OPTIMIZATION OF HEAT TRANSFER PARAMETERS TO ENHANCE COOLING PERFORMANCE IN AUTOMOBILE RADIATOR USING TIO_2 NANOFLUID AS COOLANT

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Abstract

The thermal performance of an automobile radiator plays an important role in the performance of an automobile's cooling system and all other associated systems. Normally, it is used as a cooling system of the engine and generally water is the heat transfer medium. Nanofluids have attracted attention as a new generation of heat transfer fluids building in automotive cooling applications, because of their excellent thermal performance. In this work, heat transfer enhancement using TiO_2 nanopowder is suspended in distilled + ethylene glycol. The flow rate and inlet temperature of the radiator are considered as varying parameters. The result shows that, heat transfer coefficient has been increased with increase in volume concentration of nanoparticles as well as the flow rate of circulating fluid. The optimized heat transfer coefficient was obtained at 60 radiator inlet temperature and 12 lpm flow rate of the circulating fluid.

Key words: Full Factorial Design, Heat Transfer, Nanoparticles, Radiator.

I NTRODUCTION

1.1 Introduction: Thermal properties of liquids play a decisive part in heating as well as cooling applications in industrial operation. The thermal conductivity of a liquid is an important thermal property that decides its heat carrying capacity. Conventional heat transfer fluids have inherently poor thermal conductivity which makes them inadequate for ultra high cooling applications. An Experimental Investigation of Heat Transfer Characteristics of Automobile Radiator using TiO_2 have been done by **V. Salamon et.al [1].** The authors concluded that the Nusselt number of the nanofluid, coolant increases with an increase in flow rate. At a low inlet coolant temperature the water/propylene glycol mixture showed a higher heat transfer rate when compared with nanofluids coolant. However, at higher operating temperature and higher coolant flow rate, 0.3 vol. % of TiO_2 nanofluids enhances the heat transfer rate of 8.5% when compared to base fluids. **Jaafar Albadr et.al [2]** measured heat transfer through heat exchanger using Al_2O_3 nano fluid at different concentrations. The results the convective heat transfer coefficient of nano fluid is slightly higher than that of the base liquid at same mass flow rate and at the same inlet temperature. The heat transfer coefficient of the nanofluids increases with an increase in the mass flow rate, also the heat transfer coefficient increases with the increase in the volume concentration of the Al_2O_3 nanofluid, however, increasing the volume concentration cause increase in the viscosity of the nanofluids leading to increase in friction factor. An extensive review on water/ethylene glycol based nanofluids and their applications have been done by **Azmi et.al. [3].** The authors concluded that many investigations on nanofluids with different types of nanomaterials and based fluids have shown that nanofluids possess better thermal performance. They also found that heat transfer characteristics of nanofluids were influenced by the type of base fluids, the ratio of water and ethylene glycol mixture, nanoparticles material, volume concentration, nanoparticles size and flow characteristics. **Vivek et.al. [4]** Studied the heat transfer characteristics of Al_2O_3 /water-ethylene glycol nanofluid coolant in automobile radiator. Heat transfer enhancement of about 37% was obtained with 0.1% of AlO3 nanoparticles. They also conducted experiments with water/propylene glycol mixture as base fluid. An enhancement of 9% in the overall heat conductance was obtained by the addition of 0.2% alumina nanoparticles into propylene glycol based coolant fluid. Experimental investigation of the cooling performance of an Automobile radiator using Al_2O_3 –Water + ethylene Glycol nanofluid has been done by **D. Tirupathirao et.al. [5]** Maximum heat transfer performance for 0.08% volume fraction was found 48 % higher compared to water. The effective thermal conductivity of nanofluid increases with increase in particle concentration which leads to increase the radiator cooling performance. The coolant flow rate is varied from 3 lpm to 15 lpm. It is observed that with increase in flow rate heat transfer performance increases. It is seen that most of research work done so far water and water-ethylene glycol based nanofluids with different volume concentrations of nanoparticles. Inlet temperature of coolant fluid to radiator and coolant fluid flow rate play a very important role in automobile radiator. In this paper optimization of heat transfer parameters to enhance cooling performance in automobile radiator using TiO_2 nanofluid as coolant done experimentally. The heat transfer coefficient of nanofluid compared with pure water and base coolant fluid mixture.

II EXPERIMENTAL METHODOLOGY

2.1 Experimental Setup: As shown in figure 1 the experimental setup consists of a car radiator, an electric heater, a reservoir tank, a centrifugal pump, an air blower, flow control valves and K-type thermocouples to measure the inlet and outlet fluid temperature. An electrical heater of 2 kW was used to heat the coolant in the reservoir tank. The coolant was circulated using a 0.25 HP centrifugal pump. A manually operated valve was used to vary the flow rate of the coolant fluid entering the radiator in between 3-15 lit/min. Two K-type thermocouples were placed at the inlet and the outlet of the radiator wall surface to measure air temperatures of the radiator to measure the coolant temperatures. Thermocouples were also fixed on front side to record the air temperature.

Figure 1: Experimental Setup

2.2 Experimental Procedure:

The forced convective heat transfer experiment was conducted in the radiator experimental setup using pure water, water/propylene glycol mixture (70:30), and water/ethylene glycol/TiO_2 nanofluid (0.3% and 0.6% by volume). The coolant in the reservoir tank was heated up to the desired temperature and circulated through the radiator using the pump. The inlet temperature of the coolant in the radiator is varied 60, 65 and 70. The coolant flow rate varied between 6 to 12 l/min. The air flow rate to the radiator was kept constant at an average of 15m/s. The outlet temperature of the coolant was recorded using K-type thermocouple. Furthermore, K-type thermocouples were fixed on the radiator wall on front side to record the air temperature.

2.3 Full Factorial Design (FFD):

Design of Experiments used to form the combinations. Here, two parameters with three different levels were considered. By using the Full Factorial Design in Matlab, the formula to obtain combinations was a^m where 'a' indicates the No.of levels, m indicates the No.of parameters. Here we considered two parameters with three different levels ($3^2=9$).

Table 1: Input Parameters to FFD

S. No	Parameter	Level 1	Level2	Level3
1	Inlet Temp. Of coolant fluid in Radiator (˚C)	60	65	70
2	Coolant Fluid Flow Rate (lpm)	6	9	12

The above table shows the input parameters to FFD.

Table 2: Output Parameters from FFD

Run Order	Inlet Temp. Of coolant fluid in Radiator (˚C)	Coolant Fluid Flow Rate (lpm)
1	70	6
2	65	6
3	60	12
4	70	9
5	65	9
6	65	12
7	70	12
8	60	9
9	60	6

The above table shows the output parameters from FFD. By using above data series of experiments are conducted using Water, Water+ Ethylene Glycol, Water+ Ethylene Glycol+ TiO_2 nanoparticles (0.03% volume concentration) and Water+ Ethylene Glycol+ TiO_2 nanoparticles (0.06% volume concentration) as coolant fluid. Temperature values of the wall surface and outlet temperature of coolant fluid from radiator are recorded for all series of experiments. Run Order is nothing but series of combinations order.

III NANOFLUID PREPARATION

Titanium dioxide (TiO_2) nanofluid was prepared in two different concentrations 0.03% and 0.3% by volume of the base fluid using the two-step method to understand the effects of particle concentration on the heat transfer rate. The base fluid was the mixture of water and ethylene glycol in the ratio 70:30. The dry nanoparticles were added directly in the base fluid at required concentrations. The dispersion process was carried out using probe ultrasonicator. The nanofluid was subjected to ultrasonication in the frequency of 20Hz for the duration of 6Hours.

The density, specific heat and thermal conductivity of nanofluid were calculated using two phase flow equations

$$\rho_{nf} = \varphi \times \rho_s + [(1-\varphi)\times\rho_w] \qquad (1)$$

Where ρ_{nf} =Density of nanofluid.

φ = Volume concentration of nanoparticles.

ρ_s = Density of nanoparticles.

ρ_w = Density of water (Base Fluid).

$$C_{p_{nf}} = \frac{\varphi\times\rho_s\times C_{ps} + (1-\varphi)(\rho_w\times C_{pw})}{\varphi\times\rho_s + (1-\varphi)\times\rho_w} \qquad (2)$$

Where $C_{p_{nf}}$ = Specific heat of nanofluid.

$$K_{nf} = \left[\frac{k_p + 2k_{bf} + 2(k_p - k_{bf})(1+\beta)^3\varphi}{k_p + 2k_{bf} - (k_p - k_{bf})(1+\beta)^3\varphi}\right]k_{bf}$$

(3)

Where K_{nf} = Thermal Conductivity of nanofluid.

% Volume Concentration

$$= \frac{\frac{W_{TiO_2}}{\rho_{TiO_2}}}{\left[\frac{W_{TiO_2}}{\rho_{TiO_2}} + \frac{W_{water}}{\rho_{water}}\right]} \qquad (4)$$

IV EXPERIMENTAL CALCULATIONS

The heat transfer coefficient for all the series of experiments were calculated using the following procedure

$$Q = hA_s\Delta T = hA_s(T_b - T_s) \qquad (5)$$

Where 'h' is the heat transfer coefficient, A_s is surface area and T_b is bulk mean temperature.

$$T_b = \left(\frac{T_i + T_o}{2}\right) \qquad (6)$$

Where T_i = Inlet Temperature of coolant fluid.
T_o= Outlet Temperature of coolant fluid.

$$T_s = \left(\frac{T_1 + T_4}{4}\right) \qquad (7)$$

T_s is the tube wall temperature, obtained by the average of the front side thermocouples.

Heat transfer rate is given by

$$Q = mc_p(T_i - T_o) \qquad (8)$$

Where m is the mass flow rate.
c_p = specific heat of coolant fluid.

Heat transfer coefficient obtained by

$$h_{exp} = \frac{mc_p(T_i - T_o)}{A_s(T_b - T_s)} \qquad (9)$$

By using above formula heat transfer coefficient values calculated for all nine series of experiments as earlier mentioned in the table.

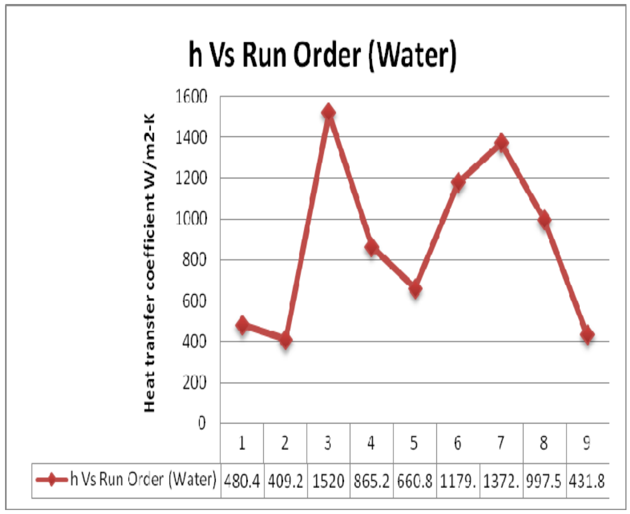
V RESULTS AND DISCUSSION

Table 3 : Heat Transfer Coefficient Values

Run Order	Heat transfer coefficient of Water (W/m^2-k)	Heat transfer coefficient of Water + EG (W/m^2-k)	Heat transfer coefficient of (Water + EG + 0.03% TiO_2 nano fluid) (W/m^2-k)	Heat transfer coefficient of (Water + EG + 0.06% TiO_2 nano fluid) (W/m^2-k)
1	480.45	422.32	710.11	749.79
2	409.23	365.62	878.00	669.45
3	1520	2383.11	2574	3259.95
4	865.22	886.15	1242.69	1414.69
5	660.86	667.27	1314.46	1874.47
6	1179.31	1409.73	1898.53	2538.35
7	1372.22	1853.53	1872.11	2473.26
8	997.5	1112.12	1144.06	1735.62
9	431.8	465.53	667.37	892.60

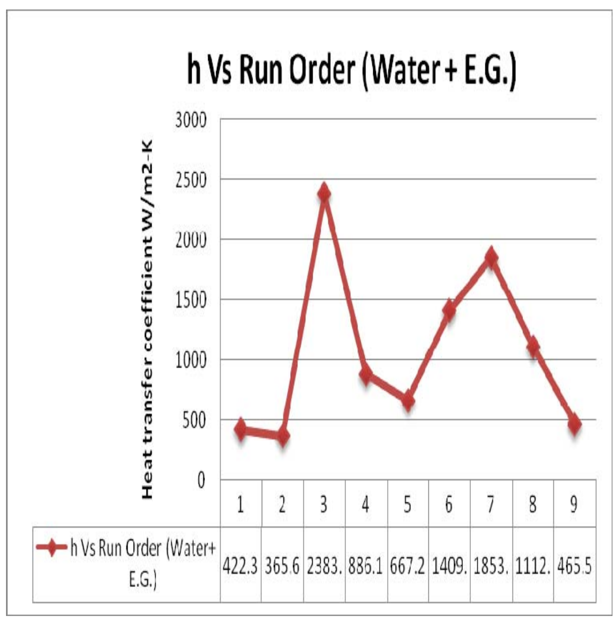
The above table shows the heat transfer coefficient values for Water, Water+ Ethylene Glycol, Water+ Ethylene Glycol+ TiO_2 nanoparticles (0.03% volume concentration) and Water+ Ethylene Glycol+ TiO_2 nanoparticles (0.06% volume concentration) as coolant fluid.

Graph 1: Heat transfer coefficient 'h' Vs Run order (Water)



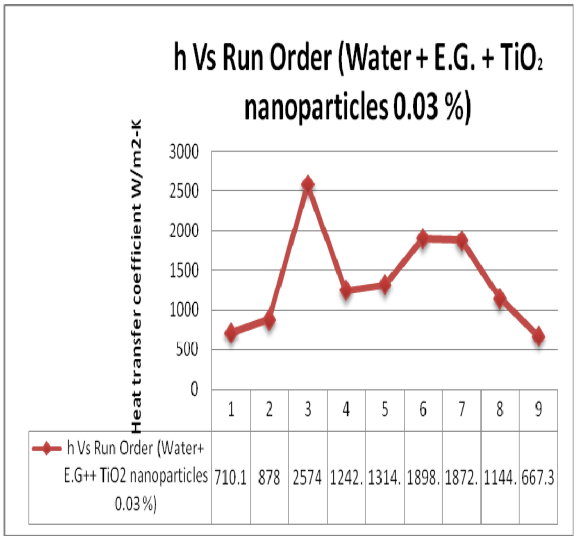
From the above graph it is observed that the maximum heat transfer coefficient at run order 3 while using water as coolant fluid.

Graph 2: Heat transfer coefficient 'h' Vs Run order (Water+E.G.)



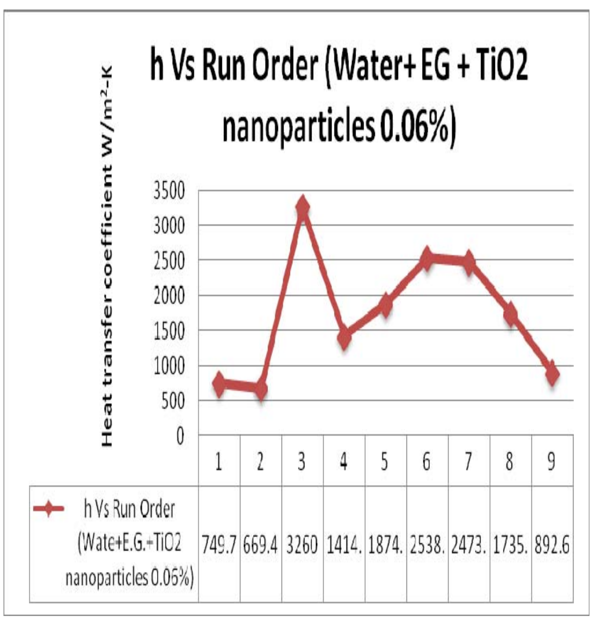
From the above graph it is observed that the maximum heat transfer coefficient at run order 3 while using water+ethylene glycol as coolant fluid.

Graph 3: Heat transfer coefficient 'h' Vs Run order (Water+E. G. +TiO_2 nanoparticles 0.03%)



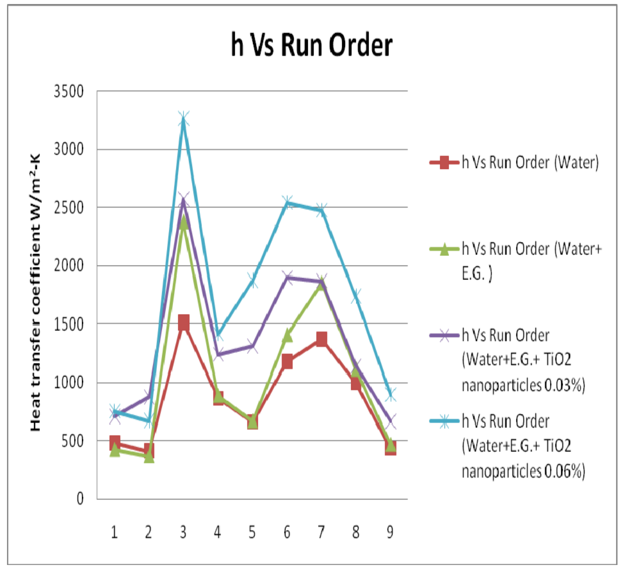
From the above graph it is observed that the maximum heat transfer coefficient at run order 3 while using water+ethylene glycol+TiO_2 nanoparticles 0.03%) as coolant fluid.

Graph 3: Heat transfer coefficient 'h' Vs Run order (Water+E. G. +TiO_2 nanoparticles 0.06%)



From the above graph it is observed that the maximum heat transfer coefficient at run order 3 while using water+ethylene glycol+TiO_2 nanoparticles 0.06 % as coolant fluid.

Graph 3: Heat transfer coefficient 'h' Vs Run order



From the above graph it is observed that comparison of heat transfer coefficient for different proportions of coolant fluid done. The optimized heat transfer coefficient obtained for water+ethylene glycol+TiO_2 nanoparticles 0.06 % of rank order 3. The optimized parameters are Inlet Temp. Of coolant fluid in Radiator is 60^0 C and coolant fluid flow rate is 12 lpm.

VI CONCLUSION

The forced convective heat transfer experimentation have been successfully performed on automobile radiator by means of coolant fluid as water, water+ethylene glycol, water+ ethylene glycol+TiO_2 nanoparticles 0.03% and water+ethylene glycol+TiO_2 nanoparticles 0.06%. Optimization of heat transfer parameters successfully completed and optimized parameters are obtained.

1. The heat transfer coefficient increases with the increase
In volume concentration.
2. The optimized heat transfer coefficient was observed in
Run order 3 for Water+E. G. +TiO_2 nanoparticles 0.06%.
3. The heat transfer coefficient increases with the increase
In flow rate of coolant fluid even at higher temperatures.

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