ENHANCEMENT OF THERMAL PROPERTIES OF FLUIDS WITH DISPERSION OF VARIOUS TYPES OF HYBRID/NANOPARTICLES

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Abstract: The main aim of the present research is to enhance the thermal properties of fluids with a dispersion of various types of hybrid/nanoparticles which has the capability of improving heat transfer properties. Thermal conductivities of Nanofluids are probably higher as compared with conventional fluids. The use of metal nanoparticles has not been intensely investigated for heat transfer applications due to a lack of stability. Research hard work has been equally put forth to improve the active performance of heat transfer fluid (HTF) through the use of hybrid nanomaterial. The particularly higher surface-to-volume ratio of nanomaterial makes them properly promote nucleation and heat switch in PCM. The right choice and training of nanomaterials pave the manner for achieving superior thermal conductivity, specific heat, and heat transfer ordinary performance of hybrid nanofluids. Nanomaterials, organized in splendid systems collectively with nanotubes, nanorods, nanoparticles, etc. would possibly display off awesome thermo-bodily factors while dispersed in heat transfer fluid (water). Therefore, various hybrid/nanoparticles have synthesized the usage of the sol-gel approach. Synthesized Nanomaterials are to be tested for XRD, SEM to recognize the crystalline structure, length, form, etc. The ultrasonic process needs to be performed during the dispersion of nanoparticles in HTF for uniform dispersion and to avoid agglomeration. Then nano-based fluids are characterized to study Physical, thermal properties. The nanofluids are tested using Fourier Transformer Infrared Spectrometry (FTIR) to check chemical compatibility between HTF and nanoparticles, later a thermal conductivity analyzer is used to verify thermal conductivity of various hybrid/nano-based fluids. A thermogravimetric analyzer (TGA) is used to check the commencement and end of decomposition temperature of various hybrid/nano-based fluids. Later several experimentations are carried out using shell and tube type heat exchanger to study heat transfer characteristics of various hybrid/nanofluids. The results from various characterization techniques and experimentation are analyzed for optimizing the nanoparticles type and proportions used in HTF for proposing in practical applications.

Keywords: Nanofluids, Silver Nanoparticles, Thermal Conductivity, Nanoparticles, Hybrid Nanofluids.
1. Introduction

In most industrial applications, heat transfer plays a vital role as heat is being released in all the practical processes. Therefore, it becomes very important to extract that heat continuously to maintain the temperature within the limit. This leads to improving the efficiency and life of the equipment [1]. Generally, heat exchangers are used to extracting the heat. In a heat exchanger, the heat is exchanged between hot fluid and cold fluid. The industries involving heat transfer such as thermal power plants, nuclear power plants, electronics, refrigeration and air conditioning, chemical processing, solar systems, automobiles, electrical transformers, etc are heavily dependent on heat transfer rate. In all of these industries, heat transfer is carried out through various heat transfer devices like evaporators, condensers, and other heat exchangers. The efficient design of these devices is intended for an increase in the heat flux and reduction in their size. Hence, there is a need for efficient heat transfer systems to improve the heat transfer rate so that size and pumping costs can be lowered. There are several techniques to improve the efficiency of heat transfer systems [2].

The heat transfer enhancement techniques may be commonly categorized into classes; lively approach and passive approach. The lively method entails providing an outside strength source to the fluid or the equipment whereas the passive technique entails turbulence promoter employing unique surface geometries, extended surfaces, twisted tape, spiral fin, or enhancing the thermal houses of the fluids used in the gadgets without the usage of any direct outside power supply. Among these two techniques, the passive technique has drawn incredible attention from the researchers due to its smooth installation or operation and economy. Enhancement of thermal properties of heat transfer fluids is one of the thrust areas of research in the fields of performance improvement of heat transfer systems [3]. The important thermal properties which influence the heat transfer rate of the fluid are thermal conductivity and heat transfer coefficient. Thermal conductivity of the traditional heat transfer fluids such as water, engine oil, transformer oil, and ethylene glycol is relatively very low compared to the solid particles [4]. The inherent poor thermal conductivity of the traditional heat transfer fluids sets a practical limitation on the heat transfer of the system.

Suspension of solid particles into a fluid can increase the thermal conductivity of the fluid. However, the suspension of the millimeter or micrometer-sized solid particles in the fluids creates major problems such as rapid sedimentation of the particles, clogging of the channels, pressure drop, and abrasion on the walls of the channel. These drawbacks put restrictions on the use of solid particles in the fluid [5]. In recent years, Nanotechnology has become an emerging field in science, medicine, engineering, and technology. Nanoscale materials have attracted a great deal of attention of many researchers and academicians in mechanical engineering because of their size and shape-dependent thermal properties. Controlling the size and shape of the nanomaterial is the key challenge in practical applications, especially in heat transfer [6], [7]. The express progress and studies in nanotechnology commanded to investigate of a upgraded class of heat transfer fluid termed as nanofluid with enhancement heat transfer characteristics.

In the present research work, the nanomaterial of silver and titania are synthesized. Further, the nanofluids are prepared using these nanomaterials. The heat transfer coefficient is increased with an increased percentage of hybrid nano in water, this might be mainly due to thermal networking of nano particles.

2. Literature Review

The number of literature has been studies on nanomaterials and nanofluids. Few important pieces of literature are mentioned in this section.

Hwang et al. [8] investigated the homogeneous dispersion of nanoparticles in nanofluids organized the use of various physical remedy techniques based totally on -step approach, inclusive of the stirrer, ultrasonic tub, ultrasonic disruptor, and high-stress homogenizer. They used carbon black– deionized water with 0.5 wt. % and silver-silicon oil with 0.5 wt. % of the nanoparticles. The high-pressure homogenizer was used to prepare utmost steady nanofluid and there is a need for a high-energy assisted deagglomeration process of particle clusters dispersed in a base fluid with suitable surfactants.
Singh & Raykar [9] prepared stable silver nanofluids in ethanol by reducing AgNO3 with polyvinylpyrrolidone (PVP) as a stabilizing agent with 1% vol. of Ag nanoparticles using microwave synthesis. The size of Ag nanoparticles was found to be in the range of 30–60 nm. They used UV-vis spectroscopy, Fourier transform infrared, energy-dispersive X-ray spectroscopy, and TEM techniques to characterize the nanofluid.

Kumar et. al [10] used a chemical reduction method for the preparation of copper-ethylene glycol nanofluids by reducing copper sulfate pentahydrate with sodium hypophosphite as a reducing agent. The nanofluid was characterized by particle size analyzer, X-ray diffraction topography, UV–vis analysis and Fourier transform infrared spectroscopy (FTIR). They used a transient hot-wire method to measure the thermal conductivity of nanofluids. They analyzed the effect of pH, dilution, the stability of the nanoparticle.

Dan Li et. al [11] synthesized Cu nanoparticles by surface modification method and prepared oil-based nanofluids using an ultrasonic disrupter. They used a capillary viscometer to measure its viscosity and a computer-controlled transient calorimeter to measure the thermal conductivity of nanofluid. They reported that there is an increase in the thermal conductivity of nanofluids with the increase in the mass fraction of the nanoparticles.

Chon et al. [12] evolved an empirical correlation with the impact of temperature and particle length for nanofluid with Al2O3 on thermal conductivity enhancement. They mentioned that the Brownian movement of nanoparticles form a key mechanism for the thermal conductivity enhancement of nanofluids with increasing temperature and lowering nanoparticle sizes.

Patel et al. [5] proposed a micro-convection model to evaluate the thermal conductivity of nanofluids which included the impact of specific surface region and Brownian movement. The authors of the paper concluded that the version is suitable to predict the thermal conductivity as it should be over an extensive range of particle sizes of 10-one hundred nm, particle concentrations of one to 8 %, metallic debris as well as metal oxides, one-of-a-kind base fluids together with water, ethylene glycol and range of temperatures from 20° to 50°C. Evaluation of the version predictions were offered with the available experimental outcomes and Hamilton-Crosser model and become observed correct agreement.

### 3. MATERIALS AND METHOD

Initially, the design of the HP is considered and then the proposed HPSO algorithm is implemented to obtain the optimal AP and DP. Since the HPC have similar architecture and computation formulation, the same algorithm can be used to design the hybrid combiner.

#### 3.1. Nanoparticles Preparation

The nanoparticles are prepared though various methods and most of them are very effective and efficient as well. However, mainly two basic approaches are generally used for the preparation of nanoparticles and these are:

1. The pinnacle-down method: This is mostly used and very fast technique to produce nanoparticles of any metals. In this process metal is crackdown into small pieces up to the level of nano particles. Various methods used to prepare nanoparticles through these techniques such as milling method, plasma arc technique, laser method, photolithography approach, anodization method, etc. Low operating cost, less skill requirement, and fast are some advantages of pinnacle down methods that make it very famous. However, the particle size obtained through this method is not same.

2. The backside-up method: This is the highly accurate and precise method for nanoparticle production. This method required more skill to prepare the nanoparticle. In this method the metal is dissolved into the chemicals where it react with the chemical and evaporate. The vapours collected and dried to get the nanoparticles. The operation required through knowledge
of chemical and reaction. The process is more time consuming as compared to top-down approach. Examples of backside-up methods encompass own-meeting of monomer/polymer molecules, chemical or electrochemical nanostructural precipitation, sol-gel processing, laser pyrolysis, chemical vapor deposition (CVD), plasma or flame spraying synthesis, and bio-assisted synthesis. In standard, NP synthesis methods may be divided into three corporations – (1) physical strategies, (2) chemical strategies, and (three) bio-assisted methods.

3.2. Synthesis of Silver Nanoparticles
- Initially, 60 ml of distilled water is taken into a three-neck flask and heated to 60°C.
- 4 g of silver nitrate is added to the distilled water in the flask.
- 0.5 g of Poly Vinyl Pyrolidone is also added to the flask which act as stabilizing agent for the solution.
- The solution is stirrer well with magnetic stirrer and the solution is maintained at 60°C with the help of heating plat.
- A solution of 0.7 g Ascobic acid and 35 ml of distilled water is added into the flask after 30 min of reaction.
- Let the reaction carried for at least 2 hours.
- The solution will turned into golden yellowish color after 2 hours.
- Filter the solution with sand paper of 3µm size.
- The filtration process will take nearly 2-3 hours depending filter paper size and environmental solution.
- After filtration silver nanoparticles left on the filter paper.
- Dry the nanoparticles and collected into airtight container.

3.3. Synthesis of Titania Nanoparticles
- 5g of TiO₂ + 30ml of Ethanol are ultra-sonicated for 6 minutes.
- The solutions is put into the three neck flask and stirred at 350 RPM at 50°C with a magnetic stirrer.
- At the same time, a solution of 0.5g PVP and 30ml distilled water is prepared in another beaker
- The prepared solution is poured slowly into the three neck flask and stirrer continuously.
- The second solution of 0.1g of Sodium borohydride and 30 ml Distilled water is also prepared which act as strong reducing agent for the reaction.
- Another solution of 30 ml od distilled water and 0.5g of Ascorbic acid is prepared which used as weak reducing agent for the reaction.
- Add the strong and weak reducing agents prepared above slowly into the reacting flask.
- Continue the stirring process until the color of the reactants changes to light pinkish/creamish/light brownish from light bluish.
- Use the required filter paper to filter the nanoparticles and other chemicals. The nanoparticles left over the filter paper whereas the other chemicals filters through it.
- Dry the nanoparticles and stored into dry air tight container.

4. RESULTS AND DISCUSSIONS

4.1. Characterization of Nanoparticles
The surface of the nanoparticles measured through scanning electron microscope (SEM). During this process, the nanoparticles are scanned with a beam of high-energy electrons. The pattern used for scanning is raster scan which provide better results. Electrons strike the nanoparticles and after deflection received by the receiver in the device. Due to striking with the nanoparticles, the electrons produce the signals. These signals contains sufficient information about the properties of the particles such as composition, surface topography, thermal conductivity, etc. It also magnifies and focus the
images of the particles and give clear information in picture as well. Fig. 1 and fig. 2 are the images captured by SEM for silver and titania respectively.

![Surface Morphology of Silver Nano Using FESM](image1)

**Fig. 1**: Surface Morphology of Silver Nano Using FESM

![Titania Nanoparticles Surface Morphology Using SEM](image2)

**Fig. 2**: Titania Nanoparticles Surface Morphology Using SEM

To investigate the size of particles and structure of material X-ray diffraction (XRD) is used. The XRD is also used to determine the atomic arrangement in the crystalline and imperfections of the nanoparticles. The XRD process used in the present work is non-destructive technique that makes it a versatile in the nature. This technique provides the detailed information about the manufactured materials by varying the angle of incidence \( \theta \).

\[ 2d \sin \theta = n \lambda \]

The graphs obtained during the XRD analysis of silver and titania are given in fig. 3 and fig. 4 respectively.
4.2. Thermal Properties of Nano Fluids

The thermal conductivity of pure water is 0.573 W/m K. With Ag-TiO2 nano inclusion in the pure water it was a regular trend of increasing thermal conductivity, a maximum of 0.728 W/m K. there was a 10.7% increase in thermal conductivity. The enhanced thermal conductivity is mainly due to three factors such as shape factor as the particles are spherical which have more surface area exposed to the cooling media, size factor also plays an important role, as the size of particles decreases with the same unit volume surface area exposed increases. Apart from that these particles are metal and metallic oxides which have increased thermal conductivity. Because of the following reasons, there was an enhancement, however, beyond the increased percentage of nanoparticles, there is a possibility of agglomeration and settlement of particles.

With the nano inclusion in the water, thermal conductivity was enhanced heat transfer coefficient also increased, these particles which were dispersed in water act as heat carriers thereby enhancing the heat
transfer rate. However, there should not be any settlement of particles to happen. The effective heat transfer rate takes place when the particles deagglomerate and float in the water without a settlement. The Reynolds number is directly correlated with density, velocity, and diameter and inversely proportional to dynamic viscosity. However, with nano inclusions in the water, there is a possibility of increased density of the sample, which increases the Reynolds number. With a varying percentage of Ag-TiO2 hybrid nano inclusions in the pristine water, there was negligible change in the Reynolds number.

Thermal conductivity was gradually increasing this is mainly due to the above-said reasons, these nanoparticles form a thermal network, thereby enhancing heat transfer characteristics. It was also noticed that when the setup is not working the fluid in the heat exchanger remains steady position with no dynamic molecular motion, the consequences are few nanoparticles settle down. Once the setup is started initially nano inclusions may not be effective, but within no time due to very little fluid pressure, most of the few settled particles will also get dispersed in the working fluid and possibility of enhancing thermal properties further. The major thermal properties of the Nanofluids are given in table 1 and table 2.

Table 1: Heat transfer characteristics of Ag-TiO2 dispersed in water

| Nano Particles Type | Sample Type | Volume Fraction (%) | % Of Nanoparticles Added | Weight of Nanoparticles (Gm) | Heat Transfer Coefficient | Thermal Conductivity | Reynolds Number |
|---------------------|-------------|---------------------|--------------------------|-----------------------------|--------------------------|---------------------|-----------------|
| Ag-TiO2             | Sample 1    | 0.0001              | 0.2%                     | 0.0631                      | 2353.048543              | 0.6588              | 4993.096        |
| Ag-TiO2             | Sample 2    | 0.0005              | 0.4%                     | 0.315502                    | 4096.89547               | 0.698               | 9986.193        |
| Ag-TiO2             | Sample 3    | 0.00075             | 0.6%                     | 0.473254                    | 5666.669588              | 0.718               | 14979.29        |
| Ag-TiO2             | Sample 4    | 0.001               | 1%                       | 0.631006                    | 5721.22                   | 0.728               | 15011.27        |

Table 2: Heat transfer characteristics of Ag-ZnO dispersed in water

| Nano Particles Type | Sample Type | Volume Fraction (%) | % Of Nanoparticles Added | Weight of Nanoparticles (Gm) | Heat Transfer Coefficient | Thermal Conductivity | Reynolds Number |
|---------------------|-------------|---------------------|--------------------------|-----------------------------|--------------------------|---------------------|-----------------|
| Ag-ZnO              | Sample 1    | 1000                | 0.2                      | 0.00028                     | 2325.42                  | 0.597               | 4993.096        |
| Ag-ZnO              | Sample 2    | 1000                | 0.4                      | 0.0014                      | 4048.80                  | 0.616               | 4901.23         |
| Ag-ZnO              | Sample 3    | 1000                | 0.6                      | 0.0021                      | 5600.15                  | 0.799               | 4810.11         |
| Ag-ZnO              | Sample 4    | 1000                | 0.8                      | 0.0028                      | 5609.11                  | 0.811               | 4798.22         |

5. Conclusions

Considering the above results, the following are the important key points been high lighted

1. For the synthesis of nanoparticles, a standardized sol-gel procedure was developed after several attempts.
2. Several trials have been done varying proportions and chemical type
3. Interestingly, the FESEM images of all nanoparticles (Ag, TiO2, ZnO) depict that the surface morphology is somehow rough and the shape is almost spherical.
4. The XRD peaks of Ag, TiO2, and ZnO are highly crystalline, the 2-theta angles of the peaks induced for these nanoparticles were exactly injustice with standard XRD of respective nanoparticles.
5. Thermal characteristics were studied with hybrid nano inclusions in the pristine water, the result depicts that Ag-TiO2 and Ag-ZnO exhibited nearly the same thermal performance.
6. There was a regular trend of increased thermal conductivity with a dispersion of nanoparticles in water.
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