Experimental Study of Heat Transfer Enhancement of Automobile Radiator using nano fluid as a Coolant with AL_2O_3 nano particles and Water as a base fluid.

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ABSTRACT

Traditionally forced convection heat transfer in a car radiator was performed to cool water-containing circulating fluid. In this paper, the heat transfer performance of water has been compared with their binary mixtures. The radiator's upright tubes are filled with pure water and nanofluid. Different % of Al2O3 nanoparticle have been mixed with the base fluid (H2O) and its effect on the heat transfer performance of the car radiator have been found experimentally. Liquid flow rates from 10, 12, 14, 16 liter per minute and the fluid inlet temperature has been changed from 40o C to 70o C for the experiment. Utilizing the results of the experiments, the effectiveness, and overall heat transfer coefficients, U, were calculated. At various inlet temperatures and concentrations, overall heat transfer coefficients, U, were calculated. Heat transfer by nanofluids is clearly enhanced compared to base fluid i.e water, as demonstrated by the results. The best conditions result in a 0.4% increase in heat transfer compared with base fluids.

Keyword: - *Nanofluid, AL2O3, Car-Radiator, Heat transfer*

1. INTRODUCTION

Recently, automakers have focused on reducing weight to improve fuel efficiency and operating costs. If the cooling system fails or does not work properly, even for a short period of time, it can increase fuel consumption, cause fuel evaporation, increase pollutants and permanently damage the vehicle's engine components. Due to the lower fuel and energy consumption of cooling systems, it is necessary to optimize and improve the performance of cooling systems. Therefore, researchers are looking for various ways to improve heat transfer and engine cooling. Miniaturization and better performance of heating systems are important requirements for automotive cooling systems. The "thermal conductivity" of the fluids used in the production of energy saving fluids plays an important role. In the literature on the application of nanofluids in heat exchangers, Humic defines nanofluids as liquid suspensions containing nanoparticles

[1.]. Nanotechnology aims to change the properties of materials. Metal oxides and carbides contain ultrafine particles (1-100 nm), considered as nanoparticles, preparation of nanoparticles, mixed with alkaline liquids such as water, EG, etc., to create solutions for thermal systems. In addition to CuO, Al2O3 can also be used as a metal oxide. Coarse or fine particles should be avoided because they can cause pressure drop, corrosion and sedimentation during heat transfer [1.]. Peyghambarzadeh and others. The heat transfer properties of nanofluids mixed with Al2O3 and water in an automobile radiator were studied. The experiments were performed with different volumetric concentrations of Al2O3 nanoparticles between 0.1% and 1.0% (vol/vol) and different flow rates between 2 and 5 liters per minute. It was clearly found that by using nanofluids, the heat transfer rate increased by 45% compared to a lower concentration of pure water [3.]. Brownian motion associated with nanofluids also enhances thermal conductivity, not just thermal conductivity. It will now be launched with another Renault. The range is from Re9000-Re23000 for water-mixed nanofluids to Re1200-Re2500 for glycol-mixed nanofluids. Different regions have different parameters, such as: coolant inlet temperature, water-based nanofluid is 350°C to 500°C, glycol-based nanofluid is 450°C to 600°C, the flow is from 2 to 600 °C. 6 liters per minute. The content of microparticles and nanoparticles is from 0 to 0.1% by volume. Nanofluids were prepared without dispersants or stabilizers, and with 1% (vol/vol) nanoparticles, the heat transfer rate was improved by 40% compared to the pure liquid, and the heat transfer rate increased more when Na was used in water. based on nanofluids. Peyghambarzadeh and others. [4] performed an experimental study of the total heat transfer coefficient of dilute nanofluids in automotive radiators using copper oxide (CuO) and iron oxide (Fe2O3) particles. Three concentrations (0.15%, 0.4% and 0.15%). 65% nanofluids (water-based) and pH-adjusting dispersants were considered. With variable flow rates from 0.05 to 0.11 LPS per tube and variable temperatures from 500 to 800 °C. Compared with water, the overall heat transfer coefficient of the nanofluid was increased by 0.65% (vol/vol), which is an improvement of 9%. It is obtained from Fe2O3 and 7% CuO. Herez et al. [5.] Here, using Al2O3 mixed with nanoparticle water as a heat transfer agent, the constant wall temperature of a circular tube is investigated along with its boundary conditions and heat transfer properties. Various observations were obtained by changing the Nusselt number with the Reynolds and Peclet numbers. The heat transfer coefficient is found to increase with increasing particle size concentration fraction and number of nozzles. Ali and Younes [6.] Experimental analysis of the thermal conductivity and thermal diffusivity of specific nanoparticles, and the parameters that affect them, such as volume fraction and material. The use of nanofluids, especially those containing metals, has been found to improve thermal performance compared to non-metallic nanofluids. Nathan et al. [7] studied the effect of two different nanofluids on heat transfer performance, one was an alumina-based nanofluid and the other was a copper-based nanofluid mixed with water as the base fluid. It was concluded that the heat transfer rate increased for each of the nanofluids. Siddiqui et al. [8.] studied the cooling rate of a fat cooler for cooling a microprocessor heat generator using Al2O3-Cu-based nanofluids and deionized base liquid, and then compared the cooling rate with the cooling rate. Water volume Naraki et al. [9] experimentally investigated the enhancement of heat transfer in an automobile radiator after mixing CuO with water in nanofluids. To stabilize the nanofluid, sodium dodecyl sulfonate was used as a surfactant to adjust the pH of the solution. The experiments were carried out at different flow rates ranging from 0.2 to 0.5 m^3/h. Different volume fractions of the nanoparticles were also used: 0, 0.15 and 0.4% (vol/vol). The heat transfer coefficient of 0.4% (Vol.) CuO increases by 8% as the flow rate increases. Conversely, the overall heat transfer coefficient decreases with increasing nanofluidic inlet temperature. Tarek et al [10] Based on the study of the thermal efficiency of a small beehive structure using water as the cooling fluid, the experimental results were calculated and verified by computational fluid dynamics results. Sajid and Ali [11.] His work focuses on nanofluids and their applications. Emphasis is placed on various thermal parameters such as thermal conductivity, thermal resistance, friction coefficient, Nusselt number, heat transfer coefficient and pressure drop, as well as the effect of nanoparticle concentration, the size, shape and flow over them. Our tests evaluated the performance of an automotive radiator using nanofluids in a heat exchanger.
This study's experimental set-up is utilized to assess the process of heat transfer of an Al2O3-based nanofluid with different/varying nanoparticle content. This study's experimental set-up is implemented to assess the properties of heat transfer of an Al2O3-water-based nanofluid with various nanoparticle content levels.

In our experiment, the performance of an automobile radiator using nanofluid in the heat-exchanger is evaluated. This study's experimental set-up is utilized to assess the process of heat transfer of an Al2O3-based nanofluid with different/varying nanoparticle content. This study's experimental set-up is implemented to assess the properties of heat transfer of an Al2O3-water-based nanofluid with various nanoparticle content levels

2. EXPERIMENTAL SETUP

The main parts are the water circulation pump, air distribution fan, a sump or a storage with heating element such as heater, and an automotive radiator. Rotameters, temperature sensors, and temperature controllers are among the tools used to record the measurements and manage heating. The nanofluid is heated by the heater to a specific temperature before flowing through the pipes to the radiator. Air is forced to pass from the fan to the radiator perpendicular to the direction where the nanofluid is meant to flow through/inside pipes of radiator. The valve controls the required flow rate and inlet temperature. The experiment was carried out at different/varying inlet temperatures ranging from 40 to 70 °C of heated nanofluid. The study made use of a variety of flow rates in the 10–16 LPM range. To measure the temperatures of the hot and cold fluid at various points, four thermocouples (J-type) were positioned at different locations around the radiator. The cold air's speed as it circulated across the heat exchange was adjusted between 2 and 3 m/s. To assess the improvement in automobile radiator’s performance, we firstly conducted our experiment using distilled water as the base or working fluid.
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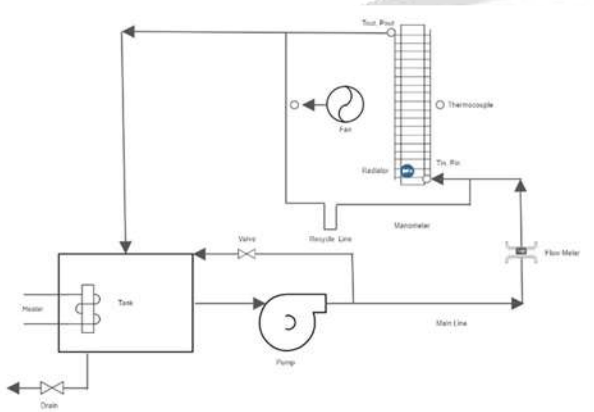

Figure-1: Block Diagram and Actual Experimental Setup

There are 20 vertical tubes in the experiment's car radiator make up the radiator. Along the whole length of said tubes, a number of fins encircle and join said tubes. Aluminum is used to make the fins and tubes. The area of transmission of heat is increased, by the fins provided above the tubes of the Automobile Radiator. The water enters from the inlet, travels through the system of tubing, passes through the lower tank as indicated, and finally exits through an outlet port after being cooled by the air.

Table -1: Radiator Dimensions

Dimensions	Values
Materials of tubes	Aluminium
Number of tubes	20
Inner diameter of tubes	10mm
Outer diameter of tubes	11.25mm
Material of fin	Aluminium
Thickness of fin	0.16mm

Figure-2: Automobile Radiator used in Experimental Setup

3. PREPARATION OF NANOFLUID

The performance using Al2O3–water (H2O), -based nanofluid is carried out and presented below. The description of nano-particle used (Al2O3) is given below in Table 2.

Table -2: Nanoparticles Properties

Chemical name	**AL2O3**
Appearance	White powder
Morphology	Spherical
Purity	99.5%
Average particle size	30-50 nm
Specific surface area	17.8 m2 /gm

The experiment's nanofluids were obtained from P.E.S. Modern College of Pharmacy in Nigdi, Pune, where the nanofluids were prepared using a magnetic stirrer and a Probe Sonicator. Next, water (H_2O), -based nanofluids were used with varying volume fractions respectively. The required amounts of nanoparticles for the required volume concentrations is given below.

Figure-3: Different Volume Concentrations of Nanofluid

Figure-4: Probe Sonicator

Figure-5: Magnetic stirrer

4. CALCULATIONS

Equation (1) was used to calculate the number of nanoparticles needed to achieve the known volumetric concentration percentage.

(1) Volume concentration Ø= $\frac{\frac{w_{np}}{\rho_{np}}}{\frac{w_{bf}}{\rho_{bf}} + \frac{w_{np}}{\rho_{np}}} * 100$

Based on a mathematical model (refer to Equation (2) and (3)) provided by Pak et al. [12.], the density and specific heat capacity of the nanofluid at various concentrations are calculated. Table displays the calculated outcomes.

(2) Density of nanofluid (ρ_{nf}) = $\varphi \rho_p + (1- \varphi)\ \rho_{bf}$

(3) Specific Heat $(C_p)_{nf}$ = $\frac{(1-\phi)(\rho C\rho)_f + \phi(\rho C\rho)\rho}{P_{nf}}$

Table -3: Volume concentration % (Nanofluid)

Property	Volume concentration % (Nanofluid)			
	0.1	**0.2**	**0.3**	**0.4**
Specific Heat (Cp) (J/kg °C)	3868	3536	3204	2872
Density (ρ)	1289	1578	1867	2156

(4) To determine the overall heat transfer coefficient, the logarithmic mean temperature difference method findings from the experiments were calculated. This approach made use of the subsequent equations.

$$q = \dot{m}_h c_{vh}(T_{hi} - T_{ho})$$
$$q = \dot{m}_c c_{vc}(T_{co} - T_{ci})$$

(5) Reynolds number (Re) $\frac{\varrho_{nf}\ vD}{\mu nf}$

(6) $p_r = \mu C_v / K$

(7) LMTD = $[\Delta T_1 - \Delta T_2]$ / $\ell_n\{[\Delta T_1/\Delta T_2]\}$

(8) NTU, or Number of Transfer Unit, is a term frequently used in heat exchanger analysis.

NTU= UA/C_{min}

$$\varepsilon = 1 - [(\frac{1}{C^*})](NTU)^{0.22}\{\exp[-C^*(NTU)^{0.78}] - 1\}$$

For cooling hot water and nanofluid that circulate through radiator tubes, air was blown over the radiator by an exhaust fan. For a set flow rate and fixed inlet temperature of the liquid, heat transfer rates were computed for distilled water and various volume fractions of alumina-based nanofluid.

5. RESULT

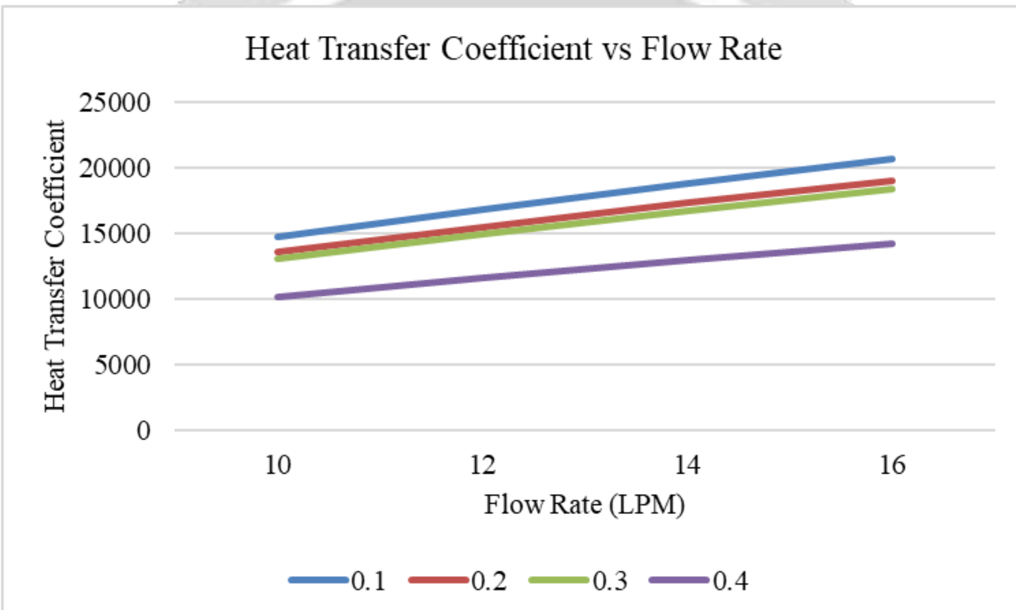

Chart-1: Heat Transfer Coefficient vs Flow Rate

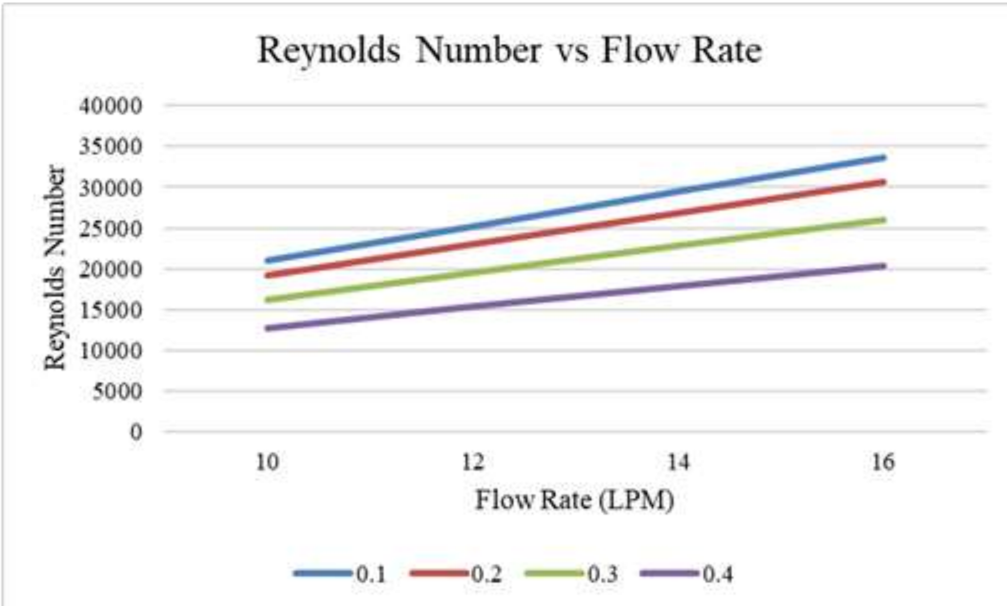

Chart-2: Reynolds Number vs Flow Rate

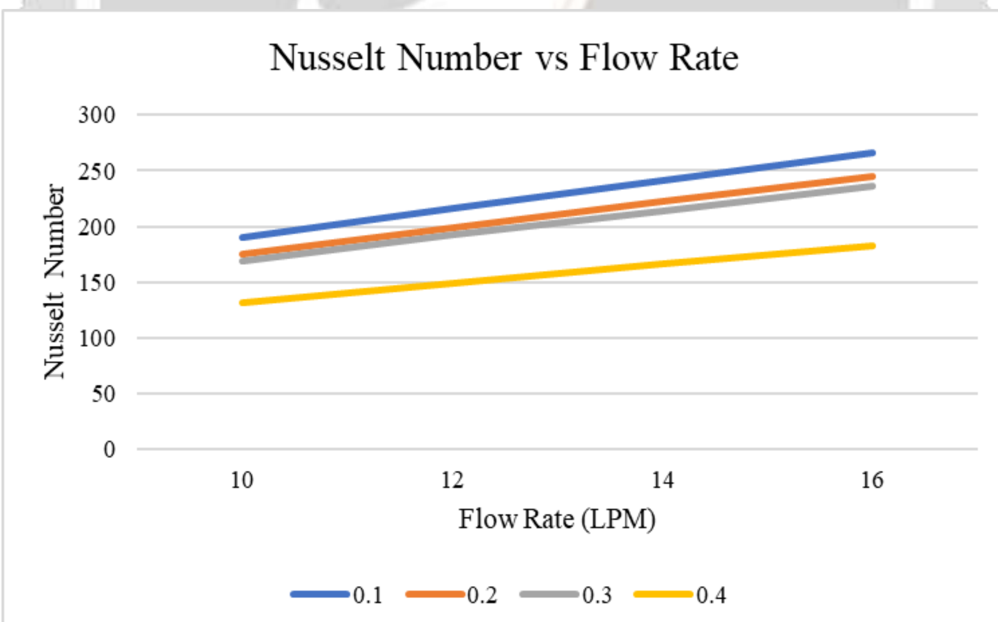

Chart-3: Nusselt Number vs Flow Rate

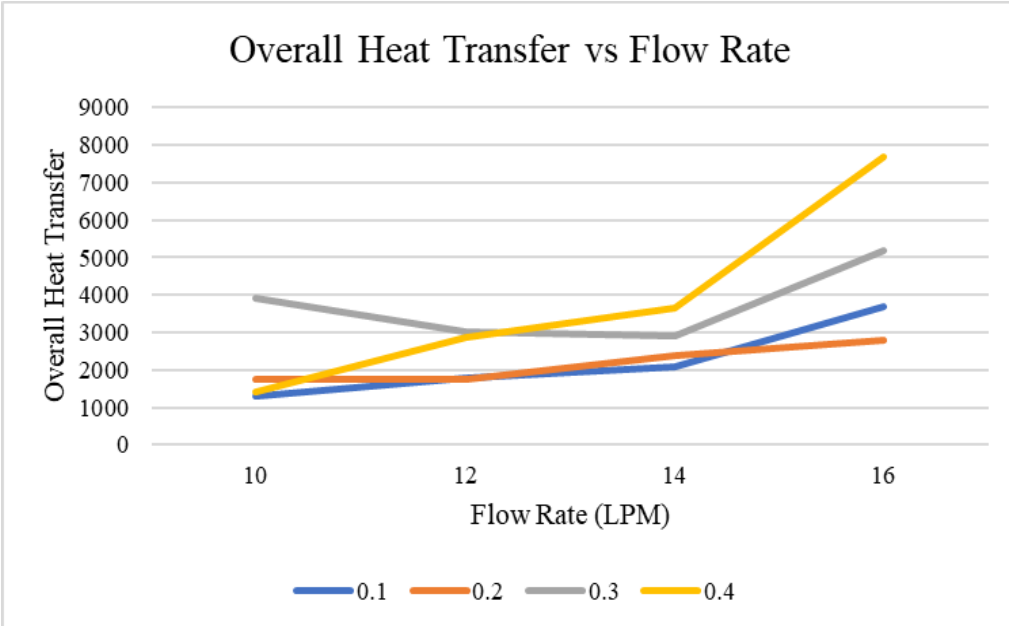

Chart-4: Overall Heat Transfer vs Flow Rate

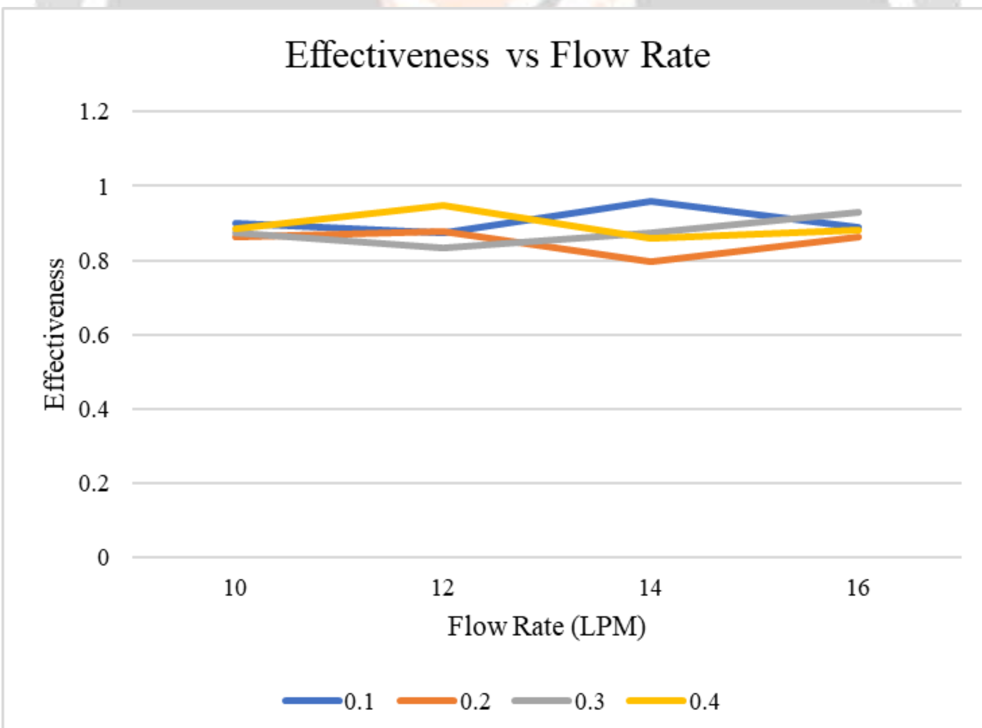

Chart-5: Effectiveness vs Flow Rate

The results show that for a given flow rate and velocity, the heat transfer rate increases with increasing nanofluid volume concentration and mass flow rate. To determine the efficiency of the spiral, calculations were performed using distilled water and the produced nanofluid at different flow rates and different fluid inlet temperatures. For all volume concentrations, a cooling inlet temperature of about 80-40°C can be used for best efficiency. Figure 7 shows the change in heat transfer rate due to nanofluid concentration. Observations show that for a given flow rate and volume concentration, the nanofluid heat transfer rate increases with increasing volume concentration and inlet temperature.

For varying inlet temperature and fixed airflow rate at the inlet, it can be seen that the rate of heat transfer increases as the volumetric flow rate increases. The efficiency of distilled water and the fabricated nanofluid cooler was evaluated using different flow rates and different liquid inlet temperatures. Figure 11 shows the calculated efficiency for a fixed air supply quantity and a fixed air flow. The results show that the efficiency initially increases as the cooler inlet temperature increases; but when the temperature reaches about 45-50 °C, it starts to drop according to the simulated flow rate and air velocity. In addition, it was found that as the volume concentration of the nanofluid increases, its efficiency increases.

At all volume concentrations, the cooling inlet temperature should be around 80-40°C to operate at optimum capacity.

The following results can be derived from the above graphs.

- The heat transfer coefficient increases in proportion to the flow rate (see Chart 1)
- The Reynolds number increases in proportion to the flow velocity (see Chart 2) • Nusselt number increases with flow rate (see Chart 3).
- Total heat transfer increases with flow rate. Nanofluids with volume concentrations of 0.1, 0.2, and 0.3 dramatically increase total heat transfer with a flow rate of 14 LPM (see Chart 4).
- For a given nanofluid with a volume concentration of 0.3, it is observed that the efficiency first decreases from 10 LPM to 12 LPM and then increases at flow rates of 14 LPM and 16 LPM. So, the optimal value is 16 LPM flow rate because it has the highest efficiency.
- Similarly, the efficiency of the nanofluid with a volume concentration of 0.4 first increases at a flow rate of 12 LPM and then decreases at a flow rate of 14 LPM and then increases slightly at a flow rate of 16 LPM (see Chart 5).

6. CONCLUSION

Using Al2O3 mixed with water nanofluid at different volume concentrations of nanofluid, mass flow rates, fluid inlet temperatures, and air inlet velocities, an experimental research of radiator cooling systems has been conducted.

- Due to the presence of Al2O3 nanoparticles in water, the heat transfer rate of the car radiator is improved. Effectiveness of the nanofluid increases with the volume concentration of 0.3 with increasing flowrates.
- As there is increase in the base fluid's nanoparticle fraction, there is increment of heat transfer rate. The effectiveness of the radiator reduces as the flow rate and inlet temperature rise.
- Use of Al2O3 based Nanofluid can help increasing the heat transfer rate, hence reducing the time required for cooling of hot fluid which has the heat carried from the engine can be reduced.

7. REFERENCES

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