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Research Paper

Experimental Investigation for Enhancement of Heat Transfer Coefficient in Car Radiator by Using Multiwall Carbon Nanotube (MWCNT) Nanofluid

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Abstract

Improving heat transfer coefficient is a significant subject of study in many engineering domains. The use of nanofluids in car radiators might boost the heat transfer coefficient. The current study investigates a car's radiator's heat transfer coefficient and thermal conductivity. The heat transmission parameters of a car radiator were analyzed for coolant mass flow rates ranging from 600 to 1200 liters/hour and nanofluid concentrations ranging from 0.2 to 0.8% by volume. The primary coolant was prepared by combining water and ethylene glycol in a 60:40% combination with multi-walled carbon nanotube nanoparticles. The coolant's input temperatures were varied between 30 °C and 80 °C by impinging an air jet into the car radiator through a hallow cone nozzle plate with and without spacing. The result demonstrates that the volume flow rate of coolant on the tube side increases considerably as the heat transfer coefficient increases. At a nanoparticle concentration of 0.8 vol. %, the nanofluid's total heat transfer coefficient is enhanced by 12% compared with the base fluid. The heat transfer coefficient is improved by 42.6% for 0.8% volume of MWNCT nanofluid without spacing of the hallow cone nozzle plate and by 51.9% with spacing of the hallow cone nozzle plate.

Keywords: Jet impingement; Cone nozzle plate; Heat transfer enhancement; Thermal conductivity; Nanofluid

1. Introduction

Fluids like ethylene glycol, water, and coolant oil often have low thermal characteristics. This issue can be solved by distributing thermally conductive particles in these standard fluids. Previous research involving the dispersion of particles measuring in the micrometer range revealed difficulties with the particles' distribution and flow. Subsequently, [1] researched nanoparticles and documented a notable improvement in thermal conductivity by incorporating nanoparticles into traditional heat transfer fluids [2], [3]. Nanofluids refer to fluids that consist of particles of nanoscale dimensions [4]. These fluids have been discovered to have much more excellent thermal conductivity than primary fluids. Nanofluids have gotten a lot of attention because they have better thermal properties, rendering them suitable for various applications, including microelectronics, manufacturing, and biotechnology. The enhancement of thermal efficiency in vehicle engines necessitates the use of an efficient thermal management technique [5].

Water and ethylene glycol are usually mixed to make via vehicle refrigerant that is used in the radiators of cars. Due to their lesser thermal conductivity relative to water, these fluids are less effective in transferring heat. According to [6], the current cooling system has some limitations due to conventional coolants and lubricants' poor heat transfer capabilities. Considering this perspective, it is imperative to develop novel methodologies that can enhance the current cooling efficiency of engines in heavy vehicles [7]. The automobile radiator constitutes an integral component of the engine's cooling system. Incorporating nanoparticles into conventional engine coolant can enhance the cooling efficiency of vehicle radiators and heavy-duty engines [8], [9].

Examined the use of Al_2O_3-water nanofluids as a coolant for the jacket of a diesel generator [10]. The researchers reported a decrease in cogeneration efficiency. The observed phenomenon can be attributed to reduced specific heat, directly impacting the efficiency of recovering waste heat in the engines combustion process. [11] documented the effectiveness of the unused heat recovering heat exchanger was enhanced due to the improved convection heat transfer shown by the nanofluid. Vatshsav [12] studied a numerical investigation on heat transfer behaviour in two distinct types of fluids: Al_2O_3 and CuO. These nanofluids were circulated through an automotive radiator, which contained an EG and water. The nanofluids significantly enhanced heat transmission compared to water. Ramadhan et al. [2] employed Al_2O_3-water nanofluids within the vehicle radiator to evaluate thermal conductivity on the tube side. The heat transfer rate was calculated for different weight concentrations of Al_2O_3 ranging from 0.1% to 1%, mass flow ranging from 2 to 5 liters per minute, and input temperatures from 30 to 50 °C. He found that heat transfer improved up to 45% for turbulent flow conditions compared to water [13].

The use of copper nanofluids based on ethylene glycol in automotive coolant method was documented by [14]. Incorporating copper nanoparticles at a concentration of 2% in a base fluid, results in a heat transfer increase of 3.8%. In their experimental examination, [15] determine the heat transfer efficiency of copper nanofluids in a radiator operating flow conditions [16]. A decrease in heat transmission was found as the nanofluid inlet temperature raised from 20 °C to 90 °C. The nanofluid, when present a volume concentration of 0.4%, demonstrated a notable enrichment in the total heat transfer coefficient, exhibiting an increase of up to 8% compared to water.

According to previous research [17], it has been observed that multi-walled carbon nanotubes exhibit superior thermal resistance in comparison to aluminium oxide/ copper oxide/ water nanofluids. The experimental thermal characteristics of multi-walled carbon nanotubes have been shown to significantly improve heat transmission, as indicate by many studies [18]–[22]. Sadri et al. [23] formulated a multi-walled carbon nanotube nanofluid using 0.1 wt. in their research. 0.6% of sodium sulphate to improve the constancy of the mixture. At a volume concentration of 0.6%, the adding of carbon nanotubes to water as a base fluid resulted in an increase in thermal efficiency, reaching a maximum enhancement of 38%. In their study, [24] compared the efficiency of several nanofluids, especially CuO-water nanofluids. The nanofluid of CuO dispersed in water at a concentration of 1.0 vol. % demonstrated the most significant increase in thermal efficiency, with a measured increase of 11.3%.

Fikri et al. [25] investigated the viscosity and thermal conductivity of a SiO_2-TiO_2 nanofluid using EG/water in an automobile radiator, and the nanofluids were prepared in one step method. The results demonstrate that at a concentration of 1% and a temperature of 60 °C, there is an increase of thermal conductivity. Ramadhan et al. [26] studied the physical characteristics of SiO_2-Al_2O_3-TiO_2 nanofluids containing in EG / water mixture with a volume ratio ranging from 60:40%. The findings demonstrate that nanofluid had the most significant thermal conductivity at 0.3%, having an average rise of up to 9% above the base fluid combination.

From the available literature, no research has been carried out on the car radiator using a hallow cone nozzle plate. This study aims to investigate the heat transfer coefficient and thermal conductivity of a car radiator by utilizing a nanofluid composed of MWCNTs dispersed in a mixture of EG and water as a coolant. The coolant's input temperature was varied between 30 °C and 80 °C, and the coolant was positioned between the car radiator and the fan.

2. Methods

2.1. Preparation of Nanofluids

The liquid employed in the current study was prepared using multi-walled carbon nanotubes obtained at a volumetric concentration and a water and ethylene glycol in a 60:40% [27]. The base fluid were utilized entirely as coolants. The multi-walled carbon nanotubes were procured rom Sigma-Aldrich chemicals Ltd. and exhibited a diameter of 10 nm. The volume concentration of the MWNCT nanoparticles is calculated using the given equation [28].

$$\text{Volume concentration }(\emptyset) = \frac{\frac{m_n}{\rho_n}}{\frac{m_n}{\rho_n}+\frac{m_f}{\rho_f}} \tag{1}$$

The preparation of nanofluid samples involved the utilization of 150 grams of base fluid. The calculated quantity of multi-walled carbon nanotubes was also directly incorporated into the base liquid. The nanofluid solution was subjected to sonication, while a mechanical stirrer was employed to ensure continuous stirring of the nanofluid for around 6 to 8 hours, aiming to achieve a homogeneous dispersion within the base fluid [29]. The primary purpose of the sonication is to disperse the MWNCTs uniformly inside the base fluid as shown in **Figure 1**. The weight of these additives was measured to be one-tenth of weight of the nanoparticles. The nanoparticles were dissolved after adding the surfactant to the base fluid, and the resulting mixture was used to create nanofluids. According to the solid-fluid blend formulae the nanofluids thermo-physical characteristics were assessed. **Table 1** shows MWCNT and water thermophysical properties.

The Eq. (2) to Eq. (5) are used to calculate the viscosity, density, thermal conductivity, and specific heat are listed in **Table 1**.

$$\mu_{nf} = A\left(\frac{1}{T}\right) - B \tag{2}$$

A = $20587\emptyset^2 + 15857\emptyset + 1078.3$

B = $-107.12\emptyset^2 + 53.54\,\emptyset + 2.8715$

$$\rho_{nf} = \emptyset\rho_p + (1-\emptyset)\rho_{bf} \tag{3}$$

$$K = \frac{k_\rho + (n-1)K_f - 2(n-1)\emptyset(K_f - K_p)}{K_p + 2K_f - (K_f - K_p)}K_f \tag{4}$$

$$Cp_{nf} = \emptyset C_p + (1 - \emptyset Cp_f) \tag{5}$$

2.2. *Scanning Electron Microscope Analysis*

The morphology of nanoparticles composed of multi-walled carbon nanotubes was investigated using scanning electron microscopy analysis. **Figure 2** exhibits SEM images of the multi-walled carbon nanotube nanofluid. The size of the MWCNTs was calculated based on the scanning electron microscopy micrographs. The measurement of the diameter of most typical nanotubes from each sample determined the mean values of these characteristics. An inverse relationship between the mean diameter and the amount of carbon atoms present in the volume concentration is noticed. The findings derived from the SEM micrographs indicate that the mean diameter of the synthesized is 10 nm.

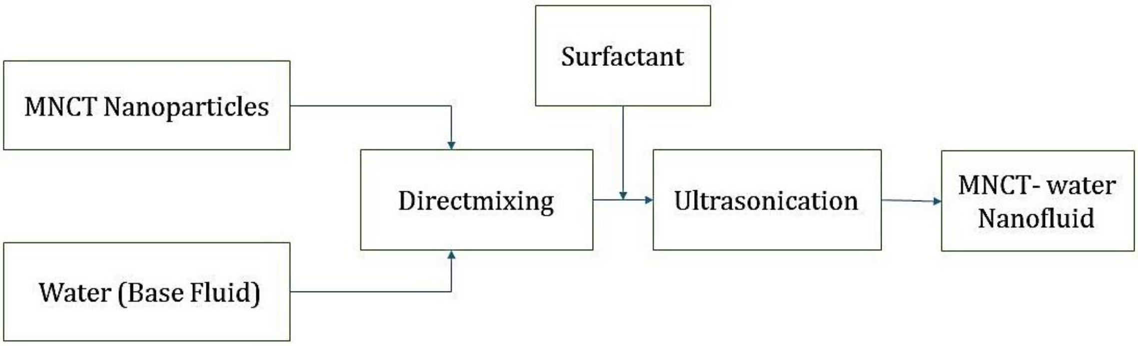

Figure 1. Two stem method for preparation of nanofluids [22]

Table 1. Thermo-physical characteristics of nanofluids

Material	Viscosity	Density	Thermal Conductivity	Specific Heat
	MPa s	Kg/m^3	W/mK	KJ/Kg K
MWCNT	--	180	14.25	6.693
EG	0.016	1100	0.253	2.20
Water	0.0008	1000	0.613	4.184
Air	0.000018	1.183	0.024	1.005

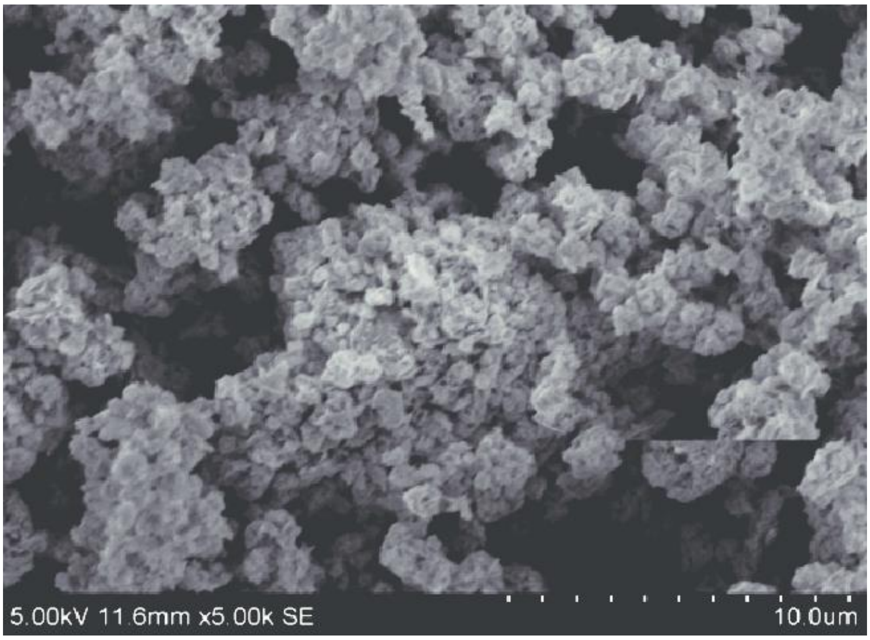

Figure 2. SEM image of MWCNT nanoparticles

2.3. *Experimental Setup*

The experimental test facility is illustrated in Figure 3, consisting of the coolant storage tank, pump, heater, and fan. Figure 4 shows the experimental test rig utilized for a car radiator, whereby a hallow cone nozzle plate is positioned between the car radiator and the fan. The coolant contained within the tank is subjected to thermal energy until it reaches the required temperature. Subsequently, the pump is activated, facilitating coolant circulation via the radiator. Concurrently, a fan is employed to propel air over the radiator. The coolant can circulate via 98 tubes; each length and diameter are 0.3 m and 5 mm. The radiator permits coolant circulation at multiple flow rates, especially 600 to 1200 LPH, under three distinct air velocities of 2, 3, and 4 m/s. T-type thermocouples are used for measuring the temperature of the car radiator on both sides. The heater is subjected to a heating process, raising its temperature to 30 °C, after which it is subsequently circulated via the radiator. For L/d ratios ranging from 10 cm to 15 cm, the test is conducted with and without the hallow cone nozzle plate.

Figure 5 shows a side view of the test rig, which includes temperature thermocouples for the coolant and air inlets and outlets. Photographs of the nozzle sheet arrangement, which is located between the fan and the radiator, are shown in Figure 6.

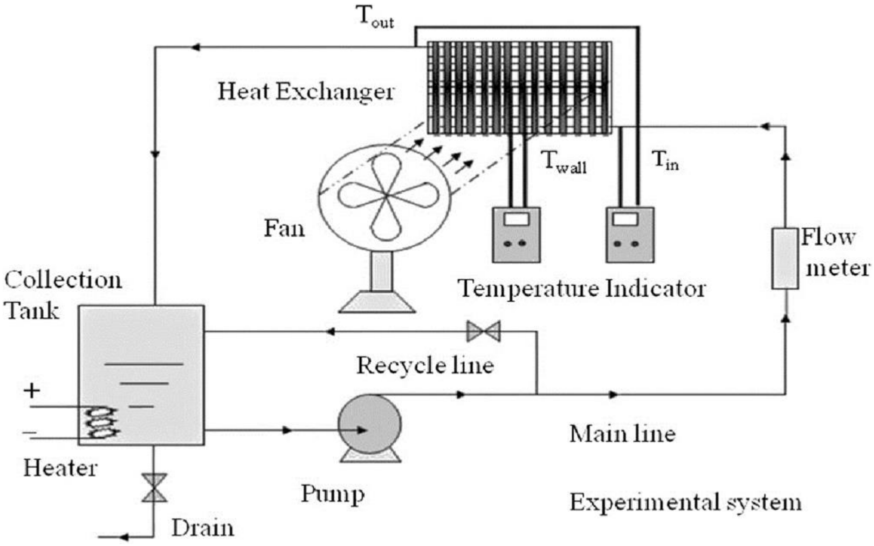

Figure 3. Line diagram of experimental setup

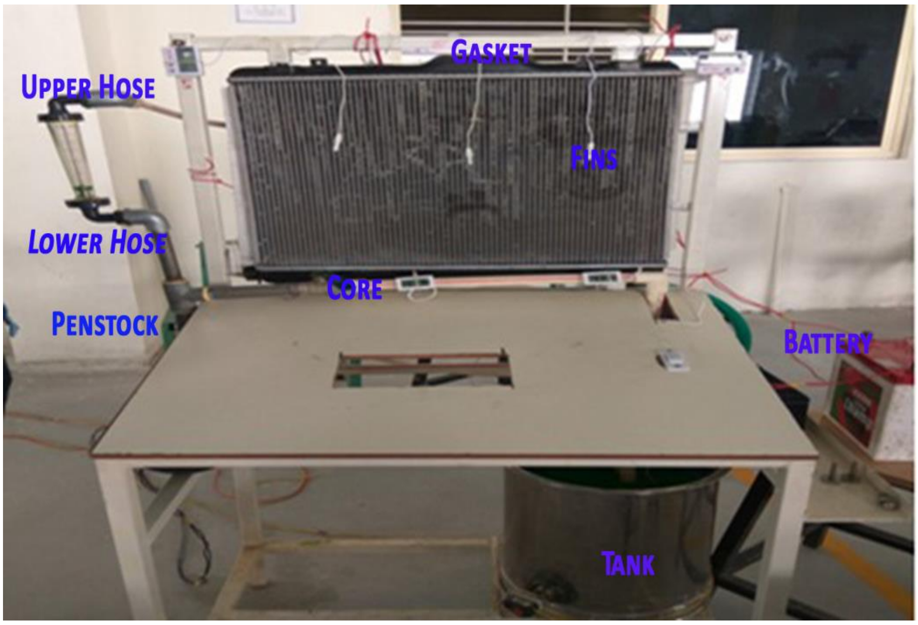

Figure 4. Experimental setup

Figure 5. The experimental setups side view

Figure 6. Nozzle arrangement plate with a diameter of 30 mm

2.4. *Calculation of Heat Transfer Coefficient*

The heat transfer rate is determined by using the following formula.

$$Q = hA(T_b - T_w) \tag{6}$$

$$Q_c = \dot{m}_c C_c (Tc_{in} - Tc_{out}) \tag{7}$$

$$Q_h = \dot{m}_h C_h (T_{h\,in} - T_{h\,out}) \tag{8}$$

$$Q_{average} = \frac{(Q_h + Q_c)}{2} \tag{9}$$

$$\text{Reynolds number (Re)} = \frac{4m}{\pi d\mu} \tag{10}$$

$$\text{Nusselt Number (Nu)} = mC_p(T_{in} - T_{out}) \tag{11}$$

By using Newton's law

$$h = \frac{Q_{average}}{A(\Delta T)_{LMTD}} \tag{12}$$

$$(\Delta T)_{LMTD} = \frac{(T_{h\,in} - Tc_{out}) - (T_{h\,out} - Tc_{in})}{\ln\left(\frac{T_{h\,in} - Tc_{out})}{T_{h\,out} - Tc_{in}}\right)} \tag{13}$$

Table 2 shows the calculated values of Reynolds and Nusselt numbers for MWCNTs with and without hallow cone nozzle plate by using the Eq. (10) and Eq. (11).

3. Results and Discussion

In present experimentation uses a 60:40% MWCNTs, EG, and water nanoparticles. The nanofluid is imposed at various concentrations from 0.2% to 0.8% and is also pumped into the car radiator as the coolant at varying flow rates of 600 to 1200 LPH.

3.1. *X-Ray Diffraction Analysis*

The XRD analysis was used to characterise the structural characteristics of nanofluids changed by MWCNT nanoparticles. As shown in **Figure 7**, the corresponding graphs overall pattern confirms the nanoparticle presence. The database maintained by the joint committee on powder diffraction standards (JCPDS) aids in determining the diffracted patterns determined from all recognized crystal structures. The analysis shows that the average particle size is determined using the Scherrer formula based on the peaks of the crystal structures. The nanoparticle's mean sizes according to JCPDS number 00-035-0437 (MWCNT). The peaks observed at an angle of 23.14° indicates an interplanar spacing in multi-walled carbon nanotubes.The distinctive peaks associated with nanoparticles may be observed at specific wavelengths, namely 8.25, 33.2, 37.8, 39.6, 41.4, 60.2 and 70.6.

3.2. *Effect of Temperature Difference*

Figure 8 (a-c) depicts the variation in car radiator intake temperature for 1 hour, corresponding to various volume concentrations from 0.2% to 0.8%. Based on **Figure 8** (a-c) data, higher volume concentration levels lead to car radiator inlet temperature throughout under three distinct air velocities of 2, 3, and 4 m/s, all flow rates [30]. The data demonstrated an increase in the average temperature of the car radiator inlet with time, which may be attributed to the expansion of the volume concentration. A rise in the flow rate results in a decrease in temperature

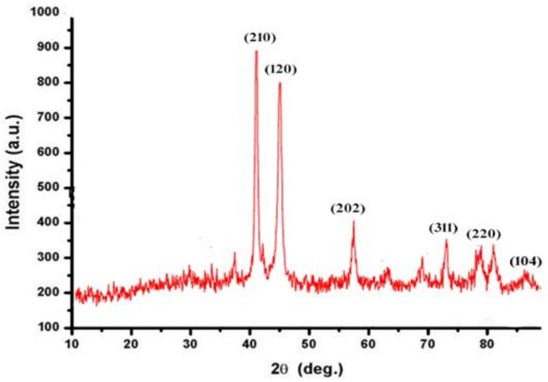

Figure 7. XRD pattern of MWCNT nanoparticles

Table 2. The calculated values of Reynolds and Nusselt numbers for MWCNTs with and without hallow cone nozzle

Mass flow rate (LPH)	Reynolds number		Nusselt number		T_{in} (°C)	T_{out} (°C)
	With nozzle	Without nozzle	With nozzle	Without nozzle		
300	2233.70	2453.81	3600	3721	95	85
600	3545.51	3703.13	3999	4012	88	81
900	3659.32	3820.01	4412	4789	85	80
1200	4130.39	4253.17	4787	4938	83	78

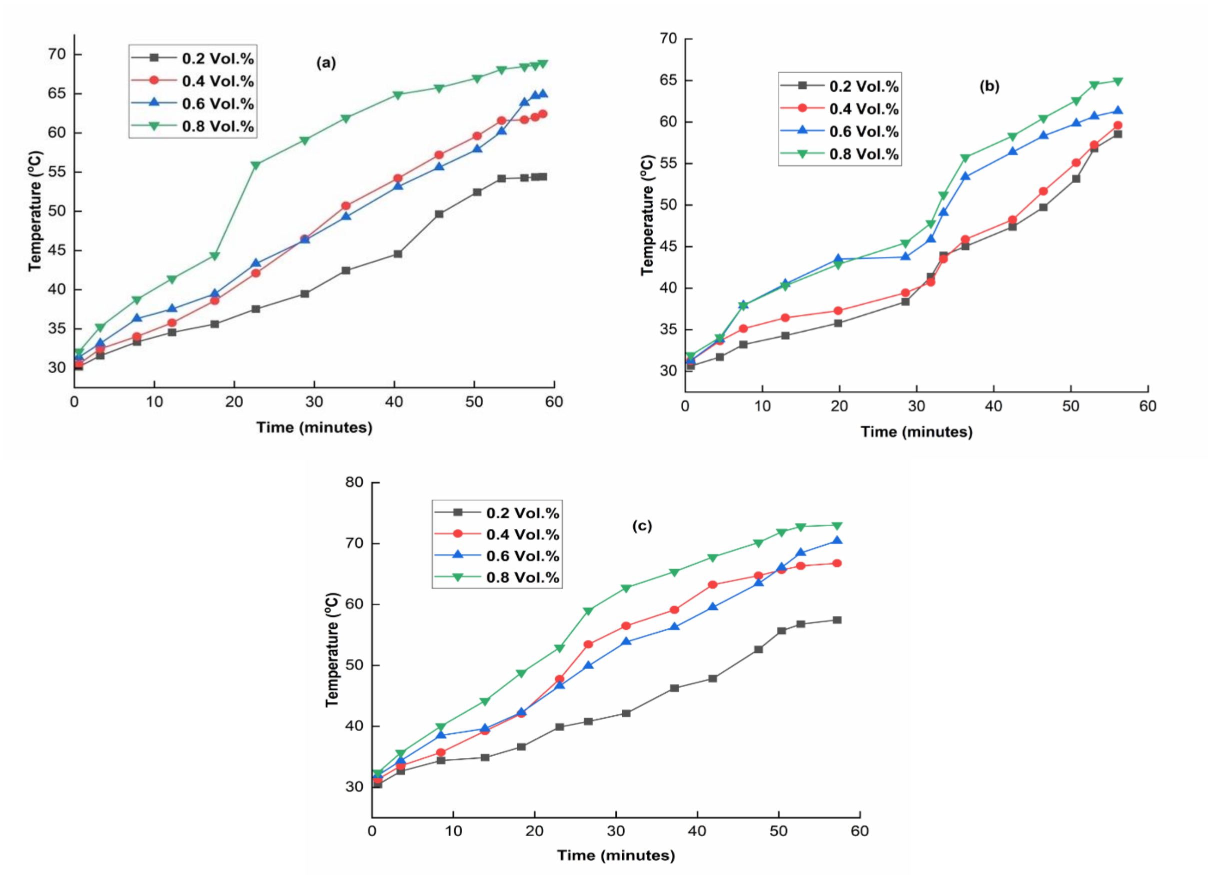

Figure 8. (a-c). Variation in car radiator intake temperature at different volume concentrations

at the entrance of the car radiator. This phenomenon occurs due to an increase in the heat transfer rate from the radiator tube to the working fluid, which indicates a corresponding increase in heat transfer owing to the elevation in volume concentration.

Figure 9 (a-c) depicts the variation in temperature in between the intake and out of a car radiator during a one-hour time interval, under three distinct air velocities of 2, 3, and 4 m/s. **Figure 9** (a-c), an increase in flow rate is associated with a lower temperature differential between the car radiators inlet and outlet car radiator inlet and outlet [31]. Conversely, an increase in volume concentration increases the temperature differential among the car radiator intake and exit. This effect occurs due to increased convective heat transfer coefficient inside the car radiator.

3.3. *Effect of Heat Transfer Coefficient*

Figure 10 shows that increasing the nanofluid flow rate significantly raises the nanofluid's total heat transfer coefficient. When comparing the base fluid to the nanofluid, the total heat transfer coefficient increases as the nanoparticle concentration increases [15]. At a nanoparticle concentration of 0.8 vol. %, the nanofluid's total heat transfer coefficient is enhanced by 12% compared with the base fluid [32]. The increase in heat transfer coefficient using nanofluid may be described by heat transfer [33], the reduction in boundary layer thickness, and an increase in thermal conductivity. Furthermore, the significant reason for this improvement in thermal conductivity (K) of nanofluid in the reactor pipe flow [34]. This represents the inconsistent particle concentration in the tubes. It has increased the heat transfer coefficient by 42.6% for 0.8 vol. % of MWNCT nanofluid without hallow cone nozzle plate spacing and by 51.9 with hallow cone nozzle plate spacing.

3.4. *Effect of Thermal Conductivity*

Figure 11 depicts the relationship between thermal conductivity and mass flow rate for three different substances: A multi-walled carbon tube, ethylene glycol, and water with a hallow cone nozzle plate. The thermal conductivity of water

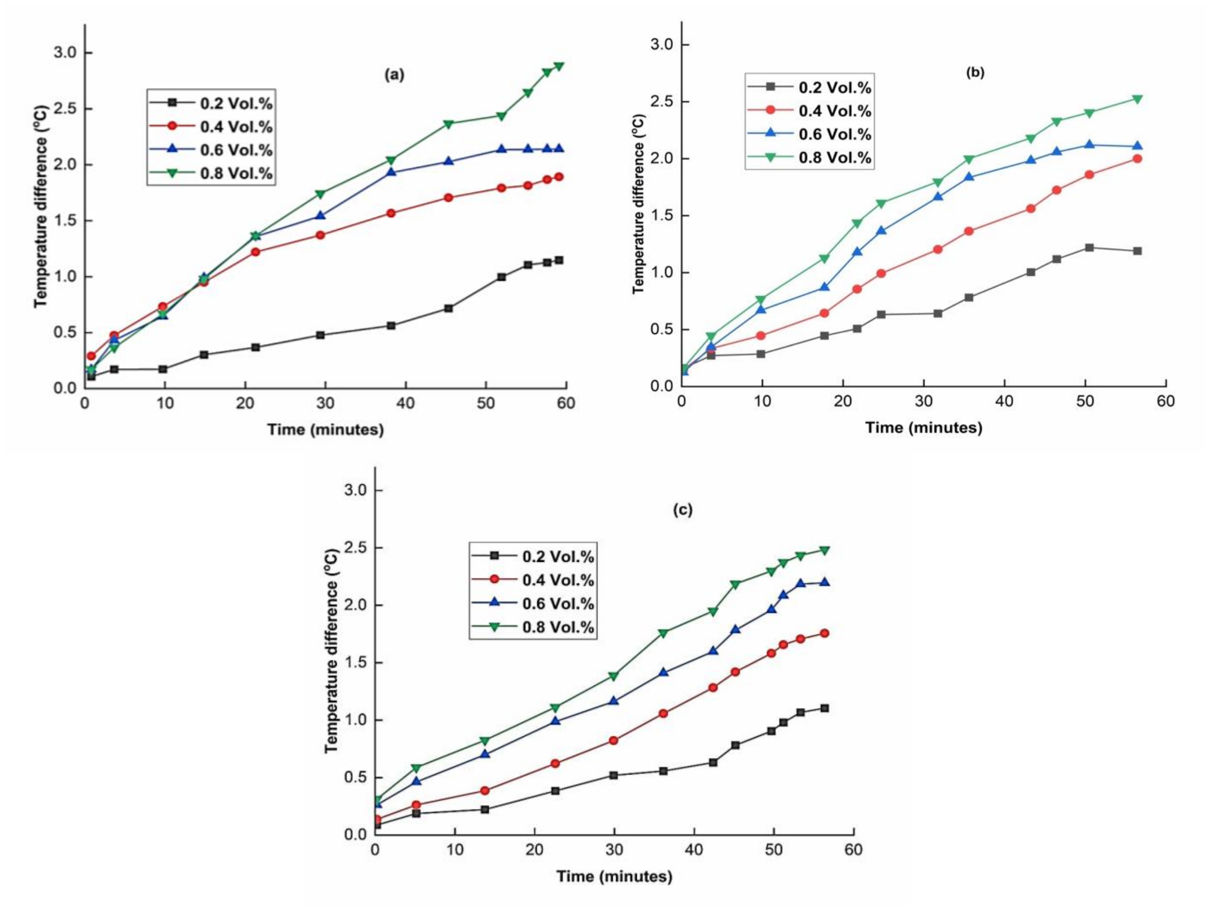

Figure 9. (a-c). Variation in temperature between the intake and out of a car radiator at different volume concentrations

nanofluids with MWNCTs and nanofluids with a hallow cone nozzle plate exhibit an increase with the mass flow rate from 600 to 1200 LPH. The conclusion may be drawn that there is a steady rise in the flow rate from the base fluid to multi-walled carbon nanotubes when using a hallow cone nozzle plate, achieved by altering the length-to-diameter (L/d) ratio.

The changes in thermal conductivity with volume concentration for different coolants are shown in **Figure 12**, which indicates that the lines containing MWCNTs lead to enhanced thermal conductivity in this specific instance. The thermal conductivity of the base fluid was 0.66 W/m K, whereas that of the MWNCT nanofluid was 0.709 W/m K with a concentration of 0.8 vol. %. This

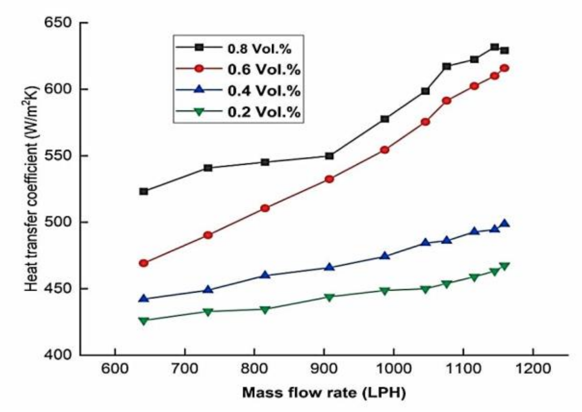

Figure 10. Variation in nanofluid flow rate as a function of concentration and heat transfer coefficient

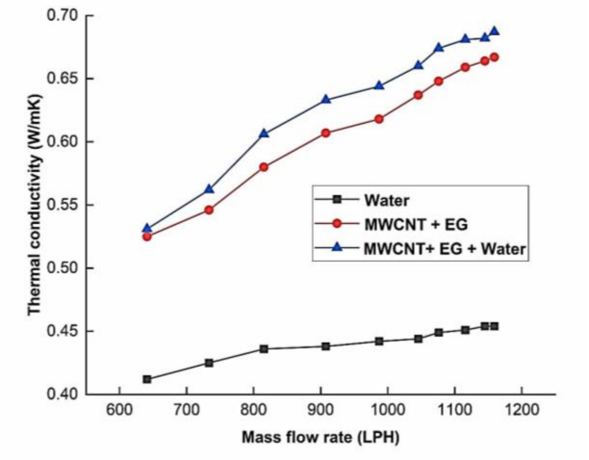

Figure 11. Thermal conductivity vs. mass flow rate

indicates that the MWNCT nanofluid's thermal conductivity improves as its concentration rises. With a concentration of 0.8 vol. %, the thermal conductivity of MWNCT nanofluid is 4.9 % higher than that of the base fluid [35].

3.5. *Create a Discussion*

Figure 13 illustrates the comparison of thermal conductivity as a dependent on volume concentration between the present study and earlier experimental results for the base fluid, with and without a hallow cone nozzle plate. The diagram illustrates two lines representing the MWNCT, EG nanofluid and MWCNT, EG nanofluid with a hallow cone nozzle plate were compared to the results obtained by Oliveira et al. [36] and is shown in **Figure 13**. In this scenario, nanofluid coolant is implemented alongside the hallow cone nozzle plate between the exhaust fan and the car radiator. This is achieved by modified length to diameter ratio. The thermal conductivity (K) is improved by 44% compared to the nanofluid coolant without the presence of a nozzle plate. The concentration of nanoparticles significantly influences the heat transmission rate.

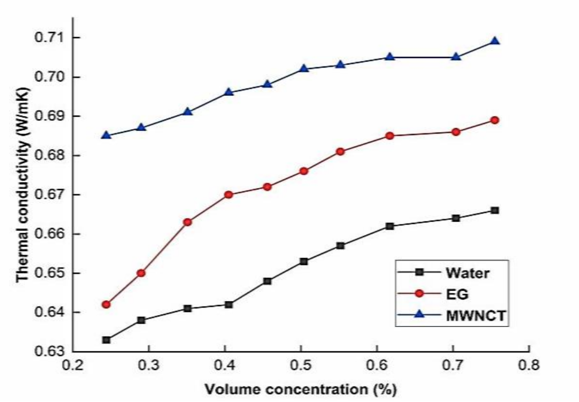

Figure 12. Thermal conductivity vs. volume concentration for MWNCTs, EG, and water

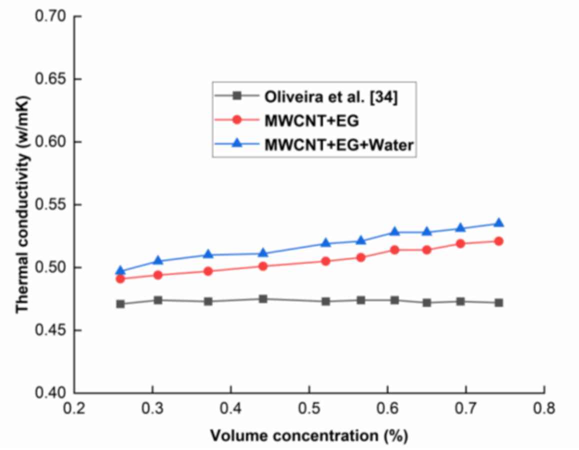

Figure 13. Comparison of thermal conductivity vs. volume concentration of nanofluid with present study and Oliveira et al. [36]

Furthermore, it was observed that at a temperature of 78 °C and a volume concentration of 0.8 vol. % of multi-walled carbon nanotubes combined with a hallow cone nozzle plate, the gain in performance was 52.1 % higher compared to using nanofluid without the hallow cone nozzle plate. The concentration of a nanofluid has a direct impact on the outlet volume flow rate in a car radiator. As the volume concentration rises, the exit temperature of the nanofluid decreases [37]. The parameters of nanofluids with nozzle plates exhibit modest variations compared to those without nozzle plates. Specially, there is an increase in thermal conductivity while specific heat experiences a slight drop.

The **Figure 13** shows that for all models, thermal conductivity improves as nanoparticle volume concentration increases. The improvement is linear by increased volume concentration of nanoparticles.

4. Conclusion

The heat transmission parameters of a car radiator were analyzed for coolant mass flow rates ranging from 600 to 1200 liters/hour and nanofluid concentrations ranging from 0.2 to 0.8% by volume. The primary coolant was prepared by combining water and ethylene glycol in a 60:40 % combination with multi-walled carbon nanotube nanoparticles. The coolant's input temperatures were varied between 30 °C and 80 °C by impinging an air jet into the car radiator through a hallow cone nozzle plate with and without spacing.

a. The heat transfer coefficient is enhanced by 42.6% for 0.8% volume of MWNCT nanofluid without spacing a hallow cone nozzle plate and by 51.9% with spacing of hallow cone nozzle plate.
b. When compared the base fluid to the nanofluid, the total heat transfer coefficient increases as the nanoparticle concentration increases.
c. At a nanoparticle concentration of 0.8 vol. %, the nanofluids total heat transfer coefficient is enhanced by 12% compared with the base fluid.

d. With a concentration of 0.8 vol. %, the thermal conductivity of MWNCT nanofluid is 4.9% higher than that of the base fluid.
e. Thermal conductivity improves as volume concentration of nanoparticle increases.

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Author's Declaration

Authors' contributions and responsibilities

The authors made substantial contributions to the conception and design of the study. The authors took responsibility for data analysis, interpretation and discussion of results. The authors read and approved the final manuscript.

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All data are available from the authors.

Competing interests

The authorsdeclare no competing interest.

Additional information

No additional information from the authors.

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