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A review: Enhancement of Internal Combustion Engine performance by using Nano-particles

Ketaki G. Dabade[1] , Neha H. Mahajan[2], Ruchi D. Patil[3], Sayali S. Ingawale[4] , Tanaji B. Shinde[5], Nilesh S. Desai[6]

Department of Mechanical Engineering

SGI, Atigre, India

Corresponding author's email id: *- ketakidabade1131@gmail.com[1], nehamahajan2442@gmail.com[2], ruchip147@gmail.com[3], shinde.tb@sginstitute.in[5], desai.ns@sginstitute.in[6]*

Abstract

In past few decades there have been rapid advances in Nano-technology which have led to emergence of neophyte generation of heat transfer fluids called "Nano-fluids." These fluids contain suspension of nanometer sized (1-100nm) particles to enhance thermodynamic and physical properties. Nano-lubricants are a special type of nano-fluids which are mixture of nano-particles in base oil to improve heat transfer and energy efficiency in several areas including automobile, nuclear, space and power generation.

This paper presents the application of nanoparticles in various corners of engine, so the performance of engine can be improved. We have presented the several conclusions which were made by different researchers by doing some experimental work. Some of the researchers worked on Radiator, some of them on lubricant and some of them are worked on heat recovery. These reviews will help to finding out the new gaps and technology to improve better I.C. engines in coming era.

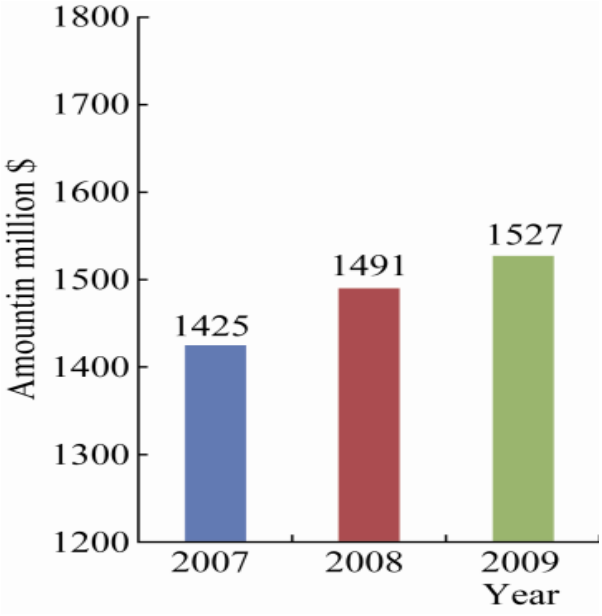
Keywords: *- Nanotechnology; Nano-fluid; Thermodynamic and physical properties; Thermal conductivity*

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INTRODUCTION

With a growing demand for transportation, IC engines have gained a lot of importance in automobile industry. The NSF (Nano science and foundation) estimates the demand for nano technology to exceed up to $1 trillion in the U.S.A respectively until 2015. Following graph represents the R&D funding for Nano-technology in consecutive years. Due to their minute size, their chemical and physical properties are influenced.

In 1995 USA based research laboratory prepared a special kind of fluid by suspension of nano particles in water, oil, Ethylene Glycol etc. This fluid is named as "Nano-fluid" by Choi in 1995.



From literature reviews it has been found out that there is an enhancement in thermo-physical properties, such as thermal conductivity, thermal diffusivity, viscosity and convective heat transfer co-efficient in contrast to those of base fluids like water, oil, Ethylene Glycol etc. The advances in this field of Nano-technology combined with the urge to make improvements in I.C. engine has substantially contributed towards the consideration and ability to produce highly efficient engines with better properties such as friction resistance, heat transfer, lubrication etc.

This has promoted the development of wide applications in this field and design of compact vehicles with high efficiency.

Figure No. 1 Summary of R&D funding for Nano technology from 2007 to 2011 [1]

REVIEW OF RECENT RESEARCH

A. Nanofluid as a coolant:

Cooling is one amongst the most important challenges faced by numerous industries such as automobile, electronics and manufacturing. I.C engines find a wide application all over the world for the purpose of transportation and mobile power generation. Tremendous heat is generated when the engine is in running

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condition, it is a vital factor to tame this heat generated by the engine which can be done by means of a coolant. The conventional heat transfer fluids such as ethylene glycol, oil, and fluro-carbon have poor heat transfer performance due to their low thermal conductivities. Thermal conductivities of solid particles are greater than that of the liquids on account of the molecular spacing between them. To overcome the limitation of low heat transfer the suspension of solid particles in the respective liquid can be carried out. Another factor of vital importance is the dimension of the solid particles which have to be dispersed. If they are in millimeters and micrometers there is a threat of sedimentation and corrosion of the medium in which they are in working conditions viz. pipes, channels, tanks. When this solid particle dimension is reduced to Nano-scale there is stability and substantial improvement in thermal and physical properties of the fluids. Choi and Eastman have carried out this practice. [2-5]

The independence of different metals and metal oxides when suspended in fluids with respect to part loading was observed by Putnam et al. [8]Experiments on convection heat transfer of Nano-fluids were conducted by several research groups. Singh et al. and Ravikanth et. al. have also made use of this application in car radiators. Vasu et al. made use of aqueous alumina and gave concluding remarks of decrease in heat transfer rate when ambient temperature is increased .

Ravikanth et al. made a conclusion that concentration of nano particles is directly proportional to concluded that the average heat transfer co-efficient increases with the Reynolds number and the particle volumetric concentration. The Reynolds number and the pumping power requirements for various concentrations of Al2O3 & CuO nanofluids were measured and are as shown in Fig.2.

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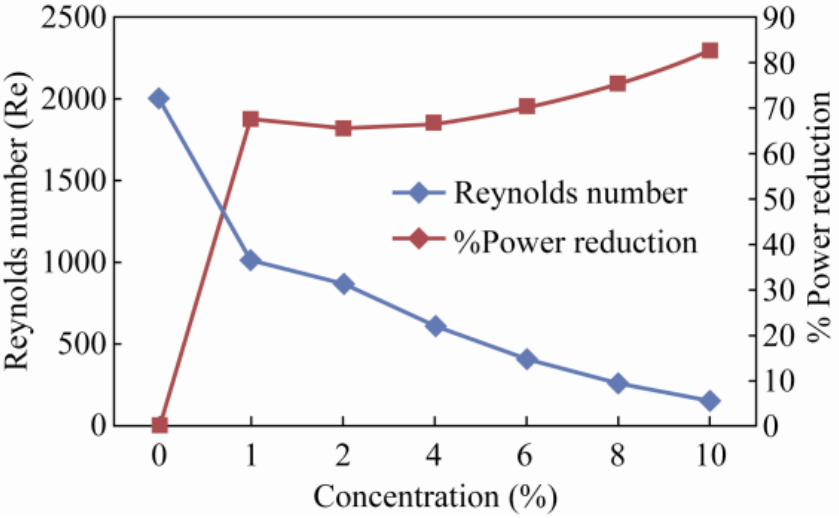


Figure No. 2 Comparison of Reynolds number and percent power reduction for different concentration of Al2O3 nanofluid.[1]

The X-axis scales the concentration of the nanofluids in percentage and Y-axis has power reduction and Reynolds number. The required pumping power is reduced upto 80% for both Al2O3 & CuO. Similarly A. T. Pise and Durgeshkumar Chavan have studied forced convective heat transfer in an Al2O3/water. Nano fluid has experimentally been compared to that of pure water in automobile radiator. Five different concentrations of Nano fluids in the range of 0–1.0 vol. % have been prepared by the addition of Al2O3 nanoparticles into the water [19]. Aqueous form of alumina was used by Vasu et al. as a coolant in a heat exchanger.

S.M. Peyghambarzadeh et. al. 2011 [24] In this paper, the heat transfer performance of pure water and pure EG has been compared with their binary mixtures. Furthermore, different amounts of Al2O3 nanoparticle have been added into these base fluids and its effects on the heat transfer performance of the car radiator have been determined experimentally. Liquid flow rate has been changed in the range of 2–6l per minute and the fluid inlet temperature has been changed for all the experiments. The results demonstrate that nanofluids clearly enhance heat transfer compared to their own base fluid. In the best conditions, the heat transfer enhancement of about 40% compared to the base fluids has been recorded.

S.M. Peyghambarzadeh et. al 2013 [34] In this study, the heat transfer performance of the automobile radiator is evaluated experimentally by calculating the overall

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heat transfer coefficient (U) according to the conventional 3-NTU technique. Copper oxide (CuO) and Iron oxide (Fe_2O_3) nanoparticles are added to the water at three concentrations 0.15, 0.4, and 0.65 vol. % with considering the best pH for longer stability. In these experiments, the liquid side Reynolds number is varied in the range of 50 - 1000 and the inlet liquid to the radiator has a constant temperature which is changed at 50, 65 and 80 ^oC. The ambient air for cooling of the hot liquid is used at constant temperature and the air Reynolds number is varied between 500 and 700. However, the effects of these variables on the overall heat transfer coefficient are deeply investigated. Results demonstrate that both nanofluids show greater overall heat transfer coefficient in comparison with water up to 9%. Furthermore, increasing the nanoparticle concentration, air velocity, and nanofluid velocity enhances the overall heat transfer coefficient. In contrast, increasing the nanofluid inlet temperature, lower overall heat transfer coefficient was recorded.

M. Ali et. al. studied forced convection heat transfer in radiator filled with AL2O3 water nanofluid with different concentrations: 0.1%, 0.5%, 1%, 1.5%, and 2% by volume. The experiments are done for three cases; each case corresponds to different heat load, coolant flow rate, and air flow rate to simulate the vehicle engine cooling system at various loads relevant to the cooling system of Toyota Yaris 2007. The coolant and air heat transfer coefficients, Nusselt numbers, heat rate lost by the coolant and absorbed by the air, heat exchanger effectiveness, overall heat transfer coefficients, Reynolds number, and the pumping power are calculated. Log mean temperature difference (LMTD) and effectiveness-number of transfer units (ε-NTU) are used to determine the outside air heat transfer coefficient. Results show gradual enhancement in the heat transfer with concentrations 0.1%, 0.5%, and 1% by volume (optimum at 1%); however deterioration occurs at concentrations 1.5% and 2% [18].

Results show that heat transfer by the coolant increases as the nanofluid concentration increases up to $\phi = 0.01$ by volume where it reaches its optimum value. Beyond that it deteriorates as the concentration increases. It has also shown that the heat transfer by the coolant increases at higher loads. The coolant and air heat transfer coefficient reach their maximum at $\phi = 0.01$ and beyond that they decrease as the concentration increases.

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The maximum percentage increase of the coolant heat transfer rate, coolant heat transfer coefficient, and coolant Nusselt number is 14.79, 14.72, and 9.51, respectively, which occurs at maximum load 1 and at ϕ= 0.01. The maximum values of air side heat transfer coefficient and Nusselt number also occur at the same load and concentration and have 14.45% and 13.94% increase over that of the base fluid, respectively. Beyond that they deteriorate as the concentration increases. It is recommended that the optimum nanofluid concentration to be used for heat transfer enhancement of the radiator cooling system is ϕ= 0.01 [18].

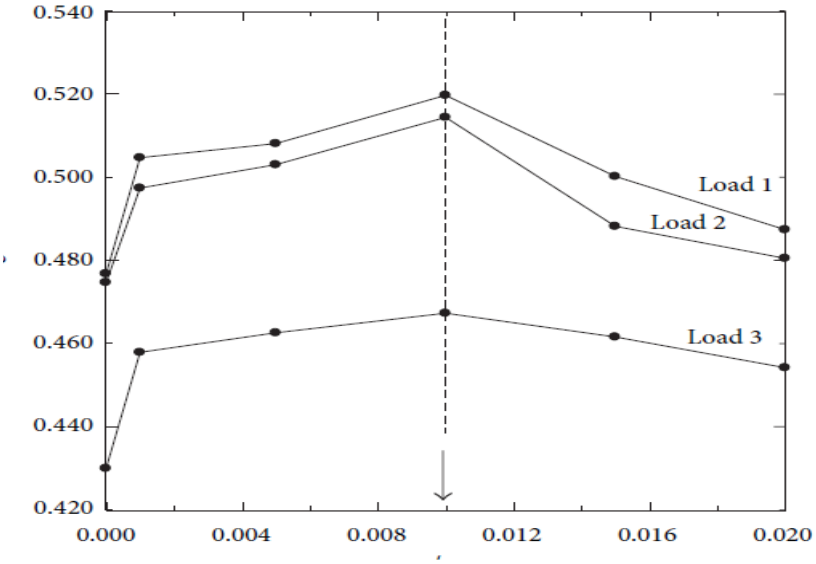


Figure No. 3 Effectiveness of the coolant at different loads for different volume fraction.

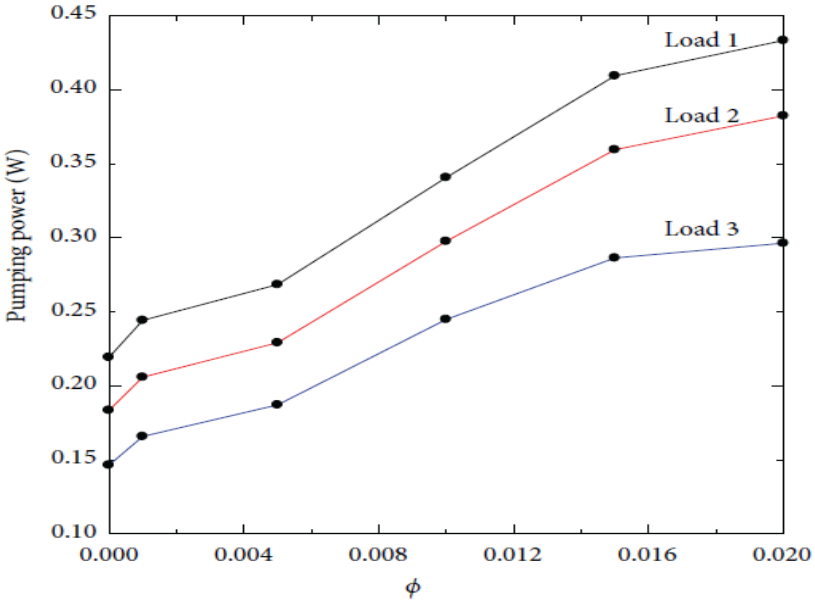


Figure No. 4 Coolant pumping power at different loads for different volume fraction.

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Hwa-Ming Nieh et. al. [32] studied an alumina (Al2O3) and titania (TiO2) nano-coolant (NC) to enhance the heat dissipation performance of an air-cooled radiator. The two-step synthesis method is used to produce different concentrations of Al2O3 and TiO2/water (W) nanofluid by using a 0.2 wt.% chitosan dispersant, and the nanofluid is mixed with ethylene glycol (EG) at a 1:1 volume ratio to form NC1 to NC6. The experiments were conducted to measure the thermal conductivity, viscosity, and specific heat of the NC with different concentrations of nanoparticles and sample temperatures, and then the NC was used in an air-cooled radiator to evaluate its heat dissipation capacity, pressure drop, and pumping power under different volumetric flow rates and heatingtemperatures. Finally, this study evaluates the relationship of the heat dissipation capacity and pumping power by using the efficiency factor (EF). The experimental results show that the heat dissipation capacity and the EF of the NC are higher than EG/W, and that the TiO2 NC is higher than the Al2O3 NC according to most of the experimental data. The maximum enhanced ratios of the heat dissipation capacity, pressure drop, pumping power, and EF for all the experimental parameters are approximately 25.6%, 6.1%, 2.5%, and 27.2%, respectively, compared with EG/W. Overall, the NC improves the heat dissipation capacity and EF of the cooling system; however, the enhanced ratio of the pressure drop and pumping power is not obvious in this study.

M.M. Elias et. al. [22] presents new findings on the thermal conductivity, viscosity, density, and specific heat of Al2O3 nanoparticles dispersed into water and ethylene glycol based coolant used in car radiator. The nanofluids were prepared by the two-stepmethod by using an ultrasonic homogenizer with no surfactants. Thermal conductivity, viscosity, density, and specific heat have been measured at different volume concentrations (i.e. 0 to 1 vol.%) of nanoparticles and various temperature ranges (i.e. from 10 °C to 50 °C).
It was observed that

(a) For the Al2O3–radiator coolant nanofluid as well as the base fluid, thermal conductivity increases with the increase of temperature from 10 °C to 50 °C and higher thermal conductivities were found for higher volume concentrations of the nanoparticles. The highest thermal conductivity enhancement was found to be 8.30% for 1 vol.% of Al2O3–RC nanofluid.

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(b) The obtained nanofluid viscosities were higher than the base fluid and greater viscosities were found for higher volume concentrations. The highest viscosity enhancement was found to be 150% for 1 vol.% of Al2O3–RC at 10 °C whereas the lowest viscosity enhancement was found to be 4% for 0.2 vol.% of Al2O3–RC at 50 °C. The average viscosities of Al2O3–RC nanofluid decrease about 195% when temperature increases from 10 °C to 50 °C.

(c) The highest density enhancement was found at 2.91% for 1 vol.% of Al2O3–RC at 15 °C whereas the lowest density enhancement was found to be 0.36% for 0.2 vol.% of Al2O3–RC at 50 °C. The average density for Al2O3–RC nanofluid decreases 1.71% when temperature increases from 15 °C to 50 °C.

(d) Contrary to the thermal conductivity, viscosity and density, the specific heat capacity of nanofluid decreased with the increase of particle concentrations. However, it increased with the increase of temperature.

(e) Unlike thermal conductivity; viscosity and density of the nanofluids decreased with the increase of temperature. Moreover, in the case of viscosity, when temperature increases from 10 °C to 50 °C, viscosity of the nanofluid at 1 vol.% concentration and the base fluid, decreases by 50.4%. That means, the decreasing trend is about exponential, whereas this trend for density is almost linear.

(f) By increasing the temperature, thermal conductivity increases, while viscosity and density decrease. Therefore, the nanofluid can show better performances at higher temperatures.

S. Zeinali Heris et. al. [33] In this study, CuO (60 nm) nanoparticles were used in a mixture of water/EG as a base fluid. Then, the thermal performance of a car radiator was studied. The experiment was performed for different volumetric concentrations (0.05–0.8 vol%) of nanofluids of different flow rates (4–8 lit/min) and inlet temperatures (35, 44, 54_C). The results showed that nanofluids clearly enhanced heat transfer compared to the base fluid. In the best condition, the heat transfer coefficient enhancement of about 55% compared to the base fluid was recorded.

S.S. Chougule, S.K. Sahu [23] studied, the forced convective heat transfer performance of two different nanofluids, namely, Al2O3-water and CNT-water has been studied experimentally in an

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automobile radiator. Four different concentrations of nanofluid in the range of 0.15–1 vol. % were prepared. The heat transfer performance of CNT-water nanofluid was found to be better than Al2O3-water nano coolant.

S.M. Peyghambarzadehet. Al. [24] presented forced convective heat transfer in a water based nanofluid has experimentally been compared to that of pure water in an automobile radiator. Maximum enhancement of thermal conductivity of nano fluids was 3.0% with 1.0 vol% of Al2O3nanoparticles. However, with 1.0 vol% of nanoparticles, maximum enhancement of heat transfer of the nanofluids was 45% when compared to water only.

D. Chavan, A.T. Pise [11] studied, forced convective heat transfer in an Al2O3/water nanofluid has experimentally been compared to that of pure water in automobile radiator. Five different concentrations of nano fluids in the range of 0–1.0vol % have been prepared by the addition of Al2O3nanoparticles into the water. The increase in heat transfer coefficient due to presence of nanoparticles is higher than the prediction of single phase heat transfer Dittus Boelter correlation used with nanofluid properties. These results can be implemented to optimize the size of an automobile radiator.

K. Y. Leong et. al. [25] focused on the application of ethylene glycol based copper nanofluids in an automotive cooling system. It is observed that, about 3.8% of heat transfer enhancement could be achieved with the addition of 2% copper particles in a base fluid at the Reynolds number of 6000 and 5000 for air and coolant respectively. In addition, the reduction of air frontal area was estimated.

J. Sarkar, R. Tarodiya [26] studied effects of various operating parameters using Cu, SiC, Al2O3 and TiO2 Nano-fluids with 80% water - 20% ethylene glycol as a base fluid are presented in this article. Use of nanofluid as coolant in radiator improves the effectiveness, cooling capacity with the reduction in pumping power. SiC-80% H2O-20% EG (base fluid) yields best performance in radiator having louvered fin geometry followed by Al2O3-base fluid, TiO2-base fluid and Cu-base fluid. The maximum cooling capacity improvement for SiC is 15.34%, whereas that for Al2O3 is 14.33%, for TiO2 is 14.03% and for Cu is 10.20% as coolants and enhancement in second law efficiency for SiC is highest

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(20.13%) followed by Al2O3 (19.60%), TiO2 (19.14%), Cu (16.85%) nanofluids compare to base fluid as a coolant alone.

A. Nano-fluid as Lubricant

It was observed in the performance of automobiles that when nano-particles with some modification are dispersed into mineral oil there is substantial reduction in the friction and the load capacity of the engine. Engine parts and components continuously are in motion in the course of their working condition and there exists tremendous amounts of friction between mating parts which gives rise to the necessity for lubrication and control over the heat that is generated.

S. C. Tzeng, C. W. Lin, K.D. Huang [31] adds CuO and Al2O3 Nano particles and antifoam respectively into cooling engine oil. A comparison is made between their heat transfer performance and that of oil without adding such substances. The experimental platform is a real-time four-wheel-drive (4WD) transmission system. The experiment measures the temperature distribution of RBC exterior at four different rotating speeds (400rpm, 800rpm, 1200rpm and 1600rpm), simulating the conditions of a real car at different rotating speeds and investigating the optimum possible compositions of a Nano fluid for higher heat transfer performance.

K.J. Zhang et. al. [17] studied the characteristic of heavy-duty diesel (HDD) engine coolant using the ASTM for reference, and developed the testing devices and procedures, such as water pump circulating cavitation-rust test-bed, ultrasonic cavitation-pitting on a cylinder liner tester, liquid-vapor corrosion tester. With the help of these studies, the test of the new products according to FAW product lines, such as all season HDD engine coolants and the run in HDD engine coolant which could protect the water jacket from the rusting for 180 days were carried out. The investigation on the nano-fluids shows the cooling capability of the HDD coolant with 3%wt nano-graphite is increased by 15%.

S.K. Mohammadi et. al. [19] investigated that, nanofluids were prepared by dispersing γ-Al2O3and CuO nanoparticle in engine oil. The maximum enhancement of thermal conductivity of γ- Al2O3–engine oil nanofluid was 5%, whereas CuO–engine oil nanofluid was 8% with 2.0 vol. % of respective nanoparticle concentrations.

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M. Vasheghani [20] have been carried out for determining the thermal conductivity of nanofluids with nanoparticles (α- and γ-Al2O3, and AlN) dispersed in an engine oil as the base fluid (up to 3 wt.%). The conductivity was recorded to be equal to about 26.10%, 31.47%, 37.49%, and 75.23% for α-Al2O3 (100 nm and 20 nm), γ-Al2O3 (20 nm) and AlN (20 nm), respectively, while their corresponding viscosities rise up to 41.2%, 41%, 40.7%, and 44.14%, respectively.

E. O. L. Ettefaghi et. al. [21] researched; the effect of multi-walled carbon nanotubes (MWCNTs) in different concentrations on some of the properties of engine oils was studied. Viscosity, pour point, flash point and thermal conductivity as four quality parameters, which are effective in functionality of engine oil, were also studied. According to the obtained results, thermal conductivity and flash point of nano-lubricants with 0.1 wt% improved by 13.2% and 6.7%, respectively, with respect to the base oil.

B. Nano fluid as a fuel additive

The use of petroleum products in the transportation sector has been steadily increasing, which contribute in a larger extent to the rapid depletion of the natural resources. Even a 10% increase in the efficiency of engines, by decreasing friction is considered to be a significant improvement. Lubrication is essential to reduce friction and wear in engine parts thus minimizing the associated dissipative energy loss. Thermal conductivity is the most important property of lubricating oil, which accounts for its heat transferring ability. Other important properties of lubricating oil include the flash point and the pour point, which are related to oil storage and handling. These properties of lubricant can be further improved by the use of various wear reducing agents.

The scientists in the USA council of nano science and technology attained better efficiency by addition of just 0.5% of aluminum in a rocket engine solid fuel .Aluminum nanoparticles serve as a catalyst to decompose the water. M.J. Kao et al. also observed that the fuel consumption will reduce by using aluminum nanofluid and diesel nanoparticles serve as a catalyst to decompose the water. They also observed that the fuel consumption will reduce by using aluminum nanofluid and diesel mixture [13]. Aluminum reacts with water at high temperature to produce hydrogen. The experimental investigation was carried out to improve the performance and emission characteristics of C.I engine

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using cerium oxide nanoparticles with diesel and biodiesel mixture fuel by Arul Mozhi Selven et al. [26]. Cerium oxide absorbs the pollute gases such as NOx [27].

Stability of nanofluid

Stability of nanofluid is the factor that limits the real time applications of nanofluids. Stability of nanofluids means that the dispersed nanoparticles should not sediment as well as not to form agglomerates. The mechanisms and methods to achieve longer stability are addressed by several researchers with conventional diesel engine oil properties. In summary, as compared with conventional diesel engine oil with and without Al2O3nanoparticles, the current study by S.A. Rafiq et al. proves that the hBN nanoparticles dispersed in SAE 15W40 diesel engine oil could improves or at least maintain the key lubrication properties of VI, TBN and flash point temperature etc.

CONCLUSION

- Nanoparticle shows the promising result when it added to the engine lubricating oil and coolant as well.
- Some of the US researchers have used the nanoparticle in solid fuel in the application of Rocket engine.
- Maximum engine performance is enhanced by 19% when used in the engine coolant and 15% when used in the lubricating oil of the engine.

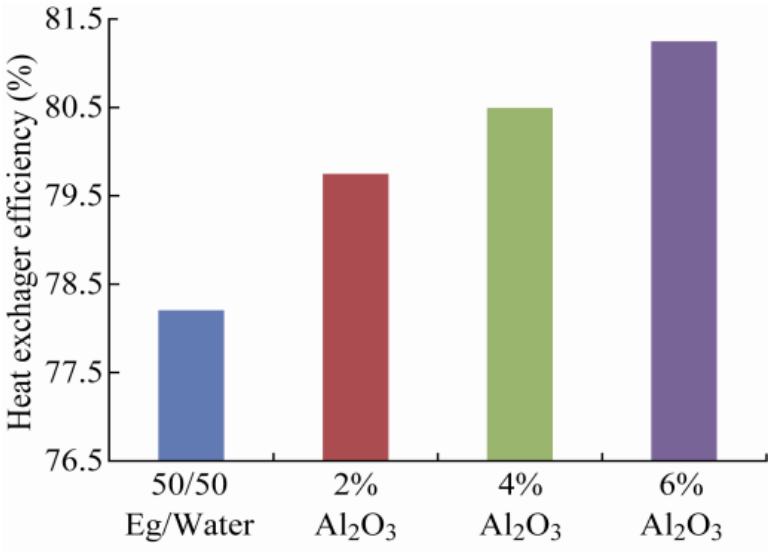


Figure No. 5 Comparison of heat exchanger efficiency for different concentration of nanofluids.

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- From the literature review, remarks on the viscosity stated that there is no substantial change in the viscosity of oils when nano particles are added to them.

- Nano fluid stability and its production cost are major factors that hinder the commercialization of nanofluids. By solving these challenges it is expected that nanofluids can make substantial impact in enhancing I.C engine performance

- Exact mechanism of enhanced heat transfer for nanofluids is still unclear as reported by many researchers.

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