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REVIEW ON AUTOMOBILE RADIATOR USING ALUMINUM OXIDE AND LEMON JUICE AS NANOFLUID

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ABSTRACT: Nanofluid is a colloidal mixture of nano-sized (100 nm) particles in a base liquid that is the next generation of heat transfer fluid for a variety of heat transfer applications where the thermo-physical characteristics are significantly better than the base liquid. The effects of temperature and concentration on thermo-physical properties (thermal conductivity, viscosity, and density) of hybrid Nano fluids are examined in this research. The current study focuses on determining the thermal conductivity and viscosity of a fluid combination. This, however, has not been adequately addressed thus far. It demonstrates that thermal conductivity rises with both nanoparticle concentration and temperature. Viscosity and density, on the other hand, drop with increasing temperature and increase with increasing nanoparticle concentration. More research is needed to understand the process behind the usage of hybrid nanofluids to improve heat transmission and to apply hybrid nanofluids in real-world applications.

KEYWORDS: Hybrid Nanofluids, Car Radiator, thermo-physical characteristics, Al_2O_3.

I. INTRODUCTION

Heat is produced in an automobile engine as a result of combustion, and part of it is used to generate power, while the remainder is squandered as exhaust heat. If the surplus heat is not eliminated, the engine temperature rises, resulting in overheating, viscosity breakdown of the lubricating oil, wear of the engine parts, and the possibility of engine failure due to thermal stress. As a result, an efficient cooling system is required. In order to remove heat from the cooling jacket of the car engine, a heat exchanger device known as a radiator is used. The radiator is an integral part of the engine's cooling system. It is typically employed as part of an engine's cooling system, with water serving as the heat transfer medium. Waste heat is eliminated from this liquid-cooled system by circulating coolant around the devices or by entering the cooling channels in the devices. The coolant is pumped around, and the heat is mostly taken away via radiators.
Alumina is now one of the most widely utilized oxides, with applications including thin film coatings, heat-resistant polymers, and improved ceramic abrasive grains. Understanding the thermal, mechanical, electrical, and optical properties of the nanostructures involved, as well as their production process, is required for improved devices incorporating nanoscale structures. The goal is to improve heat transfer rate by using selected nanofluids as a coolant. Nanofluids are a relatively new group of fluids that contain Nano sized particles (1-100 nm) floating in a base fluid. These particles, which are usually made of metal or metal oxide, improve conduction and convection coefficients, allowing more heat to be transferred from the coolant. There have been a number of recent developments that have made nanofluids more stable and appropriate for usage in real-world applications.

Heat transfer performance of conventional fluids such as water, engine oil, ethylene glycol, and others is low, thus high compactness and effectiveness of heat transfer systems are required to achieve the required heat transfer. The application of chemicals to liquids stands out among the efforts to improve heat transmission. Recent breakthroughs in nanotechnology have enabled the production of a new class of fluids known as nanofluids.

hybrid nanofluids are a type of nanofluid that combines two or more Such fluids are liquid suspensions that contain particles smaller than 100 nm and have a bulk solids thermal conductivity that is higher than the base liquids. The suspension of metallic or non-metallic oxide nanoparticles in typical heat transfer fluids produces nanofluids. When compared to traditional heat transfer fluids, these so-called nanofluids have excellent thermal characteristics. Nanofluids are a new window that has recently opened, and various authors have confirmed that these working fluids can improve heat transfer performance.

Heat transfer plays a significant role in industries. Rate of heat transfer can be increased with increase in heat transfer area, temperature gradient or by improving the thermal properties of the fluid. Modernization of technology provides a huge opportunity in the production of nanoparticles. Since then, much experimentation has been performed to study heat transfer characteristics of different type of nanofluids. Basically, nanofluid consists of nanoparticles of size 1-100nm suspended in a base fluid. These particles are metals or metal oxides, which enhance the heat transfer coefficient for better heat transfer **[1]**, e.g. Cu and CuO nanoparticles suspended in ethylene glycol and water respectively to form a nanofluid. Nanofluids are developed in 1995 by Stephen Choi **[2]** for increasing the thermal conductivity of various fluids, which have now developed as a technological area called nanotechnology. Prasher et al. **[3]** reported that thermal conductivity of nanofluid increases due to convection caused by brownian motion of nanoparticles. There are many industrial sectors like power generation, transportation, chemical process plants and electronics where heat transfer plays a significant role. Nasiri et al. **[4]** shows that the compound which consists of millimeter or micrometer particles in basefluids causes pressure drop, sedimentation of particles and clogging. Therefore, small and low volume fractions of these particles will eliminate these problems. Palm et al. **[5]** shows the increase in heat transfer using nanofluids in radial flow cooling systems. There is 25% increase in heat transfer coefficient when there is dispersion of only 4% (v/v) of Al_2O_3 in water.

In fact, nanotechnology can be integrated into many of technological areas like in refrigeration systems, thermal processing, oil recovery, gas absorption, cooling, hydrate formation, steam generation, wettability alteration and in various types of heat exchangers. The paper also includes two methods for preparation of nanofluids i.e. one-step process and two-step process. Eastman et al. **[6]** shows with the addition of 0.3% (v/v) of Cu nanoparticles in ethylene glycol, the thermal conductivity increases by 40% in comparison of basefluid. Similarly, Choi et al. **[7]** shows that with the addition of 1% (v/v) MWCNT's in poly (α-olefin), the thermal conductivity increases by 150% in comparison of basefluid. Kang et al. **[8]** suggested that with the addition of 1.2% (v/v) diamond nanoparticles (between 30-50nm in diameter) in ethylene glycol, the thermal conductivity increases by 75% in comparison of basefluid. These data shows that the addition of nanoparticles have tremendous effect on thermal conductivity of basefluids. CO_2 capturing with the help of nanofluids as solvents increases the rate of absorption of CO_2, which in turn reduces the energy consumption **[9]**.

Nanoparticles are preferred in increasing thermal conductivity, viscosity, heat and mass transfer coefficient of base fluids. Kim et al. **[10]** reported that for alumina (Al_2O_3) based nanofluids the heat transfer coefficient increases by 15% and 20% in laminar and turbulent flow conditions respectively, as compared to basefluid. Farajollahi et al. **[11]** reported the heat transfer characteristics of γ-Al_2O_3-water and TiO_2-water based nanofluids in shell and tube type heat exchanger under turbulent flow conditions. The overall heat transfer coefficient of γ-Al_2O_3-water nanofluid enhances by 20% (maximum) at 0.5% (v/v). For TiO_2-water nanofluid the overall heat transfer coefficient enhances maximum at 0.3% (v/v). Further, Fotukian & Esfahany **[12]** observed the increment of 25% in heat transfer coefficient of CuO-water nanofluid in comparison of pure water. This article will be useful to find application of nanofluids in various industries and is expected to improve the performance of these applications to a further level.

Preparation methods of nanofluids

The basic requirement of nanofluids for heat transfer application is long term stability. Stability of nanofluids depends upon its method of preparation, characteristics of nanoparticle, type of basefluid, pH and type of surfactant used. The presence of high surface charge on the nanoparticles leads to its unstability, which involves the significant problem of agglomeration **[13]**. For preparation of nanofluid there should be stable suspension, no accumulation of nanoparticles to form clusters and no chemical change of basefluid. Xuan & Li **[14]** reported methods for stabilization of suspensions such as variation in pH, use of surfactants and ultrasonication. These methods can prevent the formation of clusters in order to obtain stable nanofluids. Basically, there are two methods to produce nanofluid: one-step and two-step process, which are discussed below.

One-step process

One step process includes direct evaporation and condensation of nanoparticles in the basefluids which occurs in single step. The single step direct evaporation process was developed by Akoh et al **[15]**. The separation of particles from the fluid is difficult through this method. Another one is single step laser ablation process to produce alumina nanofluids. Zhu et al. **[16]** reported the process for preparation of Cu based nanofluids by reducing $CuSO_4.H_2O$ with $NaH_2PO_2.H_2O$ in ethylene glycol under microwave irradiation. Lo et al. **[17]** suggested the preparation of CuO, Cu_2O and Cu based nanofluids through vacuum based submerged arc nanoparticle synthesis. In one-step process the accumulation of nanoparticles to form clusters is less which contributes towards the stability of nanofluids. But the major problems are that only low vapour pressure fluids can be processed through the process and it is impossible to scale-up as the production cost is quite high.

Two-step process

In this process nanoparticles obtained from different mechanical, physical and chemical mechanism are mixed with different basefluids to form a nanofluid. Ultrasonication and addition of surfactants are usually required to reduce agglomeration in this process. The most commonly used surfactants are sodium dodecylsulphate (SDS), poly vinyl pyrrolidone (PVP), poly ethylene glycol (PEG), oleic acid, sodium dodecylbenzene sulphonate (SDBS) and acetic acid. It can be used to prepare almost all kinds of nanofluids. Xuan & Li **[18]** prepare Cu based nanofluids by suspending these nanoparticles in both water and transformer oil. Kim & Kwak **[19]** used two- step process to prepare CuO-EG based nanofluid with the help of sonication and without using any type of stabilizer. This process can also be used to prepare carbon nanotube based nanofluid. Also, this process is apt to prepare nanofluids which consist of oxide nanoparticles rather than those which consist of metallic nanoparticles **[20]**. The summary of preparation of nanofluids is discussed in Table 1.

Table 1: Summary of nanofluids preparation

Researcher	**Nanofluid (Conc. v/v %)**	**Basefluid**	**Method of preparation**	**Stability**
Yang & Liu **[21]**	SiO_2 (10%)	Water	Two-step	Stability of 12 months can be achieved by using 3-Glycid oxyl proyl tri-methyl oxy silane (with silane/silica mass ratio= 0.115) and the solution is kept at 50°C for 12 h
Hamid et al. **[22]**	TiO_2 (0.5-1.5%)	EG/water	Two-step	Stability can be achieved after ultrasonic bath of 2h
Researcher	**Nanofluid (Conc. v/v %)**	**Basefluid**	**Method of preparation**	**Stability**
Bhagat et al. **[23]**	ZnO (0.1, 0.5 & 1.0%)	EG/water	Two-step	Stability can be achieved by 5wt.% PVP or 1wt.% PVA and solution stirred by magnetic stirrer before ultrasonication
Hung et al. **[24]**	Al_2O_3 (0.5, 1.0 & 3.0%)	Water	One-step	Stability of more than 2 weeks can be achieved by homogenizing at 8000rpm for about 30min and by using electromagnetic agitator at 600rpm
Lee et al. **[25]**	CuO (NR)	Water	One-step	Stability can be achieved by usinga single pulsed laser beam for 8h
Yu et al. **[26]**	Fe_3O_4 (1.0%)	Kerosene	Two-step	Stability can be achieved with the help of Oleic acid.
Kole & Dey **[27]**	ZnO (0.005 & 0.0375%)	EG	Two-step	Stability can be achieved with ultrasonication at 200W upto 100hr. + no surfactant
Vermahmoudi et al. **[28]**	Fe_2O_3 (0.02%)	Water	Two-step	Stability of 7 days can be achieved at pH= 11.1 + PEG as surfactant followed by magnetic stirring for 1h
Karimi et al. **[29]**	α-Fe_2O_3 (0.25, 0.5, 1.0, 2.0, 3.0 & 4.0%)	Water	Two-step	Stability can be achieved with the help of sonication and by treating it with tetramethyl-ammonium hydroxide.
Aliabadi et al. **[30]**	Cu (0.1-0.3%)	Water	One-step	Stability of more than 2 weeks for0.1% and 5 days for 0.3%
Murshed et al. **[31]**	TiO_2 nanorods (0.05%)	Deionized water	Two-step	Stability can be achieved with ultrasonic dismembrator by using it for 8-10h

Harikrishnan & Kalaiselvam **[32]**	CuO (1.0, 1.5 & 2.0%)	Oleic acid	Two-step	Stability can be achieved by ultrasonification at frequency of 40kHz
Michael & Iniyan **[33]**	CuO (0.05%)	Distilled water	Two-step	Stability of this nanofluid can be achieved by using sodium dodecyl benzene sulphonate of 10wt% + sonication for 60min
Wongvises **[34]**	TiO_2 (0.01%)	Distilled water	Two-step	Stability can be achieved by ultrasonication for 30min
Wang et al. **[35]**	ZnO nanorods (0.01-0.1%)	Deionized water	Two-step	Stability can be achieved with the addition of ammonia citrate at a ZnO/ammonium citrate ratio of 1:1 followed by sonication for about 15min

Inspite of problem of agglomeration, two-step process is still in demand due to its economic advantage in production of different types of nanofluids. The Table 2 consists of compilation of data to study heat transfer enhancement by nanofluids through various experiments.

Table 2: Summary of heat transfer enhancement by nanofluids

Researcher	**Nanofluid (Conc.)**	**Particle size (in nm)**	**Basefluid**	**Geometry/ flow nature**	**Remarks**
Pak & Cho **[36]**	Al_2O_3 (3.0% v/v)	13.0	Water	Tube/ turbulent	Convective heat transfer coefficient enhances by 12% in comparison of base fluid
Ding et al. **[37]**	CNT (0.5% w/w)	NR	Water	Tube/ laminar	Convective heat transfer coefficient enhances by more than 350% (at Re= 800)
Jung et al. **[38]**	Al_2O_3 (0.018% v/v)	20.0	Water	Rectangular microchannel/ laminar	Convective heat transfer coefficient enhances by 15% in comparison of base fluid
Lai et al. **[39]**	Al_2O_3 (0.01% v/v)	20.0	Deionized water	Tube/ laminar	Nusselt number increases by 8% for Re= 270
Li & Xuan **[40]**	Cu (0.3-2.0% v/v)	<100	Water	Tube/ turbulent	Nusslet number is larger for nanofluidas compared to base fluid
Heris et al. **[41]**	CuO (0.2-3.0% v/v)	50.0-60.0	Water	Tube/ laminar	Nusslet number is large in case of nanofluid
Heris et al. **[42]**	Al_2O_3 (0.2-3.0% v/v)	20.0	Water	Tube/ laminar	Nusslet number is large in case of nanofluid
Rea et al. **[43]**	Al_2O_3 (6.0% v/v)	50.0	Water	Tube/ laminar	Nusselt number enhances by 27% in comparison of base fluid under fully developed flow
Williams et al. **[44]**	Al_2O_3 (0.9-3.6% v/v)	46.0	Water	Tube/ turbulent	There is no enhancement in heat transfer
Wen & Ding **[45]**	Al_2O_3 (0.60% v/v)	27.0-56.0	Water	Tube/ laminar	Nusselt number > 4.36 for fully developed pipe flow with constant wall heat flux

II. CONCLUSIONS

1. Nanofluids have higher thermal conductivity, viscosity, heat and mass transfer coefficient as compared to basefluid, hence it has great potential in various industrial applications.
2. It has been found that some of the articles have reported the enhancement in heat transfer through nanofluids, without relating there performance with any applications.

3. Many heat exchanging devices can be made compact, more energy and cost effective due to enhancement of heat transfer through nanofluids.
4. It has been observed that there is some sort of unpredictability between model and experimental results of thermal conductivity of heat transfer.
5. It is noticed that there are some barriers which have to be considered before implementing these applications in various industries.
6. Stability of nanofluids and its production cost are the key factors that hamper the profit-orientation of nanofluids.

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