IOSR Journal of Engineering (IOSR JEN) **www.iosrjen.org**
ISSN (e): 2250-3021, ISSN (p): 2278-8719,
|| Special Issue || June-2019, || PP 63-69 ||

CFD Analysis & Experimental Validation of Car Radiator by Mgo/Water Nanofluid

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Abstract: *The objective of this project is to improve the thermal performance of car radiator (cross flow) heat exchanger by a new coolant MgO/water Nano fluid. Traditional method of cooling system of engine heat involves the use water or EG but we are now using the latest and most promising coolants (Nano fluids) which are used commonly everywhere for heat transfer applications. This project includes the study of heat transfer characteristics density, thermal conductivity, dynamic viscosity, specific heat capacity. CFD analysis is carried out for MgO/water nanofluid to analyze the heat transfer enhancement.*
Keywords: *Radiator, nanofluid, MgO particles, thermal conductivity, heat transfer rate, volume fraction.*

I. Introduction

From industry point of view, it is important to increase the efficiency of heat transfer equipment which are been installed. Heat exchanger is a device which is majorly used for heat transfer applications in areas like power engineering, food industries, petroleum refineries, chemical industries, refrigeration, air conditioning, power plants, sewage treatment, natural gas processing and so on. Heat exchanger is a device equipped for transferring heat from one medium to another in an efficient manner. Transfer of heat from one medium to another is nothing but the energy transmission from one region to another region because of temperature difference between them. Second law of thermodynamics plays a vital role among the several laws which governs the heat transfer. Second law of thermodynamics states that, “Heat cannot flow from body at lower temperature to body at higher temperature” High thermal conductivity is an important requirement for better heat transfer. Use of Nano fluids for enhancing the heat transfer capacity of heat exchanger has increased in recent years because of their anomalously high thermal conductivity. Nano fluids are recent advancements in the field of nanotechnology. Nano fluids have very high thermal conductivity compared to the base fluids from which they are formed. Many studies have been conducted for enhancing the heat transfer capacity of heat exchanger but owing to the good thermal properties and advancement in the nanotechnology in recent years Nano fluids are considered by many researchers for their studies.

1.1 What is nanofluid

A Nano fluid is a fluid contain Nanometer size metal particle, called Nanoparticles. These Nano fluids are engineering colloidal suspension of nanoparticle in base fluid by different methods. Nanoparticle used in Nano fluids are typically made of metals, oxides, carbides or carbon Nano tube. Common Nano particles are, Al_2O_3, CuO, TiO_2, CeO_2 and SiO_2. Base fluids include water, ethylene glycol and oil. Synthesis and stability of Nano fluids are the two very primary requirements to study Nano fluids [1]

1.1.1 Classification Of Nano Particals

Nano particles are broadly divided into various categories depending on their morphology, size and chemical properties.[2]

2.1. Carbon-based Nano particle

Fullerenes and Carbon Nanotubes (CNTs) represent two major classes of carbon-based Nano particles Fullerenes contain nanomaterial that are made of globular hollow cage such as allotropic forms of carbon. These materials possess arranged pentagonal and hexagonal carbon units, while each carbon is sp2 hybridized. CNTs are elongated, tubular structure, 1–2 nm in diameter. These can be predicted as metallic or semiconducting reliant on their diameter telicity. These structurally resemble to graphite sheet rolling upon itself. The rolled sheets can be single, double or many walls and therefore they named as single-walled (SWNTs), double-walled (DWNTs) or multi-walled carbon nanotubes (MWNTs)

2.2. Metal Nano particles

Metal Nano particles are purely made of the metal’s precursors. Due to well-known localized surface Plasmon resonance (LSPR) characteristics, these Nano particles possess unique opt electrical properties. Nano particles of the alkali and noble metals i.e. Cu, Ag and Au have a broad absorption band in the visible zone of the electromagnetic solar spectrum.

2.3 Ceramics Nano particles

Ceramics Nano particles are inorganic non-metallic solids, synthesized via heat and successive cooling. They can be found in amorphous, polycrystalline, dense, porous or hollow forms. Therefore, these Nano particles are getting great attention of researchers due to their use in applications such as catalysis, photo catalysis, photo degradation of dyes, and imaging applications.

2.4. Semiconductor Nano particles

Semiconductor materials possess properties between metals and non-metals and Semiconductor Nano particles possess wide band gaps and therefore showed significant alteration in their properties with band gap tuning. Therefore, they are very important materials in photo catalysis, photo optics and electronic devices.

2.5. Polymeric Nano particles

These are normally organic based Nano particles and, they are mostly Nano spheres or no capsular shaped. The former are matrix particles whose overall mass is generally solid and the other molecules are adsorbed at the outer boundary of the spherical surface

1.1.2 Application Of Nano Fluids

Nano fluid can be used to cool automobile engine and welding equipment and cool high heat flux device such as high-power microwave tube, and high-power laser diode array. [3]

Some common applications are:

• Solar water heating

• Refrigeration

Defense and space application

Thermal storage •

Engine transmission oil •

Boiler exhaust flue gas recovery • Cooling of electronic circuit • Nuclear cooling system

Bio-medical application • Drilling and lubrication • Engine cooling

1.2 Techniques of Heat Transfer Enhancements

A) Passive techniques

They employ special surface geometries, or fluid additives for enhancement.

B) Active techniques

They require external power, such as electric or acoustic fields and surface vibration..

1.2 Problem statement

It has been a keen interest of researchers for quite a long time to enhance the heat transfer in devices used in industries and in our daily life to increase their performance and efficiency. In past different techniques like free and forced convection, and extended surfaces were used for transferring heat at a higher rate. These methods have come across the limitations for their results, so there is a need to introduce the new methodology to enhance the heat transfer of heat exchanging devices used in industry and automotive field. This area has given us an opportunity to work and contribute in thermal performance improvement of heat exchanging devices by using nanofluid.

1.3 Objective

Study of increase in heat transfer rate of car radiator for the purpose of effective cooling and dissipation of engine heat and to introduce the new coolant which is more effective than the conventionally used coolant.

1.4 Scope

In this project our main focus is to improve thermal performance of automobile cooling system so that it dissipates heat more efficiently and fast to surrounding's. In twentieth century, Nano fluids is a most promising coolant or heat transmitting agent with superior heat transfer capabilities with good thermal conductivity. Nanofluids are used in various heat exchangers for heat transfer studies more efficiently than conventional fluids or coolants. Car radiator is cross flow type of heat exchanger which is prime component in automobile engine cooling system whose function is to supply coolants to engine when engine is at high temperature. In this study, we are using MgO nanoparticles having size (40 nm) combine with base fluid as water, nanofluid after preparation used as a coolant instead of conventional coolant such as water or ethylene glycol. MgO/water nanofluid is used as effective coolant and its thermal performance ability is good as compared to conventional coolants. At present, there is a huge discrepancy in the studies of enhancement of thermal conductivity of the nanofluids. For the practical heat transfer applications like in heat exchangers, this gap is needed to be eliminated for enhancing the heat transfer rate.

1.5 Selection of nanofluid

A nanofluid is a fluid containing nanometer-sized particles, called nanoparticles. These fluids are engineered colloidal suspensions of nanoparticles in a base fluid. The nanoparticles used in Nano fluids are typically made of metals, oxides, carbides, or carbon nanotubes.

Nano fluids have novel properties that make them potentially useful in many applications in heat transfer including microelectronics, fuel cells, pharmaceutical processes, and hybrid-powered engines,[5]engine cooling/vehicle thermal management, domestic refrigerator, chiller, heat exchanger, in grinding, machining and in boiler flue gas temperature reduction. They exhibit enhanced thermal conductivity and the convective heat transfer coefficient compared to the base fluid.[6] Knowledge of the rheological behavior of Nano fluids is found to be critical in deciding their suitability for convective heat transfer applications. Nano fluids also have special acoustical properties and in ultrasonic fields display additional shear-wave reconversion of an incident compressional wave; the effect becomes more pronounced as concentration increases.

1.5.1 Analysis Of Radiator With Different Types Of Nano Fluids

An emerging and new class of coolants is Nano fluids which consist of a carrier liquid, such as water, dispersed with tiny Nano-scale particles known as nanoparticles. Purpose-designed nanoparticles of e.g. CuO, alumina, titanium dioxide, carbon nanotubes, silica, or metals (e.g. copper, or silver Nano rods) dispersed into the carrier liquid the enhances the heat transfer capabilities of the resulting coolant compared to the carrier liquid alone.

Five kinds of oxides, including MgO, TiO_2, ZnO, Al_2O_3 and SiO_2 nanoparticles were selected as additives and water was used as base fluid to prepare stable Nano fluids. Thermal transport property investigation demonstrated substantial increments in the thermal conductivity and viscosity of all these Nano fluids with oxide nanoparticle addition in water. Among all the studied Nano fluids, MgO–water nanofluid was found to have superior features, with the highest thermal conductivity and lowest viscosity. The thermal conductivity enhancement ratio of MgO–water nanofluid increases nonlinearly with the volume fraction of nanoparticles. Viscosity measurements showed that MgO–water Nano fluids demonstrated Newtonian rheological behavior, and the viscosity significantly decreases with the temperature. The thermal conductivity and viscosity increments of the Nano fluids are much higher.

Particle	Base fluid	Average particle Size (nm)	Volume fraction (%)	Increase in thermal Conductivity (%)
Al2O3	Water	13	4.3	30
Al2O3	Water	33	4.3	15
Al2O3	Water	68	5	21
CuO	Water	36	5	60
CuO	Water	36	3.4	12
CuO	Water	50	0.4	17
Sic	Water	26	4.2	16
TiO2	Water	15	5	30

Table no. 1 Experimental observations of heat transfer water based Nano fluids as a new coolant for car radiators

1.5.2 Properties of selected nanoparticle (MgO)

Purity [%]	94-98%
Approximate size	40 nm
Color	white
Morphology	Nearly Spherical
True density	3.58 (g/cm^3)

Table no. 2 properties of MgO

1.5.3Preparation of nanofluid

Basically, there are two ways of preparing nanofluid. They are

1. One step method includes the direct evaporation and condensation method. In this method both processes, the preparation of the Nano fluids and synthesis of nanoparticles and are performed simultaneously. This method produced stable Nano fluids.

2.Two step method in two step method, nanoparticles are first prepared as powder. This powdered nanoparticle is then dispersed in base fluids like water or ethylene glycol to form Nano fluids. Two step methods are basically preferred nowadays as Nano powders are commercially available. Nanoparticles formed are of spherical, rod shaped, tube shaped or disc shaped

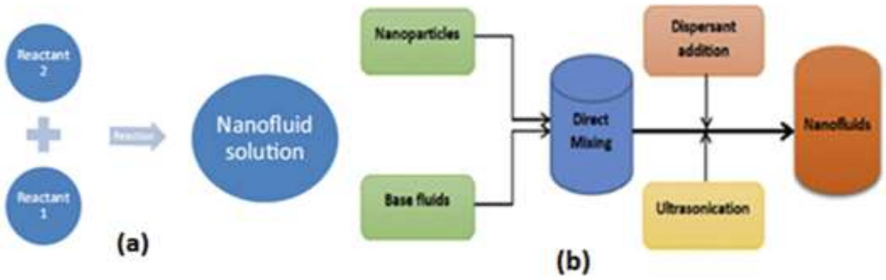

Fig 2. (a) Schematic one step and (b) Two-step preparation process of Nano fluids

1.6 PROPERTIES OF (Mgo/water) NANOFLUID

- **Base fluid (Water) :**
- Density (ρ_b)= 998.2 kg/m^3
- Specific heat(C_{pb}) = 4.187 KJ/kgk
- Conductivity (K_b)= 0.6 W/mk
- Viscosity(μ_f) = 0.001003 kg/m-s
- **Properties of MgO particles:**
- Density(ρ_p) = 3560 kg/m^3
- Specific heat(C_{pp}) = 0.955 KJ/kgk
- Conductivity (K_p)= 45 W/mk
- Size = 25 nm
- Purity = 99 %

Calculation of thermal and physical properties of nanofluid(MgO/water) by using above mentioned values of different properties of base fluid(water) and nano particle(MgO).
To calculate thermal and physical properties of nanofluid at difernt volumetric fractions(0.000625-0.2) following empirical correlations are used -

1.6.1 Thermal conductivity

Many semi empirical correlations were reported to calculate the nanofluid effective thermal conductivity, Maxwell formulated the following expression

$$\frac{k_{nf}}{k_b} = \frac{k_p+2k_b-2(k_b-k_p)\psi}{k_p+2k_b+(k_b-k_p)\psi}$$

volume fraction	Conductivity (K)
0.000625	0.642
0.00125	0.654
0.0025	0.666
0.005	0.69
0.01	0.714
0.13	1.1235
0.15	1.2323
0.17	1.4219
0.2	1.6351

1.6.2 Density

The density of nanofluid is calculated using the mixing theory as

$$\rho_{nf} = \psi\rho_p+(1-\psi)\rho_b$$

volume fraction	Density (ρ)
0.000625	999.8011
0.00125	1001.402
0.0025	1004.605
0.005	1011.009
0.01	1023.818
0.13	1331.234
0.15	1382.47
0.17	1433.706
0.2	1510.56

1.6.3 Specific heat

The specific heat capacity of MgO-water Nano fluid can be calculated according to the thermal equilibrium model:

$$C_{pnf} = \frac{\psi(\rho Cp)_p+(1-\psi)(\rho Cp)_b}{\rho_{nf}}$$

volume fraction	Specific Heat (Cp) KJ/kg.k
0.000625	4174.818
0.00125	4167.66
0.0025	4153.411
0.005	4125.185
0.01	4069.791
0.13	3060.14
0.15	2935.52
0.17	2819.809
0.2	2660.958

1.6.4 Viscosity-

According to the literature, an experimental correlation was proposed for the dynamic viscosity of MgO (with 40 nm)

$$\mu_{nf} = (1+11.61\psi+109\psi^2)\mu_b$$

volume fraction	Viscosity(μ) Kg/m.s
0.000625	0.001013
0.00125	0.001013
0.0025	0.001023
0.005	0.001043
0.01	0.001083
0.13	0.00436
0.15	0.005209
0.17	0.00614
0.2	0.0077

1.7. CFD Analysis

Computational Fluid Dynamics (CFD) is a branch of fluid mechanics that uses numerical methods and algorithms to solve and analyze problem that involves fluid flow. CFD modeling is based on fundamental governing equations of fluid dynamics: the conservation of mass, momentum, and energy.CFD helps to predict the fluid flow behavior based on the mathematical modeling using software tools.It is now widely used and is acceptable as a valid engineering tool in the industry. The CFD simulation process consists of several steps that are involved in the analysis of the fluid flow. For example; if we are talking about flow through a pipe bend. Then there are several steps that need to be followed for its analysis.

To perform CFD analysis, we need to consider some experimentally feasible input parameter for fluid flow and air which are as follows.

- Parameters of water and nanofluid(MgO/water)-

1.Mass flow rate(m) =0.05 kg/sec
2.Inlet temperature(T_i) =325 K

- Parameters of air

1.Inlet temperature(T_∞) =321 K
2.Convective heat transfer coefficient(h)=100-200 W/m^2K
3.Selecting the value of h for forced convection over cylindrical surface as 200 W/m^2K
To calculate Convective heat transfer coefficient for water and nanofluid maximax surface temperature is taken as inlet temperature of hot fluid i.e. T_s=325 K

II. Result & Discussion

There is increase in heat transfer rate (Q) of car radiator for the purpose of effective cooling and dissipation of engine heat. Study of characteristics, properties, preparation and heat transfer applications of new promising coolant MgO/water nanofluid. Study of thermo physical properties of MgO nanofluid like thermal conductivity, density, viscosity and specific heat. Study of variation of heat transfer rate and properties of MgO/water coolant for different volume fractions. Study of convection heat transfer and measurement of increase in convective heat transfer coefficient (h) for different volume flow rates and varying volume fractions MgO/water nanofluid as compared to water as a coolant for engine heat cooling.
The overall increment in heat transfer rate Q is given by:

$$Q_{nf} = \frac{Q_{nf} - Q_w}{Q_{nf}}$$

$$= \frac{1528.72 - 969.29}{1528.72}$$

$$= 36.59\%$$

The overall increment in convective heat transfer coefficient is given by

$$h_{nf} = \frac{h_{nf} - h_w}{h_{nf}}$$

$$= \frac{107.34 - 68.06}{107.34}$$

$$= 34.89\%$$

FUTURE SCOPE

The result obtained by numerical and analytical methods from this results we conclude that it is possible to improve thermal performance of radiator by using nanofluid to some extent. With all available information it is possible to carry out experimental validation of the CFD analysis. To carry an experimentation validation we need to build experiment setup. The schematic of experiment setup is shown in figure.

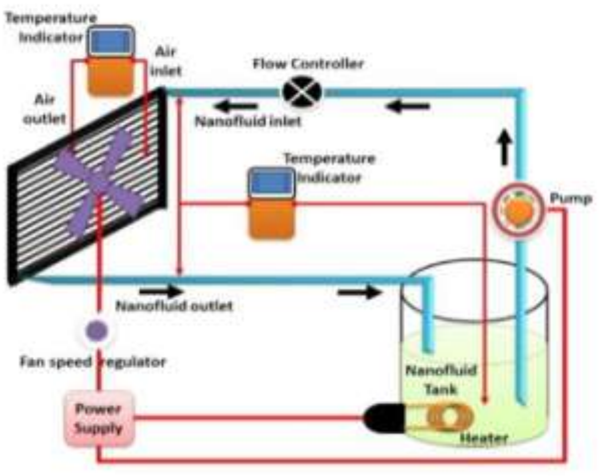

fig.8- schematic representation with nanofluid

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