COMPARATIVE STUDY OF COOLING PERFORMANCE OF AUTOMOBILE RADIATOR USING Al_2O_3-WATER AND CUO-WATER NANO FLUID

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By
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BONAFIDE CERTIFICATE

This is to certify that the project titled**COMPARATIVE STUDY OF COOLING PERFORMANCE OFAUTOMOBILE RADIATOR USING Al_2O_3-WATER AND CuO-WATER NANOFLUID is**a bonafide record of the work done by

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in partial fulfilment of the requirements for the award of the degree of**Bachelor of Technology** of **COCHIN UNIVERSITY OF SCIENCE AND TECHNOLOGY at COLLEGE OF ENGINEERING ADOOR** during the year 2014-2015.

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ABSTRACT

Nanofluids are a new class of nanotechnology-based heat transfer fluids engineered by dispersing and stably suspending nanoparticles with typical length on the order of 1–50 nm in traditional heat transfer fluids. For the past decade, pioneering scientists and engineers have made phenomenal discoveries that a very small amount of 1 vol %of guest nanoparticles can provide dramatic improvements in the thermal properties of the host fluids. For example, some nanofluids exhibit superior thermal properties such as anomalously high thermal conductivity at low nanoparticle concentrations.Nanofluids can be described as colloidal suspensions of solid particles smaller than 100 nm diluted in a base fluid. According to the literature nanofluids have better thermophysical properties and might achieve better cooling performance compared to conventional liquids.Nanofluid are hence known to produce a greater heat transfer. This study tries to link this heat transfer with automobile radiator. This study specifically aims at finding out the heat transfer enhancement when water is replaced by nanofluids as the cooling fluid in an automobile Radiator. For this, the forced convective heat transfer performance of two different nanofluids, namely Al_2O_3-water and CuO-water has been studied experimentally studied in anautomobile radiator model. Firstly, two different concentrations of both nanofluids(0.01% and0.1%)were prepared by the addition of correctly weighed nanoparticles into the water as base fluid. The Al_2O_3/H_2O nanofluid was readily formed by mixing and agitating nanopowder and water inside an ultrasonic shaker. But for forming stable solutions of CuO/H_2O nanofluid, a binder was added in addition to the Nanopowder and water. Property testing of these nanofluid was also carried out to find the various property values like viscosity. Conductivity, Specific Heat and density of the nanofluid were found by applying various correlations found in various journals.

The experimental setup consisting of a model of Automobile Radiator along with fan, Autotransformer connected heater and RTD was ran with the prepared nanofluids. The coolant flow rate was varied upto 4L/min. Nanocoolants exhibit enormous change in the heat transfer compared with the pure water. The heat transfer performance of CuO-water nanofluid, Al_2O_3-water nanofluid, and water were compared. The variation of Nusselt Number with different flow rates and concentration was also studied.

Keywords: Nanofluids, Radiator, Heat Transfer, Nusselt Number, concentration.

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C	Specific Heat at constant pressure,
ρ	Density,
Φ	Volume Fraction of nanofluid
k	Thermal Conductivity
D	Diameter of Tube
Q_{vol}	Volumetric Flow Rate
A	Cross Sectional Area of Tube
h	Heat Transfer Coefficient
A_s	Surface Area
T_{in}	Inlet Temperature
T_{out}	Outlet Temperature

T_1, T_2, T_3, T_4 represents the temperatures detected by the RTDs fixed at the wall

C	Specific Heat at Constant Pressure
D	Diameter of Tube

Subscripts used,

nf	nanofluid
bf	basefluid
p	nanoparticle

LIST OF ABBREVIATIONS

RTD	Resistance Temperature Detector
SDS	Sodium Dodecyl Sulfate
CTAB	CetylTrimethyl Ammonium Bromide
DTAB	Dodecyl Trimethyl Ammonium Bromide
SOCT	Sodium Octanoate
HCTAB	HexadecylTrimethyl Ammonium Bromide
PVP	Polyvinyl Pyrrolidone
HTF	Heat Transfer Fluid

CHAPTER 1

INTRODUCTION

Usually conventional heat transfer fluids such as water, engine oil, and ethylene glycol (EG) possess poor thermal properties. This problem can be overcome by dispersing small particles with high thermal conductivity in these conventional fluids. Earlier studies associated with the dispersion of micrometer sized particles but they exhibited problems with dispersion and flow. Later on, Choi [1] developed nanoparticles and reported an enhancement in thermal conductivity with the dispersion of nanoparticles in conventional heat transfer fluids. The fluids that contain nanosize particles are termed as nanofluids. These fluids found to possess substantially higher thermal conductivities compared to the base fluids. Because of their improved thermal properties, nanofluids are used in various applications such as micro-electronics, transportation, manufacturing, and bioengineering.

A new technique is needed to improve the existing cooling performance of heavy vehicle engines. Most of the automobiles utilize a heat exchanger device, termed as radiator, to remove the heat from the cooling jacket of the engine. The radiator is a part of the cooling system of the engine. It may be noted that the addition of nanoparticles to the standard engine coolant may improve the cooling performance of automotive radiator and heavy-duty engine. This improvement in heat removal rate by utilizing nanofluids could reduce the size of the cooling system resulting in increase in the fuel economy. In addition, the smaller size could reduce the drag and leading to lesser fuel consumption.

1.1OBJECTIVE AND SCOPE

The objective of this project is to study the heat transfer enhancement carried out on an automobile radiator when water, Al_2O_3/Water, CuO/Water Nanofluids are used as coolants. The nanofluids are used in the concentrations of 0.01% and 0.1%. The selection of 0.01% as a concentration is to study whether any significant heat transfer enhancement is done in this concentration. The effects of variations in coolant flow rate and temperature are also studied. Coolant flow rates upto 4L/min are studied. The water in the sump tank is heated to temperatures upto 60^oC before circulating it in the apparatus.

The heat Transfer Enhancement is studied by studying the heat Transfer Parameters like,

1. Heat Transfer Coefficient
2. Nusselt Number
3. Absolute Viscosity
4. Reynolds Number

The following graphs shall be plotted and analysed to this effect.

1. Nusselt Number v/s Reynolds Number for different Concentrations and Nanofluids
2. Viscosity v/s Temperature for different Nanofluids
3. Heat Transfer Enhancement v/s Concentration

CHAPTER 2

LITERATURE REVIEW

A literature review has been conducted at the start of the project in orderto obtainuseful information about the works performed similar to our project topic. Some of them were dealing with the nanofluid preparation and some of them were dealing with the heat transfer enhancement using nanofluids.The List of the collected papers, referred text books and manuals are given below.

Stephen Choi et al. (1) describes the path of the nanofluids from vision to reality. It summarizes the 15 year old history of the emergence of nanofluids as a new field of inquiry.Nanofluids are the most recent approach in more than a century of work to improve the thermal conductivity of liquids. The low thermal conductivity of conventional heat transfer fluids is a serious limitation in improving the performance and compactness of engineering equipment. What began with millimetre-to-micrometre sized particles in the late 19th century has become a part of the modern adventure into the new realm of the very small: the world of nanoparticles. Specifically, nanofluids are a new class of nanotechnology-based heat transfer fluids that are engineered by stably suspending a small amount 1 vol% or less of particles, fibres, or tubes with lengths on the order of 1–50 nm in traditional HTFs. The concept and the term were proposed by Choi in the early 1990s.

Sandesh S. Chougule , S. K. Sahuetal et al. (3) studiedthe forced convective heat transfer performance of two different nanofluids, namely, Al_2O_3-water and CNT-water has been studied experimentally in an automobile radiator. Four different concentrations of nanofluid in the range of 0.15–1 vol. % were prepared by the additions nanoparticles into the water as base fluid. The coolant flow rate is varied in the range of 2 l/min–5 l/min. Nanocoolants exhibit enormous change in the heat transfer compared with the pure water. The heat transfer performance of CNT-water nanofluid was found to be better than Al_2O_3-water nanocoolant. Furthermore, the Nusselt number is found to increase with the increasein the nanoparticle concentration and nanofluid velocity.

A nanofluid is a fluid produced by dispersion of metallic or non-metallicnanoparticles or nanofibers with a basefluid such as water. Nanofluids have attracted huge interest latelybecause of their greatly enhanced thermal properties. For instance,experiments showed an increase for thermal conductivity by dispersionof less than 1% volume fraction of Cu nanoparticles or carbonnanotubes in ethylene glycol or oil by 40% and 150%, respectively typical size of less than100 nm in a liquid. Because of their improved thermal properties, nanofluids are usedin various applications such as micro-electronics, transportation,manufacturing, and bioengineering.

2.1NANOFLUID PREPARATION METHODS

Preparing a stable and durable nanofluid is a prerequisite optimizingits thermal properties. Therefore, many combinations ofmaterial might be used for particular applications, namely nanoparticlesof metals, oxides, nitrides, metal carbides, and other non-metalswith or without surfactant molecules which can bedispersed into fluids such as water, ethylene glycol, or oils. Inthe stationary state, the sedimentation velocity of small sphericalparticles in a liquid follows the Stokes law which reveals a balance of thegravity, buoyancy force, and viscous drag that are acting on the suspendednanoparticles. The following measurescan be taken to decrease the speed of nanoparticles’ sedimentationin nanofluids, and henceforth to produce an improvement for thestability of the nanofluids: (1) reducing the nanoparticles size (2) increasing the base fluid viscosity and (3) lessening the differenceof density between the nanoparticles and the base fluid, clearly reducing the particle size should remarkably decreasethe sedimentation speed of the nanoparticles and improve the stability of nanofluids. According to the theory in colloid chemistry, when the size ofparticle decreases to a critical size, no sedimentation will takeplace because of the Brownian motion of nanoparticles (diffusion).However; smaller nanoparticles have a higher surface energy, increasing the possibility of the nanoparticle aggregation. Thus,the stable nanofluids preparation strongly link up with applyingsmaller nanoparticles to prevent the aggregation process concurrently.

Two different techniques apply to produce nanofluids namely single-step and two-step method.

2.1.1 Two-step technique

In this method, dry nanoparticles/nanotubes are first produced,and then they are dispersed in a suitable liquid host, but as nanoparticleshave a high surface energy, aggregation and clustering areunavoidable and will appear easily. Afterward, the particles willclog and sediment at the bottom of the container. Thus, making ahomogeneous dispersion by two step method remains a challenge.However, there exist some techniques to nullify this problem likehigh shear and ultrasound. Therefore, we will discuss differentmethods of making a stable nanofluid in the next section. Nanofluidscontaining oxide particles and carbon nanotubes are producedby this method. This method works well for oxide nanoparticlesand is especially attractive for the industry due to its simple preparingmethod. But its disadvantage due to quickly agglomeratedparticles brings about many challenges nowadays. As nanoparticlesdisperse partially, dispersion is poor and sedimentation happens, so a high volume concentration is needed for increasing theheat transfer (10 times of single step) and accordingly the costwould be as much as loading. The two-step method is usefulfor application with particle concentrations greater than 20 vol. %but it is less successful with metal nanoparticles. However, somesurface treated nanoparticles showed excellent dispersion.

The first materials tried for nanofluids preparation were oxide particles,mainly because they are easy to make and chemically stable in solution.

2.1.2. Single step technique

In this method nanoparticle manufacturing and nanofluid preparationare done concurrently. The single-step method is a processcombining the preparation of nanoparticles with the synthesis ofnanofluids, for which the nanoparticles are directly prepared byPhysical VapourDeposition (PVD) technique or a liquid chemicalmethod (condensing nanophase powders from the vapour phasedirectly into a flowing low-vapour–pressure fluid is called VEROS).

In this method drying, storage, transportation, and dispersion of nanoparticles are avoided, so the agglomeration of nanoparticles isminimized and the stability of the nanofluids is increased. A disadvantageof this method is that it is impossible to scale it up forgreat industrial functions and is applicable only for low vapour pressurehost fluids. This limits the application of the method. Recently, Chang et al.prepared nanofluids ofTiO_2 nanoparticles dispersed in water by a one-step chemicalmethod using a high pressure homogenizer. This method is calledmodified magnetron sputtering.

2.2 IMPORTANCE OF THE STABILITY OF NANOFLUID

Preparing a homogeneous suspension is still a technical challengedue to strong van der Waals interactions between nanoparticlesalways favouring the formation of aggregates. To obtainstable nanofluids, some methods are recommended, such as physicalor chemical treatment. They are listed as the addition of surfactant,surface modification of the suspended particles or applyingpowerful forces on the clustered nanoparticles. Spreading surface-active agents have been used to modify hydrophobic materialsto enable dispersion in an aqueous solution.Otherwise clogging, aggregation and sedimentation happen andcause declining of suspension characteristics like thermal conductivity,viscosity and increasing specific heat.

There exists a theory that clustering and aggregation is one ofthe main features in stability and extraordinary enhancement inthermal conductivity of nanofluids although this theorymay be highly specific to the high aspect ratio nanoparticles,including single wall nanotubes. The high aspect ratio structure of the fractal-likeaggregates is a key factor allowing rapid heat flow over large distances. Well dispersed composites show low thermal conductivityenhancement but composites with fractalaggregates show significant enhancements, even with considerableinterfacial resistance. Gharagozloo and Goodson also measuredfractal dimensions for the 1%, 3% and 5% volume concentrationsof Al_2O_3 in H_2O and concluded that aggregation is a morelikely cause for the measured enhancements of nanofluid. Contrarily,another theory shows that agglomeration and clustering reducestability and thermal conductivity improvement. Hong et al.(7)claimed that ultrasonicated Fe nanofluids, due to theirbroken clusters, got enhancement in thermal conductivityalthough this enhancement reduced as a function of elapsed timeafter production. Therefore, for classification of the stability theorymore experimental works are needed to clarify the role of aggregationin conductivity enhancement. But generally, to obtain a highqualitysuspension, small particles have to meet these two principles:(1) diffusion principle: particles are scattered by a liquidmedium and dispersed into the liquid medium. (2) Zeta potentialprinciple: the zeta potential absolute value among particles mustbe as large as possible, making a common repulsive force between the particles.

According to the literature, there are three effective tactics usedto manage stability of suspension against sedimentation of nanoparticles.Some of the researchers applied all of these methods togain better stability but others just applied oneortwo techniques with satisfaction. There is no standard torecognize the superlative mix up of combining methods. This areaacquires more experiments to be clarified. The techniques are summarized below:

2.2.1. Surfactant or activator adding

This is one of the general methods to avoid sedimentation ofnanoparticles. Addition of surfactant can improve the stability ofnanoparticles in aqueous suspensions. The reason is that thehydrophobic surfaces of nanoparticles/ nanotubes are modified tobecome hydrophilic and vice versa for non-aqueous liquids. Arepulsion force between suspended particles is caused by the zetapotential which will rise due to the surface charge of the particles suspended in the base fluid. However, care should be takento apply enough surfactant as inadequate surfactant cannotmake asufficient coating that will persuade electrostatic repulsion andcompensate the van der Waals attractions.

Popular surfactants are sodiumdodecylsulfate (SDS),salt and oleic acid, cetyltrimethylammoniumbromide (CTAB), dodecyl trimethylammonium bromide(DTAB) and sodium octanoate (SOCT),hexadecyltrimethylammoniumbromide(HCTAB), polyvinylpyrrolidone (PVP)and Gum Arabic . Choosing the right surfactant isthe most important part of the procedure. It could be anionic, cationic or nonionic. The disadvantage of surfactant addition is for applications at thehigh temperatures as above 60^oC are thebonding between surfactant and nanoparticles can be damaged.Therefore, the nanofluid will lose its stability and sedimentationof nanoparticles will occur.

2.2.2Ultrasonic vibration

All the mentioned techniques aim to change the surface propertiesof suspended nanoparticles and to suppress forming clusters ofparticles, with the purpose of attaining stable suspensions. Ultrasonicbath, processor and homogenizer are powerful tools forbreaking down the agglomerations in comparison with the otherslike magnetic and high shear stirrer as experienced by researchers.However occasionally after passing the optimized duration ofthe process, it will cause more serious problems in agglomerationand clogging resulting in fast sedimentation. Furthermore, there isa new method to get stable suspensions proposed by Hwang et al.(6)which consists of two micro-channels, dividing a liquid streaminto two streams. Both streams are then recombined in a reactingchamber. Breaking the clusters of nanoparticles was studied usingthe high-energy of cavitations. This work was conducted forCarbon Black with water and silver with silicon oil nanofluids.When the suspension contacted with the interior walls of theinteraction chamber, it will flow through the microchannel. Therefore,the flow velocity of the suspension through the microchannelshould be increased according to Bernoulli’s theorem, and concurrentlycavitations extensively occurred. In this fast flow region,particle clusters must be broken by the combination of variousmechanisms, including (i) strong and irregular shock on the wallinside the interaction chamber, (ii) microbubbles formed by cavitation induced exploding energy, and (iii) high shear rate of flow.This leads to obtain homogeneous suspensions with fewer aggregatedparticles at high-pressure. This procedure can be repeated a number of three times to achieve the required homogeneousnanoparticle distribution in the base fluid.

An ultrasonic disruptor is a more general accessible apparatusthan the one prepared by Hwang et al.(6) Many researchers usedthis technique to obtain a stable nanosuspension. In some cases,they mixed different methods of stabilization to fine-tune the results.Althoughit was noted that typically it is rare to maintain nanofluids synthesized by the traditional one-step and two-step methods in a homogeneous stable state for more than 24 h we gathered.

2.3EQUATIONS

Eqn 1. The volume concentration is evaluated from the following relation in percentage:

$$\emptyset = \frac{\textbf{Volume of nanoparticle}}{\textbf{Volume of nanoparticle} + \textbf{Volume of base fluid}}$$

Eqn 2. Specific Heat of nanofluid is given by,

$$\mathbf{C_{nf}} = \frac{\emptyset \boldsymbol{\rho}_\mathbf{p} \mathbf{C_p} + (\mathbf{1} - \emptyset)\boldsymbol{\rho}_\mathbf{bf} \mathbf{C_{bf}}}{\boldsymbol{\rho}_\mathbf{nf}}$$

Eqn 3. Density of nanofluid is given by,

$$\boldsymbol{\rho}_\mathbf{nf} = \boldsymbol{\rho}_\mathbf{p} + (\mathbf{1} - \emptyset)\boldsymbol{\rho}_\mathbf{bf}$$

Eqn 4. Thermal Conductivity of Nanofluid is given by,

$$\mathbf{k_{nf}} = \frac{\mathbf{k_p} + \mathbf{2k_{bf}} - \mathbf{2}\emptyset(\mathbf{k_{bf}} - \mathbf{k_p})}{\mathbf{k_p} + \mathbf{2k_{bf}} + \emptyset(\mathbf{k_{bf}} + \mathbf{k_p})}\mathbf{k_{bf}}$$

Eqn 5. Reynolds No. is given by,

$$\mathbf{Re} = \frac{\mathbf{Q_{vol}D}}{\boldsymbol{\upsilon}\mathbf{A}}$$

Eqn 6. Kinematic Viscosity is given by,

$$\boldsymbol{\upsilon} = \frac{\boldsymbol{\mu}}{\boldsymbol{\rho}}$$

Eqn 7. Heat Transfer is given by,

$$Q_{heat}=hA_sT=hA_s(T_b-T_w) \quad \text{----(1)}$$

Where,

Eqn (7.i) Bulk temperature is given by,

$$T_b=(T_{in}+T_{out})/2$$

Eqn (7.ii) Wall Temperature is given by,

$$T_w=(T_1+T_2+T_3+T_4)/4$$

Eqn 7(iii). Heat Transfer can also be found from

$$Q_{heat}=mC\Delta T=mC(T_{in}-T_{out}) \quad \text{----(2)}$$

Equating 1 and 2, we gets value of h

Eqn (8). Nusselt Number is then given by,

$$Nu_{exp}=hD/k$$

CHAPTER 3

METHODOLOGY

3.1 PROJECT PLANNING

Project Stages	
Phase 1	Semester 7 (July to November 2014)
Literature Review	August- October
Availability of Equipment	September
Familiarisation of equipment	September - October
Nanofluid Testing	October
Design Review	November
Phase 2	Semester 8 (November 2014 to March 2015)
Procurement of Design Components	November- December
Project Fabrication	December 2014- January 2015
Project Test Running	January 2015
Running of Project	February
Observations and Measurement	February
Analysis of Data	February- March
Analysis of Results	March
Project Report	March

Table 1

3.2 PROJECT DESIGN

The schematic diagram of the project design given below:

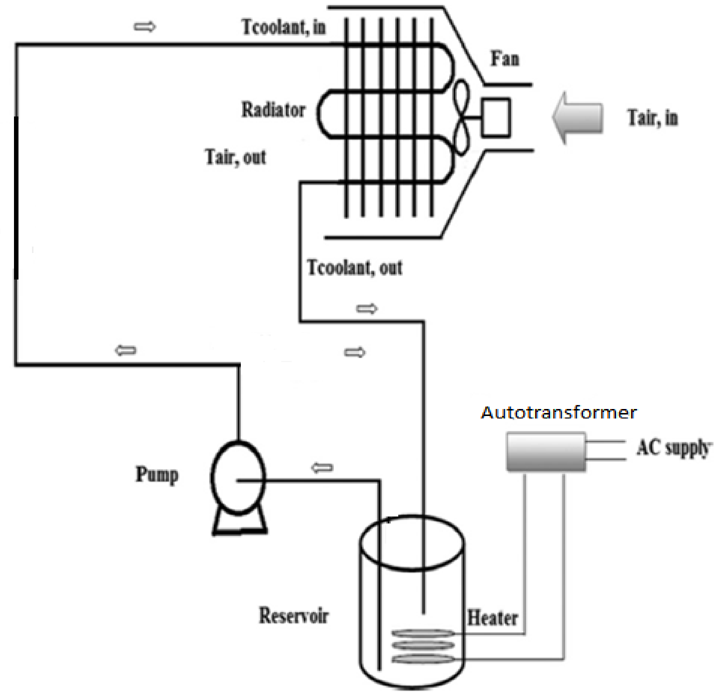

Fig .1

The test facility consists of

1. The Test Section
2. AC-Power Supply with Autotransformer
3. Coolant Supply System
4. Cooling and Instrumentation scheme for measuring the temperature.

The following materials are required directly in the construction of the apparatus

1. Radiator
2. Fan
3. Temperature controller
4. Pump.
5. Reservoir
6. Heater

In addition, the materials required for preparation of Nanofluids are

1. Al_2O_3 Nanopowder
2. CuO Nanopowder
3. Distilled Water

Al_2O_3 Nanofluid of 0.01% and 0.1% concentration are prepared using Al_2O_3nanopowder and deionized water. CuO Nanofluid of 0.01% and 0.1% concentration are prepared using CuOnanopowderand deionizedwater.

Various equipment used areas follows

1. Viscometer with water bath
2. Ultrasonic Shaker
3. Digital Mass Balance
4. Standard Laboratory equipment like test tube, beaker etc.

3.3DESIGN SPECIFICATIONS OF COMPONENTS

3.3.1 Automobile Radiator

An Automobile Radiator which is a cross flow heat exchanger is selected as a test section for the present investigation. This automobile radiator model in good condition is capable of handling a flow rate of around 4L/min.

The radiator specifications are

Fig. 2

Total tube length	531.3cm
Inner diameter	6mm
Cross Sectional Area	0.28sq.cm
Surface Area	1001.48sq. cm
Volume	150.22 mL

Table 2

Fig. 3

3.3.2 Reservoir

A storage tank of 6L capacity is used to store working fluid.

3.3.3 Pump

A centrifugal pump is used to supply coolant from the storage tank to the inlet of the test section. The outlet supply from the test section is sent back to thestorage tank and used to re-circulate through the test section. The pump is to be able to generate flow rates of around 1L/min to 4L/min and its characteristics are 0.5 HP,240 volts, 2.5Amps, 50 Hz and 2800rpm. It is capable to produce a head of 30 m and displacement of 35 litres/min.

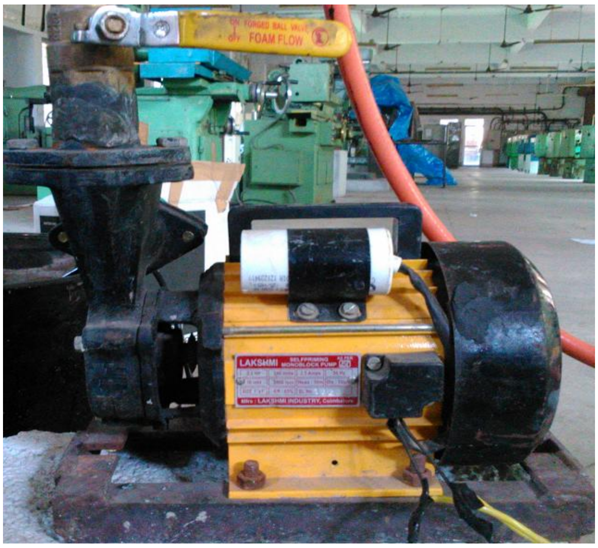

Fig. 4

Fig.5

3.3.4 Heating Element

Fig. 6

An electrical power supply (220 V, 15 A) ac is provided to the heating element (1.5 kW) in order to heat the coolant in the storage tank. The heating element were connected via an Autotransformer**.**

Fig. 7

3.3.5 Temperature Sensors

Four calibratedRTD PT100 type temperature sensors with a precision of 0.1°C are mounted on the test section to measure outside walltemperature. Two calibrated RTD PT100 type temperature sensorsare located at inlet and outlet of the test section to measure the temperature of the working fluid. In addition, one RTD PT100type temperature sensor was used to measure the temperature of coolant in the storage tank.

Fig. 8

3.3.6 Fan

A fan that provides constant air supply should be used to cool the coolantthrough the radiator. Also, it is preferable if the fan comes inbuilt with the radiator.

(Ac motor supply ,230 volts,50 HZ,1 phase ,Output 35 watts)

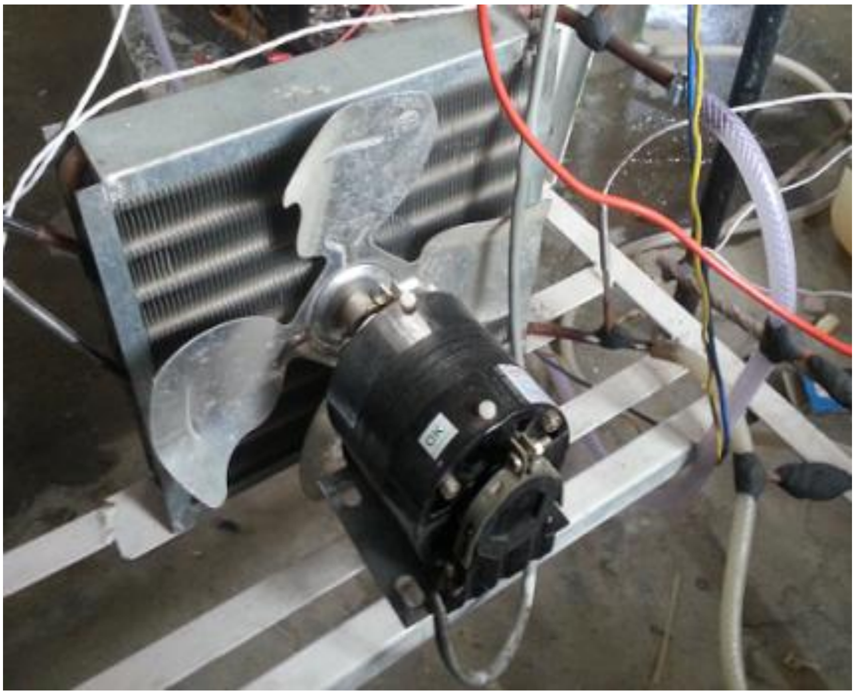

Fig. 9

3.3.7 Viscometer with water bath

Viscometer available for measuring viscosity is a Brookfield Viscometer (DV2TLVCJO), manufactured at Brookfield Laboratories, U.S.A.

It is really importantto clean and dry the sample holder before each measurement, in order to remove all settled particles to previous samples. After that nanofluid should be ready (homogenous with all particles well dispersed through Sonication process) to be injected inside the metallic sample holder and put into the water bath at the desired temperature.After 20-30 minutes time for stabilization, measurement can be noted. It is essential to do the auto zeroing process before starting the measurements.

Fig.10

Water bath is designed to take care of the heating and cooling applications. It uses a microprocessor based technology. It is fitted with a powerful pump and incorporates a heater to take care of the fast heating rates. The refrigeration system is strong to helpachieve fast cooling times. A sample of the result obtained is as follows.

4:09 PM 03/04/ 15

Results Table

Unsaved Data

Point # 1

Viscosity	0.80 cP
Torque	52.2 %
Speed	200 RPM
Temperature	49.5 °C
Time	00:01:00.0
SS	1.20 N/m²
SR	1,500 1/s
Density	0 kg/m³
Accuracy	0.02 cP

Fig. 11

3.3.8 Electronic Weighing Machine

ElectronicWeighing machine used for weighing the accurate amount ofnanopowder and binder for preparing specified concentrations of nanofluid. Before weighing it is important to make it correct by adjusting the supporting legs and then press the tare button .It is performed to neglect the weight of the paper. It is better to keep the side glasses in the closed condition during measurement

Fig.12

3.3.9 Ultrasonic cleaner

The Ultrasonic cleaner used for the preparation of nanofluids , manufactured by ANM Industries. It works based on a method known as ultrasonic cleaning. Ultrasonic cleaning is a method based on high frequency sound waves which when travelling into a solution ,creates oscillating high and low pressure and consequently ,causes the rapid formation and imploding bubbles radiate tremendous amounts of ultrasonic energy and shock waves. This is used for the preparation of nanofluids .A better Sonication requires 2 hours.It has a built in drain valve unit and a digital display to read the operation status easily .

Fig.13

3.4EXPERIMENTAL PROCEDURE

3.4.1.Dimension Measurement Process

The entire setup was divided into to 4 parts, and the dimensions such as length & diameters are measured using scale &vernier caliper. The volumes of the individual parts were computed and summed. After accounting for various errors, and imperfections in shape, the total volume to be occupied in the apparatus was found to be 2 Litres.

The dimensions of the Test Section are as follows.

Total tube length	531.3cm
Inner diameter	6mm
Cross Sectional Area	0.28sq.cm
Surface Area	1001.48sq. cm
Volume	150.22L

3.4.2. Preparation of Nanofluids

First, we weigh the required amount of Nanoparticles in the weighing balance. Then the nanoparticles are added into deionized water. If the mixture is not found to be stable, suitable binder is added. The viscosity Tests are also carried out for samples of nanofluid in Viscometer. In this manner 0.1% and 0.01 % of Al_2O_3-Water nanofluids were prepared. For preparing CuO-Water Nanofluid a suitable binder called SDS (Sodium n-dodecyl sulfate,99.5% ultrapure) was used.

Fig. 14

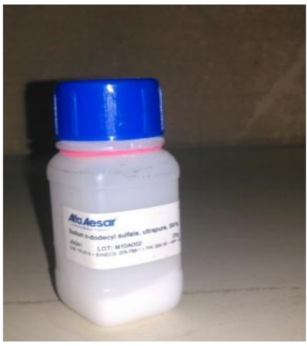

Fig. 15

Fig.16

Alumina/water nanofluids

Water **0.01alumina/water** **0.1alumina/water**

Fig 17

Copper/water nanofluids

.1 CuO/water **.01 CuO/water**

Fig 18

3.4.3 Running of Experimental setup

The experimental was first tested with water and then nanofluids were used different flow rates and varied upto 4L/ min. The immersion rod type heater which is supplied by regulated power through an autotransformer heats the coolant. The variation of temperature is measured by RTDs placed at different distances along the radiator tube. The flow rate is measured with the help of a measuring jar and stop watch.

Fig 19

3.4.4 Analysis of Data

With the help of spreadsheet program – MS Excel, the data obtained was tabulated and different calculations were performed to find the Nusselt number, Heat transfer coefficient, Reynolds Number, etc. The following graphs were also plotted.

1. Viscosity v/s Temperature for different Nanofluids
2. Nusselt Number v/s Reynolds Number for different Concentrations and Nanofluids
3. Heat Transfer Enhancement for Different Nanofluids

CHAPTER 4

RESULTS - TABLES AND GRAPHS

4.1 OBSERVATIONS

The values of Heat Transfer Coeeficient, Nusselt number, etc were calculated from the measured values and is as follows.

Water

Water							
Flow Rate (L/min)	**Bulk Temp** (^oC)	**Wall Temp.** (^oC)	**Heat TransferCoeff.** (W/m^{2}K)	**Thermal Conductivity** (W/mK)	**Nusselt No**	**Kinematic Viscosity** (m^2/sec)	**Reynolds No**
0.43	50.95	45.00	512.48	0.64	4.80	5.59E-07	2747.27
0.91	53.05	45.93	553.45	0.64	5.16	5.40E-07	6016.26
1.37	54.05	47.43	611.35	0.64	5.69	5.31E-07	9210.04
2.10	56.35	48.28	660.87	0.65	6.13	5.11E-07	14686.66
3.00	56.95	48.40	746.79	0.65	6.91	4.95E-07	21628.20

Table-3

Flow Rate	**Inlet Temp**	**Outlet Temp**	**T2**	**T3**	**T4**	**T5**	**T6**	**Bulk Temp**	**Wall Temp**	**Tin-Tout**	**Tb-Tw**
0.43	56.1	45.8	51.6	44.1	43.2	41.1	59.9	50.95	45	10.3	5.95
0.91	56.2	49.9	50.1	44.1	45.3	44.2	60	53.05	45.925	6.3	7.125
1.37	56.2	51.9	51.4	45	47.2	46.1	59.9	54.05	47.425	4.3	6.625
2.1	58.2	54.5	50.5	45.8	48.8	48	59.9	56.35	48.275	3.7	8.075
3	58.5	55.4	50.3	45.6	49.2	48.5	60.1	56.95	48.4	3.1	8.55

Table-4

T1 –Inlet Temp, T7-Outlet Temp, T6-Sump Temp

T2, T3, T4, T5 - Wall Temps

0.01 % Al_2O_3 – water Nanofluid

0.01 Alumina/ Water Nanofluid							
Flow Rate (L/min)	**Bulk Temp** (^oC)	**Wall Temp.** (^oC)	**Heat TransferCoeff.** (W/m^2K)	**ThermalConductivity** (W/mK)	**NuusseltNo**	**Kinematic Viscosity** (m^2/sec)	**Reynol No**
1.08	55.00	47.90	606.02	0.65	5.63	6.94E-07	5561.5
1.57	55.30	49.23	709.99	0.65	6.59	6.90E-07	8122.7
1.92	55.50	49.50	747.18	0.65	6.94	6.88E-07	9964.7
2.27	56.25	48.95	789.87	0.65	7.32	6.80E-07	11921.4
2.53	56.40	49.08	758.73	0.65	7.03	6.78E-07	13318.5
2.94	56.55	49.15	790.87	0.65	7.33	6.77E-07	15513.8
3.73	56.95	49.58	867.77	0.65	8.04	6.72E-07	19808.8

Table-5

Flow Rate	**T1**	**T7**	**T2**	**T3**	**T4**	**T5**	**T6**	**Bulk**	**Wall**
1.08	57.9	52.1	51.2	47	47.6	45.8	60	55	47.9
1.57	57.3	53.3	51.9	48	49.2	47.8	60.3	55.3	49.225
1.92	57.2	53.8	51.2	48	50.2	48.6	60	55.5	49.5
2.27	58.1	54.4	51.1	47.6	49.4	47.7	60	56.25	48.95
2.53	58	54.8	50.7	47.6	49.7	48.3	59.9	56.4	49.075
2.94	58	55.1	51	47.8	49.7	48.1	60.1	56.55	49.15
3.73	58.2	55.7	50.8	47.9	50.4	49.2	60.1	56.95	49.575

Table-6

T1 –Inlet Temp, T7-Outlet Temp, T6-Sump Temp

T2, T3, T4, T5 - Wall Temps

0.1 % Al_2O_3-Water Nanofluid

0.1 Alumina/ Water Nanofluid							
Flow Rate (L/min)	**Bulk Temp** (°C)	**Wall Temp** (°C)	**Heat Transfer Coeff.** (W/m2K)	**Thermal Conductivity** (W/mK)	**Nusselt No.**	**Kinematic viscosity** (m2/sec)	**Reynolds No.**
0.90	48.35	43.65	751.97	0.64	7.07	8.48E-07	3792.02
1.42	54.70	47.80	791.73	0.65	7.36	6.23E-07	8133.97
2.11	56.00	49.03	872.34	0.65	8.09	6.12E-07	12311.63
2.51	55.90	49.00	899.18	0.65	8.34	6.13E-07	14624.62
3.02	56.35	49.10	943.66	0.65	8.75	6.09E-07	17710.24
3.51	56.90	49.38	1024.42	0.65	9.49	6.04E-07	20748.16

Table-7

Flow Rate	**T1**	**T7**	**T2**	**T3**	**T4**	**T5**	**T6**	**Bulk**	**Wall**	**Tin-Tout**	**Tb-Tw**
0.9	51.2	45.5	46.1	42.9	43.3	42.3	60.2	48.35	43.65	5.7	4.7
1.42	57.5	51.9	50.6	46.4	47.8	46.4	59.8	54.7	47.8	5.6	6.9
2.11	58.1	53.9	51	47.5	49.4	48.2	60.2	56	49.025	4.2	6.975
2.51	57.7	54.1	50.7	47.4	49.7	48.2	59.8	55.9	49	3.6	6.9
3.02	58	54.7	50.3	47.3	50.1	48.7	59.9	56.35	49.1	3.3	7.25
3.51	58.5	55.3	50.7	47.4	50.4	49	60.2	56.9	49.375	3.2	7.525

Table-8

T1 –Inlet Temp, T7-Outlet Temp, T6-Sump Temp

T2, T3, T4, T5 - Wall Temps

0.01 CuO/Water Nanofluid

0.01 CuO/ Water Nanofluid							
Flow Rate (L/min)	**Bulk Temp** (^oC)	**Wall Temp.** (^oC)	**Heat Transfer Coeff** (W/m^2K)	**Thermal Conductivity** (W/mK)	**Nuusselt No**	**Kinematic Viscosity** (m^2/sec)	**Reyn.**
0.88	50.25	45.43	892.29	0.64	8.37	6.62E-07	4744.37
1.40	54.35	48.25	994.51	0.64	9.26	6.21E-07	8047.98
1.83	55.00	48.48	1041.38	0.65	9.68	6.15E-07	10631.54
2.40	55.90	49.10	1018.87	0.65	9.46	6.06E-07	14151.02
3.00	56.00	48.85	1095.84	0.65	10.17	6.05E-07	17718.14
3.54	56.85	49.43	1146.46	0.65	10.62	5.96E-07	21206.70

Table-9

Flow Rate	**T1**	**T7**	**T2**	**T3**	**T4**	**T5**	**T6**	**Bulk**	**Wall**	**Tin-Tout**	**Tb-Tw**
0.88	53.8	46.7	49.3	44.2	45	43.2	60.1	50.25	45.425	7.1	4.825
1.4	57.5	51.2	51.5	46.5	48.4	46.6	59.8	54.35	48.25	6.3	6.1
1.83	57.7	52.3	51.1	46.4	49.1	47.3	59.8	55.00	48.475	5.4	6.525
2.4	58	53.8	51.3	46.8	49.9	48.4	59.9	55.90	49.100	4.2	6.8
3.00	57.9	54.1	50.8	46.3	49.7	48.6	60.0	56.00	48.85	3.8	7.15
3.54	58.6	55.1	51.1	46.8	50.6	49.2	60.2	56.85	49.425	3.5	7.425

Table-10

T1 –Inlet Temp, T7-Outlet Temp, T6-Sump Temp

T2, T3, T4, T5 - Wall Temps

0.1 CuO/Water Nanofluid

0.1 CuO/ Water Nanofluid							
Flow Rate (L/min)	**Bulk Temp** (^oC)	**Wall Temp.** (^oC)	**Heat Transfer Coeff** (W/m^2K)	**Thermal conductivity** (W/mK)	**Nuusselt No**	**Kinematic Viscosity** (m^2/sec)	**Reynolds No**
1.06	54.30	49.65	1134.58	0.64	10.56	6.22E-07	6088.55
1.50	53.60	49.03	1224.27	0.64	11.41	6.29E-07	8519.57
1.85	54.95	50.00	1265.57	0.65	11.77	6.15E-07	10738.97
1.85	56.95	50.83	1324.55	0.65	12.27	5.95E-07	15001.75
1.85	56.65	51.58	1439.48	0.65	13.32	5.98E-07	17075.58
1.85	56.05	51.13	1549.96	0.65	14.35	6.04E-07	19801.70

Table-11

Flow Rate	**T1**	**T7**	**T2**	**T3**	**T4**	**T5**	**T6**	**Bulk**	**Wall**	**Tin-Tout**	**Tb-Tw**
L/min	**°C**	**°C**	**°C**	**°C**	**°C**	**°C**	**°C**	**°C**	**°C**	**°C**	**°C**
1.06	57.9	50.7	53.9	47.5	49.7	47.5	60	54.3	49.6	7.2	4.6
1.5	56.3	50.9	51.3	47.3	50.2	47.3	59.9	53.6	49.0	5.4	4.5
1.85	57.4	52.5	52.6	47.6	51.1	48.7	59.9	54.9	50.0	4.9	4.9
2.5	59.3	54.6	53.1	48.5	52.4	49.3	59.9	56.9	50.8	4.7	6.1
2.86	58.5	54.8	53.4	48.1	53.1	51.7	60	56.6	51.5	3.7	5.0
3.35	57.7	54.4	52.6	48.7	53.6	49.6	60.1	56.0	51.1	3.3	4.9

Table-12

T1 –Inlet Temp, T7-Outlet Temp, T6-Sump Temp

T2, T3, T4, T5 - Wall Temps

4.2SAMPLE CALCULATION

(For flow rate of 0.53)

1. **Bulk temperature, T_b** =(57.5+ 42.4)/2

=49.95 ^{0}C.

2. **Wall temperature,T_W** =($T_2+T_3+T_4+T_5$)/4

=(52.5+45.4+43.2+40.6)/4

=45.425 ^{0}C.

3. **Density of water at T_b** =990 kg/m^3
4. **Mass flow rate** = ((0.00053/60) x 990)

=8.745 x (1/1000) kg/sec.

5. **Specific heat capacity of water at (T_b** of 49.95) is 4180.5 J/kg ^{0}C.

6. **T_{in} -T_{out}** = 15.1^{0}C
7. **T_B-T_W** = 4.525 ^{0}C.

8. **A**= surface area of the tube and is equal to 1001.48 x (1/10^4) m^2

9. **Heat transfer coefficient ,h**

= (mass flow rate x specific heat x (T_{in}-T_{out}))/(surface area x (T_b-T_w))

10. Using these equation value of h can be obtained , h = 558.07/0.453

=1218.48

(Thermal conductivity at T_b =49.95 is k = 0.6396 (from HMT data book))

11. **Nusselts number,**

=(Heat transfer coefficient x hydraulic diameter)/ Thermal conductivity
=(1218.8 x 0.006)/.63965 =11.482

12. **Reynolds number**

= (volumetric flow rate x hydraulic diameter)/(kinematic viscosity x cross sectional area)

13. **cross sectional area** =0.28 cm^2

14. **kinematic viscosity at T_b**=0.56 x (1/10^6) m^2/s (from property tables)

15. **volumetric flow rate**

=(0.53/(60 x 1000))
=8083 x (1/10^6) m^3/ sec

16. **Now, Reynolds number**

=(8083 x (1/10^6) x 0.006)/(0.56 x (1/10^6) x 0.28 x (1/10^4)) =3378.83

4.3**GRAPHS**

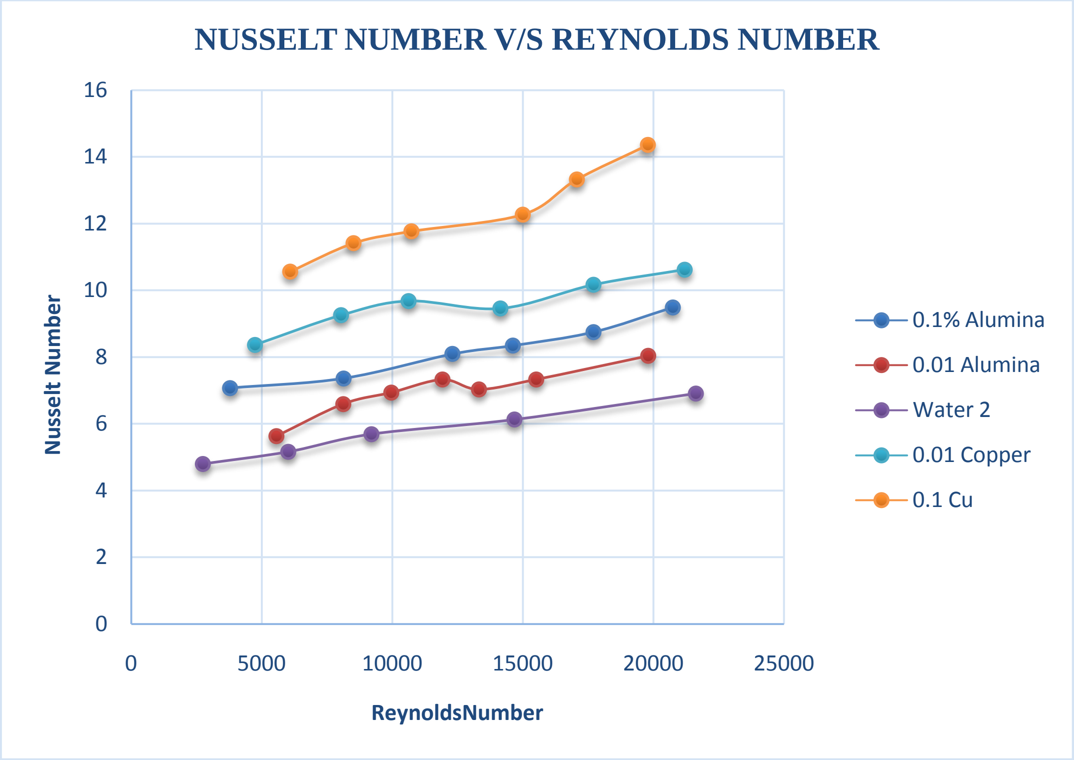

Fig. 20

1. In the Nusselt No. v/s Reynolds No. graph, the increase in Nusselt No. clearly indicates better heat transfer.
    - Nusselt number clearly increases with Reynolds number.
    - Water occupies the bottom spot, and Alumina Nanofluid is found to have better Nusselt number than water, CuO/Water nanofluid has even better Nusselt number
    - As concentration increases, Nusselt number further increases.

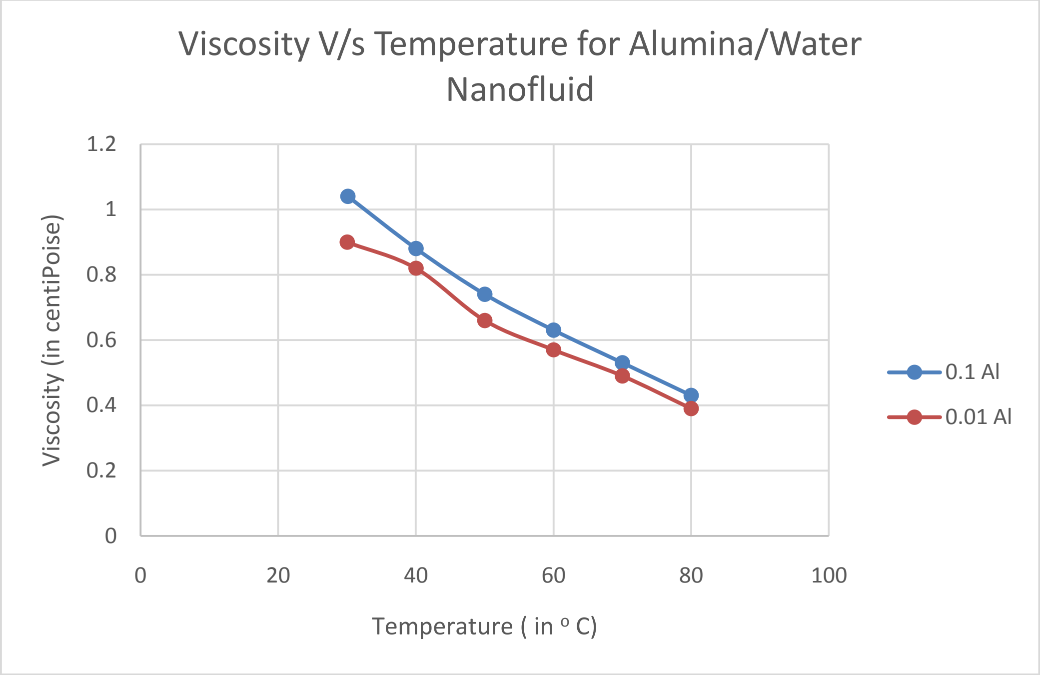

Fig 21

2. Viscosity v/s Temperature Graph
    - As temperature increases, viscosity decreases

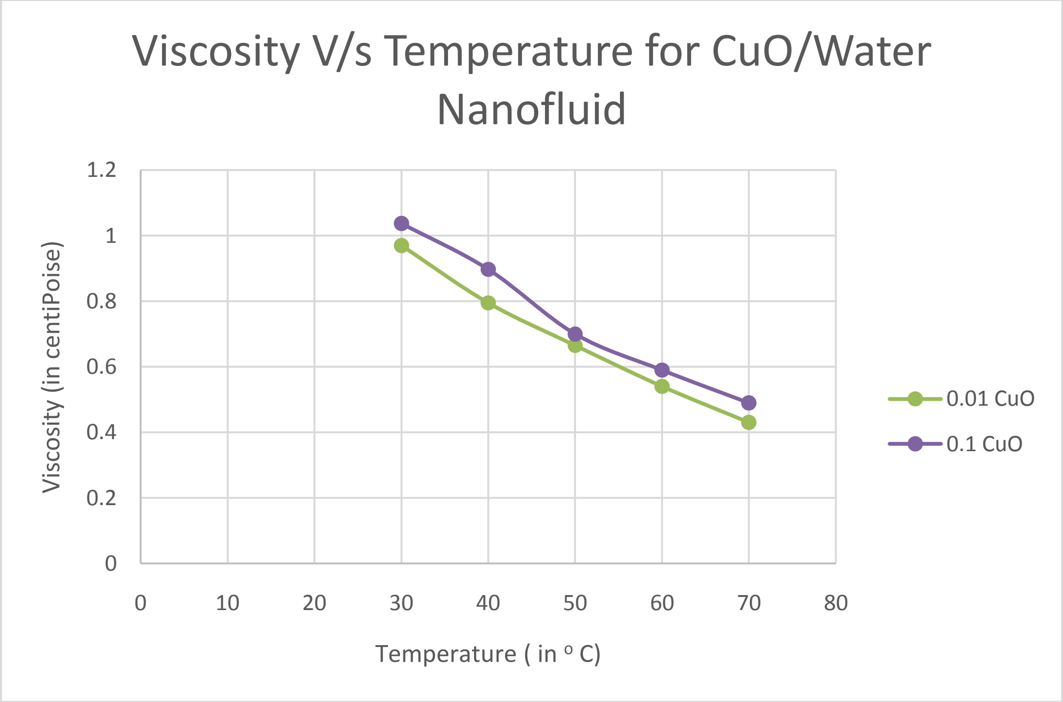

Fig.22

3. In heat transfer Enhancement Graph, in which enhancement is calculated with respect to water, 0.01% Alumina nanofluid has recorded a heat transfer enhancement of 6.86%, while 0.1 % Alumina nanofluid has recorded 26.41%. Similarly, CuO/Water nanofluid at 0.01 and 0.1% has recorded 47.20 and 97.32 % heat transfer enhancement respectively.

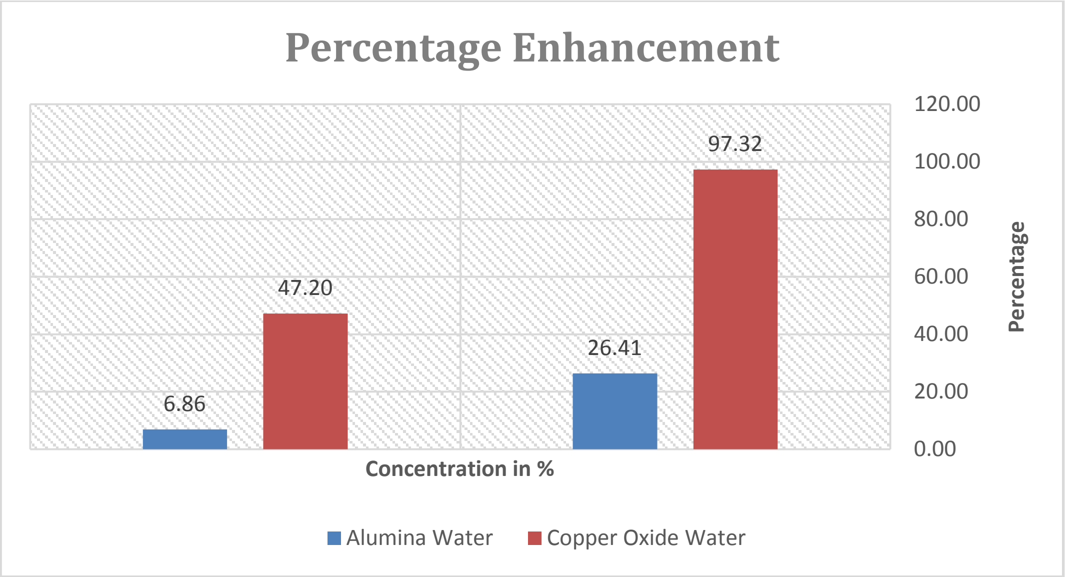

Fig. 23

The LHS signifies the 0.01% concentration and RHS signifies the 0.1% concentration.

CHAPTER 5

CONCLUSION

Our project work to find out the heat transfer improvements (in forced convective heat transfer) while using Al_2O_3/H_2O and CuO/H_2O nanofluid in the concentrations of 0.01 and 0.1 percentages, was successful as is evident from the conclusion which can be drawn from the graphs as follows.

1. In the Nusselt No. v/s Reynolds No. graph, the increase in Nusselt No. clearly indicates better heat transfer.
   a. Nusselt Number clearly increases with Reynolds Number.
   b. Water occupies the bottom spot, and Alumina Nanofluid is found to have better Nusselt number than water, CuO/Water nanofluid has even better Nusselt No.
   c. As concentration increases, Nusselt No. further increases.

Increasing Nusselt number is undisputedly a testimony to the fact that heat transfer is increasing. Increasing flow rate clearly increases heat transfer, and when more of nanoparticles are present in water, heat transfer increases. Thus these nanofluids at higher concentrations can be employed in automobile radiators.But these radiators should beredesigned for the application of nanofluids. This redesign is very important, as when more heat transfer can be achieved, and then number of turns of tube and the size of radiator itself can be reduced, asrequired heat transfer is achieved within a small radiator. This can give the vehicles more aerodynamic shape, reducing drag and increasing the performance of the automobile as a whole.

2. Viscosity v/s Temperature Graph
   a. As temperature increases, viscosity decreases

Though this well established fact has been verified once again, this decreasing viscosity contributes to decreasing Reynolds number which further makes the Nusselt Number v/s Reynolds Number Graph more favourable for our result, i.e., higher Nusselt Number as flow and temperature increases.

3. In heat transfer Enhancement Graph, in which enhancement is calculated with respect to water, 0.01% Alumina nanofluid has recorded a heat transfer enhancement of 6.86%, while 0.1 % Alumina nanofluid has recorded 26.41%. Similarly, CuO/Water nanofluid at 0.01 and 0.1% has recorded 47.20 and 97.32 % heat transfer enhancement respectively.

This shows that our choice of the concentration of nanofluids, i.e., 0.01 % and 0.1% are relevant, especially for CuO/Water nanofluid in which high enhancement to the values of 47% and 97% were recorded. This would imply that even a small concentration of nanofluids can be employed in Automobile Radiators and this would mean smaller costs of preparation of these nanofluids. Hence, the running cost of vehicles need not increase to a large extent.

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