the radiator increases with increasing of the water flow rate, but decreases as the air flow velocity is getting faster. The new decontaminated radiator performs the best at air flow velocity of 40 km/h. Refer to Figure 6, the experiment of new decontaminated radiator with using tap water with additive shows better performance compared to the experiment using cooling fluid of tap water and followed by used radiator water. Selecting tap water with additive as cooling fluid of vehicle cooling system does slightly improve the radiator effectiveness compared to normal cooling fluid which is tap water only.

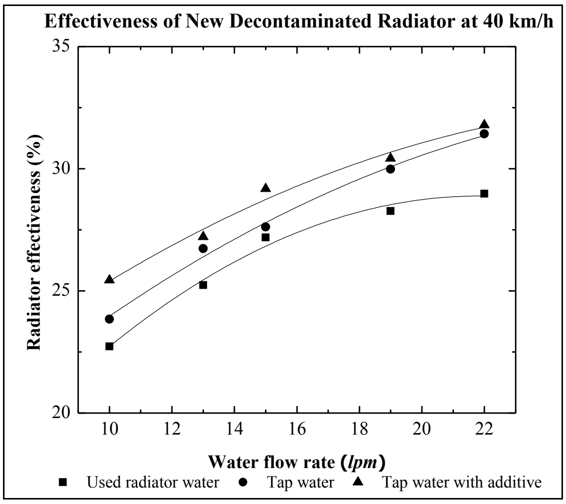

Figure 6: Effectiveness of new decontaminated radiator at 40 km/h

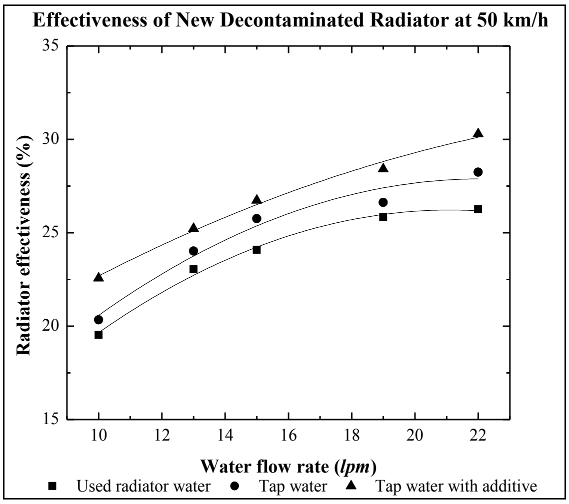

Figure 7: Effectiveness of new decontaminated radiator at 50 km/h

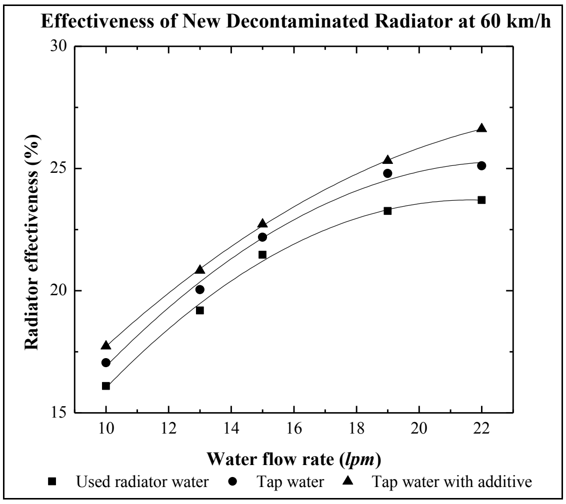

Figure 8: Effectiveness of new decontaminated radiator at 60 km/h

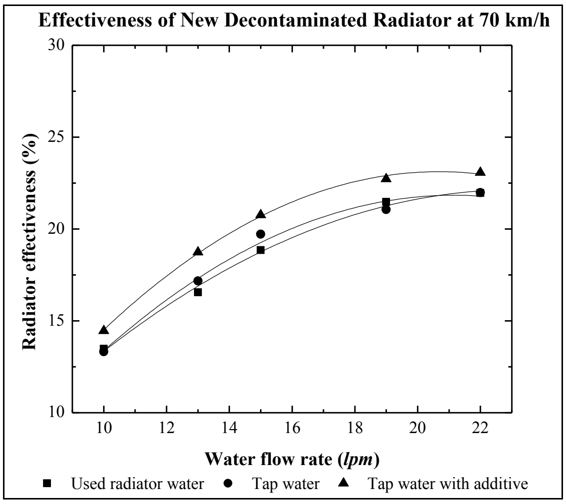

Figure 9: Effectiveness of new decontaminated radiator at 70 km/h

4. CONCLUSION

From the aspect of performance of water pump efficiency, the efficiency of water pump increases with increasing water flow rate until it reaches maximum efficiency which is 8.20%, and then decreases when the water flow rate is increased. The performance of the water pump is following the same trend as for different types of radiators at air flow velocity of 40 km/h, 50 km/h, 60 km/h and 70 km/h. The process of contamination and decontamination on radiator does not give any impact on the efficiency of the pump, in other words the behavior of the water pump remains the same as in as-it-is condition.

For the performance of the radiator in external analysis, the effectiveness of the radiator is better after decontamination treatment than contamination and follow by as-it-is condition. The new coated radiator shows the highest performance, which is 43.60% in decontaminated condition, followed by 28.55% in as-it-is condition, and 24.40% in contaminated condition. It means that the decontaminants applied on the radiators are effective to increase the performance of the radiator in order to better the vehicle cooling system efficiency.

Overall, the effectiveness of new coated radiator is higher than effectiveness of new radiator and lastly effectiveness of used radiator. In decontaminated condition, the performance of new coated radiator which is 43.60% is higher compared to the performances of new radiator and used radiator which are 31.42% and 30.16%. Each type of the radiator in either condition performs the best at air flow velocity of 40 km/h, and its performance decreases from 50 km/h, 60 km/h and 70 km/h.

For the case of the internal analysis, the effectiveness of new decontaminated radiator using tap water with additive is 31.79%, which is the highest compared to the performances of radiator using tap water and used radiator water which are 31.42% and 28.98%.The effectiveness of the radiator is proved to be higher when the cooling fluid chosen is tap water with additive. The performance of the radiator is lower when tap water is used to be the cooling fluid, and the lowest for used radiator water as coolant. Similarly, the radiator works more effective at air flow velocity of 40 km/h, and its effectiveness drops from 50 km/h, 60 km/h and 70 km/h. In short, the internal treatment additive added into the cooling fluid does increase the performance of the radiator in cooling system.

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