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Effect of Al_2O_3 Nano fluids with citrus limonum juice on heat transfer rate in automobile radiators

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Abstract: Recently, heat transfer enhancement for automobiles by adding solid nanoparticles to liquid is significant. The nanomaterial's have high heat transfer rate. Most of the research has been conducted using nanoparticles alone for radiators. A natural preservative with nanofluids for further improvement of heat transfer is proposed. Lemon juice is one of the traditional and best cooling medium. Accordingly, an attempt is made by adding natural lemon juice as an additional fluid with nanofluids. Experimental analysis is carried out by varying different input temperatures and mass flow rate. This research included the heat transfer rate by forced convection. The juice which is extracted from the natural available lemon and dispersed in the Aluminum oxide nanofluids prepared previously. Additionally, comparison is conceded with the CFD analysis have done. The experimental result shows that the heat transfer rate increases and proves that the proposed combination of additives is an enriched solution for the heat transfer enhancement.

Keywords: Radiator, Lemon juice, Aluminium oxide nanofluids, heat transfer rate, CFD.

Nomenclature

ρ_{nf} Density of nanofluids
C specific heat [W/kg ^oC]
D diameter [m]
E energy [W]
ΔT Temperature difference
htc convection heat transfer coefficient [W/m2 ^oC]
k thermal conductivity [W/m ^oC]
Nu Nusselt Number [htcD/Knf]
P pressure [N/m2]
Pr Prandtl number [Cμ/Knf]
Re Reynolds number [ρnfDhu/Knf]
u velocity [m/s]
μ viscosity [N s/m2]
ρ density [kg/m3]
τ shear stress [N/m2]
 volume concentration

1. Introduction

In an automobile, fuel and air produce power within the engine through combustion. Only a portion of the total generated power actually supplied to the automobile with power, the rest is wasted in the form of exhaust and heat. If this excess heat is not removed, the engine temperature becomes too high which results in overheating and viscosity breakdown of the lubricating oil, metal weakening of the overheated engine parts, and stress between engine parts resulting in quicker wear, among the related moving posts . A cooling system is used to remove this excessive heat. Automotive engine cooling system takes care of excess heat produced during engine operation. It regulates engine surface temperature for engine optimum efficiency. Most automotive engine cooling systems consist of the radiator, water pump, cooling fan, pressure cap and thermostat. Radiator is the prime component of the system. Radiator is a heat exchanger that removes heat from engine coolant passing through it. Heat is transferred from hot coolant to outside air. Radiator assembly consists of three main parts core, inlet tank and outlet tank. Core has two sets of passage, a set of tubes and a set of fins. Coolant flows through tubes and air flows between fins. The hot coolant sends heat through tubes to fins. Outside air passing between fins pickups and carries away heat. Heat transfer has been a great challenge for the industrial applications during various operations in order to achieve better performance and efficiency. Many techniques were used in past to enhance heat transfer i.e. pure liquid forced convection and extended surfaces were used to enhance the heat transfer, however due to ever increasing heat flux requirement, these techniques have reached their limits. Nanofluids were developed recently by suspending solid particles (ranging from 10 nm to 100 nm) in a base fluid, these fluids have displayed better thermal characteristics and exhibited excellent heat transfer properties even at low concentration of nanoparticles in base fluid.

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 SiO_2 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 transfer 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 our 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 is 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 thermophysical 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 nanofluids 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 thermophysical 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 nano fluid (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 Al2O3-base fluid, TiO2-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 Al_2O_3 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 transfer 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 ^{0}C. 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^{0}C. The air Reynolds number is varied between 500 and 700. Result indicates 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 Fe2O3/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. Methodology

(1) Preparation of nanofluids
(2) Preparation of lemon juice
(3) Mixing of lemon juice with nanofluids
(4) PH value measurement
(5) Thermal properties measurement
(6) Data analysis
(7) CFD analysis

(1)Preparation of nanofluids

The nanoparticles of Aluminium oxide of size 50nm purchased in zigma rich, Bangalore, india. The nano particles are used at the ratio of 0.09% with distilled water. Ultrasonicator is used to mix the aluminium oxide nanoparticles with base fluid (distilled water).The nanoparticles are weighed to the required ratio and then mixed with base fluid and then allowed for sonication to get the entire particles for soluble in the distilled water. The sonication is done for 4 hours continuously.

Fig. 1. Ultrasonicator

The properties of aluminum oxide nanoparticles is shown in table 1

Property	**Al_2O_3**
Appearance	White powder
Purity	99.99%
Diameter	50nm
Surface area	15-20 m2/gm
Density	3.428 gm/cm3

Table.1. Aluminium oxide nanoparticles properties

Fig. 2. Prepared aluminium oxide nanofluids

(2)Preparation of lemon juice

The lemon bought from lemon tree in a farmer. The lemon 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%, 1.0% & 1.5% directly.

Fig. 3.lemon, extractor & filter

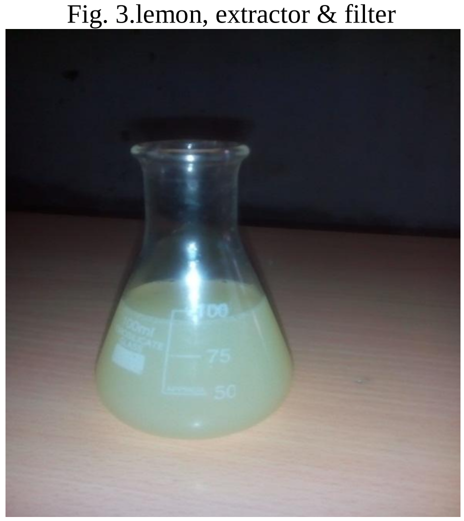


Fig. 4. Prepared lemon juice

(3)Mixing of lemon juice with nanofluids

The lemon juices are mixed with nanofluids in the ratio of 0.5%, 1.0% & 1.5% directly.

(4)PH value measurement

A ph meter is used to measure the ph value of the lemon juice. The lemon juice of 0.5%,1%, & 1.5% with distilled water and then the same ratio of nanofluids and lemon juice ph value were measured.

Fig. 5. Ph value of 0.5% lemon juice

Fig. 6. Ph value of 1% lemon juice

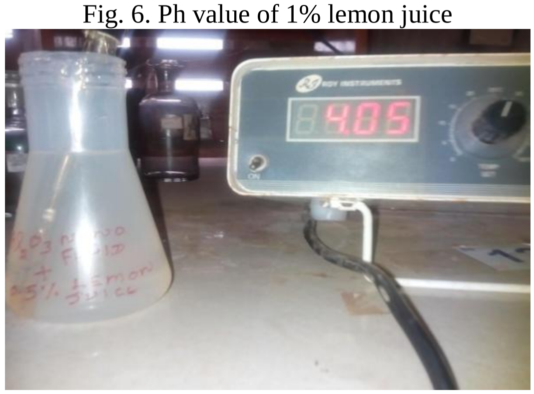


Fig. 7. Ph value of 0.09% Al_2O_3 nanofluids & lemon juice

(5)Thermal properties measurement

Thermal conductivity measurement

The thermal conductivity of Al_2O_3/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 and Al_20_3 nanofluid and lemon juice were 0.611, and 1.12 W/mK, respectively.

Viscosity measurement

The viscosity of the distilled water, lemon juice & nanofluids and 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 and nanofluids & lemon juice were 0.82, 10.7 and 369.5 cP, respectively.

(6)Data analysis

According to Newton's cooling law the following procedure followed to obtain heat transfer coefficient and corresponding Nusselt number as

$$Q = hA\Delta T = hAs(Tb - Ts) \quad (1)$$

As is surface area of tube, Tb is the bulk temperature,

Density of nanofluid

$$\rho_{nf} = \varphi\rho_{np} + (1-\varphi)\rho_{bf} \quad (2)$$

Specific heat of nanofluid

$$C_{p_{nf}} = \frac{(1-\varphi)\rho_{bf}\, C_{p_{bf}} + \varphi\rho_{np}\, C_{p_{np}}}{\rho_{nf}} \quad (3)$$

Dynamic viscosity of nanofluid

$$\mu_{nf} = \mu_{bf}\,(1 + 2.5\varphi) \quad (4)$$

Thermal conductivity of nanofluid

$$k_{nf} = (1 + 8.73\varphi)k_{bf} \quad (5)$$

Prandtl Number of nanofluid

$$Pr = \frac{\mu_{nf}\, C_{p_{nf}}}{k_{nf}} \quad (6)$$

Renolds number of nanofluid

$$Re = \frac{\rho v d}{\mu} \quad (7)$$

Nusselt number of nanofluid

$$Nu = 0.036(Re)^{0.8}(Pr)^{0.33}\left(\frac{d}{l}\right)^{0.055} \quad (8)$$

Heat transfer coefficient of nanofluid

$$h = \frac{Nu \times k}{d} \quad (9)$$

Heat transfer rate of nanofluid

$$Q = h\ A\ \Delta T \quad (10)$$

(7)CFD analysis

The CFD analysis were also done while adding lemon juice with aluminium oxide nanoparticles.

4. Experimental work

The Nanofluids performances are based on particles agglomeration and particles suspension in the base fluid. If failing to achieve these then there will be difficult to get good performance of the nanofluid. In this experimental setup the nanofluid is prepared by using ultra sonication method. The nanoparticles used in this research is aluminium oxide of 50nm is mixed together 0.09% with base fluid. After preparing nanofluid it is mixed with the newly prepared lemon juice in the same ratio. The nanoparticles purchased from zixma ricn, bangalore. The sonication is applied for 5 hours. The pH value of the nanofluids is measured. The measurement of heat transfer that determines the performance of nanofluids. The schematic diagram of the experimental setup used is shown in Fig 8 and the actual picture of apparatus is shown in Fig 9. 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 identified 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 (rotometer-mechanical type)) that has an accuracy of ±2% of reading.3 heaters has been used in this set up o balance he 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 with 40^{0}c to 75^{0}c. The thermocouple is used here with an accuracy of ±0.5 ^{0}C. A pump is used to suck the water from the tank to the radiator in the range of 0.5 hp. 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. A duct is provided at the inner side of the radiator to maintain constant velocity of air at inlet and exit of the radiator.

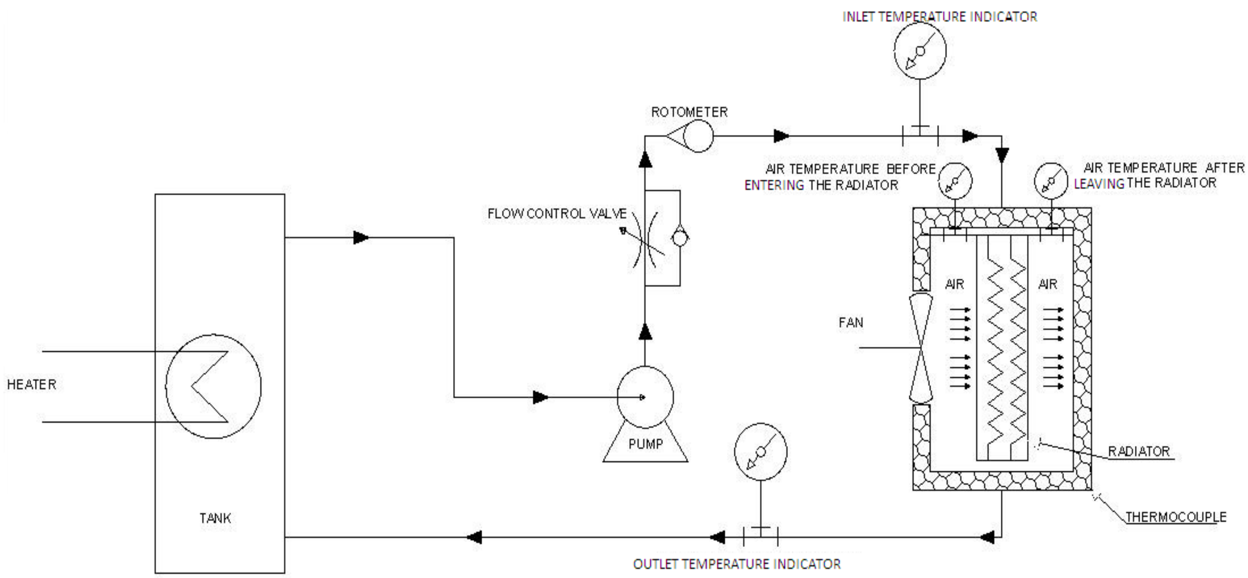


Fig. 8. The schematic diagram of the experimental setup

Fig. 9. 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- 16 liters 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
Anemometer	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 tank- 900mm, tank to pump- 450mm, rotometer to radiator- 202.5 mm)

Table. 2. specification experimental setup

5. Result & Discussion

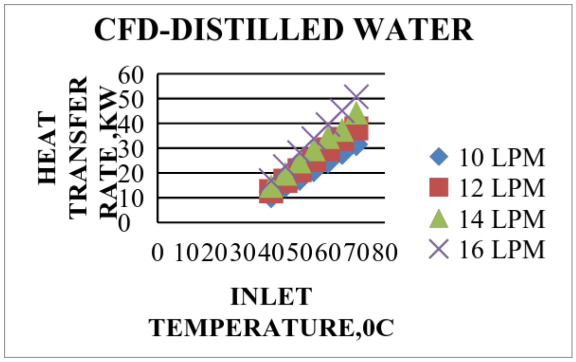


Fig. 10. Heat transfer rate for distilled water (CFD)

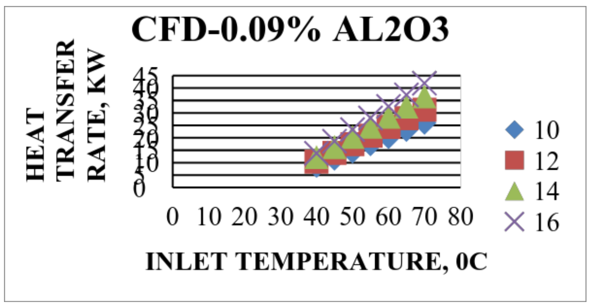


Fig. 11. CFD analysis for 0.09% Al_2O_3

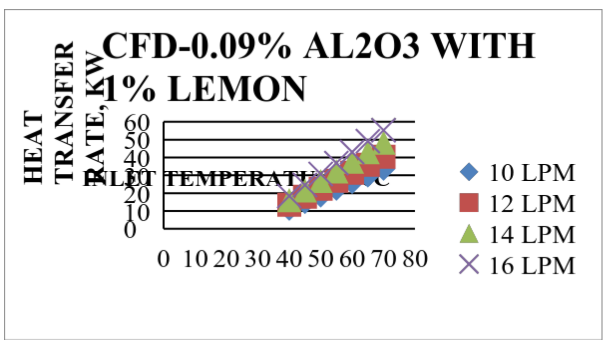


Fig. 12. CFD analysis for 0.09% Al_2O_3 with 1% lemon

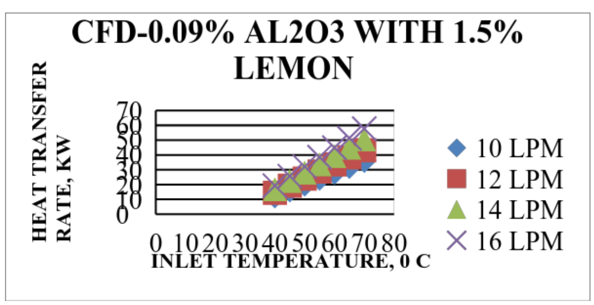


Fig. 13. CFD analysis for 0.09% Al_2O_3 with 1.5% lemon

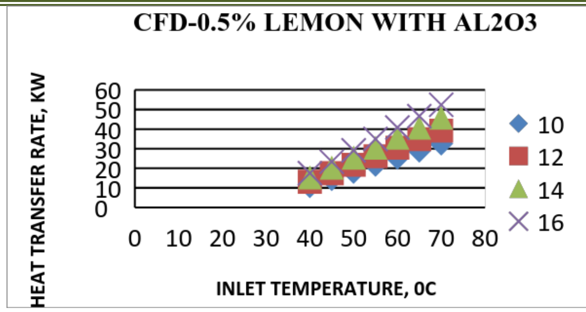


Fig. 14. CFD analysis for 0.5% lemon with Al_2O_3

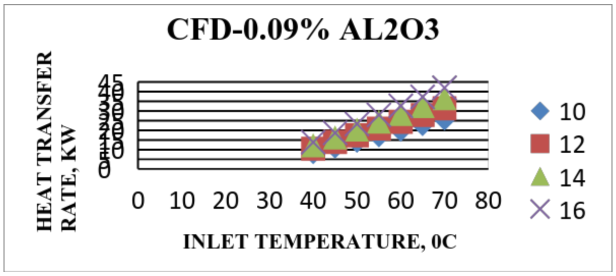


Fig. 15. CFD analysis for 0.09% Al_2O_3

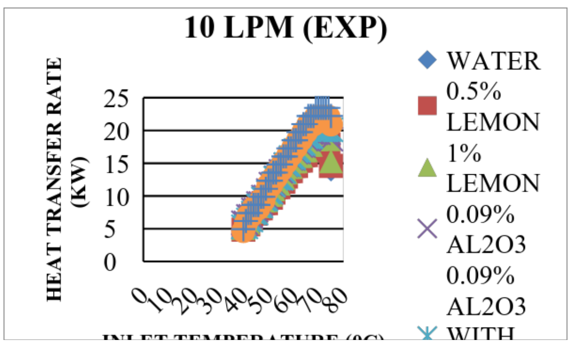


Fig. 16. Experimental comparison of heat transfer rate for various percentage of lemon, water and Nano fluids (10lpm)

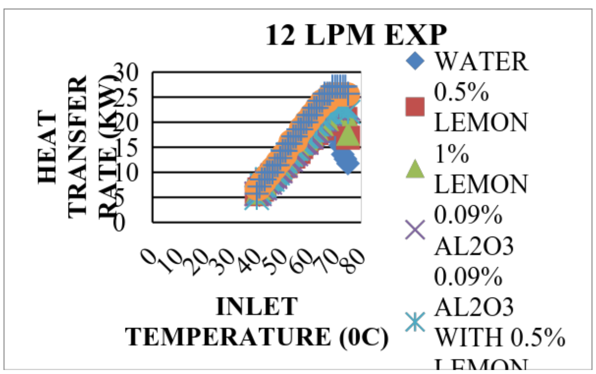


Fig. 17. Experimental comparison of heat transfer rate for various percentage of lemon, water and Nano fluids (12lpm)

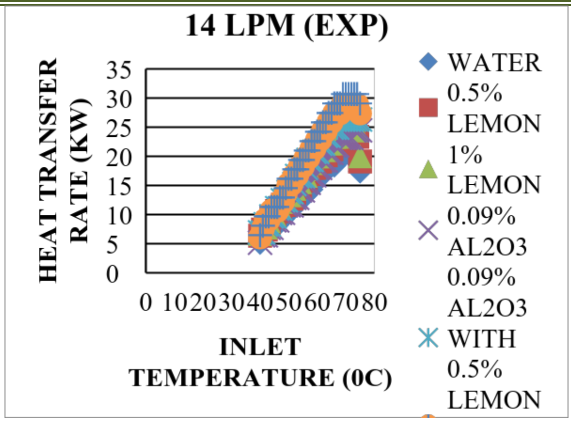


Fig. 18. Experimental comparison of heat transfer rate for various percentage of lemon, water and Nano fluids (14lpm)

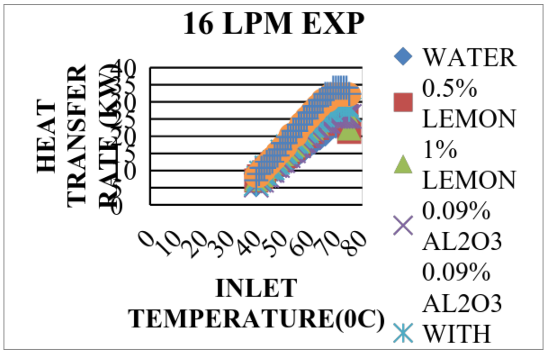


Fig. 19. Experimental comparison of heat transfer rate for various percentage of lemon, water and Nano fluids (16lpm)

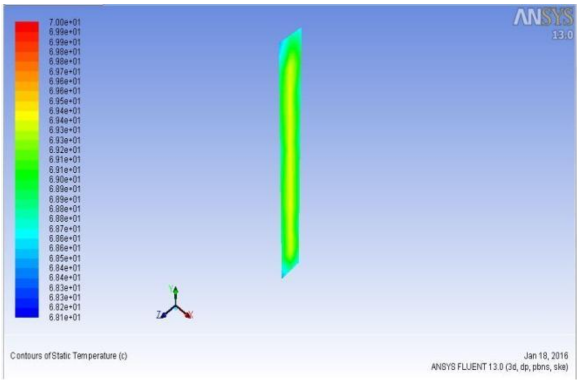
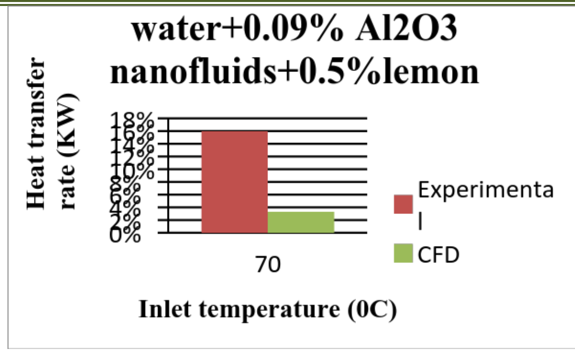


Fig. 20. CFD results for outlet temperature (10lpm, 0.05% lemon with 0.09% Al_2O_3 and 70^0c)

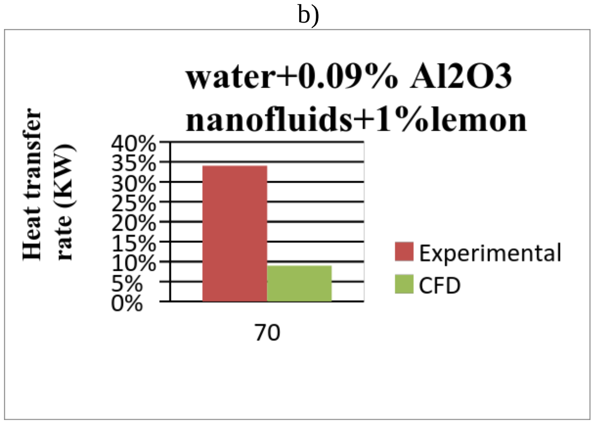
At figure 10 , the heat transfer rate for the mass flow rate 10, 12, 14, &16lpm is done to the inlet temperature of 40, 45, 50, 55, 60, 65 and 70^0 c . At 70^0c inlet temperature & 16lpm mass flow rate, the high heat transfer rate of is obtained. Similarly at 40^0 c inlet temperature, a minimum of heat transfer rate is obtained while doing in cfd. By experimental analysis it is obtained 30kw heat transfer rate where as in cfd analysis 50kw heat transfer rate has been obtained. At 10lpm mass flow rate the heat transfer rate by cfd analysis and experimental analysis are 18kw,and 21kw respectively. At figure 11, the for 0.09% Al_2O_3 nanofluids, the CFD analysis shows that, a small increment in heat transfer rate of 14kw is obtained to the given mass flow rate(10lpm) and 40c temperatures. For the 70^0 c, 16lpm mass flow rate a maximum of 41kw heat transfer rate has been received analysis by cfd. For the experimental analysis it is observed that the heat transfer rate of 18kw and 27kw respectively. In Figure 12, the for 0.09% Al_2O_3 & 1% lemon juice nanofluids, the CFD analysis shows that, a small increment in heat transfer rate of 19kw is obtained to the given mass flow rate(10lpm) and 40c temperatures. For the 70^0 c, 16lpm mass flow rate a maximum of 56kw heat transfer rate has been received analysis by CFD. It is observed that while adding 1% lemon juice with Al_2O_3 nanofluids 26% heat transfer rate increased in CFD analysis. In Figure 13, the for 0.09% Al_2O_3 & 1.5% lemon juice nanofluids, the CFD analysis shows that, a small increment in heat transfer rate of 20kw is obtained to the given mass flow rate(10lpm) and 40c temperatures. For the 70^0 c ,16lpm mass flow rate a maximum of 59kw heat transfer rate has been received analysis by CFD. It is observed that while adding 1% lemon juice with Al_2O_3 nanofluids 28% heat transfer rate increased in CFD analysis. In Figure 14 the for 0.09% Al_2O_3 & 0.5% lemon juice nanofluids, the CFD analysis shows that, a small increment in heat transfer rate of 18kw is obtained to the given mass flow rate(10lpm) and 40c temperatures. For the 70^0 c, 16lpm mass flow rate a maximum of 52kw heat transfer rate has been received analysis by cfd. By the experimental analysis, it is observed that while adding 1% lemon juice with Al_2O_3 nanofluids 21kw and 29kw heat transfer rate has been achieved. It is observed that at 10lpm mass flow rate 10% of heat transfer rate has been increased by experimental analysis. In Figure 15 the for 0.09% Al_2O_3 nanofluids, the CFD analysis shows that, a small increment in heat transfer rate of 14kw is obtained to the given mass flow rate(10lpm) and 40c temperatures. For the 70^0c, 16lpm mass flow rate a maximum of 42kw heat transfer rate has been received analysis by CFD. By the experimental analysis, it is observed that while adding 1% lemon juice with Al_2O_3 nanofluids 21kw and 26kw heat transfer rate has been achieved. It is observed that at 10lpm mass flow rate 12% of heat transfer rate has been increased by experimental analysis. The Figure 16 shows that, the heat transfer rate at 10lpm mass flow rate for pure distilled water, 0.5% lemon juice,1%lemon juice and 1.5% lemon juice with distilled water, ,0.09% Al_2O_3 nanofluids with 0.5% lemon juice, 1% lemon juice and 1.5% lemon juice. From this graph it is cleared that 0.09% of Al_2O_3 nanofluids have the heat transfer rate followed by 1% lemon juice and 0.5%lemon juice by experimentally. While considering the comparison the same with CFD analysis it has high heat transfer rate. The Figure 17 shows that, the heat transfer rate at 12lpm mass flow rate for pure distilled water,0.5% lemon juice,1%lemon juice and 1.5% lemon juice with distilled water, ,0.09% Al_2O_3 nanofluids with 0.5% lemon juice, 1% lemon juice and 1.5% lemon juice. From this graph it is cleared that 0.09% of Al_2O_3 nanofluids have the heat transfer rate followed by 1% lemon juice and 0.5%lemon juice by experimentally. While considering the comparison the same with CFD analysis it has high heat transfer rate. The Figure 18 shows that, the heat transfer rate at 14lpm mass flow rate for pure distilled water,0.5% lemon juice,1%lemon juice and 1.5% lemon juice with distilled water, ,0.09% Al_2O_3 nano fluids with 0.5% lemon juice, 1% lemon juice and 1.5% lemon juice. From this graph it is cleared that 0.09% of Al_2O_3 nanofluids have the heat transfer rate followed by 1% lemon juice and 0.5%lemon juice by experimentally. While considering the comparison the same with CFD analysis it has high heat transfer rate. The Figure 19 shows that, the heat transfer rate at 16lpm mass flow rate for pure distilled water,0.5% lemon juice,1%lemon juice and 1.5% lemon juice with distilled water, 0.09% Al_2O_3 nanofluids with 0.5% lemon juice, 1% lemon juice and 1.5% lemon juice. From this graph it is cleared that 0.09% of Al_2O_3 nanofluids have the heat transfer rate followed by 1% lemon juice and 0.5%lemon juice by experimentally. While considering the comparison the same with CFD analysis it has high heat transfer rate. In figure 20, the CFD analysis of [0.05% lemon juice and 0.09% Al_2O_3] the output result at 10lpm is shown. It indicates that an increase of 2% of heat transfer rate is noted.

6.Conclusion

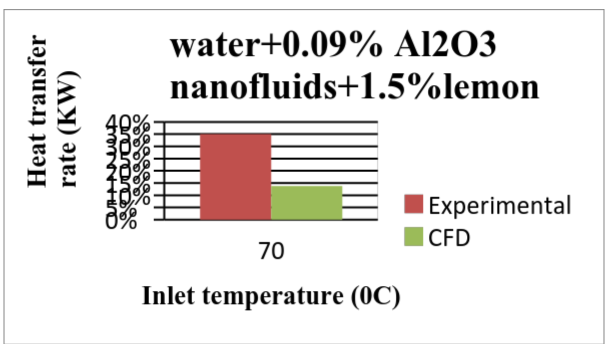
The experimental analysis and CFD were done. The lemon juice which added with 0.09% Al_2O_3 nanofluids. The input temperature varied from 40, 45, 50, 55, 60, 65 and 70^0c. The mass flow rate is varied from 10lpm, 12lpm, 14lpm and 16lpm respectively. 0.5%, 1% and 1.5% lemon juice added with nanofluids and heat transfer rate were found. Accordingly by CFD analysis the 0.5% of lemon juice & 0.09 percentage Al_2O_3 nanofluids have obtained 3.31% increasing in heat transfer rate, the 1% lemon juice & 0.09%Al2o3got 8.96% increasing in heat transfer rate, and similarly 1.5%lmon juice which added with Al_2O_3 nanofluids the heat transfer rate of 13.814% is obtained. In case of experimental analysis, it has been while adding 0.5% lemon juice with 0.09% Al_2O_3 nanofluids, a maximum of 16% heat transfer rate is obtained at a mass flow rate 16lpm. For 1% lemon juice with 0.09% Al_2O_3 nanofluids the heat transfer rate increased by 34%.Similarly for 1.5% lemon juice and 0.09% Al_2O_3 nanofluids the heat transfer rate increases by 35%It has been , lemon juice has an significant improvement of heat transfer while it is added with Al_2O_3 nanofluids.



a) water+0.09% Al_2O_3 nanofluids+0.5%lemon
b)



b) water+0.09% Al_2O_3 nanofluids+1%lemon



c) water+0.09 % Al_2O_3 nanofluids+1.5%lemon

Fig. 21. a,b,c- comparison between experimental and CFD analysis

The comparison is made between CFD analysis and experimental analysis and where the high heat transfer rate has been reported by experimental analysis, it is given by in figure 21.

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