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IMPROVING THE COOLING PERFORMANCE OF AUTOMOBILE RADIATOR WITH MGO-CUO COMPOSITE NANOFLUIDS

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Abstract:* Cooling system plays important role to control the temperature of car's engine. One of the important component in car in cooling system is the radiator. To intensify heat transfer with minimum pumping power innovative heat transfer fluids called nanofluid have become the major area of research now a days. Therefore with the development of new technology in the field of 'nano-material' and 'nan-fluid',it seems to efficiency use these technologies in car radiators to improve engines efficiency, reduce weight of vehicle and size of radiator. In this paper, forced convective heat transfer in a water based nanofluid has experimentally been compared to that of pure water in an automobile radiator. Five different concentrations of nanofluids in the range of 0.1–1 vol.% have been prepared by the addition of MgO – CuO composite nanoparticles into the water. Naomaterials have a higher surface to volume ratio and hence composites made from nanomaterials (nanocomposites) have better thermal, optical, magnetic, electrical properties compared to their bulk composites.. Liquid flow rate has been changed in the range of 2–5 l/min to have the fully turbulent regime (3× 103 < Re < 11 × 104). . Results demonstrate that increasing the fluid circulation rate can improve the heat transfer performance while the fluid inlet temperature to the radiator has little or no effect.

***Key words:* Nanofluid, thermal conductivity viscosity, convective heat transfer, heat exchanger, radiator.**

I. INTRODUCTION

Conventional coolants have been widely employed to dissipate heat in majority of the engineering applications. Typical coolants include matter in all three states namely solid, liquid and gas based on the requirements of application and possible mode of heat transfer. However, with the latest technological advancements, an emerging class of new coolants namely nano-coolants (coolants with dispersed nanoparticles) find their applications in a variety of engineering applications and are expected to replace conventional coolants in the near future. A typical nanofluid is prepared by dispersing certain types of select nanoparticles in a suitable base fluid (water, ethylene glycol and coolant) with different volume concentrations, some of the specific advantages of nanofluids include enhanced thermal properties when compared to the base fluid. Mixing of additives in coolants has been in use from decades to enhance the heat transfer and reduce the pressure drop along the flow. However, enough care is to be exercised when additives are employed since they not only improve the heat transfer but also responsible to reduce the life of the components by fouling and other factors like increased pressure drop and sedimentation. Composites are tailor made materials to achieve desired range of properties. Naomaterials have a higher surface to volume ratio and hence composites made from nanomaterials (nanocomposites) have better thermal, optical, magnetic, electrical properties compared to their bulk composites. Nanofluids are suspension of nanoparticles in a suitable base fluid. The solid nanoparticles are dispersed in a liquid phase. With the increased demand for higher power and clean exhaust gas regulations necessity for hybrid vehicles and vehicles with higher power are increasing enormously. On the other hand only 60% of the heat developed during combustion is utilized for generating useful power and remaining heat is rejected to exhaust. Hence there is a necessity to regulate this heat and maintain the temperature of the engine so as to enhance the performance. Common additives used in cooling system of an automobile include ethylene glycol which improves the properties of water such as freezing point and boiling point. Majority of the automobile radiators uses a liquid cooling system where water with ethylene glycol is employed as cooling medium to transfer the excess heat from the engine. However, such conventional coolants provide inadequate heat transfer and therefore a necessity for high performance thermal systems arise. This can be achieved by increasing the size of the thermal system/cooling system. Due to the stringent design conditions, increased frontal areas, drag coefficients, in an automobile, the necessity for improving the heat transfer phenomenon in the cooling medium is becoming essential. To present the state of the art, a review has been carried out highlighting the contributions of each article and summarized below.S.Balamurugan[1], nanocrystalline MgO particles were prepared through combustion method using magnesium nitrate as oxidizer and hexamine as a fuel. The materials obtained by combustion method were subsequently annealed at 800∘C for 3 h to improve the crystalline and phase purity. The obtained MgO nanomaterials were characterized by powder X-ray diffraction analysis (XRD), infrared (IR) spectroscopy, photoluminescence (PL), near-infrared (NIR) spectroscopy, and scanning electron microscopy (SEM). The cubic crystal structure with lattice parameter, a = 0.4210(4)nm with average crystalline size of 22 nm, is obtained for the nano-MgO particles. Esmaeil Ayoman[2], In this research, nearly spherical CuO nanopowders (NPs) were synthesized in a high-energy ball-milling method at room temperature for different milling times (20 and 40 h) at dry medium. The structure, particle size, purity and morphology of the resulting CuO NPs were characterized by X-ray diffraction, inductively coupled plasma and scanning electron microscopy (SEM) techniques. The results showed that the NPs obtained after 40 h have the smallest particle with only 31 nm. A. Subramaniyan[3], Composites are tailor made materials to achieve desired range of properties. Naomaterials have a higher surface to volume ratio and hence composites made from nanomaterials (nanocomposites) have better thermal, optical, magnetic, electrical properties compared to their bulk composites. The particle size dependence of nanocomposites. R. Ilangovan[4], Investigationthermal conductivity of Cu2O-TiO2 nanocomposites with water as base fluid using Maxwell model for different volume fractions of nanophase. The thermal conductivity variation is analyzed with respect to volume fraction of each phase of the nanocomposite.also by varying volume fraction of the individual phase of nanocomposites. The highest thermal conductivity was obtained for the Cu2O-TiO2 (1:9). Xuan et al. [5] measured the thermal conductivity of Cu/water nanofluids with hot wire method. They studied the effect of various parameters such as particle volume fraction, size and properties of nanoparticles on the thermal conductivity and revealed that thermal conductivity was highly dependent on these parameters. They concluded that for 2.5 % to 7.5 % nanoparticle volume fraction, the thermal conductivity was increased by factor of 1.24 to 1.78. Kakaç et al. [6] reviewed that heat transfer capabilities of ordinary fluids such as water, oils and ethylene glycol can be increased significantly by addition of nanoparticles. They marked the importance of heat transfer fundamentals for a diverse advancement in the field of nanotechnology. Theoretical and experimental understanding of microscopic particle mechanism is vital. Peyghambarzadeh et al. [7] studied the effect of Al2O3/water nanofluid on the cooling performance of an automobile radiator. Five different concentrations varying from 0.1 to 1 % (vol.) of Al2O3/water nanofluids were taken. Flow rate of fluid inside the tubes were changed from 2 to 5 litre per minute. With respect to pure water, heat transfer was enhanced by 45 % by adding Al2O3 nanoparticles. By increasing the Reynolds number of working fluid, effective thermal conductivity was increased by 3%. Chavan *et.al.*, 2014 [8] compared experimentally the forced convection in an Al2O3/water nanofluid to that of fresh water in automobile radiator. Using different concentrations of nanofluids in the range of (0 vol. % – 1 vol. %) were prepared by mixing of Al2O3 nanoparticles with the water. Flow rate of fluid was varied in range of 3-8 L/min to make fully turbulent regime.Rahul and Kothawale, 2014 [9]built an experimental system to study impact of adding Al2O3 nanoparticle to base liquid (EG - water) in radiator was examined experimentally. Enhancing the thermal efficiency of motor led to enhance the motor performance, reduced the fuel utilization and lessening the pollution emissions. Heris *et.al.*, 2014 [10] examined tentatively traditional heat transfer liquids, for example, water and ethylene glycol, utilized for cooling liquids as a part of auto radiators. CuO (60 nm) nanoparticles were utilized as a part of a blend of EG/water as a base liquid. The experiments was performed for various volumetric fraction (0.05 vol.%-0.8 vol.%) of nanofluids of various flow rates (4-8 L/min) and inlet temperatures (35 ºC, 44 ºC, 54ºC).

II. PREPARATION OF (MgO –CuO) NANO PARTICLES

Nanoparticles are particles between 1 and 100 nanometres (nm) in size with a surrounding interfacial layer. The interfacial layer is an integral part of nanoscale matter, fundamentally affecting all of its properties. The interfacial layer typically consists of ions, inorganic and organic molecules. Organic molecules coating inorganic nanoparticles are known as stabilizers, capping and surface ligands, or passivating agents. In nanotechnology, a particle is defined as a small object that behaves as a whole unit with respect to its transport and properties. Particles are further classified according to diameter. Particle of any shape with dimensions in the 1 × 10−9 and 1 × 10−7 m range. The basis of the 100-nm limit is the fact that novel properties that differentiate particles from the bulk material typically develop at a critical length scale of under 100 nm.The term "nanoparticle" is not usually applied to individual molecules; it usually refers to inorganic materials. Ultrafine partic les are the same as nanoparticles and between 1 and 100 nm in size, as opposed to fine particles are sized between 100 and 2,500 nm, and coarse particles cover a range between 2,500 and 10,000 nm.

2.1.SYNTHESIS OF NANOMATERIAL: It is classified as bottom-up manufacturing which involves building up of the atom or molecular constituents as against the top method which involves making smaller and smaller structures through etching from the bulk material as exemplified by the semiconductor industry. Preparation MgO nano particles using sol gel synthesis process as fallowed.

2.1.1Sol-Gel Techniques: Sol-gel auto combustion is a novel method of preparing nanometer materials. Combustible organics such as citric acid, urea, glycine and nitrate are used as raw materials, gel is formed after continuous stirring and exhibits self propagating combustion behavior. Here, we will report the synthesis of nanometer MgO using the sol-gel auto combustion technique in which magnesium nitrate and citric acid act as chelating agent, and also a comparison study with the product prepared using the traditional sol-gel technique .


(a) (b)

Fig 1: (a) Slow evaporation and observation of flame during combustion between nitrate and fuel (b) In the synthesis of MgO.

Citric acid was added to a 0.4 mol/L solution of Mg(NO3)2 (magnesium nitrate) to make the molar ratio of citric acid to nitrates 4:1. A small amount of ammonia was added to the solution to adjust the pH value to about 4, Then the solution was evaporated at 80^0C in a thermostatic water bath followed by drying at 120uC in a vacuum oven, until it turned into dry gel. The dried gel was precalcined at 350^0C for 1.5 hrs, and then calcined at 600^0C for 3hrs.

Table1: Properties of (Mgo) nanoparticles at 30^0c (From HMT book page no 34)

	ρ(kg/m3)	cp(J/kg ºC)	k (W/m.ºC)	μ (kg/m.s)
MgO	3560	955	45	-
Water at 30 ºC	995	4178	0.6280	0.000372
Air at 30 ºC	1.165	1005	0.02675	0.00001863

XRD analysis of MgO nanoparticles:

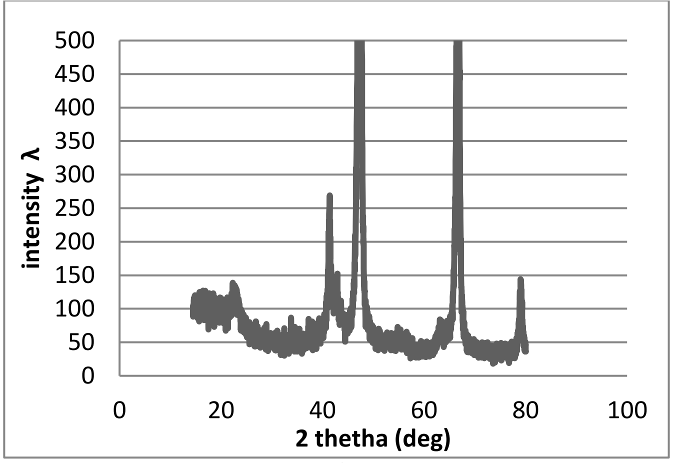


Fig2..XRD analysis of MgO nanoparticles

2.3.Preparation of CuO nanoparticals using planetary high energy ball mill by two step method:

It's far a ball milling method in which a powder aggregate placed in the ball mill is subjected to high-energy collision from the balls. This system was developed through Benjamin and his coworkers on the international Nickel agency in the overdue of 1960. It turned into found that this approach, termed mechanical alloying, may want to successfully produce quality, uniform dispersions of oxide debris (Al_2O_3, Y_2O_3, ThO_2) in nickel-base tremendous alloys that could not be made through greater conventional powder metallurgy strategies. Planetary Ball turbines are used anywhere the best degree of fineness is required. Further to well-tested mixing and size reduction methods, these turbines also meet all technical requirements for colloidal grinding and offer the energy input important for mechanical alloying. The extremely excessive centrifugal forces of a planetary ball mill bring about very excessive pulverization power and therefore quick grinding times.

(a) (b)

Fig 4: (a) PM 100 High energy ball mill (b) Cuo nanopowder

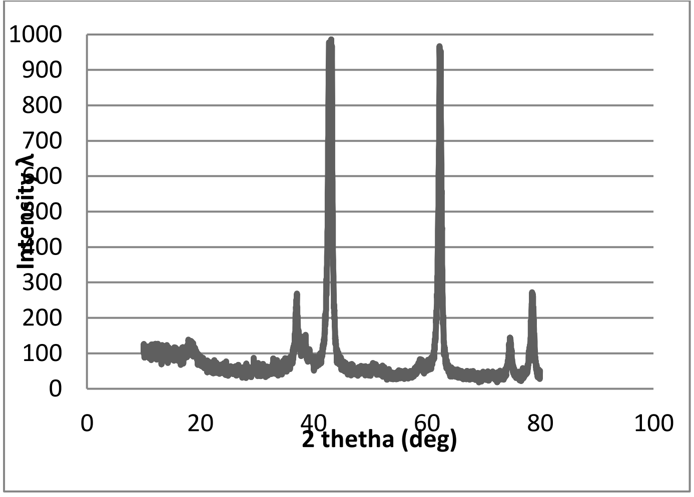


Fig3: X-Ray diffraction (XRD) of CuO nanoparticle

In this research, nearly spherical CuO nanopowders (NPs) were synthesized in a high-energy ball-milling method at room temperature for unique milling instances (20 and 40 hrs) at dry medium. The shape, particle size, purity and morphology of the resulting CuO NPs have been characterized by X-ray diffraction, inductively coupled plasma and scanning electron microscopy (SEM) techniques. The outcomes showed that the NPs obtained after forty hrs have the smallest particle with handiest 30 nm [13].

Table2: Properties' of Cuo nanoparticles: (From HMT data book pg no 34)

S. No		Mean diameter	Specific surface	Density(Kg /m3)	Thermal conductivity (W/mk)	Specific Heat (J/kg K)
1.	CuO	45	29	6310	32.9	550.5
2.	Water	-		997.5	0.628	4178

III. PREPARATION OF(MgO-CuO) NANOPARTICALS:

The present work deals with investigation on thermal conductivity of (MgO-CuO) nanocomposites with water as base fluid the use of Maxwell version for special quantity fractions of nanophase. Thermal conductivity was obtained for the MgO-CuO (8:2) with water as base fluid. The particle size dependence of nanocomposites has made them more attractive and advantageous. Thus nanocomposites can be tailored by size of nanoparticle and shape of nanoparticle. Nanocomposites are nanomaterials with any one of the phase in 1-100nm rang. Many reviews on thermal conductivity of nanofluid signify the enhancement in thermal conductivity of base fluid for a small volume fraction of nanoparticles. Nanofluids have been shown to be useful in manufacturing, automotive, medical and transportation industry in addition to thermal cooling applications [7].

3.1.Thermal conductivity of composite:

Thermal conductivity of nanofluids is practically measured by hot wire method, Transient method and oscillatory method. Several theoretical models like Maxwell, Hamilton crosser, Wasp, Bruggeman, Patel model etc have been applied to metallic, ceramic and CNT nanofluid for the measurement of thermal conductivity [4].

3.2.Thermal conductivity of composite:

The thermal conductivity values of MgO, CuO water and engine oil are taken as 45.8, 32.9, 0.613 and 0.141 in W/m-k respectively. These are approximate values of the thermal conductivity of solids and liquids at temperature of 25°C [2, 7 , 15].

Thermal conductivity of composite according to[9]

$$K_{comp}=K_{Cu0}\ V_{Cu0}+K_{MgO}\ V_{MgO}$$

Density of composite (CuO-MgO)

ρ (composite)= density of Mgo x % of mgo + density of CuO x % of C

Fig 11:MgO-CuOcomposite nanoparticle.(8:2)

Table3: Properties of composite nanoparticles

S.No	ρ (kg/m 3)	cp(J/kg ºC)	k (W/m.ºC)	μ (kg/m.s)
MgO	3060	955	48.4	-
CuO	6310	550.5	32.9	-
MgO-CuO (8:2)	1772	910.41	45.26	-
Water	997.8	4191	0.668	0.000372
Air	1.1614	1005	-	0.00001846

IV. PREPARATION OF MgO- CuO(COMPOSITE NANOFLUID) BY MAXWELL MODEL

This model deals with investigation on thermal conductivity of (MgO-CuO) nanocomposites with water as base fluid the use of Maxwell model for special quantity fractions of nanophase. Thermal conductivity was obtained for the MgO-CuO (8:2) with water as base fluid. The particle size dependence of nanocomposites has made them more attractive and advantageous. Thus nanocomposites can be tailored by size of nanoparticle and shape of nanoparticle. Nanopowders have been blended with water and stabilizers and then sonicated through bath type mixer Sonix VCX 130 (20 kHz, 400 W) with amplitude of 123 μm a set time period. In this work, the nanofluids at extent concentrations of 0.25% , 0.5%, 0.75%, and 1% are organized with two step method approach by using dispersing MgO-CuO nanoparticles in the mixture of DI water as the base fluid. Relying on the extent fraction, specific quantity of MgO-CuO nanoparticle with a mean diameter of 40 nm is dispersed in mixture of water and after that, the mixture is properly stirred. The aggregate is stirred for 60 to 80 min, after which the suspension is inserted internal an ultrasonic homogenizer (Topsonic, 400 W, Iran) for 4 h to interrupt down the agglomeration of particles. After 12 h, no sedimentation becomes discovered in any pattern of nanofluids with naked eyes. The volume fraction of the powder was calculated from the load of dry powder using the density and the total volume of suspension. The nanoparticle–fluid aggregate became stirred and sonicated continuously for three h to make certain the uniform dispersion of nanoparticles within the base fluid.

Fig 5: MgO-CuO nanofluid at 1%

4.1.Thermal and physical properties of MoO-CuO composite nanofluid at (8:2) ratio :

The physical properties of nanofluid like density, viscosity, specific heat, and thermal properties is conductivity is calculated by using correlations [15].

$$\rho nf = \varphi\ \rho p + (1-\varphi)\rho bf.$$

$$\mu_{nf} = \mu_{bf}\ (123\varphi_2 + 7.3\varphi + 1).$$

$$Cp\ nf= = \varphi\ \rho_p\ c_{p,p} + (1-\varphi)\rho bf\ c_{p,nf}\ /\ \rho nf$$

$$K_{nf} = ([\{kp + (n-1)kw - \varphi(n-1)(kw - kp)\}) / (\{kp + (n-1)kw + \varphi(kw - kp)\})] \quad X\ \ k_w$$

$$n= 3/\ \psi$$

Table (4) calculation of properties to nanofluid at bulk temperature 30^0C

φ%	**ρ (kg/m3)**	**cp(J/kg ºC)**	**k (W/m.ºC)**	**μ (kg/m.s)**
0.25	1772	2260.55	0.7290	3.79466
0.5	2548.9	1552.8	1.0921	3.86722
0.75	3324.375	1156.6	1.2345	3.9642
1	4100	910.41	1.5432	4.037316

V. EXPERIMENTAL SETUP AND PROCEDURE

Fig6: Schematic of experimental rig

Fig 5 shows the test rig, in which coolant is heated in heat source and it is then circulated in the radiator with the help of pump. Rotameter is used to adjust the flow of water in the radiator. Due to forced convection, heat of coolant is rejected to surrounding with the help of radiator fan. The fins provided on radiator improve heat transfer rate. The coolant is again recirculated back to the heat source. MgO- CuO (composite nanofluid) is prepared by two step method because two-step process works well in many cases, especially for oxide and nonmetallic Nanoparticles [9].The preparation starts by adding 25mg of composite nanoparticles to coolant, then the solution is stirred well and placed under UV light in dark room. This will help to disperse nanoparticles properly in solution and avoid sedimentation. The solution is kept for a 5-6 hrs under UV light, then it is ready for use as a coolant.

Specifications:

S.No	Equipment	Dimensions
1	A Centrifugal Pump	A centrifugal pump is operated by electrical motor (220-240V), (0.5 hp), (50 Hz) and it has a maximum flow rate of (30 liter\min) with 2500 rpm
2	Tank	Capacity- 5 liter Material- PVC Height - 100 cm Diameter -10 cm
3	Liquid Flow Meter	A Platon type flow meter Flow rate ranging from (0.4- 10) L/min
4	Fan	Variable air discharge from 3 to 7 m/sec
5	Radiator	Radiator type is compact heat exchanger

Testing Procedure:

Ensure all the connections are proper and leak proof. Open the radiator cap and pour clean water in the radiator. Close the radiator cap properly and connect the radiator, pump and heater to power supply. Switch on the supply for Pump and Heater. Open the knob of rotameter to complete 10 Ipm. Run the pump and heater for 20 to 30 min until there is sufficient temperature raise. Switch on the supply to radiator, subsequently the radiator fan will start. Adjust the flow of coolant to 10 lpm and take two reading for each flow rate after every 2 min (up to 8 lpm). Observe the inlet and outlet temperature of radiator on thermocouple and note it down. Also measure the outlet temperature of air from radiator.

VI. CALCULATIONS

To obtain heat transfer coefficient and corresponding Nusselt number, the following procedure has been performed. According to Newton’s cooling law.

$$q = m_{air} \times C_{p,air} \times (T_{air,out} - T_{air,in}) = m_{nf} \times C_{pnf} \times (T_{nf,in} - T_{nf,out})$$

Heat transfer rate can be calculated as follows:

$$Q = h\ A\ \Delta T = h\ A\ (T_b - T_s)$$

Heat transfer rate can be calculated as follows:

$$Q = m\ Cp\ \Delta T = m\ Cp(T\ in - T\ out)$$

Regarding the equality of Q in the above equations

$$Nu\ nf = \frac{h \exp Dh}{knf} = \{m\ Cp(T\ in - T\ out)\ D / A\ (T_b - T_s)\ knf\}$$

Nu is average Nusselt number for the whole radiator, m is mass flow rate which is the product of density and volume flow rate of fluid, Cp is fluid specific heat capacity, A is peripheral area of radiator tubes, Tin and Tout are inlet and outlet temperatures, Tb is bulk temperature which was assumed to be the average values of inlet and outlet temperature of the fluid moving through the radiator, and Tw is tube wall temperature which is the mean value by two surface thermocouples. In this equation, k is fluid thermal conductivity and D is hydraulic diameter of the tube. It should also be mentioned that all the physical properties were calculated at fluid bulk temperature

Correlations for Nusselt number estimation for single phase fluids

DittuseBoelter Correlations

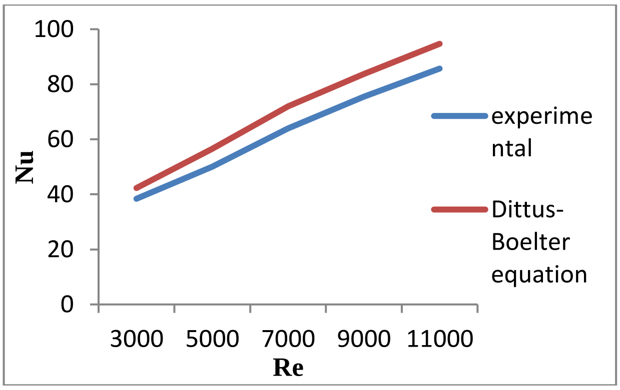
$$Nu = 0.023\ Re^{0.8}\ Pr^{0.3}$$

VII. RESULTS AND DISCUSSION

7.1.Data Validation:

A thorough check of the instruments and the test set-up was followed by experimentation on Radiator. The average values of Nusselt number were determined. These values are compared with the values obtained from the standard correlation with Dittus-Boelter equation for Nusselt number in case of Radiator. The standard equations for Nusselt number is given as:

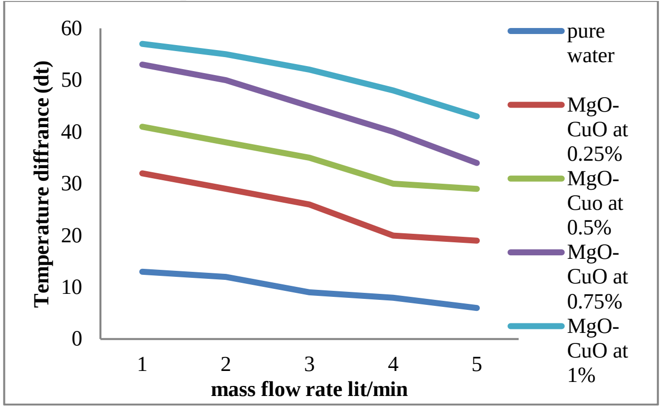
$$Nu = 0.023\ Re^{0.8}\ Pr^{0.3}$$



Graph:1 Nusselt number Vs Reynolds Number

Experimental calculated value, Graph 1 shows the validation of Nusselt number over the radiator equation. Deviation of ±10 % is seen in the case of Nusselt number. This small deviation in experimental result allows proceeding with the experimentation.

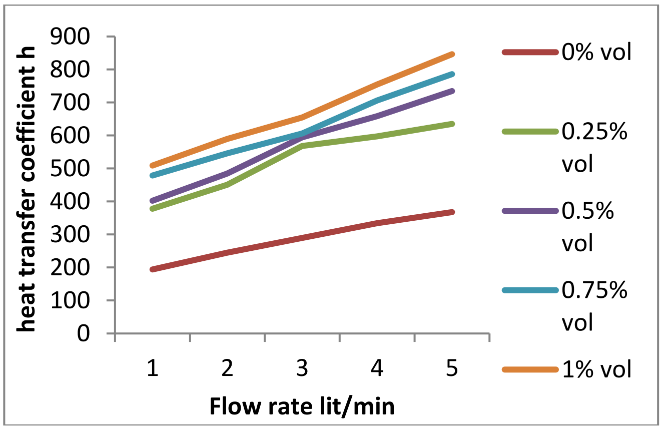
7.2.Effect of temperature difference:



Graph 2: Mass flow rate (lpm) vs. Temperature difference (°C)

Graph 2: shows that graph with decrease in mass flow rate, temperature distribution of the inlet and outlet temperature of the coolant will growth because the coolant is getting extra time to take in warmth from the warm temperature supply. Amongst all of the curves, nanofluid with (mgo-cuo) at 1% nanofluid is having better temperature difference.

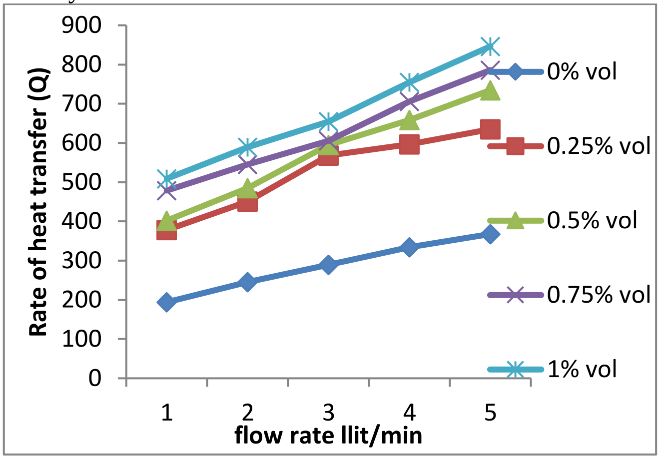
7.3.Effect on heat transfer coefficient:



Graph 3 Mass flow rate Vs. Heat transfer coefficient

In this study, the nanofluid was used at different MgO-CuO(composite) nanoparticles concentrations, that is, 0.1, 0.25, 0.5, 1 vol% and in different flow rates of 1, 2, 3, 4, and 5 lit/min were implemented as the working fluids. , the experiment was done at constant inlet temperatures in order to study the effect of temperature on thermal performance of the radiator. Nu number increased with the increase in Re number and nanoparticle concentrations. In high flow rates the dispersion effect and chaotic movement of the nanoparticles intensified the mixing fluctuations and increased heat transfer coefficient. Also, increasing the concentration nanoparticles intensified the mechanisms responsible for the enhanced heat transfer.

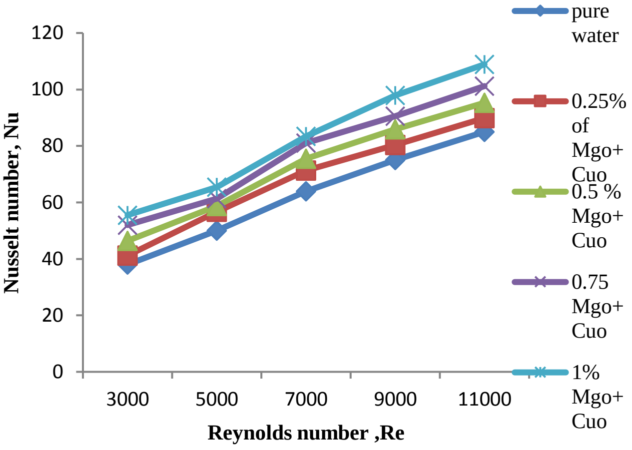
7.4 Reynolds number vs rate of heat transfer:



Graph 4:Mass flow rate Vs rate of heat transfer

Graph 4 represents Relation between heat transfer rate and mass rate of MgO-Cuo (8:2) nanofluid at completely different volume fraction. Results showed that increment the mass rate of nanofluid and volume fraction increased the entire heat transfer rate.

7.5.Nusselt number Vs Reynolds Number:



Graph 5: Reynolds number vs Nusselt number of MgO-Cuo of nanofluid at different fraction

Graph 5. compares the variation of Nusselt number for nanofluids with various volume concentrations as a function of Reynolds number at radiator inlet temperature of 90 °C. It is clearly observed from the figure, that the Nusselt number increases with increase of particle concentration and Reynolds number. The enhancement of 45% was obtained for 1% volume concentration of Mgo – Cuo 3nanofluid compared with the 0% volume concentration of Mgo – Cuo 3nanofluid. These higher heat transfer coefficients obtained by using nanofluid instead of base fluid allow the working fluid in the automobile radiator to be cooler.

VIII. CONCLUSION

It is miles concluded that nanofluids are having better heat transfer rate compared to other coolants and that they can be taken into consideration as a capacity candidate for numerous programs involving heat transfer and their use will keep growing. The nearness of (mgo- cuo) nanoparticle in water increases the heat transfer rate of the automobile radiator. The increment of heat transfer is predicated on upon the amount of nanoparticle added to natural water. On the quantity fraction of 0.25 vol%, the warmth transfer increment of 6 % contrasted with pure water turned into recorded at 1 vol %, increment as much as 35%.the size of radiator may be decreased via including of nanoparticles with the bottom fluid of water. the volume fraction of nanoparticle in the nanofluid extensively have an effect on upgrade of heat transfer coefficient ,properties of fluid as thermal conductivity , density , and viscosity , however it prompted reducing the unique heat transfer.

REFERENCES

[1] S. Balamurugan,1 L. Ashna et al., “Synthesis of Nanocrystalline MgO Particles by Combustion Followed by Annealing Method Using Hexamine as a Fuel ,” Progress in Surface Science, vol. 76,no. 3-5, pp. 71–146, 2004.
[2] Huaqing Xie , Wei Yu & Wei Chen (2010) et. al MgO nanofluids: higher thermal conductivity and lower viscosity among ethylene glycol-based nanofluids containing oxide nanoparticles, Journal of Experimental Nanoscience, Vol. 5, No. 5, October 2010, 463–472.
[3] Esmaeil Ayoman, Sineenart Suphankija , Wanichaya Mekprasarta,b and Wisanu Pecharapaa,b et., al Synthesis of CuO Nanoparticles by Precipitation Method Using Different Precursors Energy Procedia 34 (2013) 740 – 745 Volume 34, 2013, Pages 740-745
[4] Subramaniyan1* and R. Ilangovan2 et.,al Thermal “Conductivity of Cu2O-TiO2” Composite – Nanofluid Based on Maxwell model Int. J. Nanosci. Nanotechnol., Vol. 11, No. 1, March 2015, pp. 59-62.
[5] Xuan, Y., & Li, Q. (2000). Heat transfer enhancement of nanofluids. International Journal of heat and fluid flow, 21(1), 58-64
[6] Kakac, S., & Pramuanjaroenkij, A. (2009). Review of convective heat transfer enhancement with nanofluids. International Journal of Heat and Mass Transfer, 52(13), 3187-3196.
[7] Vajjha, R. S., Das, D. K., & Namburu, P. K. (2010). Numerical study of fluid dynamic and heat transfer performance of Al 2 O 3 and CuO nanofluids in the flat tubes of a radiator. International Journal of Heat and fluid flow, 31(4), 613-621.
[8] Heris, S. Z., Shokrgozar, M., Poorpharhang, S., Shanbedi, M., & Noie, S. H. (2014).Experimental study of heat transfer of a car radiator with CuO/ethylene glycol-water as avcoolant. Journal of Dispersion Science and Technology, 35(5), 677-684.
[9] Leong, K. Y., Saidur, R., Kazi, S. N., & Mamun, A. H. (2010). Performance investigation of an automotive car radiator operated with nanofluid-based coolants (nanofluid as a coolant in a radiator). Applied Thermal Engineering, 30(17), 2685-2692.
[10] Energy Technology Division Argonne National Laboratory. Choi, S. U. S., Enhancing thermal conductivity of fluids with nanoparticles, in :D.A. Siginer, H.P. Wang (Eds.),
[11] Developments and Applications of Non-Newtonian Flows, ASME, New York, FED-vol. 231/MD-vol. 66, pp.99–105, 1995.
[12] Eastman, J. A., Choi, S. U. S., Li, S., Yu, W., Thompson, L. J.,“Anomalously increased effective thermal conductivities of ethylene glycol-based nanofluids containing coppernanoparticles”, Applied Physics Letters, Vol. 78, Issue 6, 2001, pp. 718–720.
[13] Misawa T., Moriyoshi Y., Yajima Y., Takenouchi S., Ikegami T. (1999) J. Ceram. Soc. Jpn., 107(4), 343-348. Patil K.C., Aruna S.T., Mimani T. (2002) Current Opinion in Solid State and Materials Science, 6, 507-512.
[14] Maxwell, J.C. A Treatise on Electricity and Magnetism; Clarendon Press: England, UK, 1873; Volume Choi, S.U.S.; Eastman, J.A. Enhancing thermal conductivity of fluids with nanoparticles. ASME Int. Mech. Eng. Congr. Expos. 1995, 66, 99–105.
[15] Y. J. Li, Y. W. Kwon, M. Jones, Y. W. Heo, J. Zhou, S. C. Luo, P. H. Holloway, E. Douglas, D. P. Norton, Z. Yunus.A. Cengel, 2012, " Heat Transfer book " Tenth Edition Zeinali Heris S., Shokrgozar M., Poorpharhang S., Shanbedi M., and Noie S. H., 2014" Experimental Study of Heat Transfer of a Car Radiator with CuO/Ethylene Glycol-Water as a Coolant " Journal of dispersion science and technology, Vol. 35: PP.677–684.
[16] Kannan C., Raja Jayasingh T., Vinoth .M & Vijayakumar .T, 2014, "An Experimental Study on the Influence of Operating Parameters on the Heat Transfer Characteristics of an Automotive Radiator with Nano Fluids" International Journal of Recent Trends in Mechanical Engineering (IJRTME—ISSN: 2347 - 7326) Vol. 2, Issue. 3.
[17] Sureshkumar. G, Rajakumar .S, Ayyappan .S, 2016, "Experimental and numerical analysis on Car radiator by using Nanofluids" (IJRST), Vol. No. 6, Issue No. III.