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Experimental Investigation of Heat Transfer Rate for Automobiles Using Natural Preservative

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Abstract:
The heat transfer enhancement for car radiator by adding solid nanoparticles to liquid is significant topics recently. The nanomaterials have high heat transfer rate. Most of the researches have been conducted using nanoparticles alone in the radiator. But the cost of nano sized particle is very high. Also the characterization of nanoparticles is difficult and time consuming. It is the right time to have an alternative materials rather than using nanoparticles in the car radiator. So that a different type additive is tried to add with base fluid for further improvement of heat transfer. The lemon juice is traditionally one of the best cooling medium. Accordingly an attempt is made by adding lemon juice (natural) as an additional fluid with base fluid. in the car radiator. Then it is planned to mix the lemon juice in the car radiator and conducting the experiments. By varying different input temperatures and mass flow rate the experimental is done. This research included the heat transfer rate by forced convection. The juice which is extracted from naturally available lemon and dispersed in the base fluid as the lemon is easily soluble. The experiment is conducted in a maruthi make Alto car radiator. Two different concentrations of lemon juice in the ratio of 0.5% & and 1.5 % by volume have been added with distilled water. The flow rate has chosen in the range of 10–16 LPM (Litre per minute). The CFD analyses also have done. CFD nanstran software has been used. The experimental results compared with CFD software. The results showed that the heat transfer rate increases by 30% for a volume of 0.5% of lemon juice. The heat transfer rate improves 35% for 1.0% of lemon liquid. It shows that by increasing the lemon juice the heat transfer rate also increases.

Nomenclature

C specific heat [W/kg ^{o}C]	μ viscosity [N s/m2]
D diameter [m]	ρ density [kg/m3]
E energy [W]	τ shear stress [N/m2]
f friction factor	ϕ volume concentration
htc convection heat transfer coefficient [W/m2 ^{o}C]	u velocity [m/s]
k thermal conductivity [W/m ^{o}C]	P pressure [N/m2]
Nu Nusselt Number [htcD/Knf]	
Pr Prandtl number [Cμ/Knf]	
Re Reynolds number [ρnfDhu/Knf]	
Cplf Specific heat of lemon juice fluid [W/kg ^{o}C]	
Cpbf Specific heat of base fluid [W/kg ^{o}C]	

1. Introduction

In an automobile, fuel is used to produce power in the engine by combustion. A portion of the total power generated is actually supplied to the automobile. The remaining is wasted in to heat and exhaust .This heat should be removed from the engine unless or otherwise the metal weakening of the overheated engine parts, which results in faster wear rate, among the related moving parts. Generally A cooling system is must to remove this excessive heat in automobiles. The engine cooling system takes care of excess heat produced during engine combustion. It keeps engine surface temperature in controlled state. The automotive engine cooling systems consist of the radiator, water pump, cooling fan, and thermostat. Among this Radiator is the prime component of the system. It acts as a heat exchanger and removes heat from engine by passing coolant. Heat is transferred from hot coolant to outside air. The radiator has a set of tubes and fins. The coolant flows through tubes and air flows between the fins. The coolant after collecting the engine heat sends it heat through tubes and passed to outside. Outside air passing between fins pickups and carries away heat. Water is used as coolant in automobiles. By using only water as coolant it is difficult to achieve better performance and efficiency in the radiator. Many techniques were used in past to enhance heat transfer. However due to ever increasing heat flux requirement, these techniques have reached their limits. The Nano fluids were developed recently by suspending solid particles ranging from 10 nm to 100 nm in a base fluid. The Nano fluids have produced better thermal efficiency and exhibited excellent heat transfer rate in more literature survey. But the cost of nanoparticle is very high that's why a different additive is needed to mix with base fluid. Accordingly, lemon juice has been identified to mix with distilled water. The naturally available lemon is traditionally used into reduce the heat of human body as lemon juice during summer season. It transfers the heat from the human body quickly. It is a universal truth also. The lemon is easily available everywhere. Hence it is planned to add lemon juice with base fluids and finding the heat transfer rate in the car radiator.

2. Related Works

Adnan M. Hussein et al. [1] The friction factor and forced convection heat transfer enhancement of SiO_2 suspended in water done. The maximum values of friction factor increased up to 22% for SiO_2 nanoparticles dispersed in water with 2.5% volume concentration. The highest Nusselt number enhance upto40% got for SiO2 nanoparticles. The SiO_2 nanoparticles added with base fluid in the ratio of 1%, 1.5%, 2%, &2.5%. P.C. Mukeshkumar et al. [2] The heat transfers coefficients of shell and helically coiled tube heat exchanger using Al2O3 / water nanofluid were done. In this paper parallel flow and counter flow were taken into account. The Al_2O_3 / water nanofluid at 0.4% and 0.8% particle volume concentration were used. It is observed that the overall heat transfer coefficient of counter flow was 4-8% higher than that of parallel flow for 0.4% nanofluid. S. Bhanuteja et al. [3]In the shell and tube heat exchanger The heat transfer rate Among the nanofluids tested in this paper SiO_2 nanofluid has the highest value followed by, CuO, Al_2O_3, TiO_2, Ag, and finally water. Among the fluids tested, SiO_2 nanofluid has the highest pressure drop, followed by Al_2O_3, TiO_2, water, CuO and finally Ag. Water did not obtain the lowest pressure drop in this case due to higher average velocity it had compared with CuO and Ag along the channel length. Amirhossein Zamzamian et al. [4] In this study, nanofluids of aluminum oxide and copper oxide were prepared in ethylene glycol separately. The effect of forced convective heat transfer coefficient in turbulent flow was calculated using a double pipe and plate heat exchanger. Aluminium oxide nanoparticles added with base fluid in 0.1%, 0.5%, and 1%. The increase in convective heat transfer of nanofluid compared to the base fluid. However, both theoretical and experimental data suggest that homogenously dispersed and stabilized nanoparticles enhance the forced convective heat transfer coefficient of the base fluid significantly. The maximum and minimum increases in the experiments were 49% and 3%, respectively. Pawan S. Amrutkar et al. [5] This paper deals on parameters which influence radiator performance along with reviews some of the conventional and modern approaches to enhance the radiator performance. Also efforts to be taken to implement use of nano-technology and to stabilize the results of these systems. The Performance of engine cooling system (radiator)is influenced by factors like air and coolant mass flow rate, air inlet temperature, coolant fluid, fin type, fin pitch, tube type and tube pitch etc. Sarit kumar Das et al. [6] In this paper the base fluid with various nanoparticles added and the heat transfer rate studied. Cu+ acid nanoparticles shows that higher thermal conductivity. In this paper a minimum volume concentration of acid with Cu nanoparticles which increasing in higher thermal conductivity. Dadui Guerrieri et al. [7] This study is a comparison of the thermophysical properties of the fluids conventional water and ethylene glycol with nanofluids Al_2O_3 and CuO. The propylene glycol based nanofluids have low thermal conductivity compared to water based Nanofluids. A significant modification of thermo physical properties due to emulsion nanostructured particles in the fluid based, in this case water and ethylene glycol, provided a significant decrease in the dimensioning of the heat exchanger. The concentration of water based nanofluids shows better overall heat transfer coefficient than water ethylene glycol combinations. Lee et al. [8] In this paper the thermal conductivity of different nanofluids of Al_2O_3 / water, Al_2O_3 / EG, CuO/ water and CuO/ EG using the method hot wire technique applied. The results showed that thermal conductivity is a function of size and shape of particle, and thermo physical properties of base fluid and nanoparticles. Thermal conductivities of both nanofluids were found to be considerably higher than their base fluids. Esfe et al. [9] conducted an investigation which showed that addition of less than 1% vol. MgO nanoparticles in a base fluid enhanced the heat transfer capability of that fluid. Pressure drop was higher in nanofluid than base fluid; however without significant increment in consumed power nanofluids increased the heat transfer. It was reported that increase in nanoparticle volumetric concentration increases the thermal conductivity of nanofluids, however, this increase also increase the viscosity which leads to an increase in the boundary layer thickness; therefore it may cause a decrease in the convective heat transfer. Fotukian and Esfahany [10] experimentally investigated convective heat transfer of CuO Water nanofluid in circular fin tube. It shows that 25% increase in heat transfer was observed using 0.3% vol. fraction of nanoparticles. P. K. Trivedi et al. [11] The preliminary design for the performance of the radiator accessed through Computational Fluid Dynamics (CFD). For that purpose one geometrical parameter of pitch of tube is varied. As a result of this parametric study, the effect of pitch of tube for best configured radiator for optimum performance is suggested. The Results Shows that as the pitch of tube is either decreased or increased, the heat transfer rate decreases. So we can say that optimum efficiency is coming at the pitch of 12 mm. Kevin G. Wallace [12] Reported a study in heat exchanger and it showed that the introduction of CuO nanofluid to the tank had varying effects. At low flow rate and low temperature the CuO nanofluid achieved a steady state very quickly. However, at high flow and high temperature there was task to maintain a constant flow and constant temperature. Any adjustments required significant amount of time to stabilize and then would only be stable for a 10-15 minutes while the flow rate would decrease over time. This has been attributed to deposition of nanoparticles on the surface of the heat exchanger (helical coiled copper tubing). J.R. Patel et al. [13] This paper deals with the effect of various nanofluids efficiency of radiator at various mass flow rate. The CFD gives the exact results to study the effect of mass flow rate, pitch of tubes and Nanofluids. The coolants properties play significant roles in the improvement of radiator performance. The mass flow rate of air one of the operational parameter is play significant effect as the vehicle speed must be controlled by vehicle speed and it feasible to vary the parameter of mass flow rate of air. Pitch of tube for radiator is feasible to air – volume ratio constant. The nano fluids give much higher heat transfer rate than base fluid. It has fluid flow heat transfer characteristics. Hwa-Ming Nieh et al. [14] This study reports an alumina (Al_2O_3) and titania (TiO_2) nanofluids to enhance the heat dissipation performance of an air-cooled radiator. The two-step synthesis method is used to produce different concentrations of Al_2O_3 and TiO_2/water (W) nanofluid by using a 0.2 wt.% chitosan dispersant, and the nanofluid is mixed with ethylene glycol (EG) at a 1:1 volume ratio to form nanofluids. The experimental results show that the heat dissipation capacity and the EF of nanofluids are higher than EG/W, and that the TiO_2 nanofluids are higher than Al_2O_3 nanofluid in most of the experimental data. Compared with EG/W, the maximum enhanced ratios of heat dissipation capacity, pressure drop, pumping power, and EF for all the experimental parameters in this study are approximately 25.6%, 6.1%, 2.5%, and 27.2%, respectively. Overall, using TiO_2 nanofluids in the heat dissipation system yields increased heat dissipation performance levels compared with using the Al_2O_3 nanofluids. The enhanced percentage of the average EF increases as the concentration and volumetric flow rate of the TiO_2 nanofluids increases. Yu Feng et al. [15] Using a new, experimentally validated model for the thermal conductivity of nanofluids, numerical simulations have been executed for alumina-water nanofluid flow with heat transfer between parallel disks. The results indicate that nanofluids are better coolants when compared to pure water. Specifically, smoother mixture flow fields and temperature distributions can be achieved. The Nusselt number increases with higher nanoparticle volume fraction, smaller nanoparticle diameter, reduced disk-spacing, and, of course, larger inlet Reynolds number. Gabriela Huminic et al. [16] this paper presents an overview of the recent investigations in the study the thermo physical characteristics of nanofluids and their role in heat transfer enhancement from heat exchangers. General correlations for the effective thermal conductivity, viscosity and Nusselt number of nanofluids are presented. Compared to the reported studies on thermal conductivity, investigations on convective heat transfer of nanofluids are limited. Most of the experimental and numerical studies showed that nanofluids exhibit an enhanced heat transfer coefficient compared to its base fluid and it increases significantly with increasing concentration of nanoparticles as well as Reynolds number. S.A. Fadhilah et al. [17] The thermal conductivity of Cu/Water nanofluid is increasing significantly with nanoparticle volume fraction of 1 % to 10 % but decreasing with the increment of particle size. The suspension of nanoparticles has increased the heat transfer coefficient of the nanofluid up to 26000 W.m-2K-1 with the percentage enhancement is about 92 %. The overall heat transfer rate of louvered-fin and flat tube radiator shows the percentage enhancement is approximate to 0.03 % as considering both types of coolants of the nanofluids and air. Vishwa Deepak Dwivedi et al. [18] An automotive radiator (Wavy fin type) model is modeled on modeling software CATIA V5 and performance evaluation is done on pre-processing software ANSYS 14.0. The temperature and velocity distribution of coolant and air are analyzed by using Computational fluid dynamics environment software CFX. Results have shown that the rate of heat transfer is better when nanofluid (Si C + water) is used as coolant, than the conventional coolant. Cooling capacity increases with increase in mass flow rate of air and coolant. Reduction in cooling capacity with the increase in inlet air temperature while cooling capacity increases with the increase in inlet coolant temperature. The pressure drop also increases with the increase in air and coolant mass flow rate through radiator. About 5% increment in cooling capacity with the use of nanofluid as coolant in Wavy fin heat exchanger as compared to Conventional coolant. Rahul Tarodiya et al. [19] the Effects of various operating parameters using Cu, SiC, Al_2O_3 and TiO_2 nanofluids with 80% water-20% ethylene glycol as a base fluid are presented. Use of nanofluid as coolant in radiator improves the effectiveness, cooling capacity with the reduction in pumping power. SiC-80% H2O-20% EG (base fluid) yields best performance in radiator having plate fin geometry followed by Al_2O_3-base fluid, TiO_2-base fluid and Cu-base fluid. The maximum cooling improvement for SiC is 18.36%, whereas that for Al_2O_3 is 17.39%, for TiO_2 is 17.05% and for Cu is 13.41% as coolants. This study reveals that the nanofluids may effectively use as coolant in automotive radiators to improve the performance. Navid Bozorgan et al. [20] γ-Al_2O_3 nanoparticles with diameters of 20 nm dispersed in water with volume concentrations up 2% are selected and their performance in a radiator of Chevrolet Suburban diesel engine under turbulent flow conditions are numerically studied. The effects of the automotive speed and Reynolds number of the nanofluid in the different volume concentrations on the radiator performance are investigated. The results show that for 2% γ-Al_2O_3 nanoparticles in water with Renf=6000 in the radiator while the automotive speed is 50 mph, the overall heat transfer coefficient and pumping power are approximately 11.11% and 29.17% more than that of water for given conditions, respectively. These results confirm that γ-Al_2O_3/water nanofluid offers higher overall heat transfer performance than water and can be reduced the total heat transfer area of the radiator. Vinod M. Angadi et al. [21] The heat transfer performance of pure water has been compared with their binary mixtures of Al_2O_3. Different amounts of nanoparticle have been added into these base fluids and its effects on the heat transfer performance of the car radiator have been analysis done using STAR CCM+ tool. The liquid flow rate has been changed in the range of 2-6 litter per minute and fluid inlet temperature has been changed for all the experiments. The result shows that nanofluids clearly enhance heat transfer compared to their own base fluid. In the best conditions, the heat transfer enhancement of nanofluids more which can be compared to usual coolant used in radiator. Rahul A et al. [22] In this study, effect of adding Al_2O_3 nanoparticle to base fluid (mixture of EG+Water) in automobile radiator is investigated experimentally. Effects of fluid inlet temperature, the flow rate and nanoparticle volume fraction on heat transfer are considered. Results show that Nusselt number, total heat transfer, effectiveness and overall heat transfer coefficient increases with increase, nanoparticle volume fraction, air Reynolds number and mass flow rate of coolant flowing through radiator. The Heat transfer rate is increased with increase in volume concentration of nanoparticles (ranging from 0% to 1%). About 40% heat transfer enhancement was achieved with addition of 1% Al_2O_3 particles at 84391 air Reynolds number and constant mass flow rate (0.05 Kg/s).The Overall heat transfer based on air side increased up 36% with addition of 1% Volume Al_2O_3 particles than the base fluid at constant air Reynolds number and constant mass flow rate. The Effectiveness of the radiator increased up to 40% with addition of 1& volume fraction of Al2O3 particles than the base fluid at constant air Reynolds number and constant mass flow rate. M. Naraki et al. [23] In this research, the overall heat transfer coefficient of CuO/water nanofluids is investigated experimentally under laminar flow regime in a car radiator. The results show that the overall heat transfer coefficient with nanofluid is more than the base fluid. The overall heat transfers coefficient increases with the enhancement in the nanofluid concentration from 0 to 0.4 vol.%. Conversely, the overall heat transfer coefficient decreases with increasing the nanofluid inlet temperature from 50 to 80 0C. The implementation of nanofluid increases the overall heat transfer coefficient up to 8% at nanofluid concentration of 0.4 vol.% in comparison with the base fluid. The overall heat transfer coefficient decreases with increasing inlet temperature of the nanofluid. The overall heat transfer coefficient enhances with the addition of nanoparticles to the base fluid. At the concentrations of 0.15 and 0.4 vol.% of CuO nanoparticles, the overall heat transfer coefficient enhancements compared with the pure water are 6% and 8%. The overall heat transfer coefficient increases with enhancing volumetric flow rate of the nanofluid. S.M. Peyghambarzadeh et al. [24] In this study, the heat transfer performance of the automobile radiator is evaluated experimentally by calculating the overall heat transfer coefficient (U) according to the conventional 3-NTU technique. Copper oxide (CuO) and Iron oxide (Fe_2O_3) nanoparticles are added to the water at three concentrations 0.15, 0.4, and 0.65 vol.% with considering the best pH for longer stability. In these experiments, the liquid side Reynolds number is varied in the range of 50 to1000 and the inlet liquid to the radiator has a constant temperature which is changed at 50, 65 and 80^0C. The air Reynolds number is varied between 500 and 700. Results indicate that both nanofluids show greater overall heat transfer coefficient in comparison with water up to 9%. By increasing the nanofluid inlet temperature, lower overall heat transfer coefficient was recorded. Overall heat transfer coefficient increases while the liquid inlet temperature decreases. Overall heat transfer coefficient enhances with increasing the liquid flow rate and the air flow rate. Increasing the concentration of nanoparticles enhances the overall heat transfer coefficient especially for Fe_2O_3/water nanofluids. Parashurama M S1 et al. [25] This experimental work was conducted to investigate the heat transfer rate of automobile radiator of base fluid water and 10% mixture of copper oxide. The results show that, the highest heat transfer rate along the nanofluids and lower heat transfer rate along the water. Here using CuO /water nanofluid as a coolant and 2.5 Kg/s, 3.34Kg/s and 4.17Kg/s mass flow rate of air optimum performance of radiator can be performed. For each mass flow rate of water, experiments are conducted for three different air velocities of 3 m/s, 7.2 m/s, &11.41 m/s. The results show that the nanofluids have large thermal conductivity than the original base fluids under the same mass flow rate and air velocity. The overall heat transfer coefficient of nanofluid is greater than that of water alone.

3. Problem Identification

It is cleared from the literature survey that copper plus acid has high thermal conductivity [26]. So that the naturally available lemon juice is to be used as an additional fluid with base fluid since it has citric acid. Also collecting lemon is simple. It is plenty available in India. The rate of lemon is very cheap. The lemon juice is easily soluble in the base fluid.

4. Methodology

(1) Preparation of lemon juice
(2) Mixing of lemon juice with base fluid
(3) PH value measurement
(3) Thermal properties measurement
(4) Data analysis
(5) Cfd analysis

4.1. Preparation of Lemon Juice

The lemon have purchased from a farmer. The lemons are cut in to half piece size using knife. Then extractor is used to get the juice. It is done for the required level. The lemon juices are mixed with nanofluids in the ratio of 0.5% & 1.5% directly.

Figure 1: Lemon, Extractor & Filter

Figure 2: Prepared Lemon Juice

4.2. Mixing of Lemon Juice with Base Fluid
The lemon juice is mixed with distilled water in the ratio of 0.5%, 1.0% directly.

4.3. pH Value Measurement
A ph meter is used to measure the ph value of the lemon juice. The lemon juice of 0.5%, & 1%, with distilled water were measured.

Figure 3: pH Value of 0.5% Lemon Juice

Figure 4: pH Value of 1% Lemon Juice

4.4. Thermal Properties Measurement

4.4.1. Thermal Conductivity Measurement
The thermal conductivity of Al2O3/water nanofluid was measured by using a KD2 Pro thermal properties analyzer (Decagon Devices, Inc., USA) available at nit, Trichy. The measured values for distilled water, lemon juice added base fluid were 0.611, and 0.97 W/mK, respectively.

4.4.2. Viscosity Measurement
The viscosities of the distilled water, lemon juice were measured at Nit, Trichy. The viscosity of the nanofluid was measured using Brookfield cone and plate viscometer (LVDV-I PRIME C/P) supplied by Brookfield engineering laboratories of USA. The values of viscosity for distilled water, lemon juice were 0.82, and 369.5 centi poise, respectively.

4.5. Data Analysis
According to Newton's cooling law the following procedure followed to obtain heat transfer coefficient and corresponding Nusselt number as
$Q = hA\Delta T = hAs\ (Tb - Ts)$-----------------------------------(1)
As is surface area of tube, Tb is the bulk temperature,
Density of lemon juice and base fluid
$\rho_{bf} = \varphi\rho_{lf} + (1-\varphi)\rho_{bf}$--------------------(2)
Specific heat of lemon juice and base fluid
$C_{p_{lf}} = \frac{(1-\varphi)\rho_{bf}C_{p_{bf}} + \varphi\rho_{lf}C_{p_{lf}}}{\rho_{lf}}$-----------------------(3)
Dynamic viscosity of lemon fluid
$\mu_{lf} = \mu_{bf}(1 + 2.5\varphi)$-------------------------------------(4)
Thermal conductivity of lemon juice
$k_{lf} = (1 + 8.73\varphi)k_{bf}$---(5)
Prandtl Number of lemon juice
$Pr = \frac{\mu_{lf}C_{p_{lf}}}{k_{lf}}$---(6)
Renolds number of fluid
$Re = \frac{\rho v d}{\mu}$ ---(7)
Nusselt number of lemon juice
$Nu = 0.036(Re)^{0.8}(Pr)^{0.33}\left(\frac{d}{l}\right)^{0.055}$---(8)
Heat transfer coefficient of lemon juice
$h = \frac{Nu \times k}{d}$--(9)
Heat transfer rate of nanofluid $Q = h\ A\ \Delta T$------------------------------------(10)

4.6. CFD analysis

The CFD analysis were also done while adding lemon juice with base fluid.

Figure 5: Samples of Base Fluid,0.5% Lemon Juice & 1% Lemon Juice

5. Significant of Lemon Juice

The solubility of nanoparticles in the base fluid is a challenging task. It needs more technique. So that it is not convenient to use in the radiator. That's why the different materials used in this research. Also nanofluids set clocked in the pipe channels when it is passed through the radiator. But lime juice is different as it has a property of easily soluble with water while adding distilled water with lime juice no sediment is formed. It is easily soluble with the water

6. Experimental Work

The schematic diagram of the experimental setup used is shown in Fig 6 and the actual picture of apparatus is shown in Fig 7. The setup consist of a pump, a flow meter, a car radiator (made by maruthi alto), cooling fan, storage tank, heater and a heat controller to heat the working fluid, thermocouples to measure the temperatures at inlet and outlet and flow lines and to regulate the fluid in a loop. Two additional thermocouples have been provided to measure the air temperature at inlet and exit of the radiator. Totally 4 temperature measurement is provided in this experimental set up. A gate valve have also been provided in the setup to regulate the fluid flow at desired flow rate through the loop. The pump is used to take the fluid from storage tank. By using a gate valve, the required flow rate of the fluid is passed to the flow meter that has an accuracy of ±2% of reading. 3 heaters have been used in this set up to balance the required temperature in the steady condition. It is having a temperature controller in the three heaters where we can get the required temperature very quickly. A fan is used to cool the radiator in two different speed controls. The experiment is carried out at constant flow rates for specific interval of time at 10, 12, 14 & 16 LPM (liter per minutes). The input temperature is selected as at 40 ^{0}C. Fluid inlet temperature is varied from 40^{0}c to 75^{0}c. The thermocouple is used here with an accuracy of ±0.5 ^{0}C. A pump of 0.5hp is used to suck the water from the tank to the radiator. A duct is provided in the radiator in order to obtain a uniform velocity of air while passing into the radiator and leaving the radiator. An anemometer is used to measure air temperature at radiator inside and outside. Similarly by measuring the inlet and outlet temperature of air side (radiator) to check the heat lost by hot fluid (water) to heat gained by cold fluid (air).The readings are taken three times and then the average value taken for each run.

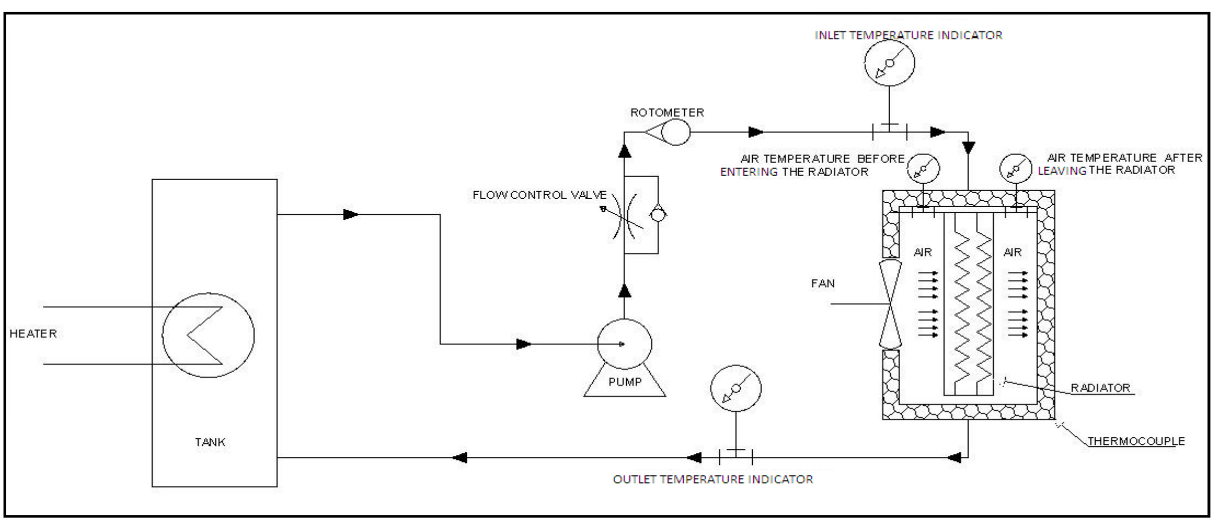


Figure 6: The Schematic Diagram of the Experimental Setup

Figure 7: Actual picture of apparatus

The specification of experimental setup as shown in table 2

Radiator	Width- 370mm Height- 400mm Tube size - 20×2 mm Fin thickness- 1mm Fin Pitch – 1mm
Tank	Capacity- 18 litre Material- stainless steel Diameter- 260mm Height – 300mm
Heater	Type- Epson made Number of heater- 3 Power- 2kw Thermostat- range 0 to 75 ^{0} c (Girsheg) Accuracy- ±0.5 ^{0} c
Pump	Made by CRI Capacity 0.5 hp Speed- 2800rpm Water capacity- 1080 l/h
Thermometer	Type- digital Make- nanotech Range- 0to 400 ^{0} c Accuracy – ±0.5 ^{0}c
Fan	Power -80 watts (motor) Number of speed-2 Diameter – 400mm Number of blade- 6 Type of blade- curve
Rotometer	Make- Accrylic Type- micro Capacity-10 to 100 l/m
Anemo meter	Model-AVM 06 display-LCD make-BEE tech max. show value- 9999 accuracy- ± (2.0% reading + 50 characters)
Hose	Type-rubber Length- 1552.5 mm (radiator to tank- 900mm, tank to pump- 450mm, rotometer to radiator-202.5 mm)

Table 2: Specification Experimental Setup

7. Result & Discussion

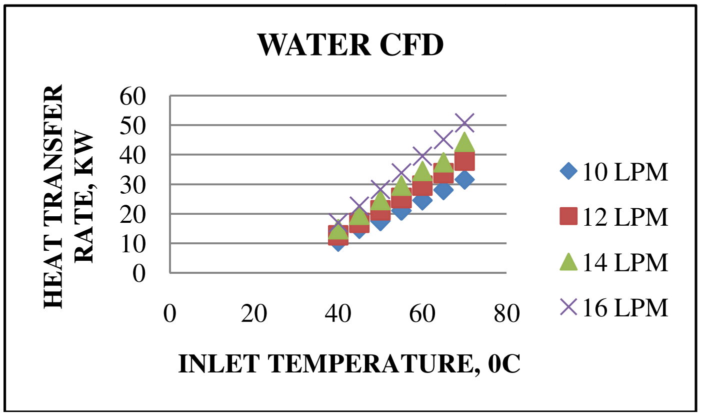


Figure 8: CFD analysis of Distilled water

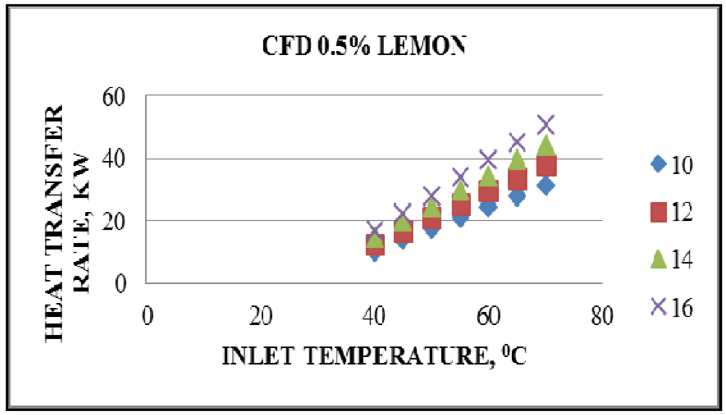


Figure 9: CFD analysis for 0.5% lemon

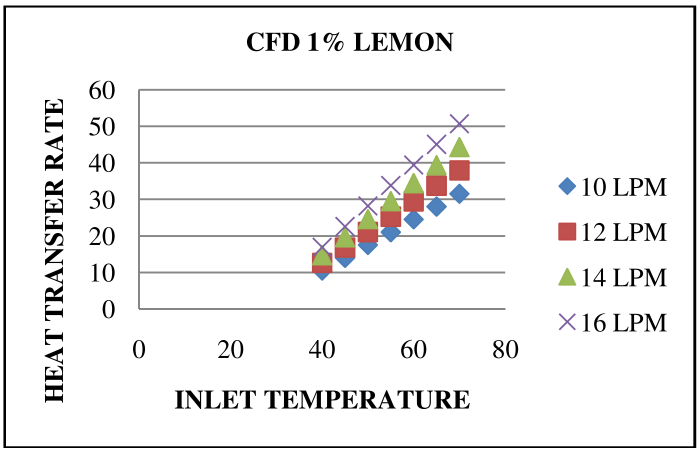


Figure 10: CFD analysis for 1% lemon

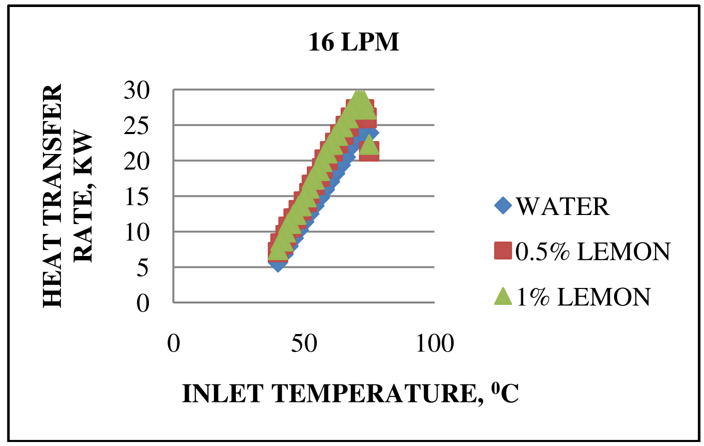


Figure 11: Experimental analysis of heat transfer rate (16lpm)

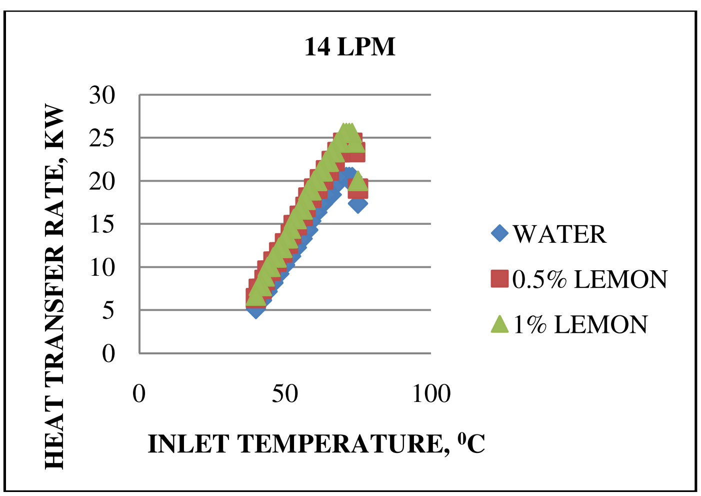


Figure 12: Experimental analysis of heat transfer rate (14lpm)

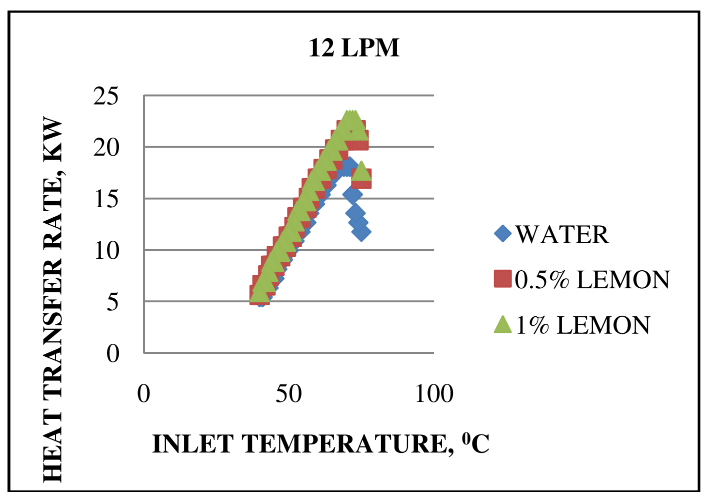


Figure 13: Experimental analysis of heat transfer rate (12lpm)

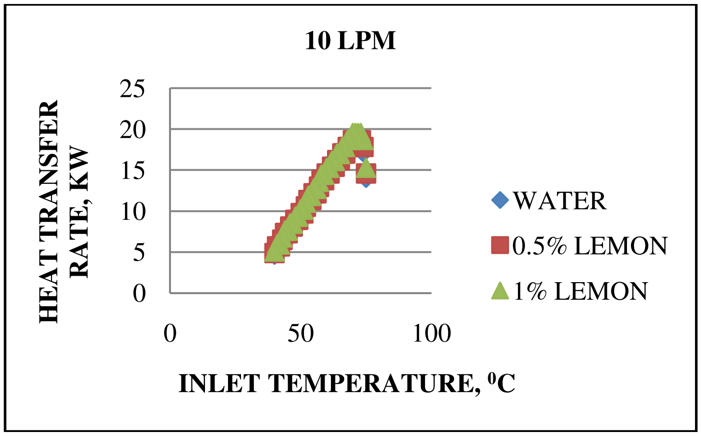
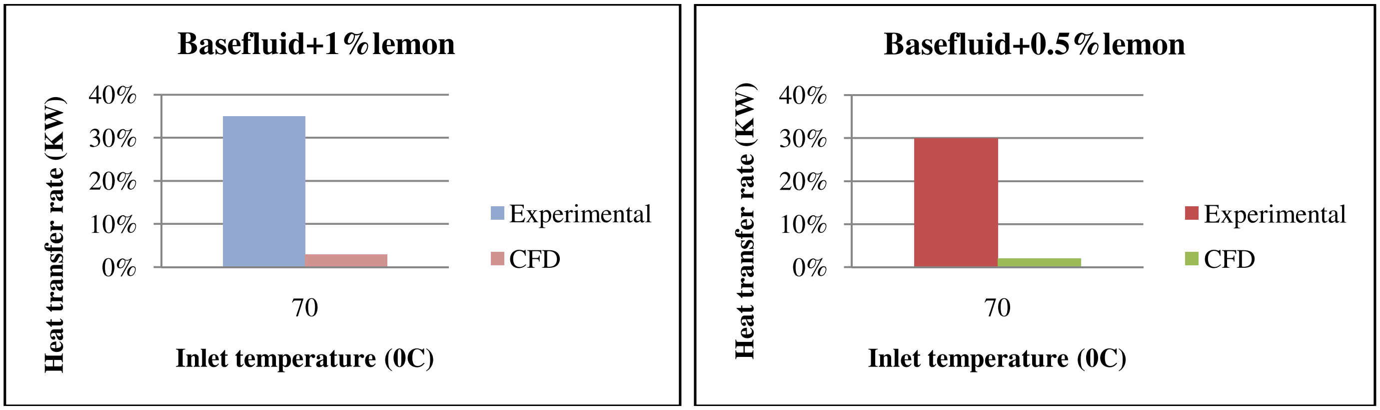


Figure 14: Experimental analysis of heat transfer rate (10lpm)

At figure 8, by CFD analysis for distilled water, for 10lpm mass flow rate , the input temperature of 40^0c, 45^0c, 50^0c, 55^0c, 60^0c, 65^0c and 70^0c, the heat transfer rate are 10kw, 15 kw, 18 kw, 21 kw, 25 kw, 28 kw and 31 kw respectively. For 12lpm mass flow rate for the same input temperature, the heat transfer rate are 11 kw, 18 kw, 20 kw, 25 kw, 30 kw, 33 kw and 38 kw respectively. For 14lpm mass flow rate and the same input temperature, the heat transfer rate are 14 kw, 20 kw, 22 kw, 28 kw, 32 kw, 37 kw and 43 kw respectively. For 16lpm mass flow rate and for the same input temperature, the heat transfer rates are 18 kw, 22 kw, 28 kw, 32 kw, 40 kw, 45 kw and 50 kw respectively. At figure 9, by CFD analysis for 0.5% lemon juice with base fluid, for 10lpm mass flow rate, for the input temperature of 40^0c, 45^0c, 50^0c, 55^0c, 60^0c, 65^0c and 70^0c, the heat transfer rate are 10kw, 13 kw, 18 kw, 20 kw, 24 kw, 28 kw and 31 kw respectively. While compare the same with base fluid, an increase of 2% is obtained. For 12lpm mass flow rate and for the same input temperature, the heat transfer rate are 11 kw, 18 kw, 20 kw, 25 kw, 30 kw, 32 kw and 38 kw respectively. For 14lpm mass flow rate and the same input temperature, the heat transfer rate are 12 kw, 20 kw, 23 kw, 27 kw, 32 kw, 40 kw and 42 kw respectively. For 16lpm mass flow rate and for the same input temperature, the heat transfer rate are 16 kw, 21 kw, 28 kw, 32 kw, 40 kw, 45 kw and 50 kw respectively. At figure 10, by CFD analysis for 1% lemon juice with base fluid for 10lpm mass flow rate, and for the input temperature of 40^0c, 45^0c, 50^0c, 55^0c, 60^0c, 65^0c and 70^0c, the heat transfer rate are 11kw, 14 kw, 18 kw, 21 kw, 25 kw, 28 kw and 32 kw respectively. While compare the same with base fluid, an increase of 2% is obtained. For 12lpm mass flow rate and for the same input temperature, the heat transfer rates are 11 kw, 18 kw, 21 kw, 26 kw, 30 kw, 33 kw and 40 kw respectively. For 14lpm mass flow rate and the same input temperature, the heat transfer rate are 13 kw, 20 kw, 24 kw, 28 kw, 32 kw, 41 kw and 43 kw respectively. For 16lpm mass flow rate and for the same input temperature, the heat transfer rates are 16 kw, 22 kw, 29 kw, 32 kw, 41 kw, 46 kw and 51 kw respectively. At figure 11 by experimental analysis for 1% lemon juice, and for 16lpm mass flow rate the base fluid has a heat transfer rate of 28 kw for the inlet temperature of 70^0c. While 0.5% lemon juice added with base fluid and it has a heat transfer rate of 26kw. But for base fluid alone, at the same mass flow rate, and inlet temperature, it has a heat transfer rate of 18kw. Thus 35% of heat transfer rate increases is identified. At figure12, for 14lpm mass flow rate, and at 70^0c inlet temperature, 26kw heat transfer rate has been obtained. For the same condition while adding 0.5% lemon juice with base fluid, 24 kw heat transfer rate is obtained and for base fluid only 20 kw heat transfer rate has been obtained. So while adding 1% lemon 23% heat transfer rate increases compare with base fluid, while adding 0.5% lemon juice with base fluid 16% heat transfer rate increases. At figure 13, for 12lpm, by experimental analysis, while adding 1% lemon juice with base fluid, 22 kw heat transfer rate has been obtained, and for 0.5% lemon juice, 21 kw heat transfer rate is obtained. But for base fluid alone only 18 kw heat transfer rate has been obtained. So while adding 1% lemon juice, and 0.5% lemon juice, the heat transfer rate increases of 18% and 14% respectively. At figure 14, for 10lpm mass flow rate, for the given temperature of 70^0c, the base fluid, 1% lemon juice, and 0.5% lemon juice have been obtained a heat transfer rate of 19 kw, 18 kw and 17 kw respectively. It is concluded that while adding 1% lemon juice with base fluid an increase of 10% has been obtained. Similarly, while adding 0.5% lemon juice with base fluid an increase of 5% has been obtained.

8. Conclusion

The experimental analysis and CFD were done for heat transfer rate. The lemon juice which added with base fluid in the ratio of 0.5% and 1% respectively. The mass flow rate is varied from 10lpm, 12lpm, 14lpm and 16lpm. The input temperature varied from 40^0c, 45^0c, 50^0c, 55^0c, 60^0c, 65^0c and 70^0c respectively. Accordingly by CFD analysis, while adding 1% lemon juice with base fluid a heat transfer rate increases of 3% has been obtained. Similarly, while adding 0.5% lemon juice with base fluid 2% improvement in heat transfer rate has been obtained. While considering experimental analysis, an increase of 35% has been reported for 1% lemon juice at a mass flow rate of 16lpm. Similarly, while adding 0.5% lemon juice with base fluid 30% increases in heat transfer rate has been obtained. The figure 14 a, b shows the comparison of cfd and experimental analysis.



a) b)

Figure 14: a, b Comparison between experimental and CFD analysis

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