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A Review on Nanofluids: Preparation & Applications in Solar collector

Prem Sagar[1], Vikash[2] and Ishank[3]

[1]Research scholar, PTU, JALANDHAR,
[2]Mechanical Engineering Department, PPIMT, Hisar
[3]M.Tech Scholar, Mechanical Engineering Department, PPIMT, Hisar
E-mail: [1]jasujaprem@gmail.com, [2]vikash.j.ppimt@ppu.edu.in, [3]Ishank.me@ppu.edu.in

Abstract: *nanofluid a fluid containing nanometer sized particles, called nanoparticles. Nanofluids are engineered colloidal suspensions of nanoparticles in a base fluid. These fluids are mainly used to enhance heat transfer rate by improving thermophysical properties like thermal conductivity, viscosity, etc. This paper summarizes the recent progress on the study of nanofluid, such as the preparation methods and presents its applications in solar collectors. At last, the paper identifies the opportunities for future reseaech.*

Keywords: *Nanofluids, Solar collector, Thermal Conductivity, Viscosity*

1. INTRODUCTION

Nanofluids are basically new generation fluids engineered by dispersing nano sized materials (nanoparticles, nanofibers, nanotubes, nanowires) in base fluids. In other words, nanofluids are the fluids in which nano sized solid particles are suspended. Nanofluids have been found to possess enhanced thermo physical properties such as thermal conductivity, thermal diffusivity, viscosity, and convective heat transfer coefficients compared to conventional fluids like oil or water. Nanofluids show great potential applications especially in thermal science field. In order to extract heat from high heated surfaces, nanofluids shows advantageous results over conventional fluids like water, ethylene glycol, propylene glycol and oil.

In solar heat transfer applications Nanofluids shows their effective results. Conventional solar flat plate collectors use water as a medium but now days nanofluids are used because of good thermal load carrying capacity.

Nanofluids possess two phase system i.e solid and liquid phases. However, many researchers considered it as a single phase fluid. These are not simply liquid-solid mixtures. In practical work, preparation of nanofluid is most important. Basically there are two methods used for the preparation of nanofluids.

2. PREPARATION METHODS FOR NANOFLUIDS

2.1. Two-Step Method

Two step method is most economical method for preparing large scale nanoparticles. In first step chemical method is used for producing all noanosized particles into powder form. In second processing step this powder will dispersed into liquid by high-shear mixing. However, preparation of Nanofluids faces challenges to achieve better stability.

Many researches use various techniques to enhance the stability of nanoparticles in fluids. Surfactants are used to gain better stability. However, the functionality of the surfactants under high temperature is also a big concern, especially for high-temperature applications. Because of difficulty in preparing stable nanofluids by two-step method, several new techniques are developed to produce nanofluids, including one-step method. In the following part, we will introduce one-step method in detail.

2.2. One-Step Method

In one-step method solid particles are prepared and mixed together with fluid at the same time. Eastman et al. produced Cu/ethylene glycol nanofluids by one-step physical vapor condensation method [1]. Y. Li et al. Shortened the processes of drying, storage, transportation, and dispersion of nanoparticles so the agglomeration of nanoparticles is reduced, and the stability of fluids is increased [2].

In one-step processes uniformly prepared dispersed nanoparticles can be stably suspended in the base fluid.

C. H. Lo et al. developed vacuum-SANSS (submerged arc nanoparticle synthesis system) for preparing nanofluids using different dielectric liquids. The nanoparticles prepared possess needle-like, polygonal, square, and circular morphological shapes. This new phenomenon avoids the undesired particle aggregation fairly well [3, 4].

Zhu et al. reduced $CuSO_4 \cdot 5H_2O$ with $NaH_2PO_2 \cdot H_2O$ in ethylene glycol under microwave irradiation and prepare copper nanofluids.Well-dispersed and stably suspended copper nanofluids were obtained [5]. Mineral oil-based nanofluids containing silver nanoparticles with a narrow-size distribution were also pre-pared by this method [6]. The particles could be settled by Korantin, which coordinated to the silver particle surfaces via two oxygen atoms forming a dense layer around the particles. The silver nanoparticle suspensions were stable for 1 long month. Thus stable ethanol-based nanofluids containing silver nanoparticles and may be prepared by microwave-assisted one-step method [7]. In the method, polyvinylpyrrolidone (PVP) was employed as the stabilizer of colloidal silver and reducing agent for silver in solution.

The cationic surfactant octadecylamine (ODA) is also an efficient phase-transfer agent to synthesize silver colloids [8]. The phase transfer of the silver nanoparticles arises due to coupling of the silver nanoparticles with the ODA molecules present in organic phase via either coordination bond formation. Where Phase transfer process is being used for preparing homogeneous and stable graphene oxide colloids. Graphene oxide nanosheets (GONs) were successfully transferred from water to n-octane after modification by oleylamine, and the schematic illustration of the phase transfer process is shown in Fig. 1 [9].

However, there are some disadvantages for one-step method. The most important one is that the residual reactants are left in the nanofluids due to incomplete reaction or stabilization. It is difficult to elucidate the nanoparticle effect without eliminating this impurity effect.

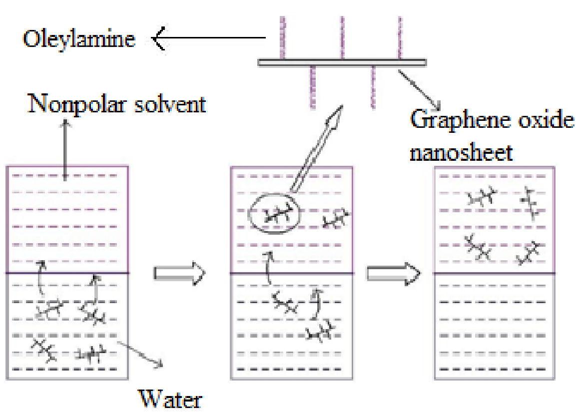

Fig. 1: Schematic illustration of the phase transfer process.

2.3. Other Novel Methods

Wei et al. developed a continuous-flow microfluidic microreactor to synthesize copper nanofluids. By this method, copper nanofluids can be continuously synthesized, and their microstructure and properties can be varied by adjusting parameters such as reactant concentration, flow rate, and additive. CuO nanofluids with high solid volume fraction (up to 10 vol%) can be synthesized through a novel precursor transformation method with the help of ultrasonic and microwave irradiation [10]. The precursor $Cu(OH)_2$ is completely transformed to CuO nanoparticle in water under microwave irradiation. The ammonium citrate prevents the growth and aggregation of nanoparticles, resulting in a stable CuO aqueous nanofluid with higher thermal conductivity than those prepared by other dispersing methods. Phase-transfer method is also a facile way to obtain monodisperse noble metal colloids [11]. In a water-cyclohexane two-phase system, aqueous formaldehyde is transferred to cyclohexane phase via reaction with dodecylamine to form reductive intermediates in cyclohexane. The intermediates are capable of reducing silver or gold ions in aqueous solution to form dodecylamine-protected silver and gold nanoparticles in cyclohexane solution at room temperature. Feng et al. used the aqueous organic phase-transfer method for preparing gold, silver, and platinum nanoparticles on the basis of the decrease of the PVP's solubility in water with the temperature increase [12]. Phase-transfer method is also applied for preparing stable kerosene-based Fe_3O_4 nanofluids. Oleic acid is successfully grafted onto the surface of Fe_3O_4 nanoparticles by chemisorbed mode, which lets Fe_3O_4 nanoparticles have good compat-ibility with kerosene [13].

The Fe_3O_4 nanofluids prepared by phase-transfer method do not show the previously reported "time dependence of the thermal conductivity characteristic". The preparation of nanofluids with controllable microstructure is one of the key issues. It is well known that the properties of nanofluids strongly depend on the structure and shape of nanomaterials. The recent research shows that nanofluids synthesized by chemical solution method have both higher conductivity enhancement and better stability than those produced by the other methods [14]. This method is distinguished from the others by its controllability. The nanofluid microstructure can be varied and manipulated by adjusting synthesis parameters such as temperature, acidity, ultrasonic and microwave irradiation, types and concentrations of reactants and additives, and the order in which the additives are added to the solution.

3. APPLICATIONS OF NANOFLUIDS

Modern concepts of nanofluids offer efficient heat transfer characteristics compared to conventional heat transfer fluids. Many researchers work on the enhancement of heat transfer properties of nanofluids especially on thermal conductivity and convective heat transfer. Some applications of Nanofluids are:

- Heat-transfer nanofluids
  - Electronics

- Transportation
- Industrial cooling application
- Heating building and Reducing pollution.

- Tribological nanofluids.
- Surfactant and coating nanofluids.
- Chemical nanofluids.
- Process/extraction nanofluids.
- Environmental (pollution cleaning) nanofluids.
- Bio- and pharmaceutical-nanofluids.
- Medical nanofluids (drug delivery and functional tissue–cell interaction).
- Nuclear System Cooling.
- Solar Absorption

Applications of nanofluids in solar drying, solar collectors and solar absorbers appear promising with effective thermal conductivity and convective heat transfer characteristics.

Solar Absorption:

Solar energy is inexhaustible source of energy which could supply all the present and future energy needs of the world. The power from the sun intercepted by the earth is approximately 1.8 × 10 11 MW, which is many thousands of times larger than the present consumption rate on the earth of all commercial energy sources .Solar energy is one of the best sources of renewable energy with minimal environmental impact. The conventional direct absorption solar collector is a well-established technology, and it has been proposed for a variety of applications such as water heating; however, the efficiency of these collectors is limited by the absorption properties of the working fluid, which is very poor for typical fluids used in solar collectors. Recently, this technology has been combined with the emerging technologies of nanofluids and liquid-nanoparticle suspensions to create a new class of nanofluid-based solar collectors. In past decade some studies were reported about using the nanofluids in solar collectors.

Natarajan [14] used carbon nanotubes and reported enhancement in thermal conductivity and efficiency of solar water heater. Otanicar [15] has studied environmental and economic influence of using nanofluids to enhance solar collector efficiency. Otanicar [16], experimentally investigated up rise in efficiency improvement up to 5% in solar thermal collectors by utilizing the CNTs,graphite and silver as nanofluids. Yousefi et al. [17] suggested the effect of Al_2O_3 nanofluid in a flat-plate solar water heater and reported that using the surfactant the maximum enhanced efficiency is 15.63%.

Otanicar and Golden evaluated the overall economic and environmental impacts of the technology in contrast with conventional solar collectors using the life-cycle assessment methodology [18]. Results showed that for the current cost of nanoparticles the nanofluid-based solar collector had a slightly longer payback period but at the end of its useful life has the same economic saving as a conventional solar collector. Sani et al. investigated the optical and thermal properties of nanofluids consisting of aqueous suspensions of single-wall carbon nanohorns [19]. The observed nanoparticle-induced differences in optical properties appeared promising, leading to a considerably higher sunlight absorption. Both these effects, together with the possible chemical functionalization of carbon nanohorns, make this new kind of nanofluids very interesting for increasing the overall efficiency of the sunlight exploiting device.

4. CONCLUSION

A detailed description of nanofluids application in solar collector is demonstrated in this paper. It is essential to note that preparation of nanofluids is an important step in experiments on nanofluids. Having successfully engineering the nanofluids, the estimation of thermo physical properties of nanofluids catches the attention. Great quanta of attempts have been made to exactly identify them but large amount of variations were found. Almost all the works showed that the dispersion of nanoparticles into the base fluids has produced a considerable augmentation of the heat transfer coefficient that clearly increases with an increase of the particle concentration. It was noticed that the increase in the effective thermal conductivity and huge chaotic movement of nanoparticles with increasing particle concentration is mainly responsible for heat transfer enhancement. The outcome of all heat transfer researches using nanofluids showed that our current understanding on nanofluids is quite limited. There are a number of challenges facing the nanofluids community ranging from formulation, practical application to mechanism understanding. Besides thermal conductivity effect, future research should consider other properties, especially viscosity and wettability, and examine systematically their influence on flow and heat transfer.

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