Influence of High Voltage on Heat Transfer Performance in Automobile Radiators

S.K.Dhinesh, R.Parameshwaran, S.Praveen Kumar

Abstract: ***Radiators are heat-exchanging devices used to transfer heat from one medium to other medium. The radiators are used for variety of applications such as vehicles, mining operations, constructions, industries, etc. In automobiles, radiators are mainly used reduce the heat in the engine block. In recent days, a special type of coolant is used to circulate through the engine block and the heat transfer takes place. Heat transfer takes place between the hot water stream to the cold air stream passing through the fins of the radiator. The heat transfer performance of the radiator is studies for the three different coolant compositions subjected to the high voltage electric field, the efficiency is calculated, and the radiator fan speed is optimized.***

Keywords: ***Cooling performance, Established techniques, Optimal fan speed***

I. INTRODUCTION

Radiators are heat exchangers, which are used for the purpose of heating and cooling in order to transfer the heat energy from one medium to another medium. Radiators are used for cooling internal combustion (IC) engines in automobiles. Engine coolant oil is mostly used to dissipate the heat from the IC engines through the engine chamber, where it is heated, then through the radiator itself, where it drops the heat to the surroundings and then back to the chamber in a closed loop.

Water-based engine coolant is normally used as a liquid medium in order the radiate the heat, but even oil is used in most cases. A water pump is commonly used to circulate the fluid from the radiator to the engine chamber, which is normally attached engine shaft in heavy-duty vehicles. In cars and low-duty vehicles, a battery operated pump is used with an axial fan to force air through the radiator. For example, Dehghandokht et al. [1] studied the flow rate and the heat transfer characteristics of water and ethylene glycol mixture and studied the performance of the meso-channel heat exchanger. Ethylene glycol is added to the different concentration of copper nanoparticles and the heat transfer efficiency is measured by Leong et al. [2]. Srinivasu et al. [3] used three different combinations of Al2O3 based nano coolant and the results were analysed using computational fluid dynamics (CFD). Hwa-Ming et al. [4] used the combination of Al2O3 and TiO2 nano coolants with ethylene glycol and the performance is studied. Peyghambarzadeh et al. [5] used water with Al2O3 nano-fluid coolant to improve the cooling performance of the automobile radiator and it is compared with pure water and demonstrated that the efficiency is increased with 45%. Peyghambarzadeh et al. [6] experimented water with ethylene glycol based nano-fluid coolant and the improvement (more than 40%) in the heat transfer characteristics is verified. Ravikanth et al. [7] examined the heat transfer performance of Al2O3 with copper oxide nano-fluid and demonstrated the performance improvement with the flat tubes of a radiator. Based on Bernoulli's law, a new method of coolant circulation in liquid droplet radiator has been studied by Tsuyoshi et al. [8].A new approach of introducing high voltage electric field (0 kV to 12 kV) beside the heat exchanger is examined by Vithayasai et al. [9] The effect of high voltage electric field on the heat transfer efficiency was studied with automobile radiator for which water is used as a coolant. Many attempts have been made to improve the cooling performance of the radiator, in which by combining Vithayasai et al. [9], Ravikanth et al. [7] and Peyghambarzadeh et al. [5], the heat transfer performance of automobile radiator is studied by applying high voltage electric field of (0-5 kV) with different combinations of nanofluid coolants.

1.1 Corona Wind

Corona wind or ionic wind occurs due to photonic induction. When high voltage is applied between the electrodes the ionization of the air above the electrode tip takes place therefore a small faint purple jet of plasma is seen in the dark on the conductive tip as shown in the Figure 1. Ionization of the nearby air molecules result in generation of ionized air molecules which creates a flow of air called corona wind.

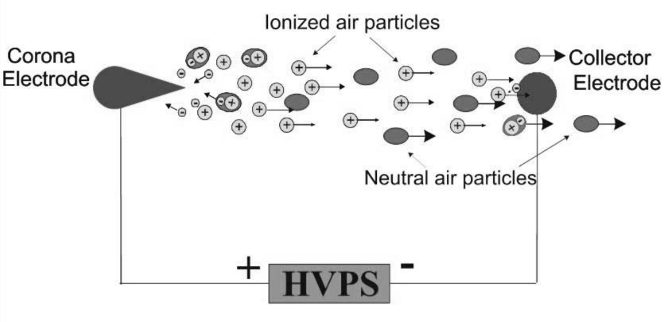

Figure 1: Ionized air particles movement using corona wind when high voltage is applied: (Reference: http://thefutureofthings.com/upload/image/articles/2007/ionic-wind/)

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II. EXPERIMENTAL SETUP

2.1 Selection of Materials

The TATA ACE radiator (Aluminium-Plastic) is used with the dimensions of 365 x 361 x 18mm with single row type. The bottom and top collecting tanks are made up of a special type of plastic, which nearly stands at the temperature of 80oC. The fins of the radiator made up of aluminium. The electric fan coupled to the radiator force the air. An electronic fan regulator is used to control the fan speed, which is measured using a non-contact type digital tachometer. The electrical type water pump (0.5 hp) is used to circulate the coolant through the engine chamber, which can be controlled with help of gate valve.

The different components are assembled and fitted with an iron frame inorder to replicate the same setup of an automobile engine block with radiator setup. A temperature controlled water heater is used to heat the coolant with 90oC. The cooling system has a number of rubber hoses that move the fluid from one place to the other. The hoses are tightened using the steel screw clips. The electric field is supplied by the help of (0-200) V variable transformer. A series of electrodes are placed infront of the radiator in which the supply voltage is given, such that the distance between the radiator and the electrode is exactly 1cm as shown in the Figure 2.

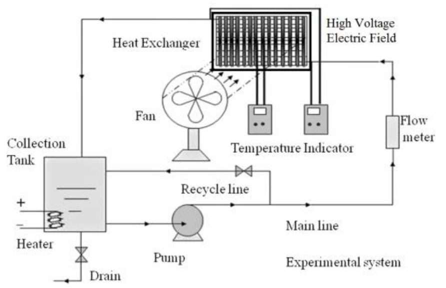

Figure 2: Schematic sketch of the experimental setup (Reference: Peyghambarzadeh et al. [5])

2.2 Placement of Thermocouple

The J-type thermocouple (2 Nos.) is selected to measure the temperature of the coolant in the inlet and outlet of the radiator, which is connected to the DAQ (Data Acquisition Card) inorder to measure the temperature readings. These type of thermocouples are normally used in various applications, especially in automobile to find the engine temperature and exhaust gas temperature.

2.3 Selection of Coolant Materials

Different coolant compositions are selected with ethylene glycol, aluminium oxide, copper oxide, magnesium oxide and distilled water. Four different compositions are considered using the literature review.

The compositions are

a) 5 litre ordinary water

b) 2% of Al_2O_3, 5% of Ethylene Glycol, 2% of CuO in 5 litre distilled water solution. (Peyghambarzadeh - 2011) (COMPOSITION - 1)

c) 5% of Al_2O_3, 5% of Ethylene Glycol, 2% of MgO in 5 litre distilled water solution. (Leong - 2010) (COMPOSITION - 2)

d) 2% of Al_2O_3, 10% of Ethylene Glycol, 2% of CuO, 2% of MgO in 5 litre distilled water solution. (Peyghambarzadeh - 2011) (COMPOSITION - 3)

2.4 Software Used

LabVIEW 2012 is used by which the temperature difference is calculated. The output of the thermocouple is connected to the DAQ (NI MyDAQ) card from which the reading is measure. Data acquisition card is used to convert any physical phenomenon such as voltage, current, temperature, pressure, or sound to voltage signals.

III. EXPERIMENT

The different combinations of coolants are circulated through the radiator and the heat transfer performance is studied. The heat transfer rate is measured with and without the application of the electric field. Based on the output result from the LabVIEW the temperature difference is calculated. The electric field is varied between (0 to 5 kV). The coolant that exhibits more heat transfer rate is calculated. The experimental setup is shown in the Figure 3.

Figure 3: Experimental Setup

3.1 Optimising the Radiator Fan Speed

Once the heat transfer performance is calculated, the optimum fan speed is calculated. The experimental setup is shown in the Figure 4. The maximum revolution per minute (rpm) of the radiator is about 1800. The fan speed is varied by passing the coolant that gives more heat transfer rate.

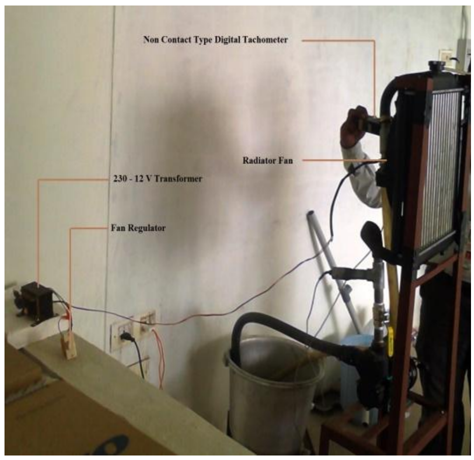

Figure 4 Radiator Fan Speed Optimisation

3.2 Tests for the Coolant Compositions

Various tests are conducted for the coolants such as pH test, electrical conductivity test, turbidity test, density test, boiling point test as shown in the Table 1. These tests are conducted in order to find that maximum heat transfer performance.

COMPOSITIONS/TESTS	COMPOSITION 1	COMPOSITION 2	COMPOSITION 3
pH	6.94	7.32	7.98
TURBIDITY	37.3 NTU	33.3 NTU	30.6 NTU
DENSITY	1.051 (g/cm^3)	1.031 (g/cm^3)	1.06 (g/cm^3)
VISCOSITY	0.97 cP	1.15 cP	1.26 cP
BOILING POINT	71^{o}C	43^{o}C	51^{o}C

*NTU - Nephelometric Turbidity Unit
*cP - centipoise

Table 1: Labscale test for different compositions

IV. RESULTS AND DISCUSSIONS

The results are obtained using the LabVIEW software. The graph is drawn between the temperature difference and the time as shown in the Figure 5 and 6.

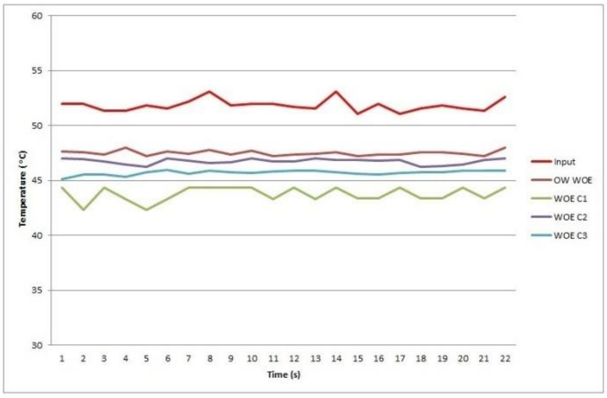

Figure 5 Output without Electric Field

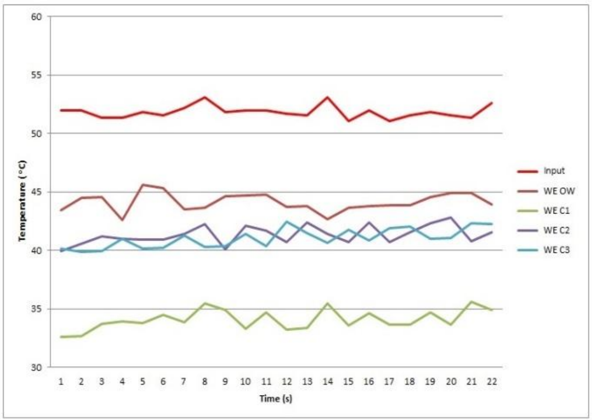

Figure 6 Output with Electric Field

Therefore from the experimentation result it is clear that the composition 1 (2% of Al_2O_3, 5% of Ethylene Glycol, 2% of CuO in 5 litre distilled water solution) shows more heat transfer performance compared to other coolants. Nearly upto 8oC is achieved more.

When the viscosity and turbidity rate are low the heat transfer rate is high. The boiling point should be also high. The pH of the solution must be also equal to neutral. From the experimental and the Labscale tests we can conclude that composition 1 exhibits more heat transfer performance.

4.1 Fan Speed Optimisation

The fan speed is optimised by varing the fan speed from 1800 rpm. The radiator fan runs in a constant speed through battery in light duty vehicles. The optimisation is carried out with the help of a fan regulator and non-contact type tachometer. The composition 1 is used as the coolant and the heat transfer performance is calculated. The graph is drawn between the temperature difference and radiator fan speed as shown in the Figure 6.

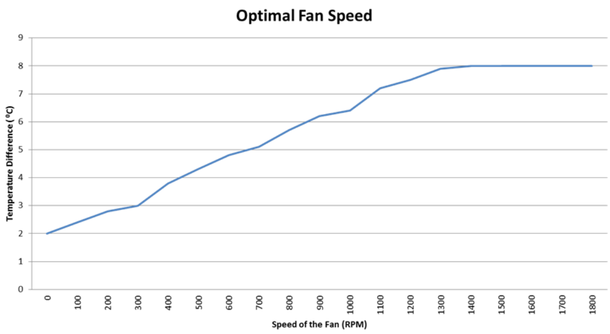

Figure 6 Radiator Fan Speed Optimisation

V. CONCLUSIONS

The conclusion states that the composition 1 (2% of Al2O3, 5% of Ethylene Glycol, 2% of CuO in 5 litre distilled water solution) exhibits 12.5% more heat transfer characteristics that the other compositions. The radiator fan speed is optimised such that after a certain limit the fan has constant heat transfer characteristics i.e. above 1500 rpm, which states that a fan running at 1500 rpm is sufficient. The parameters to be considered are the distance between the electrode and radiator, flow variation, direction of the flow of coolant, etc.

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