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Experimental Analysis of Thermal Properties of Magnesium Oxide Nanofluids

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Abstract:- This paper summarizes the important results regarding the thermophysical properties of nanofluids consisting Magnesium Oxide nanoparticles. The influence of important parameters like metaloxide quantity, base fluid type, temperature, and additives will be considered. There are manyreports on the influence of parameters on thermal properties and the literature in this field is widespread. This project aims at finding the thermal conductivity of MgO nanofluid with three different base fluids such as distilled water, ethylene glycol, and engine oil and to propose the quantity of MgO and the type of base fluid that have better properties. This project also emphasizes on the applications of nanofluids in industries and other major sectors.

Keywords: *Nanofluids[1], Magnesium oxide[2], Thermophysical properties[3]*

1. Introduction

Fluids used in heat transfer are crucial in many industrial fields. However, as compared to conventional heat-transfer fluids like water, ethylene glycol, oil, etc., the use of nanofluids for heat transfer yields far better outcomes. There are generally two ways to increase the rate of heat dissipation. The first is to determine the ideal geometry for cooling systems, and the second is to boost heat transmission. When compared to base fluids, nanofluids with higher thermal conductivities will transport heat more quickly. Nanoparticles are particles of matter having diameters between 1 and 100 nano-meter. A nanofluid is a basic fluid that also contains nanoparticles. The most popular materials used to create nanoparticles for nanofluids include metals, oxides, carbides, or carbon nanotubes. Water, ethylene glycol, and oils are examples of typical base fluids. The onestep method and the two-step method are the two fundamental ways to prepare a nanofluid. Intensive magnetic force agitation and ultrasonic agitation are utilised in this project's two-step approach to disperse the nanoparticles into the base fluid after they are created as dry powders. The stability of nanofluids is crucial for the implementation of their use. We need surfactants to make sure a nanofluid is stable. The compounds known as surfactants work to lower the surface tension between two liquids, a gas and a liquid, or a gas and a solid.

2. Literature Review

Nanoscale colloidal solutions containing condensed nanomaterials are known as nanofluids. They consist of a two-phase system with a solid phase in one phase (liquid phase). The two-step procedure is among the most cost-effective ways to produce nanofluids on a wide scale because nanopowder synthesis techniques have already been scaled up to commercial production levels. Nanoparticles have a propensity to assemble into larger particles due to their large surface area and surface activity. The use of surfactants is a crucial strategy to improve the stability of nanoparticles in fluids. In addition to settling and blockage of microchannels, the agglomeration of nanoparticles lowers the thermal conductivity of nanofluids. Consequently, nanofluid stability is also crucial. The stability of nanofluids can be evaluated using a variety of methods. Sedimentation is the most straightforward technique.

[1] Since nanofluid, which is a two-phase fluid, a complicated combination with entirely different thermo-physical properties from the base fluid that was created as a result of scattering the nanoparticles into it.

Compared to common fluids like water, ethylene glycol, and oil, a stable nanofluid offers better thermal performance. [2] In order to create stable nanofluids, five different types of oxides— The additions MgO, TiO2, ZnO, Al2O3, and SiO2 nanoparticles, and ethylene glycol (EG) as the base fluid were selected. With the addition of oxide nanoparticles to EG, thermal transport property analysis revealed appreciable increases in the thermal conductivity and viscosity of all these nanofluids. The MgO-EG nanofluid was discovered to have exceptional characteristics, with the best thermal conductivity and lowest viscosity of all the tested nanofluids.. The augmentation of thermal conductivity for MgO-EG nanofluids grows nonlinearly with the addition of nanoparticles. [3] By raising the volumetric concentration up to a specific tested volumetric concentration, the heat transfer rate has demonstrated an increasing tendency. After one week of experimental testing, the MgO/water nanofluids demonstrated good repeatability; nevertheless, in order to be used in engineering applications, it is necessary to create more stable nanofluids over the long term. [4] Particle aggregation may make the stability, which is the most important issue, more difficult. The total of the attraction and repulsive interactions between particles causes nanoparticles to aggregate. Particles form clusters when attractive forces outweigh repulsive ones. The prevention of particle aggregation can therefore be achieved by increasing repulsive forces relative to attractive forces. [5] The heat transfer rate was improved by adding nanoparticles to the base fluid; this enhancement grew progressively as concentration rose, reaching its maximum at the highest volume concentration. [6] The surfactants TMAH, SDS, and SLS are suggested for water-based nanofluids due to their high thermal conductivity, low viscosity, and good stability. [7] According to research, smaller nanoparticles in nanofluids have a higher surface area to volume ratio, which increases heat conductivity. [8] The use of oxide nanofluid results in significantly better heat transfer properties at a particle volume concentration of 3%. [9] Metal oxide nanoparticles have grown to be important elements in applied.

Nanotechnology is used in many different fields including architecture, medicine, food,agriculture, cosmetics, batteries, magnetic storage media, solar cells, catalysis, energy conversion, and trace gas sensors. [10] Using a thermal conductivity analyser, the effective thermal conductivity of nanofluids was measured from 20°C to 45°C. According to the experimental findings, the volume fraction of nanoparticles increases thermal conductivity of MgO-glycerol nanofluids. As the temperature rises, there is no change in the thermal conductivity ratio. The thermal conductivity ratio of MgOglycerol nanofluids decreases with increasing particle size in the specified volume fraction and temperature range. [12] Studies on nanofluid at concentrations of 0.015, 0.025, 0.05, 0.1, 0.2, 0.35, 0.45, and 0.55 have been conducted at temperatures ranging from 25 to 50 °C. The findings demonstrated that at higher temperatures, the percentage of thermal conductivity rise with volume fraction fluctuation is significantly more than at lower temperatures. [13] The thermal conductivity ratio was greater than one for all Reynolds numbers, nanoparticle volume fractions, and diameters taken into consideration. The highest volume fraction and the smallest nanoparticle diameter were linked to the highest thermal conductivity. Additionally, in all cases, increasing temperature increased thermal conductivity. Additionally, it was discovered that the rate of heat transfer increases with the nanoparticles' volume fraction and Reynolds number while also reducing their diameter. [14] Nanofluids may be generated on a large scale and employed in a variety of applications once the physics and engineering behind them are thoroughly understood. The utilisation of colloids, which are also nanofluids, will rise in the fields of biomedical engineering and biology. [15] The various researchers' rates of heat transfer varied from one another. It depends on a number of variables, including the length of the ultrasonication, the duration of the magnetic stirrer, and the choice of the appropriate surfactant. By changing these parameters, different results can be obtained. We need to determine the ideal particle size and surfactant for nanofluid because as the particlesize grows, thermal conductivity reduces while also leading to agglomeration and settling. [16] APG and ECA surfactants' relative maximum mineralization decreased as surfactant and nanoparticle concentrations in the test medium increased. These findings suggest that when surfactants are manufactured as nanofluids with or without nanoparticles and with an initial surfactant concentration of 25 mg/L, they may be regarded as environmentally safe at low doses. [17] Nowadays, a wide range of applications are accounted for by multiple studies on nanomaterials (NMs) and nanofluids (NFs). The toxicity, biodegradability, bioaccumulation, and potential health consequences of any material must be considered along with any quantities that can exist in the environment without upsetting the delicate balance in order to run the systems involved. This is especially important in fields as diverse as health, food security, or energy. Future human food and transportation systems (8.5 billion people by 2030) will need to take into account the direct effects of CO_2 emissions. [18]

3. Methodology

By preparing the nanofluids using ethylene glycol, water and oil, we can enhance the thermal properties of the conventional fluids as we have inferred from the literature survey and going through various papers. Starting from the selection of the nanoparticles to be used to investigatethe thermal conductivity of the nanofluid, the experiment is carried out by preparing the nanofluids, addition of surfactants and conducting the experiment using the given apparatus.

Selection of Nanoparticles

We selected Magnesium Oxide (MgO) nanoparticles to disperse in the three base fluids. The selection of MgO nanoparticles was based on the comparison of the properties of various other nanoparticles. By comparing the properties, we found out that the MgO nanoparticles have superior properties and this was also supported by the different research papers.

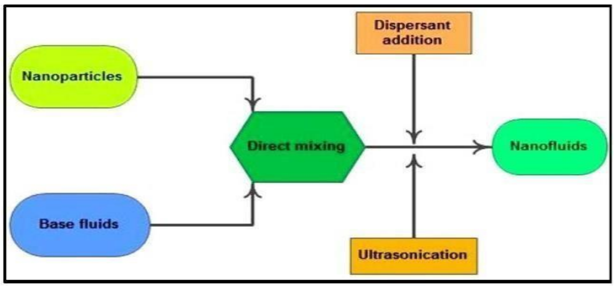

Fig.1. Block Diagram of Two-step process of nanofluid preparation.

Purity	99.9%
Average Particle Size	20-50 nm
Specific surface area	110-130 m^2/g
Molecular weight	40.3 g/mol
Morphology	Spherical
Physical form	Powder
Color	White
Bulk Density	0.6 g/cm^3

Fig.2. Properties of MgO nanoparticle

Preparation of Nanofluid

There are numerous ways to prepare nanofluids. The one-step method and the twostep method are the two main approaches. The creation and dispersion of the particles in the fluid take place concurrently in the onestep process. Nanoparticles, nanofibers, nanotubes, or other nanomaterials are initially created as dry powders by chemical or physical processes in the two-step technique. The second processing stage will then involve dispersing the nanosized powder into a fluid using high-intensity magnetic force agitation, ultrasonic agitation, high-shear mixing, homogenising, and ball milling. The most cost-effective approach is the two-step approach. Magnesium oxide (MgO) nanoparticles in powder form were employed. Three nanofluid solutions (distilled water, ethylene glycol, and engine oil) were made, each with a different concentration of nanoparticles.. Surfactants were added to increase the stability of the nanofluid. MgO-

Distilled water nanofluid was prepared having 1, 2, 3 grams of MgO in 1 litre of distilledwater. MgO-EG and MgO-Engine oil nanofluids were prepared having 0.5, 1, 1.5 grams of MgO in 0.5 litre of Ethylene Glycol and Engine oil respectively. We used Cetyl Tri-Methyl Ammonium Bromide (CTAB) and Sodium Lauryl Sulphate (SLS) as surfactants.

Their quantity was calculated according to the below formula:

FoFor "y" grams of NP

$$x = y \text{ grams / Mol. Wt. of NP}$$

(Gives the "x" mole)

$$\text{Mol. Wt. of surfactant} * x = \text{grams of surfactant}$$

(Gives the amount of surfactant that is to be added for y grams of NP)

Fig.3. Formula to calculate the amount of surfactant

Vacuum Desiccation and Weighing of the NPs: The NPs and the surfactants are placed in the vacuum desiccator and the moisture content is removed using a vacuum pump. The vacuum desiccation was kept for 45 mins and the NPs are left inside the desiccator for a day. Once the moisture is removed, the required amount of NPs and surfactants are weighed using the weighing machine. Then the weighed specimen is dispersed in the base fluid.

Magnetic stirrer and Ultrasonicator

In this step, a magnetic bead is placed inside the beaker and the beaker is kept on the magnetic stirrer. The required temperature and rpm are set. The beaker is left on the magnetic stirrer forone hour. This ensures the proper mixing of NPs and surfactant in the base fluid. After stirring the solution in a magnetic stirrer, the beaker containing the solution is placed in the ultrasonicator. Ultrasonic mixing is used to disperse nano-sized particles into liquids such as water, and oil. This helps in dispersing nanomaterials in liquids to break particle agglomerates. Ultrasonication is the term for the procedure since it typically involves ultrasonic frequencies (>20 kHz). The beaker is kept in the sonicator for 60 minutes. After that, the particles aremixed once again using a glass rod to ensure that there are no sediments of the added specimen in the solution. After preparing the solution, thermal conductivity of the prepared solution is found from the thermal conductivity apparatus. Apparatus is shown below.

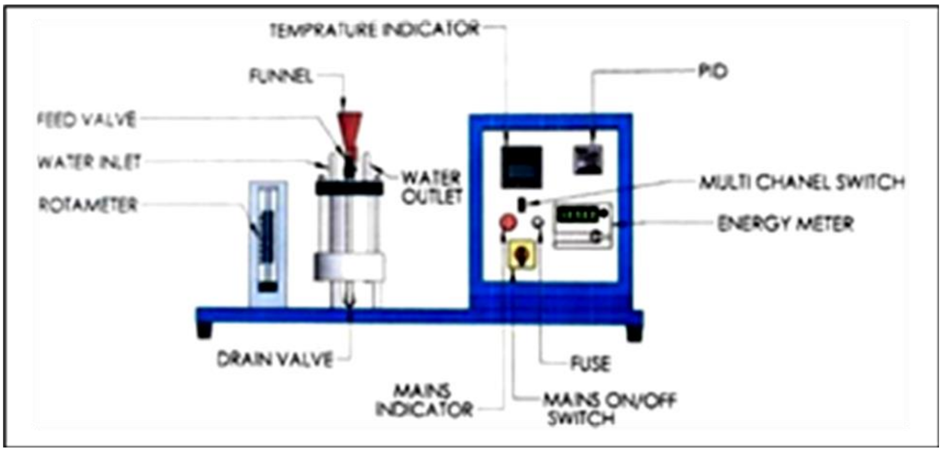

Fig.4. Thermal Conductivity of liquids apparatus with nomenclature

- Thickness of liquid chamber dx = 0.001 m
- Diameter of heater D = 0.038 m
- Length of liquid chamber = 0.116 m
- EMC – Energy Metre Constant (Taken = 3200)

Fig.5. Observations from apparatus

$$Q = \frac{P}{t_p} \times \frac{3600}{EMC} \times 1000 \text{ (W)}$$

$$A = \frac{\pi}{4} D^2 + \pi \times D \times L \text{ (m}^2\text{)}$$

$$T_h = T_O \text{ (°C)}$$

$$T_c = \frac{T_1 + T_2 + T_3 + T_4}{4} \text{ (°C)}$$

$$k = Q \frac{\Delta X}{A\,(T_h - T_c)} \text{ (W/m °C)}$$

Fig.6. Formulae used for calculations

Heat transfer area	0.015 m^2 (calculated)
Molecular weight of MgO	40.3 g/mol
Molecular weight of SLS	288.38 g/mol
Molecular weight of CTAB	364.45 g/mol
Density of distilled water	1 g/cm^3
Density of ethylene glycol	1.11 g/cm^3
Density of lubricating oil	0.70 – 0.95 g/cm^3

Fig.7. Thermal conductivity of liquids apparatus

Description of the apparatus

The device comprises of a heater that warms a thin liquid layer. A cooling plate ensures unidirectional heat flow by removing heat through the liquid layer. A PID controller is provided for varying the input to the heater and measurement of input power is carried out by a digital energymeter & stopwatch. The funnel is provided with a valve to fill the liquid. The overflow pipe is given to maintain the liquid level. A plate is for the circulation of water. A valve is provided to control the flow of water. Four temperature sensors are provided to measure the temperature across the liquid layer.

Principle:

When a body has a temperature gradient, energy is transferred from the high-temperature zone to the low-temperature area. Conduction is the method through which energy is transferred, and the typical temperature gradient affects how much heat is transferred per unit of area.

4. Result And Discussion

We carried out the experiments on the three different nanofluids for different concentrations of MgO, the results are as follows:

The graphs obtained by plotting the results is shown below. Also, the comparison of the thermal conductivities without the addition of NPs to the base fluids can be seen.

The objective of the project was to find out the thermal conductivity of MgO-based nanofluidsat different MgO NP concentrations. In order to perform this, we used three different base fluids i.e., distilled water, ethylene glycol, and engine oil. Initially, Cetyl Tri-Methyl Ammonium Bromide (CTAB) was used as a stabilizer for the MgO-Distilled water solution. Using the solution thermal conductivity was calculated. But we found that the particles settledat the bottom of the solution after a couple of hours from preparation.

Going through one of the papers we stumbled upon SLS to be one of the surfactants which had a nature opposite to thatof CTAB i.e., the former is an anionic surfactant whereas the latter is a cationic surfactant. The surfactant was used to prepare the solutions of MgO-distilled water and MgO-EG. We found out that the MgO- Engine oil nanofluid was stable even without the addition of the surfactant.

MgO (grams)	SLS (grams)	T_h °C	K W/m °C
1	7.15	40	0.6215
1	7.15	50	0.7353
1	7.15	60	0.833
2	14.3	40	0.6554
2	14.3	50	0.7813
2	14.3	60	0.8505
3	21.45	40	0.6997
3	21.45	50	0.8367
3	21.45	60	0.9141

Fig.8. Thermal conductivities of MgO-Distilled water solution

MgO (grams)	SLS (grams)	T_h °C	K W/m °C
0.5	3.577	40	0.3409
0.5	3.577	50	0.3832
0.5	3.577	60	0.3965
1.0	7.155	40	0.3548
1.0	7.155	50	0.3911
1.0	7.155	60	0.4146
1.5	10.73	40	0.3586
1.5	10.73	50	0.41
1.5	10.73	60	0.4252

Fig.9. Thermal conductivities of MgO-Ethylene Glycol solution

MgO (grams)	T_h °C	K W/m °C
0.5	40	0.2445
0.5	50	0.2613
0.5	60	0.2689
1.0	40	0.2573
1.0	50	0.2669
1.0	60	0.2839
1.5	40	0.2648
1.5	50	0.2769
1.5	60	0.3049

Fig.10. Thermal conductivities of MgO-Engine oil solution

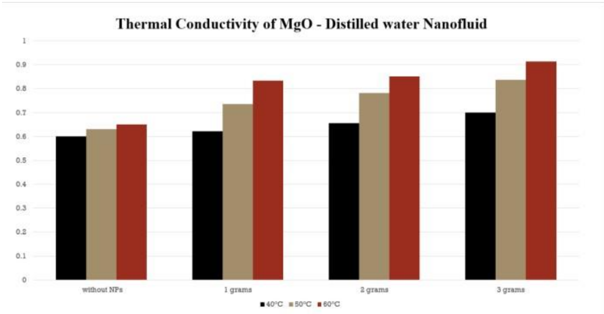

Fig.11. Comparison of thermal conductivities with varying temperatures and concentrations of MgO in MgO-Distilled water solution

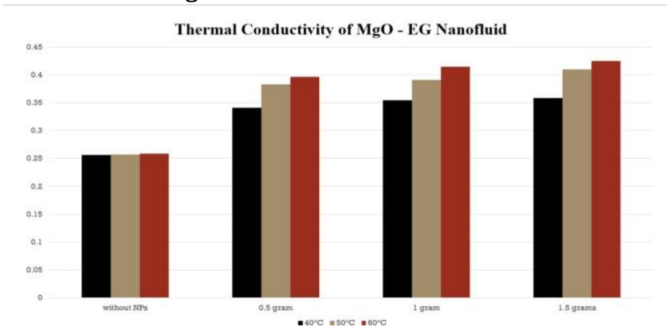

Fig.12. Comparison of thermal conductivities with varying temperatures and concentrations of MgO in MgO-Ethylene glycol solution

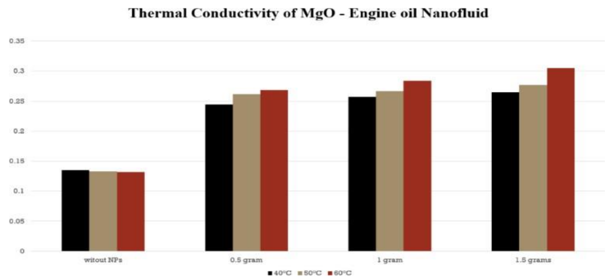

Fig.13. Comparison of thermal conductivities with varying temperatures and concentrations of MgO in MgO-Engine oil solution

The thermal conductivities of distilled water, ethylene glycol and engine oil are 0.6 W/m°C,0.25 W/m°C and 0.13 W/m°C at 40°C respectively. The above-mentioned values of thermal conductivities of those conventional base fluids were increased by the addition of MgO NPs as we found out in the experimentation. It is observed that, with the increase of the concentrationof MgO NPs and the temperature of the source, the corresponding thermal conductivities increased.

Due to limited time and resources, we could not carry out the experiments for the higher concentrations of the MgO NPs and elevated temperatures. Further, we can state that by performing experiments on hybrid base fluids at different temperatures with different combinations of surfactants and nanoparticles better thermal properties could be obtained. But, through this project, we can be sure that there is more scope for further research and study of Nanofluids and their thermal properties because of its wide applications.

5. Conclusion

Nanofluids containing MgO nanoparticles with three different base fluids were prepared. The thermal conductivities at different temperatures and concentrations were investigated. It is observed that as the heater temperature and the quantity of nanoparticles increase, there is an increase in the thermal conductivity of the nanofluids. The percentage enhancement in thermal conductivity of the nanofluids with the addition of MgO is as follows –

- The thermal conductivity of MgO – Distilled water nanofluid increased by 52.35%,39.45% and 16.61% at 60°C, 50°C, and 40°C respectively compared to the base fluid.
- The thermal conductivity of MgO – Ethylene Glycol nanofluid increased by 70.08%,64%, and 43.44% at 60°C, 50°C, and 40°C respectively compared to the base fluid.
- The thermal conductivity of MgO – Engine oil nanofluid increased by 134.5%,113%,and 103.69% at 60°C,50°C, and 40°C respectively compared to the base fluid.

From the above points we can infer that the MgO- Engine oil nanofluid showed considerable rise in the thermal conductivity among the three nanofluids. By raising the volumetric concentration up to a specific tested volumetric concentration, the heat transfer rate has demonstrated an increasing tendency. After two to three days of experimental testing, the MgO-based nanofluids demonstrated good repeatability; nevertheless, in order to be used in engineering applications, it is necessary to develop more stable nanofluids over a longer period of time.

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