Theoretical and Experimental Investigation of Heat Transfer Enhancement in Radiator of Diesel Engine Generator Using Nano Fluids

Nandkumar Sadashiv Vele
Research schollar,RSCOE,Pune
Prof. Dr. R. K. Patil
Guide

***Abstract*—**A colloidal mixture of nano-sized (<100 nm) particles in a base liquid called Nanofluid, which is the new generation of heat transfer fluid for various heat transfer applications where thermo-physical characteristics are substantially higher than the base liquid. In the present study, the effects due to temperature and concentration on thermo-physical properties (thermal conductivity, viscosity and density) for hybrid Nano fluids are discussed.The present work focuses on thermal conductivity and viscosity measurement of fluid mixture. This however, has not been addressed properly so far. It shows that thermal conductivity increases with nanoparticles concentration as well as with the temperature. Whereas, viscosity and density decreases with temperature and increases with nanoparticles concentration. Still more research is necessary to understand the mechanism behind the augmentation of heat transfer with hybrid nanofluids and to make use of hybrid nanofluids in real life applications.

Keywords
Hybrid Nanofluids, Car Radiator, Diesel Engine, Al2O3.

I.Introduction

In a Diesel engine generator heat is produced due to the combustion and some portion of heat is utilized to produce the power rest of heat is wasted in the form of exhaust heat. If this excess heat is not removed, the engine temperature becomes too high which results in overheating and viscosity breakdown of the lubricating oil, wear of the engine parts, due to thermal stress of the engine components failure may occurs in engine. So that an effective cooling system is necessary. The Diesel engine generator utilizes a heat exchanger device, termed as radiator, in order to remove the heat from the cooling jacket of the engine. The radiator considered as an important component of the cooling system of the engine. Normally, it is used as a cooling system of the engine and generally water is the heat transfer medium .For this liquid-cooled system, the waste heat is removed via the circulating coolant surrounding the devices or entering the cooling channels in devices. The coolant is propelled by pumps and the heat is carried away mainly by radiator.

Now a days, alumina is one of the most used oxides due to its use in many areas such as thin film coatings, heat-resistant materials, and advanced ceramic abrasive grains. Improved devices using nanoscale structures requires the understanding of thermal, mechanical electrical and optical properties of nanostructures involved and also their manufacturing process.Task is to use selective nanofluids as a coolant to enhance heat transfer rate. Nanofluids are a relatively new classification of fluids which consist of a base fluid with nanosized particles (1-100 nm) suspended within them. These particles generally a metal or metal oxide, increase conduction and convection coefficients, allowing for more heat transfer out of the coolant. There have been several advancements recently which have made the nanofluids more stable and ready for use in real world applications.

Conventional fluids, such as water, engine oil, ethylene glycol, etc. have poor heat transfer performance and therefore high compactness and effectiveness of heat transfer systems are necessary to achieve the required heat transfer. Among the efforts for enhancement of heat transfer the application of additives to liquids is more noticeable. Recent advances in nanotechnology have allowed development of a new category of fluids termed hybrid nanofluids. Such fluids are liquid suspensions containing particles that are significantly smaller than 100 nm, and have a bulk solids thermal conductivity higher than the base liquids. Nanofluids are formed by suspending metallic or non-metallic oxide nanoparticles in traditional heat transfer fluids. These so called nanofluids display good thermal properties compared with fluids conventionally used for heat transfer. Nanofluids are the new window which was opened recently and it was confirmed by several authors that these working fluid can enhance heat transfer performance.

II. Literature Review

Dattatraya G. Subhedar[a,*,] Bharat M. Ramani[b], AkhileshGupta[c],[1] In their research the heat transfer potential of Al2O3/ water-Mono Ethylene Glycol nanofluid is investigated experimentally as a coolant for car radiators. In this study nanoparticle volume fraction, coolant flow rate inlet temperatures are used. Also the estimation of reduction in frontal area of radiator if base fluid is replaced by nanofluids is done which will make lighter cooling system, produce less drag and save the fuel cost.

Alhassan Salami Tijani *, Ahmad Suhail bin, [2]SudirmanIn this research paper the base fluid, a mixture of water and ethylene glycol were used with concentration of 50% for each of the fluid. Al2O3 and CuOnano particles of concertation 0.05%, 0.15%, and 0.3% were added to the base fluid and then evaluate the heat transfer characteristics of the nanofluid. In thes research efforts have been conducted to improve the performance of cooling system in cars specifically the radiator and coolant fluid. And finally they concluded that the heat transfer performance of both H2O3and CuOnanofluid by comparing each other and select best nanofluid to be used as coolant in the car radiator.

J.A. RangaBabu, K. Kiran Kumar, S. SrinivasaRao, [3] they prepared hybrid nanofluids by dispersing dissimilar nanoparticles as individual constituents or by dispersing nonocompositeparticlesinthe base fluid.This hybrid nanofluids may possess better thermal network and rheological properties due synergistic effect. This review summarizes contempory investigation on behavior properties of these hybrid nanofluids.

Nor AzwadiCheSidik[a*], Muhammad Mahmud Jamil[b], Wan MogdArif Aziz Japar[a], IIsa Muhammad Adamu[a],[4]they concludedhybridnanofluids are potential fluids that offer better heat transfer performance and thermo-physical properties than conventional heat transfer fluids. Their research on recent progress related to preparation methods of hybrid nanofluids. However, they used the excess amount of surfactant which affects the viscosity, thermal conductivity and stability of hybrid nanofluid.

H.W. Chiam[a], W.H. Azmi[b,c],*, N.M. Adam[a], M.K.A.M. Ariffin[a][5]In this research the heat transfer performance of a system can be improved using combination of passive methods, namely nanofluids and various type of tube geometries with the help of this method the heat transfer coefficient and consequently reduce the weight of the system. In this paper, the effect of tube geometry and nanaofluids towards the heat transfer performance in the numerical system is reviewed. The different tube geometries in simulation work are analyzed but the flat tube has greater heat transfer coefficient with a higher friction factor compared to the circular tube.

K. Goudarzi*, H. Jamali, [6]In their researchAluminium Oxide (Al2O3) in ethylene glycol (EG) as nanofluid was used for heat transfer enhancement in car radiator together with wire coil inserts. They used two wire coils inserts with different geometry and nanofluid with volume concetration of 0.08%, 0.05% and 1% were investigated. The results indicated that the use of coils inserts enhanced heat transfer rates up to 9%. The coil wire inserts with different configuration and Al2O3nanofluid with different volume concentration were tested.

R.B. Ganvir*, P.V. Walke, V.M. Kriplani,[7]The heat transfer characteristics of nanofluids are tremendously improved by suspending nano-sized solid paricles and are considered as prospective working fluids for many applications. In this they have studied on convective heat transfer performance of nanofluids and their thermophysicalproperties. Also their most of the studies have been performed with oxides of metals. Heat transfer enhancement is much higher in case of metallic nanoparticles and enhacement is large even at very low volume fraction.

Nor AzwadiCheSidik[a],*, Isa Muhammad Adamu[a], Muhammad Mahmud Jamil[a], G.H.R. Kefayati[b],RizalmanMamat[c], G. Najafi[d],[8]they have written a comprehensive literature on synthesis of hybrid nanofluids have been complied and review. Finally, the challenges and future trend in the application of hybrid nanofluids in heat transfer application are discussed.

PaisonNapon, [9]paper reports on investigation of heat transfer and flow characteristics of the nanofluids in the horizontally spirally coil tubes. In his set up spirally coiled tubes are fabricated by bending a 8.50 mm inner diameter straight copper tube into a spiral coil of five turns. He tested three different curvature ratios of 0.035, 0.043, 0.06. Effects of curvature, nanofluid concentration and hot water temperature on the nanofluid heat transfer characteristics and pressure drop are considered by him. The results he got that Nussult number is about 21.29%, 29.02%, 34.07% for (0.01%, 0.025%, 0.05% by volume concentration resp.) higher than the Nussult number obtained for water as working fluid. He got that the friction factor as working fluid increase slightly compared that of water as working fluid. Further he had proposed two correlations for nussult number and friction factor.

AdityaChoure et al., [10]in this research paper effect of adding Al2O3 nanoparticle as a base fluid in radiator is investigated experimentally. They had studied forced convective heat transfer of water and ethylene glycol based nanofluid and compared them experimentally with water, water + ethylene glycol (60:40), water + ethylene glycol + nanoparticles had carried out. They got the results that Al2O3based coolant show better heat transfer as compared to other coolants.

Rahul A. Bhogare et al., [11] focused on applications and challenges of nanofluids as coolant in automobile radiator. They had studied latest up to date literatures on the applications and challenges in terms of PhD and master thesis, journal articles, conference proceedings, reports and web materials. Relent researchers have indicated that substitution of conventional coolants by nanofluids appears promising in automobile radiator. Nanofluids have great potential to improve automotive and heavy duty engine cooling rates by increasing the efficiency, lowering the weight and reducing the complexity of thermal management.

TABLE I
LITERATURE REVIEW SUMMARY

Sr. No.	Year of Publication	Title of paper	Methodology used	Conclusion
01	2018	Experimental investigation of heat transfer potetional of Al2O3-water-ethylene Glycol nanofluids as car radiator coolant	Nano particle volume fraction, coolant flow rate, inlet temp. used in range of 0.2 – 0.8%, 4 – 9 lpm& 65 – 85 0C	1)Enhancement of Nusselet no. increases from 3.89% to 28.47% 2)Nanofluids make possible to design compact size radiator
02	2018	Thermo-physical properties & heat transfer characteristics of water-Al2O3-CuO base nanofluid as a coolant for car radiator	Mixture of water-ethylene Glycol were used with conentration50% each &nano particles of Al2O3 &CuO of concentration 0.05%,0.15% & 0.3% with additives in flat tube radiator	Thermal conductivity of base fluid was 0.415 W/Mk & with addition of nano particles it increases to 1.287 W/Mk. CuOnanofluid exhibited higher heat transfer rate compared to Al2O3 nanofluid
03	2017	State of art review on hybrid nanofluids	Ultrasonic vibration technique was used to prepare nanofluids and also different surfactants like sodium Dodecyl sulphate&Trimethyl Ammonium Bromide are used	It gives information about preparation of nano particles &nanofluids. Adding surfactants with nanofluidsincrases heat transfer rate.
04	2017	A review on preparation methods,stability& applications of hybrid nanofluids	Preparation methods of hybrid nanofluids,factors affecting their stability and methods of enhancing thermal properties	Further research are needed to find the upper limits of volume fraction and the ratio of nano particles in the composite powder
05	2017	Numerical study of nanofluid heat transfer for different tube geometries	The thermo-physical properties such as density,Specific heat & thermal conductivity of nanofluid are measured	In this research only circular,oval& flat geometry tubes are considered.There is no study about helical twisted tube to enhance heat transfer rate of radiator using nanofluids
06	2017	Heat transfer enhancement of Al2O3-EG nanofluid in car radiator with wire coil inserts	In this experiment Al2O3-EG nanofluid was used for heat transfer enhancement in car radiator together with wire coil inserts	Results indicated that use of coil inserts enhanced heat transfer rates up to 9%
07	2017	Heat transfer charateristics in nanofluids	Preparation of nanofluid was done using one step method & two step method.Also surfactants are used as polyvinylpyrolidine	Heat transfer enhancement is higher in case of metallic nano particles compared to metallic oxide nano particles
08	2016	Recent progress on hybrid nanofluids in heat transfer applications: A comprehensive review	In this paper comprehensive survey on synthesis of hybrid nanoparticles,hybridnanofluids and thermo-physical properties have been compiled and reviewed	Heat transfer enhancement was achieved by using hybrid nanofluids but still there is scope to increase the heat transfer rate using hybrid nanofluids with helical twisted tube radiator.
09	2016	Experimental investigation of nanofluids heat transfer characteristics in horizontal spirally coiled tubes	The spirally coiled tubes are fabricated by bending copper tube of 8mm dia& used nanofluid with different concentration to improve heat transfer characteristics	Nusselt number increseses was about 21.29%,29.02% & 34.07% for 0.01%,0.025% & 0.05% concentration of nanofluids
10	2016	Performance evaluation of automobile radiator using Al2O3 as base nanofluid	Effect of adding Al2O3 nano particles as a base fluid in radiator experimentally investigated	Experimental results shows that Al2O3 based coolant shows better heat transfer as compared to other coolants

11	2013	A review on applications & challenges of nanofluids as coolant in automobile radiator	Flat tube radiator with different concentration of nanofluids were used to experimentally investigate the heat transfer rate	Nanofluids stability are major factor that hinder commercialization of nanofluids

TABLE III
THERMAL CONDUCTIVITY OF SOME MATERIALS, BASE FLUIDS AND NANOFLUIDS

	Materials	**Thermal conductivity (W/mK)**
Metallic Materials	Copper	401
	Silver	429
Nonmetallic Materials	Silicon	148
	Alumina (Al2O3)	40
Carbon	Carbon Nano Tubes (CNT)	2000
Base fluids	Water	0.613
	Ethylene glycol (EG)	0.253
	Engine oil (EO)	0.145
Nanofluids (Nanoparticle concentration %)	Water/Al2O3 (1.50)	0.629
	EG/ Al2O3 (3.00)	0.278
	EG-Water/Al2O3 (3.00)	0.382
	Water/TiO2 (0.75)	0.682
	Water/ CuO (1.00)	0.619

TABLE IIII
PREPARATION METHODS OF DIFFERENT NANOFLUIDS

S. No.	**Nanofluid**	**Method**	**Surfactant**	**Stability**	**Reference**
1.	Al2O3-Water	Two-Step	No	24h	Eastman et al (1997)
2.	TiO2-Water	Two-Step	Oleic Acid and CTAB		Murshed et al (2010)
3.	Cu-Water	Two-Step	Laurate salt	30h	Xuan and Li (2000)
4.	MWCNT-Water	Two-Step	SDS		Hong et al (2000)
5.	Ag-Water	Two-Step	No	24h	Godson et al (2005)

TABLE IVV
CONTRIBUTION OF SCIENTIST IN VARIOUS FIELDS

Scientist	**Flow**	**Performed With**	**Concentration**	**% Gain Than Base Fluids**
Wen & Ding	Laminar	Al2O3	0.6-1.6	41
Yung	Laminar	Al2O3 & H2O	1.8	32
Yu	Laminar	ZnO+EG	0.3	26.5
Eastman	Laminar	CuO+H2O	1-3.4	40
DurgeshChavan	Turbulent	Al2O3+pure H2O	1	45

TABLE V
SPECIFICATION OF DIFFERENT NANOFLUIDS

Nanofluids	Mean Diameter	Density	Thermal Conductivity
Al2O3	20	3700	46
TiO2	10	3840	11.7
CuO	20	6510	18
Fe3O4	36	5180	80.4

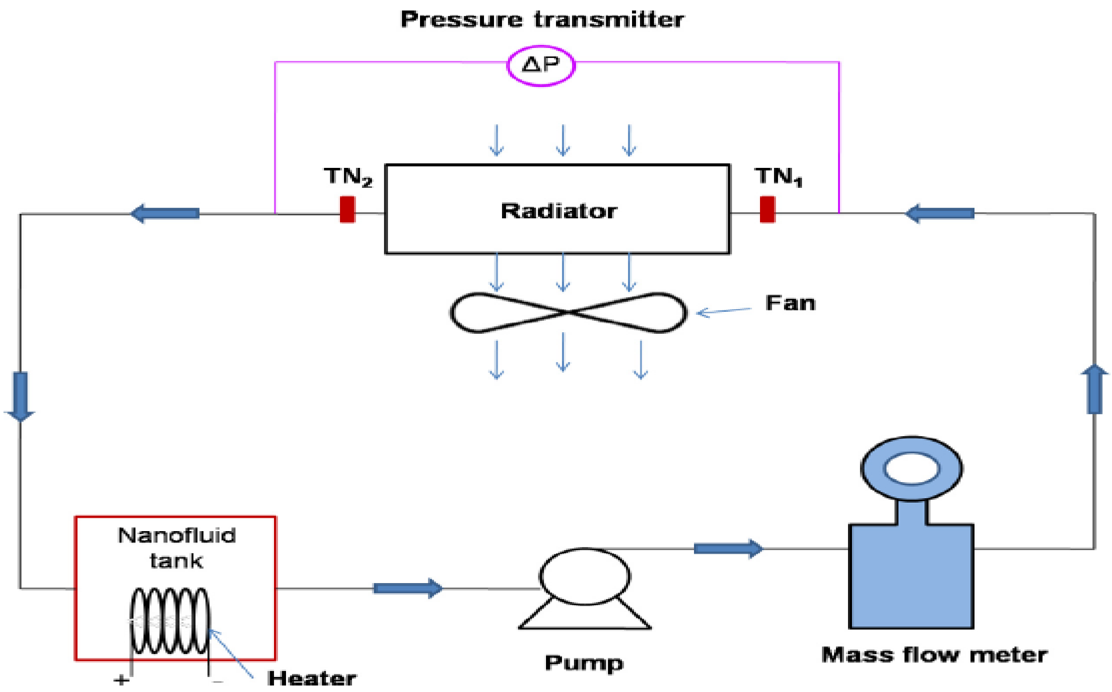

Fig.1Experimental Setup

III. EXPECTED OUTCOME

1) Using appropriate additives or surfactants with nanofluid will improve the stability of nano fluid over long period may achieve higher heat transfer coefficients.

2)Optimization in terms of volume fraction in nanofluid to enhance the heat transfer rate.

3)Heat transfer enhancement may lead to the smaller and lighter diesel engine generator radiators, which in turn lead to the lower capital and running cost.

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