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COOLING PERFORMANCE OF AUTOMOBILE RADIATOR USING NANOFLUIDS CuO-WATER AND COMPARING IT WITH Al_2O_3-WATER

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ABSTRACT:

Today it is a great challenge for automotive industries to provide an efficient and economical engine. Various systems like fuel supply system, lubrication system, transmission system, cooling system etc. affects the performance of an engine. Cooling system is one of the important system. It carries large amount of waste heat to surroundings for efficient working of an engine. Most of the I.C. engines are fluid cooled using either air or liquid coolant run through a heat exchanger(radiator)which is cooled by air. The heat transfer through radiator can be increased by increasing heat transfer area and maximising heat transfer coefficient. Heat transfer coefficient can be raised by improving thermo physical properties of the coolant. Water was widely used as a coolant in earlier days. Later ethylene glycol along with water was introduced as a coolant.

The new generation of heat transfer fluids called NANO fluids have been developed with the advancement of nanotechnology. Researchers found that these fluids offer higher thermal conductivity compared to that of conventional coolants. So conventional coolants in engine cooling system can be replaced with Nano fluids. Nano fluids are potential heat transfer fluids with enhanced thermo physical properties and heat transfer performance. So these Nano fluids can be used in automobile radiator for better performance.

In the present study the cooling performance of CuO-Water nanofluid in an automobile radiator is to be studied and compared with Al_2O_3-Water nanofluid. Furthermore, the change in Nusselt number for different concentrations of nanoparticles is to be found and compared.

Keywords: Conventional coolant, CuO-Water nanofluid, Al_2O_3-Water nanofluid, Cooling performance

1.INTRODUCTION

The demand for high efficiency engines has been increased day by day because of continuous technological development in automotive industries. A high efficiency engine is named as if not only based on its performance but also for better fuel economy and less emissions. There are many systems which influence the engine performance like fuel supply system, ignition system, transmission system, cooling system etc. Cooling system in an engine plays a vital role for better performance of engine. It carries the huge amount of heat waste from engine to the surroundings. It cools the engine which in turn protecting the engine from wear and tear. The cooling performance of the engine cooling system can be improved by increasing the heat transfer area and by enhancing thermo physical properties of the coolant. The usage of fins which is a traditional approach of increasing the cooling rate has already reached to their limit. So, there is a need to concentrate on the properties of coolant.

Water was widely used as a universal coolant in earlier days. Later water along with ethylene glycol is introduced as a coolant. Both exhibit lower thermal conductivity.Single phase fluids such as water, ethylene glycol possess poor thermal properties. Some of the investigations proposed thatby dispersing small particles with higher thermal conductivity can improve thermal performance. But the dispersion of micrometre sized particles exhibited problems with dispersion and flow.

Nano Fluids:

The advancement of Nanotechnology provided the possibility to produce nanometre sized particles that eliminate the problems of dispersion and flow when dispersed in a liquid. The fluids in which these nanosized particles are suspended are called as Nano fluids. The nanometre sized particles may be metals, and their oxides, carbides,nitrides,metal nanotubes etc. The suspension of these particles in liquids coolants exhibited enhancement in thermal conductivity compared to conventional coolants. So these nanofluids can be used in automobile radiator to improve cooling performance.

This improvement in heat removal rate by using nanofluids could reduce the size of the cooling system and improved fuel economy. The smaller size could reduce drag leading to lesser fuel consumption. Therefore nanofluids seem to be the potential replacement for conventional coolants.

2. LITERATUREREVIEW

As there was a problem with the dispersion of micrometre sized particles in engine cooling system, Choi [1] developed nano particles and used in engine cooling system along with the coolant. The investigations reported an enhancement in thermal conductivity and heat removal rate. The addition of nano particles to the standard engine coolant may improve the cooling performance of the automobile radiator and heavy duty engine.

Kulkarni et al [2] studied the application of Al_2O_3-Water nanofluid in diesel electric generator as a jacket coolant and observed a reduction in cogeneration efficiency. The efficiency of waste heat recovery heat exchanger with nanofluid increased because of its superior convective heat transfer coefficient.

Vajjah et al [3] numerically studied the laminar flow and heat transfer behaviour of two different nanofluids namely Al_2O_3 and CuO in ethylene glycol water mixture by circulating it through flat tubes of automobile radiator.

Leong et al [4] reported the application of ethylene glycol based copper nanofluids in automobile cooling system. with the addition of 2% copper particles in a basefluid, the heat transfer enhancement is found to be 3.8%

Mintsa et al [5] investigated the effect of temperature, particle size and found that the smaller the particle size, the greater the effective thermal conductivity of the nanofluids at the same volume fraction.

Namburu et al [6] numerically analysed turbulent flow and heat transfer to 3 types of nanofluids namely CopperoxideCuO, AluminiumoxideAl_2O_3, SilicondioxideSiO_2 in ethylene glycol water mixture flowing through a circular tube under constant heatflux.Results revealed that nanofluids containing smaller diameter of nanoparticles produce higher viscoscity and Nusselt number.

3. OBJECTIVES

The main objectives of this study are:

Different concentrations of nanofluid in the range of 0 to10%vol were prepared by the addition of nano particles into the water as base fluid and the coolant flow rate is varied accordingly and the forced convective heat transfer performance of two fluids namely CuO-Water and Al_2O_3-Water is going to be studied. The cooling performance of two different fluids CuO-Water and Al_2O_3-Water is compared individually and compared with water. Furthermore, the change in Nusselt number is to be found with increase in nanoparticle concentration.

4. EXPERIMENTAL SET UP AND PROCEDURE

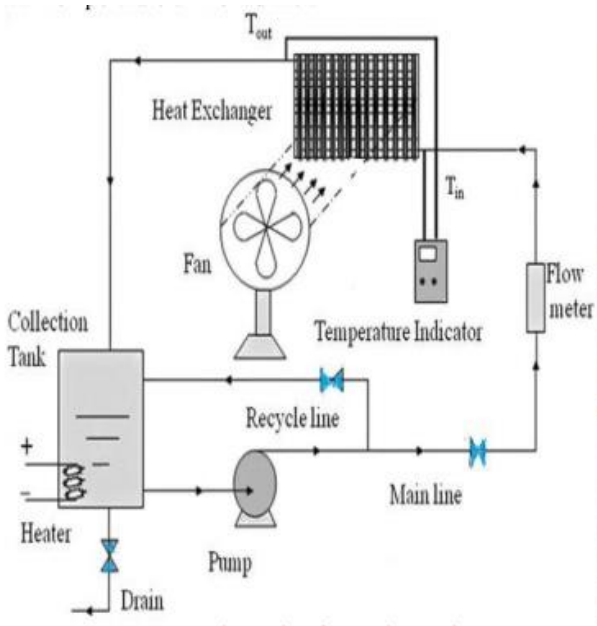
NANOFLUIDS PREPARATION:

Nano particles exhibit unique physical and chemical properties compared to those of larger particles of same material. The preparation of nanofluids is a two-step process. In the first step the particles are introduced as a dry powder and as prepared nano particles are then dispersed into a base fluid in second step. This two-step process can be used in many cases especially for oxides and non-metallic nanoparticles.

There may be certain degree of agglomeration in the process of nanoparticle preparation, storage and dispersion process and these agglomerates require very little energy to break up into smaller constituents. Even Agglomerated nano crystalline powders can be successfully dispersed into fluids and yields good properties.

In this experimentation, a two-step procedure was used for preparing nanofluid.Now the measured quantity of nano particles was taken and mixed thoroughly in water ethylene glycol mixture. The mixture was mixed uniformly with Mechanical stirrer. The mixture was kept in sonicator and subjected to vibrations so as to reduce problem of agglomeration. To check for sedimentation Nano fluid was kept still for two days. There was no appreciable sedimentation and if it occurs the mixture has to be stirred again. Then it will be turned into a uniform fluid with evenly suspended nano particles in it.

SCHEMATIC PICTURE OF EXPERIMENTAL SET UP



DESCRIPTION:

This test rig was designed to measure heat transfer coefficient of the coolant that is to be used in engine. This includes a reservoir plastic tank, an electric heater, a centrifugal pump, a flow meter, a fan , a DC power supply. Digital temperature sensors are used for temperature measurement.

An electric heater is kept inside a plastic storage tank which represents engine to heat the fluid. A voltage regulator is provided to regulate the inlet temperature to the radiator from 60 to 90°C. A flow meter and two valves are used to measure and control the flow rate. The total volume of the circulating fluid is 3L and is kept constant. Two thermocouples or temperature sensors are fixed on the flow line for recording inlet and outlet temperature of the fluid. Two more are fixed one in front of the fan and another side of the radiator to measure air temperature.

The radiator has 32 flat vertical aluminium tubes with flat cross sectional area. The distances among the tube rows are filled with thin perpendicular aluminium fins. For the air side, an axial fan is installed close on axis line of radiator. Two more temperature sensors are fixed on the air flow line to record radiator inlet and outlet temperature on air side.

EXPERIMENTAL READINGS AND FORMULAE USED:

TABLE 1: PHYSICAL PROPERTIES OF COPPER OXIDE

S.No	Property	Copperoxide	Basefluid
1	Thermal conductivity (W/mK)	400	0.605
2	Density(kg/m³)	8933	997.1
3	Specific Heat(J/kgK)	385	4195

TABLE 2:EXPERIMENTAL READINGS WHEN WATER ALONE IS ALLOWED TO PASS THROUGH RADIATOR

S.No	Coolant	Air velocity (m/s)	Mass flow rate (kg/s)	Inlet tube temperature (°c)	Outlet tube temperature (°c)	Inlet fin temperature (°c)	Outlet fin temperature (°c)	Heat Transfer (KW)
1	Water	3.2	2.45	85	77.05	29	79.33	83.36
2			3.35	85	79.32	29	80.52	85.63
3			4.15	85	80.21	29	81.55	89.23
1	Water	7.4	2.45	85	71.92	29	67.21	142.26
2			3.35	85	73.25	29	68.07	163.22
3			4.15	85	75.36	29	70.30	168.62
1	Water	11.5	2.45	85	69.25	29	62.67	170.41
2			3.35	85	70.35	29	65.32	205.27
3			4.15	85	72.05	29	66.3	226.52

TABLE 3 :EXPERIMENTAL READINGS WHEN 5% COPPER OXIDE IS MIXED WITH WATER AND USED AS COOLANT

S.No	Coolant	Air velocity (m/s)	Mass flow rate (kg/s)	Inlet tube temperature (°c)	Outlet tube temperature (°c)	Inlet fin temperature (°c)	Outlet fin temperature (°c)	Heat Transfer (KW)
1	Water + Copper oxide	3.2	2.45	85	74.8	29	81.3	90.85
2			3.35	85	77.08	29	82.34	96.63
3			4.15	85	78.31	29	83.48	102.03
1	Water + Copper oxide	7.4	2.45	85	68.925	29	70.02	145.15
2			3.35	85	70.65	29	71.57	169.8
3			4.15	85	73.38	29	72.3	173.27
1	Water + Copper oxide	11.5	2.45	85	65.18	29	64.75	177.49
2			3.35	85	67.18	29	67.56	211.22
3			4.15	85	69.6	29	68.72	229.21

TABLE 4 :EXPERIMENTAL READINGS WHEN 10% COPPER OXIDE IS MIXED WITH WATER AND USED AS COOLANT

S.No	Coolant	Air velocity (m/s)	Mass flow rate (kg/s)	Inlet tube temperature (°c)	Outlet tube temperature (°c)	Inlet fin temperature (°c)	Outlet fin temperature (°c)	Heat Transfer (KW)
1	Water + Copper oxide	3.2	2.45	85	72.55	29	83.33	98.34
2			3.35	85	74.84	29	84.15	107.64
3			4.15	85	76.40	29	85.41	114.83
1	Water + Copper oxide	7.4	2.45	85	65.93	29	72.82	148.03
2			3.35	85	68.05	29	73.08	176.38
3			4.15	85	71.4	29	74.30	177.92
1	Water + Copper oxide	11.5	2.45	85	61.10	29	66.82	184.56
2			3.35	85	64.01	29	69.83	217.17
3			4.15	85	67.12	29	71.14	231.91

Formulae used :

Volume conentration of nano fluid is calculated from the following relation in %,

Φ = [(Volume of nanoparticle) / (volume of nanoparticle+volume of base fluid)]*100

Density of the nano fluid is calculated by

ρnf = [1-ΦS] ρf + ΦS ρp,

Where Φs is the volume concentration of the nanofluid ,ρf is the density of the base fluid and ρp is the density of the nano particles

Specific heat of nanofluids is obtained through

Cnf = [φρp+ (1−φ) ρfCbf] / ρnf

Where Cbf is the specific heat of basefluid

The rate of heat transfer between nano fluid coolant and air flow in the radiator is given by,

Q = mnf Cnf (Tnfo –Tnfi) = h A (Tao – Tai)

Nusselt number is calculated by using formula,

Nu = **hdhy / k**

Where dhy is hydraulic diameter of radiator tube

5. RESULTS AND DISCUSSION

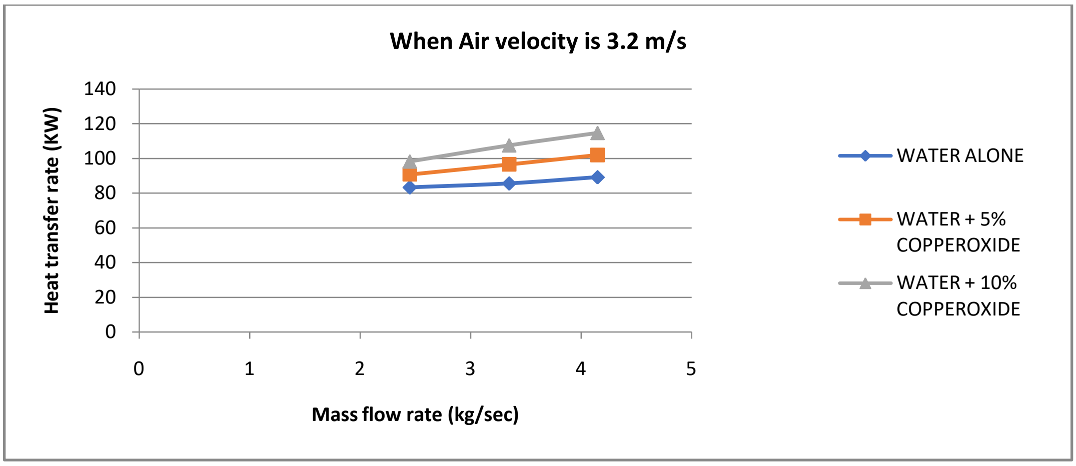


Fig1 :VARIATION OF HEAT TRANSFER RATE ALONG THE DIFFERENT MASS FLOW RATE AT AIR VELOCITY OF 3.2 M/SEC

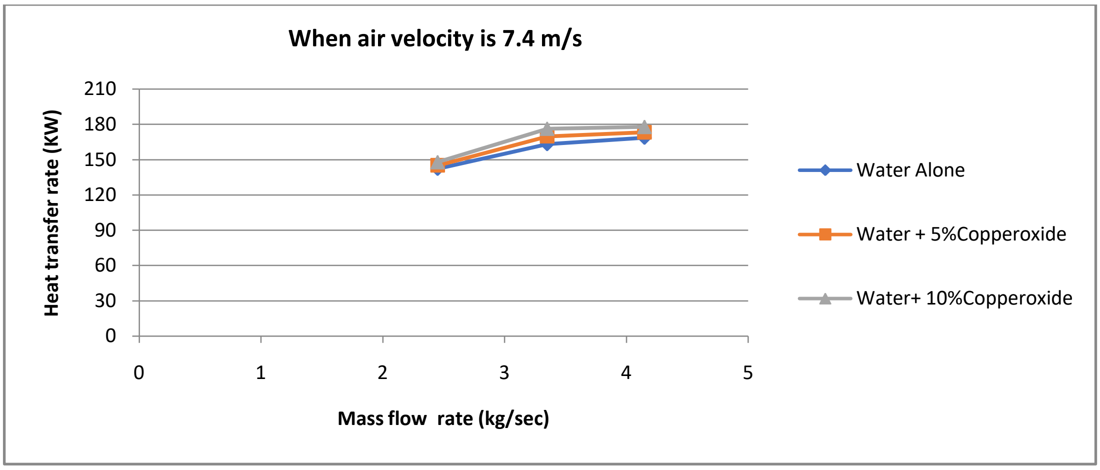


Fig 2 :VARIATION OF HEAT TRANSFER RATE ALONG THE DIFFERENT MASS FLOW RATE AT AIR VELOCITY OF 7.4 M/SEC

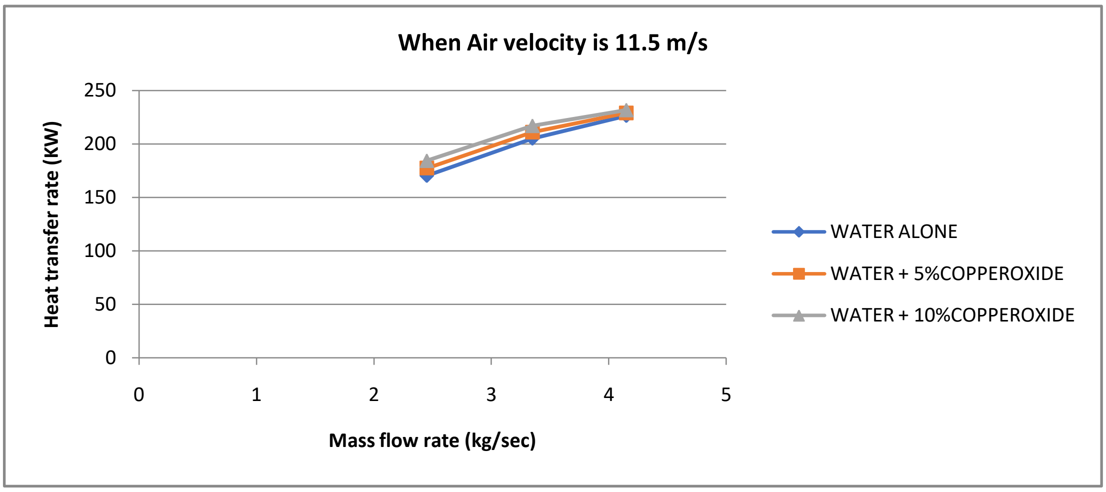


Fig 3 :VARIATION OF HEAT TRANSFER RATE ALONG THE DIFFERENT MASS FLOW RATE AT AIR VELOCITY OF 11.5 M/SEC

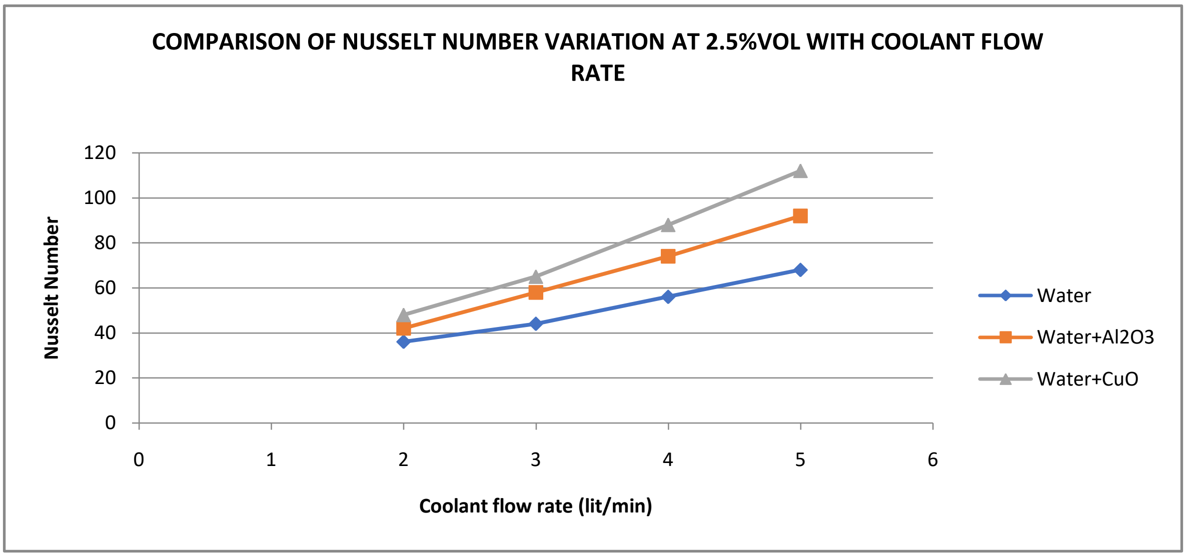
The experiment was performed by using water and nanofluids at two different concentrations with different mass flow rates. For each mass flow rate, experiment was conducted for 3 different air velocities.

As per the results and above graphs, it is clear that nanofluids (CuO) have large thermal conductivity than the original base fluid under the same mass flow rate and air velocity. The heat removal rate is more for nanofluid water + 10% copper oxide is more. So nanofluid (CuO) gives better performance when compared to base fluid alone.

COMPARISON OF CuO NANOFLUID WITH Al_2O_3 AND WATER

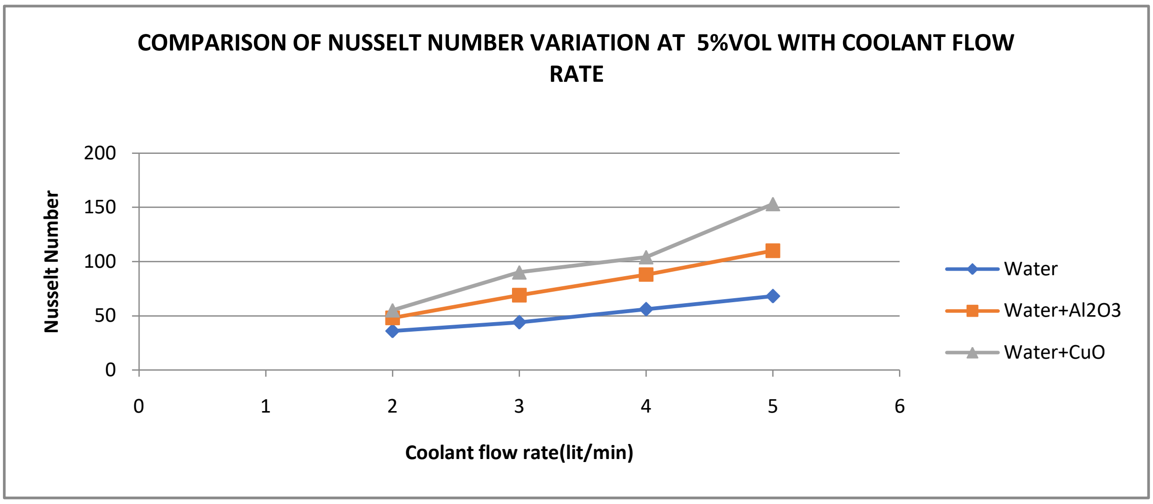
COMPARISON OF NUSSELT NUMBER VARIATION AT 2.5%VOL WITH COOLANT FLOW RATE

Coolant flow rate (lit/min)	Nusselt number		
	Base fluid (water)	Al_2O_3	CuO
2	36	42	48
3	44	58	65
4	56	74	88
5	68	92	112



COMPARISON OF NUSSELT NUMBER VARIATION AT 5%VOL WITH COOLANT FLOW RATE

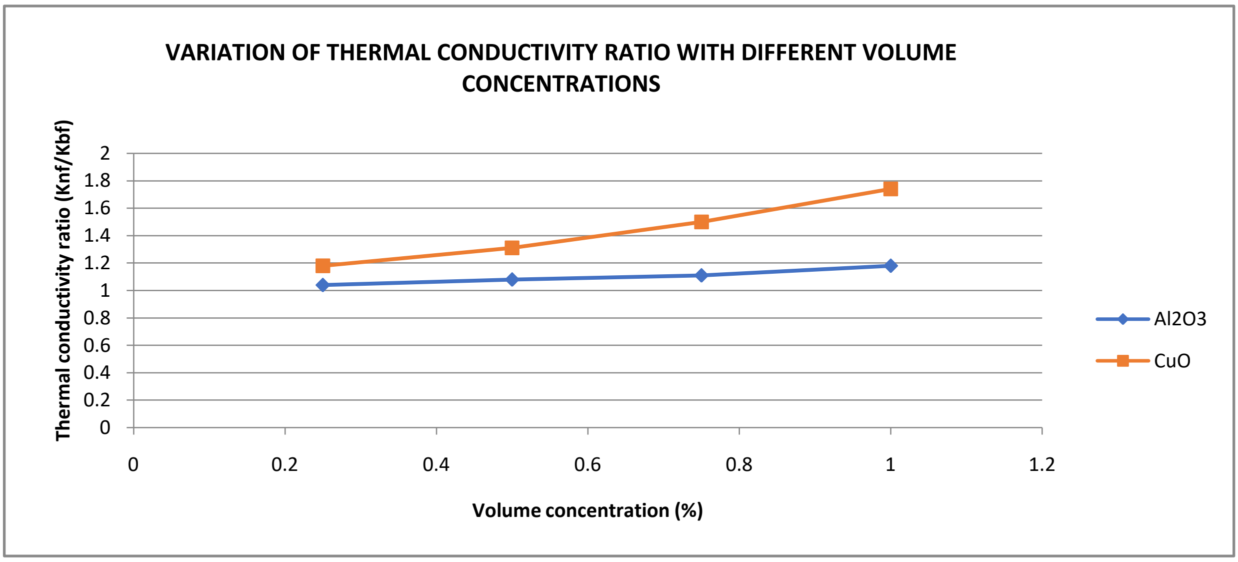
Coolant flow rate (lit/min)	Nusselt number		
	Base fluid (water)	Al_2O_3	CuO
2	36	48	55
3	44	69	90
4	56	88	104
5	68	110	153



The above two graphs shows the variation in Nusselt number with different coolant flow rates of two nanofluids. It is observed that Nusselt number increases with increase in coolant flow rate, thereby increases the heat transfer. This may be due to the fact that the enhanced thermal conductivity of nanofluids increases the heat transfer performance. CuO – Water nanofluid exhibit enormous heat transfer performance compared to Al_2O_3 - Water nanofluid .

VARIATION OF THERMAL CONDUCTIVITY RATIO AT DIFFERENT VOLUME CONCENTRATIONS OF TWO NANOFLUIDS

Vol.Concentration(%)	Knf/Kbf	
	CuO	Al_2O_3
0.25	1.18	1.04
0.50	1.31	1.08
0.75	1.5	1.11
1	1.74	1.18

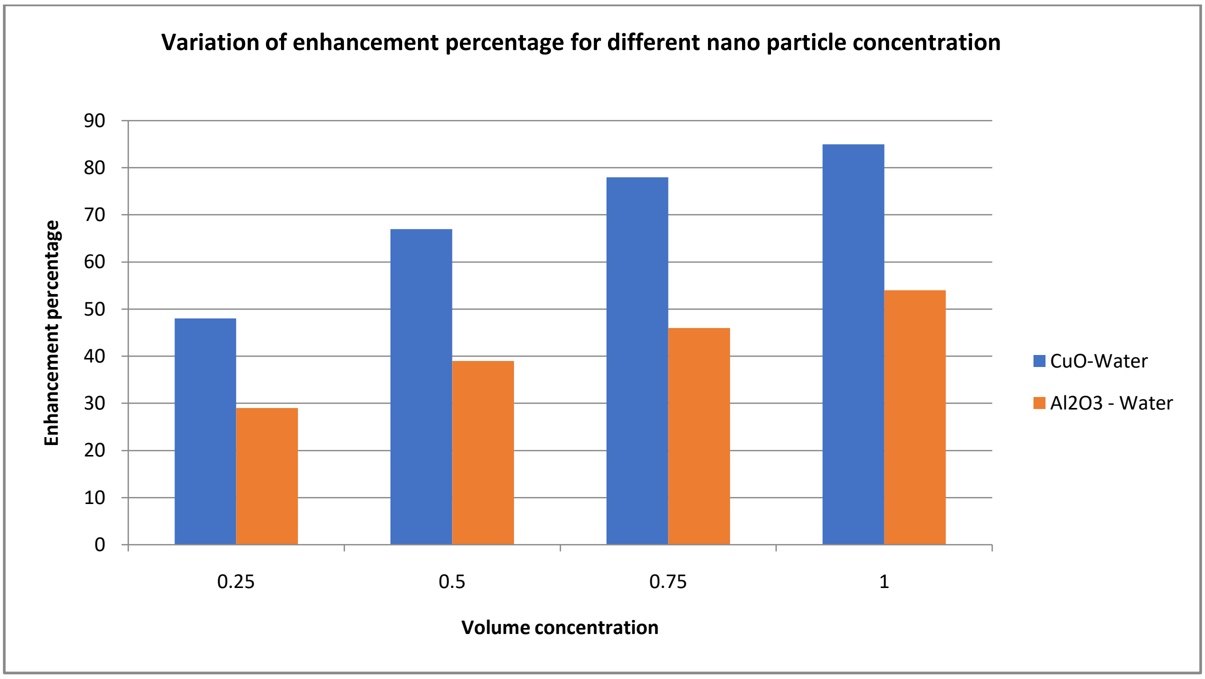


The above figure shows the variation of thermal conductivity ratio at different volume concentrations.

From the figure it is clear that CuO nanofluid gives better enhancement in thermal conductivity at all volume concentrations.

VARIATION OF ENHANCEMENT PERCENTAGE FOR DIFFERENT NANO PARTICLE CONCENTRATION

Vol.Concentration(%)	Enhancement percentage	
	CuO	Al_2O_3
0.25	48	29
0.50	67	39
0.75	78	46
1	85	54



The above figure depicts the percentage enhancement in Nusselt number for two different nanofluids at different volume concentrations.

Percentage in heat transfer enhancement is calculated by, Enhancement percentage = (Nunf-Nubf) / Nubf

The graph shows that CuO-Water nanofluid gives better enhancement percentage. This increase in heat transfer enhancement causes an improvement in cooling performance of an automobile engine. So CuO- Water nanofluid provides better cooling performance.

6. CONCLUSION

So, from this project it is clear that nanofluids can be used along with conventional coolants as it is providing better cooling performance.The Nano coolants found to enhance heat transfer when compared with water.The heat transfer performance was increased with the increase in coolant flow rate for all the 3 fluids i.e. Water, CuO-water nanofluid and Al_2O_3-Water nanofluid. The CuO-Water nanofluid exhibited enormous heat transfer performance compared with Al_2O_3-Water because of its higher thermal conductivity.

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