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Performance Improvement of Automobile Radiator by Use of Nano Fluid

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***Abstract*: In recent time automobile radiator uses water and ethylene glycol as a coolant. These coolant offers low thermal conductivity. However, to improve the thermal performance of the system automobile radiator is carried out with the coolant which have higher thermal conductivity. Nano-fluid have capability to increase the thermal performance of automobile radiator used as coolant. This study aims to evaluate the performance of the heat transfer characteristic of different Nano-fluid as coolant. The performance of heat transfer characteristic was evaluated based on certain parameter which are the heat transfer coefficient, thermal conductivity, Reynolds number, volume concentration fraction and rate of heat transfer of Nano-fluid.**

***Keywords*: Nanofluid, Automobile Radiator, Heat transfer enhancement, (Al_2O_3) Aluminium Oxide, Thermal conductivity, Viscosity.**

1. Introduction

As we progress our heat exchangers becomes compact but the reduction in size restricts the surface available for the heat exchange giving rise to use of fluid which have higher thermal conductivity with other desirable property needed for good heat exchanger fluid. Recent development in nano technology gave us nanofluid which became an important candidate for fluid with high thermal conductivity. An efficiency of heat exchanger can be increase by either introducing heat transfer enhancement techniques or efficient design or by using fluid with higher heat transfer capacity per unit mass flow rate then convectional fluid use for specific application. We have considered the later technique to increase heat transfer rate in our study.

Nanofluids are quasi single-phase medium containing stable colloidal dispersion of ultrafine or nano metric metallic or nonmetallic particles in a given fluid. Generally, the particles having size less than 100 nm are categorized as nanoparticles. Some examples of nanoparticles are alumina (Al_2O_3) Titanium oxide (TiO_2), copper oxide (CuO), pure Aluminium (Al), Copper (Cu) nanoparticles, Gold (Au), Silver (Ag), Silica (SiO_2) and Carbon Nano Fiber (CNF). Thermal conductivity of solids is greater than liquids. Commonly used fluids in heat transfer applications such as water, ethylene and engine oil have low thermal conductivity when compared to thermal conductivity of solids, especially metals. Therefore, small solid particles with nanometer diameter known as nanoparticles are added to base fluid which increases thermal conductivity of base fluid, ultimately leads to increase in heat transfer rate.

2. Engine cooling system

1. We know that in case of Internal Combustion engines, combustion of air and fuel takes place inside the engine cylinder and hot gases are generated. The temperature of gases will be around 2300-2500°C. This is a very high temperature and may result into burning of oil film between the moving parts and may result into seizing or welding of the same. So, this temperature must be reduced to about 150- 200°C at which the engine will work most efficiently. Too much cooling is also not desirable since it reduces the thermal efficiency. So, the object of cooling system is to keep the engine running at its most efficient operating temperature.
2. It is to be noted that the engine is quite inefficient when it is cold and hence the cooling system is designed in such a way that it prevents cooling when the engine is warming up and till it attains to maximum efficient operating temperature, then it starts cooling.

It is also to be noted that:

- About 20-25% of total heat generated is used for producing brake power (useful work).
- Cooling system is designed to remove 30-35% of total heat.
- Remaining heat is lost in friction and carried away by exhaust gases.

A. Nano fluid

Thermal properties of liquids play a decisive role in heating as well as cooling applications in industrial processes. Thermal conductivity of a liquid is an important physical property that decides its heat transfer performance. Conventional heat transfer fluids have inherently poor thermal conductivity which makes them inadequate for ultra-high cooling applications. Scientists have tried to enhance the inherently poor thermal conductivity of these conventional heat transfer fluids using solid additives following the classical effective medium theory (Maxwell, 1873) for effective properties of mixtures. Fine tuning of the dimensions of these solid suspensions to millimeter and micrometer ranges for getting better heat transfer performance have failed because of the drawbacks such as still low thermal conductivity, particle sedimentation, corrosion of components of machines, particle clogging, excessive pressure drops etc. Downscaling of particle sizes continued in the search for new types of fluid suspensions having enhanced thermal properties as well as heat transfer performance.

All physical mechanisms have a critical scale below which the properties of a material changes totally. Modern nanotechnology offers physical and chemical routes to prepare nanometer sized particles or nanostructured materials engineered on the atomic or molecular scales with enhanced thermo- physical properties compared to their respective bulk forms. Choi (1995) and other researchers (Masuda et al., 1993; Lee et al., 1999) have shown that it is possible to break down the limits of conventional solid particle suspensions by conceiving the concept of nanoparticle-fluid suspensions. These nanoparticle-fluid suspensions are termed nanofluids, obtained by dispersing nanometer sized particles in a conventional base fluid like water, oil, ethylene glycol etc. Nanoparticles of materials such as metallic oxides (Al_2O_3, CuO), nitride ceramics (AlN, SiN), carbide ceramics (SiC, TiC), metals (Cu, Ag, Au), semiconductors (TiO_2, SiC), single, double or multi walled carbon nanotubes (SWCNT, DWCNT, MWCNT), alloyed nanoparticles ($Al_{70}Cu_{30}$) etc. have been used for the preparation of nanofluids. These nanofluids have been found to possess an enhanced thermal conductivity (Shyam et al., 2008; Choi et al., 2001; Eastman et al., 2001) as well as improved heat transfer performance (Xuan et al., 2003; Yu et al., 2003; Vassalo et al., 2004; Artus, 1996) at low concentrations of nanoparticles. Even at very low volume fractions (< 0.1%) of the suspended particles, an attractive enhancement up to 40% in thermal conductivity has been reported on these nanotechnology based fluids (Wang et al., 1999) and the percentage of enhancement is found to increase with temperature (Das et al., 2003) as well as concentration of nanoparticles (Shyam et al., 2008). The effective thermal conductivity of these nanofluids are usually expressed as a normalized thermal conductivity value obtained by dividing the overall thermal conductivity of the nanofluid by the base fluid thermal conductivity or sometimes as a percentage of the effective value with respect to the base fluid value.

B. Properties nano fluid

- *Particle Volume Concentration:* Thermal conductivity enhancement increases with increase particle volume concentration. This can be explained by fact that thermal conductivity of metal and their oxides is more than any thermal fluid. Thus, when any metal nano particle is added to any thermal fluid, resulting nano fluid gives higher thermal conductivity then corresponding base fluid. Thermal conductivity of the nanofluid increases linearly with the increase in particle loading.
- *Particle Material:* The thermal conductivity ratio is seen to increase faster for metal than oxide particles for same increase in concentration. This is due to reason that thermal conductivity of metal nano particle is more than metal oxide.
- *Particle Size:* Smaller particle diameters produce a large enhancement in thermal conductivity. This can be explained by the fact that as particle size decreases specific surface area increases. This increase in specific surface area provide more interface between particle and fluid, lead in increment of thermal conductivity of fluid.
- *Viscosity:* There is non-linear relation between viscosity and concentration. As the concentration increases viscosity increases with increases in shear rate, but as the temperature increases viscosity decreases.
- *Particle Shape:* Elongated particles are superior to spherical for thermal conductivity enhancement. This can be explained with the theory that, for elongated shape more surface area is available than for the same size spherical shape. Thus, it led to more fluid-particles interface resulting into more thermal conductivity.
- *Temperature:* Thermal conductivity increases with increase in temperature. This increase in temperature causes in increase in random motion of the particle, thus rise in thermal conductivity of nano fluid with temperature can be explained with the phenomenon of increase in Brownian motion. In addition to Brownian motion, micro convection also occur which assist increase in thermal conductivity with the temperature.

3. Literature Survey

From Table 1 we can conclude that thermal conductivity of TiO2 nano fluid increases with increase in particle loading. The relation of enhancement in thermal conductivity with concentration obtain by researcher are almost incremental in nature with the concentration but the values obtain at specific concentration for thermal conductivity shows discrepancies and lack in consistency.

From Table 2 literature expresses that, viscosity increases with the increase in concentration leading to increase in pumping power to considerable amount. But as temperature of nano fluid increases viscosity goes on decreasing resulting in decrease in pumping power.

From Table 3 we can conclude that different work like experimentation, numerical study and CFD simulation have been carried out by the researcher taking different parameters like inlet temperature of radiator, mass flow rate of coolant, mass flow rate of air, concentration of nano fluid and size of nano fluid. The nano particles used in auto mobile radiator are mainly TiO2. The work mainly includes finding out increment in thermal conductivity of nano fluid, effect of concentration on

Table 1
Critical literature review for thermal conductivity for nano fluid

Sr. No.	Name of Author and Year	Nano Fluid Used	Thermal Conductivity
1	N.A. Usri, et al. (2015)	Al2o3 / water	The thermal conductivity of water and ethylene glycol (EG) based Al2o3 nanofluid. The 13 nm size Al2o3 nanoparticles. EG such as 40:60, 50:50 and 60:40 using a two-step method. The Thermal Properties Analyzer at working temperatures of 30 to 70 ^{0}C for volume concentration of 0.5 to 2.0 %.
2	A. Jafarimoghaddam et al. (2016)	Cu / Ethylene Glycol	The case of CuO-EG nano-fluids particles of 35 nm and 11.9 nm were taken into account. Here the 35 nm, particles gave 3% more enhancement than the 11.9 nm particles.
3	Y. Vermahmoudi et al (2014)	Fe2O3	The overall heat transfer coefficient and heat transfer rate compared with base fluid are respectively equal to 13% and 15% which is occurred at the concentration of 0.65 vol.%.
4	Reza Davarnejad et al (2015)	MgO-Water	The base fluid was pure water and the volume faction of nanoparticles in the base fluid was 0.0625%,0.125%, 0.25%, 0.5% and 1%. The applied Reynolds number range was 3000-19000.
5	V. Salamon et al (2017)	Tio2	Two different concentration of nanofluids are prepared by adding 0.1 vol. % and 0.3vol. % of Tio2 nanoparticles into water/propylene glycol mixture (70:30). The experiments are conducted by varying the coolant flow rate between 3 to 6 lit/min for various coolant temperature (50 ^{0}C, 60 ^{0}C, 70 ^{0}C and 80^{0}C) to understand the effect of coolant flow rate on heat transfer. The results show that the Nusselt number of the nanofluid coolant increase with increase flow rate. However, at higher operating temperature and higher coolant flow rate 0.3 vol. % of Tio2 nanofluid.

Table 2
Critical literature review for viscosity for nano fluid

Sr.No.	Author and Year	Nano Fluid Used	Viscosity
1	C.T Nguyen et al (2008)	Al_2o_3/water	We have performed extensive measurements of dynamic viscosity for the Al_2o_3-water nanofluid with two different particles size 36&47 nm. And this for the temp ranging from the engine temp. of nearly 75^{o}C.
2	A. Jafarimoghaddam et al. (2016)	Cu/Ethylene Glycol	The acquired experimental data were used to establish a correlation for predicting Nusselt number of nanofluid flow inside the tube. Correlation is valid for Cu/base Ethylene Glycol nanofluid flow with volume concentrations between 0.011 and 0.171 in the hydrodynamically fully developed laminar flow regime with Re<160 which is most applicable in micro heat sinks.
3	Dilan S. Udawattha, et al (2017)	Fe_2O_3	The effect of nanoparticles concentration (< 2.06 wt%) and temperature (34–55°C) on nanofluids' viscosity has been reported. Relative viscosities of nanofluids showed linear increase with nanoparticles concentration, though independent of temperature.
4	Reza Davarnejad et al (2015)	MgO-Water	The viscosity of nanofluids containing MgO nanoparticles with 20 nm average size and ethylene glycol as base fluid.
5	Alpaslan Turgut	Tio_2	The mean diameter of TiO2 nanoparticles was 21nm. The increase in viscosity with the increase of particle volume fraction was much more than predicted by the Einstein model. From this research, it seems that the increase in the nanofluid viscosity is larger than the enhancement in the thermal conductivity.
6	C. Selvama, et al (2017)	Graphene	This drop-in viscosity with respect to temperature is due to the intermolecular forces of the nanofluid being weakened. When the temperature increases from 30 to 50C the viscosity ratio (mnf/mbf) of nanofluids at 0.1 vol% increases from 1.06 to 1.16 and at 0.5 vol% it increases from 1.13 to 1.39. The rise in viscosity ratio with respect to temperature can be due to the decrement in viscosity of nanofluid being less than that of the base fluid.

viscosity, increment in heat transfer rate and reduction in heat transfer area for particular application after addition of nano particle or use of nano fluid. As one can see that the results obtain by researcher lack in consistency and further research is required for achievement of some standard and reliable data that can be base for research to apply in real life application.

4. Material and Methodology

A. Material

For this research work, one material is chosen for analysis on ANSYS Fluent. The details are shown in below table.

The particle size of nanoparticle will be between 1 to 100 nm as availability. Coolant is base material for preparation of nano-fluid, so nano-particles should be compatible with water. As we see the thermal conductivity of copper is nearly equal to silver.

Material	Chemical Sign	Thermal Conductivity (W/m-K)	Density Kg/m^3
Copper	Cu	385	8940

B. Variable Parameters

For different volume fraction of nanoparticles, the values of thermal conductivity are going to change. So, it should be considered as variable parameter. To find optimum volume fraction which perform better at wide range of different flow rate, the experimentation should be done with different vehicle as well.

Table 3
Critical literature review for automobile radiator

Author & Year	Type of work	Fluid used	Coolant side condition	Air side condition
Rahul A. Bhogare, et al (May 2014)	Heat transfer rate is increased with increase in volume concentration of nanoparticles (Experimental work)	Al_2o_3 /water/EG with concentration range (0% to 1%)	Inlet coolant temperature 50-80^{0}C Reynolds number 39343	Inlet air temperature 20-40^{0}C Reynolds number 84391
Finding	At constant Reynolds number of coolant (39343) and air (84391) an overall heat transfer coefficient, 482 W/m^{2}K can be achieved for 2% Cu/EG nanofluid compared to 304 W/m^{2}K for the basefluid. 1% Al2O3+ mixture of EG/water (50% volume concentration) At constant Reynolds number of coolant (39343) and varied Reynolds number of air (84391), about 60% of heat transfer improvement can be achieved with addition of 1% Al_2o_3 particles at 84391 and 39343 Reynolds number for air and coolant respectively.			
Bhavik P. Patel, et al (June 2016)	Performance on results demonstrate that increasing the fluid circulating rate can improve the heat transfer performance.	Cuo (60 nm)/EG with concentration (0.05% - 2%	Inlet coolant temperature 70-90^{0}C Reynoldsnumber 5000	Inlet air temperature 34-54^{0}C Reynolds number 6000
Finding	At constant Reynolds number of coolant (5000) and air (6000) an overall heat transfer coefficient, 166 W/m^{2}K can be achieved for 2% Cu/EG nanofluid compared to 142 W/m^{2}K for the basefluid. At constant Reynolds number of coolant (5000) and varied Reynolds number of air (6000), about 3.8% of heat transfer improvement can be achieved with addition of 2% copper particles at 5000 and 6000 Reynolds number for air and coolant respectively.			
Siraj Ali Ahmed, et al (July 2018)	Experiment work	Tio_2(30-60nm)/EG with concentration (0.1% to 0.3%)	Reynolds number 560-1650	Reynolds number 430-1400
Finding	TiO_2-water nanofluid with 0.2% concentration can enhance the effectiveness of car radiator by 47% as compared to 0.1 and 0.3% concentrations and pure water as a coolant. Nano particles shape is Spherical. Radiator tubes is horizontal in radiator. At performance obtained overall heat transfer value is 2050 W/m2K for 0.3% TiO2- water in which a multi-walled carbon nanotube (MWCNT) based on water/ethylene glycol is used with nanoparticle volume concentration of 0.5%, and heat transfer coefficient increase from 986.8 W/m$_2$K to 2951 W/m^{2}K, for Reynolds number from 430 to 1400.			
S.M. Peyghambarzadeh, et Al (2013)	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.	Fe_2o_3(40 nm)/ Cuo (60 nm)/EG with concentration (0.15% to 0.65%)	Reynolds number50-1000 Inlet coolant temperature 50-90^{0}C	Reynolds number 500-700 Inlet air temperature 35-40^{0}C
Finding	Water flows upward through the 34 verticals noncircular tubes with stadium-shaped cross section. The fins and the tubes are made with aluminum. The pump gives a constant flow rate of 10 l/min, the flow rate to the test section is regulated by appropriate adjusting of a globe valve on the recycle line. a forced fan (Techno Pars 1400 rpm) which is capable of adjusting the speed was installed close and face to face to the radiator at the beginning of a 2.5 m air flow duct. The nanofluids are implemented by the addition of CuO and Fe2O3 nanoparticles into the water at three different nanoparticle concentrations, i.e. 0.15, 0.4 and 0.65 vol.% and at different liquid flow rates of 0.05, 0.08, 0.11, and 0.14 l/s per each flat tube.			

C. Volume Fraction

Volume Fraction	0.05%	0.15%	0.3%

The volume fractions are selected above are referred after doing literature review of many research papers. There are some genuine reasons behind selection, such as increasing volume fraction, too many particles lead to large shear stresses and requires large pumping power and therefore selection of proper concentration of nanoparticles is important.

There for some boundary have to be set for selection of volume fraction:

- In 0.05 % volume fraction Nanoparticle 0.05 % by volume and rest of 99.95 % coolant with dispersant.
- In 0.15 % volume fraction Nanoparticle 0.15 % by volume and rest of 99.85 % coolant with dispersant.
- In 0.3 % volume fraction Nanoparticle 0.3 % by volume and rest of 99.70 % coolant with dispersant.

The volume fraction of nanoparticle also effects the aggregation, higher the volume fractions more chance of aggregation. Some treatment and additive required to prevent aggregation and increase dispersion of nanoparticle.

D. Thermal Conductivity of Nano-Fluid

It is the one of the prime thermos-physical property, which governs the heat transfer characteristics of the nano fluids. By suspending the high thermal conductive nanoparticles in base fluid, net thermal conductivity of the nano fluid enhances due to convection currents between base fluid and solid particles.

To find thermal conductivity of Nano-fluid with different volume fraction, HAMILTON AND CROSSER theory is used to find thermal conductivity of nano fluid with different volume fraction. Thermal conductivity based on theoretical predictions of two-component mixtures (Heterogeneous mixture) suggested by Hamilton and Crosser's analysis such as,

$$k = k0\frac{km + (n-1)k0 - (n-1)\alpha(k0 - kn)}{km - (n-1)kn + \alpha(k0 - kn)}$$

$$--- \textit{ Equation 1 Hamilton and crosser}$$

Where,
k = overall thermal conductivity of nano fluid
ά = particle volume fraction
k0 = fluid thermal conductivity
km = nanoparticle thermal conductivity
n = shape factor

Excel solver used to find thermal conductivity of 12 models (1 material, 3 volume fractions, and 4 different air velocities. So, total 1*4*3 = 12 models).

Thermal conductivity of nano-fluid shows dependence upon temperature nano-fluid. Brownian motion of nanoparticles by which particles move through liquid and possible collide, thereby enabling direct solid-solid transfer of heat from one another considered as a key mechanism in thermal conductivity enhancement with increase in temperature. In many research papers it shows that relative thermal conductivity of nano-fluid increased with increasing particle volume fraction.

E. *Nano Particles Thermal Conductivity*

Thermal conductivity shows in the table 4-3 is calculated from equation 1.

Table 4
Nano-fluid thermal conductivity

Material	Volume Fraction %	Nano-fluid therm. Conductivity W/m-K
Based Fluid	0	0.415
Water + EG + CuO	0.05	0.664
Water + EG + CuO	0.15	0.858
Water + EG + CuO	0.3	1.241

F. *Testing of Material*

Description:

Cupric oxide nanoparticles that are used regularly for preparing heat transfer nanofluid and as antifungal agent in paints.

Fig. 1. Cuo Powder

G. *Synthesis method*

Cupric nanoparticles are synthesized by chemical coprecipitation method in which copper salts are reduced rapidly by adding a reducing agent. The particles are then isolated and dried.

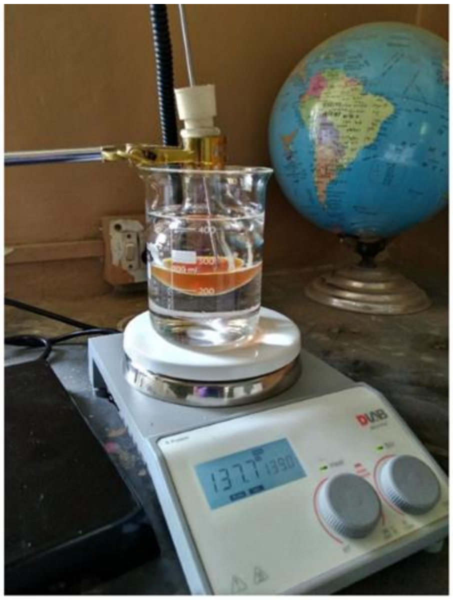

Fig. 2. Weight measurement

Specifications:
Form: Dry powder
Solvents: Dispersible in aqueous solvents
Color: dark brown/black
Polymer content: none
Stabilizer: none
Particle size range: ~ 10 nm
XRD pattern of CuO_Nano10

X-ray diffraction is used for ‘fingerprinting’ of the sample. The specific peaks occur at the specific angles for a particular material due to diffraction from crystal lattice structure. The peaks in graph below correspond to cupric oxide without any kind of crystalline impurities.

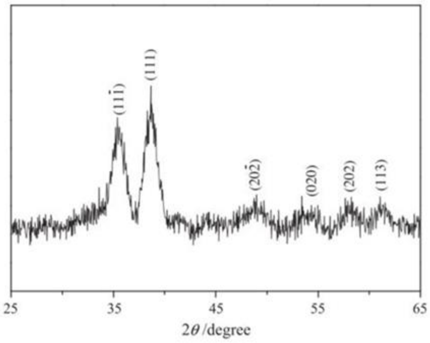

Fig. 3. XRD image

H. *TEM image*

TEM micrograph is a high-resolution image showing: (1) the

Table 5
Table of analysed parameters

No.	Tested parameter	Expected specs	Results from QC
1	Metal purity	>99% cupric oxide	>99% cupric oxide
2	Particle size (TEM)	< 100 nm	10 nm
3	Stabilizercontent (TGA)	1-3%	1-3%
4	Form and colour of product	Dark brownish powder	Dark brownish powder
5	Form and colour of suspension	Yellowish (at 0.1 mmol) to greenish yellow (at 0.1 mol)	Conforms
6	Bulk density	1-2 g/cc	1 g/cc
7	Antimicrobial activity (E. Coli, S. Aureas, C. Albicans)	Aureas, C. Albicans) MIC E. Coli: >10000 ppm, S. Aureus < 1000 ppm, MIC C. Albicans <1000 ppm (CLSI M26A) MIC E. Coli: > 10000 ppm, MIC S. Aureus < 1000 ppm, MIC C. Albicans	MIC E. Coli; > 10000 ppm, MIC S. Aureus < 1000 ppm, MIC C. Albicans < 500 ppm (CLSI M26A)

fine particles of ~10 nm when dispersed with PVP stabilizer (2) 10 nm particles clustered together in absence of stabilizer.

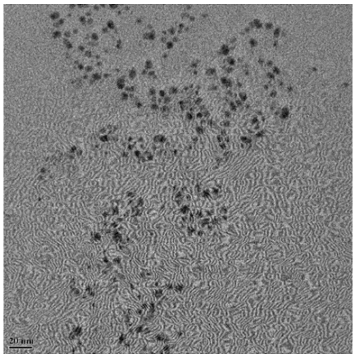

Fig. 4. TEM image

Stock: Cu-4
Batch number: 1028
CAS number: 1317-38-0
Molar mass: 79.5
Product: Copper oxide nanoparticles powder ~10 nm

I. *Fluid Preparation*

Nano-fluid preparation is a critical stage, which decides the stability of the nano-fluid. Stability, durability and chemical inertness of suspended nano particles are essential to use nano-fluid for real time applications. This section summarizes the techniques used for nano-fluid preparation. The typical approach to prepare hybrid nano-fluid is either by dispersing nanoparticles of individual constituents simultaneously or by dispersing the synthesized nanocomposite particles in a base fluid at predefined proportion. Stability of nano-fluid is a key parameter for consistent functioning of a thermal system at designed capacity. Therefore, preparation of stable nano-fluid is a technical difficulty to the researchers due to strong Vander Waal and cohesive forces among the nanoparticles. These forces are the root cause for agglomeration. The agglomerated hybrid nano-fluid loses its potential to transfer heat by diminishing the Brownian motion of particles. It also deteriorates the flow behavior by amplifying frictional resistance and consequently increases the pressure drop. Therefore, stable suspension of the nanoparticles is essential to get desired properties.

J. *Stability Enhancement Procedures*

There are some factors that enhance stability of nanoparticles,

K. *Addition of surfactants*

Stabilization of the nano fluid is done by adding surfactants to the base fluids to lower its surface tension and increase the immersion of the particles, thus avoiding fast sedimentation. Sodium dodecyl sulphate (SDS), Polyethylene Glycol (PEG) molecules, mixtures of Sorbitan trioleate and polysorbate, sodium dodecyl benzene sulphate (SDBS), polyacrylic acid are some of the example of surfactants. But the capability of this surfactant with engine cooling system is not tested. It may Damage cooling system or Engine metal parts. So, additives are neglected for safety purpose.

L. *pH control of nano fluids*

Stability of nano fluids is directly related to its electro-kinetic properties; therefore, pH control of them can increase stability due to strong repulsive forces. pH control method used in order to stabilize the test nano fluids using the HCl + NaOH to control the pH of nano fluids. Small Amount of NaCl salt added to nano-fluid to increase dispersion of particles with base fluid without forming any aggregation of particles.

M. *Ultrasonic agitation*

Ultrasonic agitation of nanoparticles breaks large agglomerates of nanoparticles into individual molecule and disperse it in the fluid and make stable suspension. Ultrasonic vibrator used to vibrate the nano-fluids and found that the vibration with 8 hours can effectively avoid nano-powder sediment.

N. *Material weight measurement*

- Copper Oxide

Fig. 5. Nano material

9 liters of nano-fluid are prepared for each volume fraction. For preparation of different volume fraction of nano-fluid, different amount of nano material is required. Below table shows the required amount of nanoparticle, for preparation of nano-fluid of particular volume fraction.

Equivalent ml required for particular V/V % volume fraction for 9 litres.

0.05 %	0.15 %	0.3 %
4.5ml	13.5ml	27ml

With help of density ml is converted to grams required for nano-fluid preparation. Using weighting scale, nanomaterial is measured and mixed with coolant for next step of preparation.

O. Ultrasonic Homogenizer

Fig. 6. Ultrasonic Homogenizer

Nano-fluid mixture placed inside ultrasonic homogenizer for duration of 45 mins. Ultrasonic sound wave breaks down the nano-particle aggregation into individual metal molecules. For better stability of nano-fluid researchers found that, use of ultrasonic homogenizer improve dispersion characteristic of nanomaterial.

Experimental reading

Table 6
During the performance of experiment, we collect the different experiment reading with base fluid and with different concentration of nanofluid which are as below.

Temp in °C	flow rate lit/min	con.	temp outlet °C	temp diff. °C	air inlet °C	air outlet °C
50	4	0	42	8	33	40
50	4	0.05	42	8	34	41
50	4	0.15	42	8	33	43
50	4	0.3	42	8	34	39
50	5	0	42	8	33	42
50	5	0.05	42	8	34	44
50	5	0.15	42	8	33	42
50	5	0.3	41	9	34	41
50	6	0	43	7	33	41
50	6	0.05	42	8	34	44
50	6	0.15	42	8	32	40
50	6	0.3	41	9	34	41
50	7	0	44	6	30	41
50	7	0.05	42	8	30	41
50	7	0.15	42	8	33	41
50	7	0.3	42	8	34	44
60	4	0	47	13	33	41
60	4	0.05	47	13	34	48
60	4	0.15	46	14	33	47
60	4	0.3	45	15	34	46
60	5	0	48	12	33	48
60	5	0.05	48	12	34	49
60	5	0.15	47	13	34	48
60	5	0.3	46	14	34	48
60	6	0	50	10	34	47
60	6	0.05	50	10	34	48
60	6	0.15	50	10	33	47
60	6	0.3	48	12	33	46
60	7	0	52	8	32	47
60	7	0.05	50	10	33	45
60	7	0.15	50	10	33	48
60	7	0.3	49	11	30	46
70	4	0	54	16	32	47
70	4	0.05	54	16	33	50
70	4	0.15	53	17	32	50
70	4	0.3	52	18	34	50
70	5	0	56	14	33	46
70	5	0.05	56	14	34	52
70	5	0.15	56	14	34	52
70	5	0.3	54	16	34	50
70	6	0	57	13	33	47
70	6	0.05	57	13	33	52
70	6	0.15	56	14	32	51
70	6	0.3	55	15	33	47
70	7	0	61	9	30	48
70	7	0.05	58	12	32	51
70	7	0.15	57	13	33	51
70	7	0.3	54	16	34	49
80	4	0	61	19	34	46
80	4	0.05	61	19	33	52
80	4	0.15	60	20	34	49
80	4	0.3	59	21	33	56
80	5	0	63	17	34	46
80	5	0.05	63	17	34	41
80	5	0.15	62	18	34	49
80	5	0.3	61	19	34	51
80	6	0	65	15	33	50
80	6	0.05	65	15	33	50
80	6	0.15	64	16	31	50
80	6	0.3	63	17	33	48
80	7	0	68	12	33	43
80	7	0.05	67	13	33	43
80	7	0.15	66	14	30	47
80	7	0.3	62	18	33	47

Table 7: Heat transfer performance of CuO nanofluid as coolant

Temp in °C	Flow rate lit/min.	Con.	Temp outlet °C	Temp diff. °C	Air inlet °C	Air outlet °C	Heat Transfer Coefficient (h)	Reynolds number	Nusselt number.	Prandtl number
50	4	0	42	8	33	40	5729.1140	12094.66	74.54750	6.537831325
50	4	0.05	42	8	34	41	5729.1140	5685.406	46.59219	10.21536145
50	4	0.15	42	8	33	43	5729.1140	4543.151	36.05736	7.905594406
50	4	0.3	42	8	34	39	5729.1140	3289.336	24.92926	5.465753425
50	5	0	42	8	33	42	7204.2751	16105.4	93.74237	6.537831325
50	5	0.05	42	8	34	44	7204.2751	7570.769	58.58898	10.21536145
50	5	0.15	42	8	33	42	7204.2751	6049.726	45.34159	7.905594406
50	5	0.3	41	9	34	41	8104.8094	5074.899	35.26669	5.465753425
50	6	0	43	7	33	41	7519.4621	16990.96	97.84360	6.537831325
50	6	0.05	42	8	34	44	8593.6710	9437.904	69.88828	10.21536145
50	6	0.15	42	8	32	40	8593.6710	7541.734	54.08604	7.905594406
50	6	0.3	41	9	34	41	9667.8798	6326.492	42.06813	5.465753425
50	7	0	44	6	30	41	7430.9978	16741.46	96.69250	6.537831325
50	7	0.05	42	8	30	41	9907.9971	11275.46	80.57708	10.21536145
50	7	0.15	42	8	33	41	9907.9971	9010.111	62.35802	7.905594406
50	7	0.3	42	8	34	44	9907.9971	6523.508	43.11296	5.465753425
60	4	0	47	13	33	41	8454.3141	19671.28	110.0079	6.537831325
60	4	0.05	47	13	34	48	8454.3141	9246.984	68.75496	10.21536145
60	4	0.15	46	14	33	47	9104.6460	8106.374	57.30196	7.905594406
60	4	0.3	45	15	34	46	9754.9779	6397.816	42.44712	5.465753425
60	5	0	48	12	33	48	9548.5233	22903.66	124.2458	6.537831325
60	5	0.05	48	12	34	49	9548.5233	10766.44	77.65365	10.21536145
60	5	0.15	47	13	34	48	10344.233	9508.691	65.10356	7.905594406
60	5	0.3	46	14	34	48	11139.943	7552.707	48.47356	5.465753425
60	6	0	50	10	34	47	9114.4995	21609.79	118.5983	6.537831325
60	6	0.05	50	10	34	48	9114.499	10158.23	74.12394	10.21536145
60	6	0.15	50	10	33	47	9114.4995	8117.342	57.36398	7.905594406
60	6	0.3	48	12	33	46	10937.347	7381.447	47.59222	5.465753425
60	7	0	52	8	32	47	8379.8981	19455.08	109.0396	6.537831325
60	7	0.05	50	10	33	45	10474.872	12087.54	85.18721	10.21536145
60	7	0.15	50	10	33	48	10474.873	9659.036	65.92577	7.905594406
60	7	0.3	49	11	30	46	11522.359	7878.176	50.13758	5.465753425
70	4	0	54	16	32	47	9037.475	21381.76	117.5960	6.537831325
70	4	0.05	54	16	33	50	9037.475	10051.04	73.49754	10.21536145
70	4	0.15	53	17	32	50	9602.3178	8663.990	60.43416	7.905594406
70	4	0.3	52	18	34	50	10167.160	6737.495	44.24063	5.465753425
70	5	0	56	14	33	46	9484.0062	22710.38	123.4063	6.537831325
70	5	0.05	56	14	34	52	9484.0062	10675.59	77.12896	10.21536145
70	5	0.15	56	14	34	52	9484.0062	8530.758	59.68955	7.905594406
70	5	0.3	54	16	34	50	10838.864	7298.416	47.16347	5.465753425
70	6	0	57	13	33	47	10426.9875	25567.20	135.6764	6.537831325
70	6	0.05	57	13	33	52	10426.9875	12018.51	84.79778	10.21536145
70	6	0.15	56	14	32	51	11229.063	10536.03	70.67242	7.905594406
70	6	0.3	55	15	33	47	12031.1394	8315.385	52.35145	5.465753425
70	7	0	61	9	30	48	8267.47146	19129.36	107.5767	6.537831325
70	7	0.05	58	12	32	51	11023.2952	12883.72	89.64728	10.21536145
70	7	0.15	57	13	33	51	11941.9032	11378.62	75.15883	7.905594406
70	7	0.3	54	16	34	49	14697.7270	10679.76	63.95465	5.465753425
80	4	0	61	19	34	46	9485.1306	22713.74	123.4209	6.537831325
80	4	0.05	61	19	33	52	9485.1306	10677.17	77.13811	10.21536145
80	4	0.15	60	20	34	49	9984.3480	9096.985	62.83855	7.905594406
80	4	0.3	59	21	33	56	10483.5654	7000.598	45.61744	5.465753425
80	5	0	63	17	34	46	10267.5386	25079.42	133.6017	6.537831325
80	5	0.05	63	17	34	41	10267.5386	11789.22	83.50106	10.21536145
80	5	0.15	62	18	34	49	10871.5115	10118.36	68.42210	7.905594406
80	5	0.3	61	19	34	51	11475.4843	7838.134	49.93361	5.465753425
80	6	0	65	15	33	50	10533.0987	25892.84	137.0571	6.537831325
80	6	0.05	65	15	33	50	10533.0987	12171.59	85.66074	10.21536145
80	6	0.15	64	16	31	50	11235.3052	10543.35	70.71171	7.905594406
80	6	0.3	63	17	33	48	11937.5118	8234.574	51.94404	5.465753425
80	7	0	68	12	33	43	9606.6132	23077.96	125.0017	6.537831325
80	7	0.05	67	13	33	43	10407.1643	11989.95	84.63657	10.21536145
80	7	0.15	66	14	30	47	11207.7154	10511.00	70.53806	7.905594406
80	7	0.3	62	18	33	47	14409.9198	10418.99	62.70231	5.465753425

Table 8
Heat Transfer rate and Effectiveness

Temp in °C	Flow rate lit/min.	Con.	Temp outlet °C	Temp diff. °C	Air inlet °C	Air outlet °C	Rate of heat transfer Q	Effectiveness
50	4	0	42	8	33	40	1904	47.05882353
50	4	0.05	42	8	34	41	1904	50
50	4	0.15	42	8	33	43	1904	47.05882353
50	4	0.3	42	8	34	39	1904	50
50	5	0	42	8	33	42	2380	47.05882353
50	5	0.05	42	8	34	44	2380	50
50	5	0.15	42	8	33	42	2380	47.05882353
50	5	0.3	41	9	34	41	2677.5	56.25
50	6	0	43	7	33	41	2499	41.17647059
50	6	0.05	42	8	34	44	2856	50
50	6	0.15	42	8	32	40	2856	44.44444444
50	6	0.3	41	9	34	41	3213	56.25
50	7	0	44	6	30	41	2499	30
50	7	0.05	42	8	30	41	3332	40
50	7	0.15	42	8	33	41	3332	47.05882353
50	7	0.3	42	8	34	44	3332	50
60	4	0	47	13	33	41	3094	48.14814815
60	4	0.05	47	13	34	48	3094	50
60	4	0.15	46	14	33	47	3332	51.85185185
60	4	0.3	45	15	34	46	3570	57.69230769
60	5	0	48	12	33	48	3570	44.44444444
60	5	0.05	48	12	34	49	3570	46.15384615
60	5	0.15	47	13	34	48	3868.5	50
60	5	0.3	46	14	34	48	4165	53.84615385
60	6	0	50	10	34	47	3570	38.46153846
60	6	0.05	50	10	34	48	3570	38.46153846
60	6	0.15	50	10	33	47	3570	37.03703704
60	6	0.3	48	12	33	46	4284	44.44444444
60	7	0	52	8	32	47	3332	28.57142857
60	7	0.05	50	10	33	45	4165	37.03703704
60	7	0.15	50	10	33	48	4165	37.03703704
60	7	0.3	49	11	30	46	4581.5	36.66666667
70	4	0	54	16	32	47	3808	42.10526316
70	4	0.05	54	16	33	50	3808	43.24324324
70	4	0.15	53	17	32	50	4046	44.73684211
70	4	0.3	52	18	34	50	4284	50
70	5	0	56	14	33	46	4165	37.83783784
70	5	0.05	56	14	34	52	4165	38.88888889
70	5	0.15	56	14	34	52	4165	38.88888889
70	5	0.3	54	16	34	50	4760	44.44444444
70	6	0	57	13	33	47	4641	35.13513514
70	6	0.05	57	13	33	52	4641	35.13513514
70	6	0.15	56	14	32	51	4998	36.84210526
70	6	0.3	55	15	33	47	5355	40.54054054
70	7	0	61	9	30	48	4748.5	22.5
70	7	0.05	58	12	32	51	4998	31.57894737
70	7	0.15	57	13	33	51	5414.5	35.13513514
70	7	0.3	54	16	34	49	6664	44.44444444
80	4	0	61	19	34	46	4522	41.30434783
80	4	0.05	61	19	33	52	4522	40.42553191
80	4	0.15	60	20	34	49	4760	43.47826087
80	4	0.3	59	21	33	56	4998	44.68085106
80	5	0	63	17	34	46	5057.5	36.95652174
80	5	0.05	63	17	34	41	5057.5	36.95652174
80	5	0.15	62	18	34	49	5355	39.13043478
80	5	0.3	61	19	34	51	5692.5	41.30434783
80	6	0	65	15	33	50	5355	31.91489362
80	6	0.05	65	15	33	50	5355	31.91489362
80	6	0.15	64	16	31	50	5712	32.65306122
80	6	0.3	63	17	33	48	6069	36.17021277
80	7	0	68	12	33	43	4998	25.53191489
80	7	0.05	67	13	33	43	5414.5	27.65957447
80	7	0.15	66	14	30	47	5831	28
80	7	0.3	62	18	33	47	7497	38.29787234

5. Result and discussion

A. Experiment result graphs

Improvement in cooling system can be justify from graphs. Graph of Nanoparticle Concentration (%) Against Thermal Conductivity (W/m k)

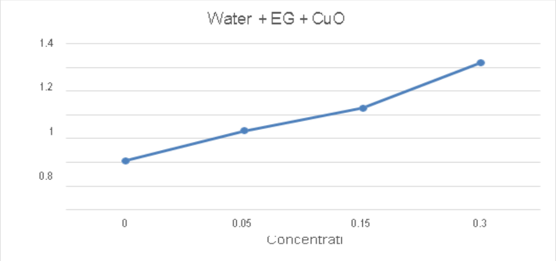

Fig. 7. Graph of Nanoparticle Concentration (%) Against Thermal Conductivity (W/m k)

B. Enhancement in heat transfer rate

The radiator is one type of heat exchanger which reject heat of engine to atmosphere. The hot coolant fluid enters radiator with higher temperature and leaves at lower temperature. So, heat transfer between coolant fluid and atmospheric air called rejected heat from radiator. For comparison between water heat rejection with different nano-fluid, the value of heat transfer rate Q is required. To find heat transfer rate, below equation is used,

$$Q = m.C_p.\Delta T \qquad \text{Equation (2) Heat transfer rate}$$

Where, Q = heat rejection rate
m = coolant flow rate
C_p = Specific heat of coolant (water)
ΔT = Temperature difference at inlet and outlet

6. Conclusion

Experimentation is done on experimental setup with copper nano particle with different nano-particle volume fraction and different Flow rate. The result compares with water + EG as a coolant. The nano particles are more time stable in the coolant.

The performance of the heat transfer characteristics was evaluated based on certain parameters which are the heat transfer coefficient, thermal conductivity, Nusselt number, and rate of hear transfer of the nanofluid. The highest heat transfer coefficient was 14409.91984 W/m^2 K. the highest thermal conductivity was 1.241 W/m K, the highest Nusselt number was 137.0571881 and the highest rate of heat transfer was at 7497 W.

The best performance is shown by copper nano fluid. Enhancement in the heat transfer in the range of 20 to 30% is observed for the 0.3% volume fraction of copper nano fluid at different Flow rate. From experimentation, it is concluded that copper nano fluid with 0.3% volume fraction show optimum performance for overall flow rate.

Automobile radiators can be made energy efficient and compact as heat transfer can be improved by nano fluids. Reduced or compact shape may result in reduced drag, increase the fuel economy, and reduces the weight of vehicle. The thermal conductivity of nano fluid is temperature dependent. As the temperature increases at higher load and speeds the heat carrying capacity of nano fluids increases. This is advantageous when engine is running at high speed and load. The use of nanofluid makes it possible to design the system with higher power- size ratio. As less coolant is needed to be circulated, due to the enhanced heat carrying capacity of the nano fluid, the pumping power required will also be reduced. It was also seen that the metallic nano particles in the coolant helped to warm-up the engine quickly when started from cold condition. And engine oil is also cool and engine oil life increase and its viscosity is also increase so Engine performance is very better.

7. Future Scope

Nanoparticles synthesis is different; it can be produced variety of by some method. to use different composite material to use different thin film nanoparticles Long term stability of nano particles dispersion is required, because after some time nano particles tends to settle down. Due to higher cost, use of nanomaterial is limited for automobile sector. A low-cost production method has to be developed. There is no numerical calculation available to find nano particle property with different volume fraction and particle size. The comparison can be done with different nano particle size to find which one is better suited for nano fluid preparation. A preparation method has to developed to reduce preparation time and increase dispersion into base fluid. Volume fraction of nanoparticles can be optimized by design of experiment for the optimum results.

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