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Synthesis, Properties and Characterization of Nanofluid - A Critical Review

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***Abstract*: In last few decades, there is a remarkable number of researches that has been carried out on nano-fluids and hybrid nanofluids because of its enhanced thermal conductivity & heat transfer characteristics. Heat transfer is a very important task that has to be carried out at regular time interval and at definite rates, failing in it, which may result in a non-recoverable damage to the component. In order to achieve a better result the use of nano sized metallic or non-metallic particles with greater thermal conductivity than the fluid in which the particle is suspended have to be used. The liquid used to carry the nano-particle is called carrier fluid or base fluid. In the present paper, efforts have been made to focus on various methods of synthesis of nano-fluid and hybrid nano-fluids, technique of Stabilization, its common types and general properties of nano-fluids and hybrid nano-fluids employed in real life application.**

Keywords - Nanofluid; Heat transfer; Base fluid; Thermal conductivity; Particle size.

I. INTRODUCTION

Nanofluids are engineered colloidal suspensions of nanoparticles in a base fluid. Generally, the nanoparticles used in nanofluids are made of metals, oxides, carbides, or carbon nanotubes. Common base fluids include water, ethylene glycol and oil. Nanotechnology is considered to be one of the important forces that could drive the next major industrial revolution. The primary method of nanotechnology is to employ the structure at the molecular level with the goal of achieving desired change in property with extraordinary precision. [1]. The performance of the nanotechnology in diverse applications which includes heat exchangers, biomedical, photocatalysts, and others. However, one of the major demands in the industry is the essential of an extremely efficient heat rejection mechanism to increase the overall proficiency of a working system [2].
Many researchers have worked by varying the concentration of the nano sized particle in the base, some researchers have changed the nano particle, few have conducted study by varying the base fluid and few use the mixture of different types of nano-particles to form a hybrid nano-fluids used to understand the behaviour of the fluid at various circumstances. It is been proven by some of the researchers that, hybrid nano fluids show more dominant thermal and fluid flow properties the just nano fluids under certain compositions and conditions [9]. It becomes our bounded responsibility to understand the various types of nano-fluids present, methods of synthesis, method of stabilization of nano fluids, and some of the important thermal properties before starting any research and hence, an effort have been put to write a review on the same.

II. SYNTHESIS AND PREPARATION OF NANOFLUID

The performance of the nano fluid depends on various factors such as concentration of nano particles in the given base fluid, size of the nano particle, dispersion quality, stability of suspension, stable chemical composition and non-corrosive nature of the nano particle with the base fluid etc., in order to achieve this, the synthesis technique adopted plays an important role.

Synthesis of nano-fluids is widely accepted by two techniques:

1. One-step process.
2. Two-step process.

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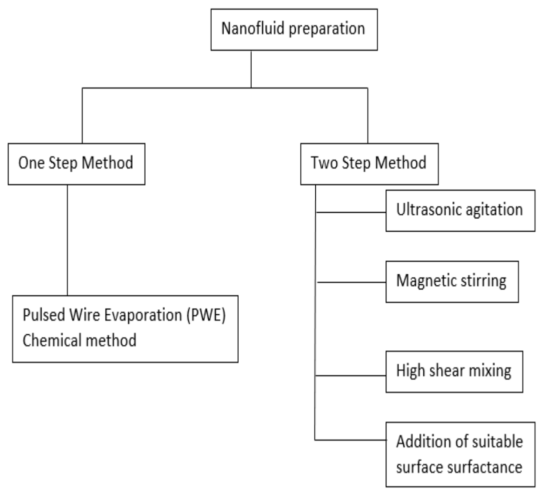

Figure 1: Classification of nanofluid preparation

Figure 1 represent the preparation of nano fluid by one step and two step methods. The details about the nanofluid preparation are described below.

A. One step method

The process of preparation of nanoparticles is done by simultaneous creation and dispersion. Pulsed wire evaporation is the most promising method of single step preparation technique which consists of high voltage DC power supply, wire feeding system, capacitor bank, condensation chamber etc. In this method, a high voltage pulse directed on a thin wire that melts and evaporates it within microsecond due to the effect of non-equilibrium heating. These vaporized particles made in contact with an inert gas such as argon or nitrogen inside the condensation chamber and condensed into nanosized powder [21]. In this method, the major problem is formation of agglomeration and its unsuitability to produce pure metallic nano powders. The agglomeration problem can be reduced to better extent by adopting direct evaporation condensation technique [1].

B. Two step method

In two-step method, the nanofluid are prepared by dispersion of nanoparticles into the base fluid one after the another, the prepared unitary nanofluids and then mixed together, and synthesized the nanocomposite and then dispersed it into base fluid [21]. This method was employed for the preparation of mono and hybrid fluid by Hong Wei Xian et al [2]

firstly, distilled water and ethylene glycol were mixed in weightage ratio of a 60:40 as base fluid. Surfactant in 1:1 concentration of nanoparticles was added into the prepared base fluid and stirred for 10 min. COOH-GnP powder was used to produce mono nanofluid. For hybrid nanofluid, TiO_2 and COOH-GnP powder were mixed into the prepared base fluid with a 50:50 weightage ratio using a magnetic stirrer Lastly, the mixture was sonicated again using a probe sonicator at 60% amplitude to disperse nanoparticles from agglomerating.

This method is most economical and common synthesis technique for the preparation of nanofluid in large quantities because the nano powder manufacturing technique have already started providing up to desired industrial level of production [3]. Ultrasonication a two-step method was used for the preparation of nanofluid by using Al_2O_3 nano particles with an average diameter of 13nm with spherical shape suspending in distilled water [4]. The advantage of this method is ability to control volume concentration [9].

III. TYPES OF NANOFLUIDS

In this section, various nanoparticles used for the preparation of nanofluids reported by different researcher are discussed in details.

A. Water/distilled water base - nanofluids

The commonly used base fluid for the preparation of nano fluid is water or distilled water which is due to easily available in the market and economical. Ethylene glycol and distilled water were mixed in equal proportion to prepare base fluid. Carboxyl-functionalized graphene nanoplatelets (COOH-GnP) powders was used to produce mono nanofluid. Titanium oxide and COOH-GnP powder were mixed in the prepared base fluid for preparation of hybrid nanofluid using magnetic stirrer [2]. Alumina-water and Alumina-iron/water hybrid nanofluids was used for the performance of flat plate collector [3]. Aluminium oxide-water nanofluid was used to analyze the consequence of ultrasonication duration on colloidal dispersion and thermophysical properties such as density, thermal conductivity, viscosity and microstructure of Al_2O_3-water nanofluid for different ultrasonication duration [4]. Titanium oxide-distilled water nanofluid preparation was done to know the influence of surfactant and ultrasonic processing on improvement of stability, thermal conductivity and viscosity [5]. Graphene/water, Silicon/water and Graphene-Silicon oxide/water hybrid nanofluid was prepared and evaluated for viscosity measurement, stability of nanofluid, structural analysis [6]. Different nanoparticles such as Al_2O_3 [9, 11, 12, 14, 15 & 16], MgO, SiC, aluminum nitride, MWCNT [18] and copper was used with base fluid as distilled water under different PH value for evaluation of heat transfer and pressure drop characterization, combined hydrothermal performances and entropy generation [8]. Synthesis of Graphene-Silver/water hybrid nanofluids was reported for enhanced heat transfer [17]. Copper-water nanofluid was prepared for heat transfer in the jet arrays impingement cooling system [19].

B. Ethylene glycol base - nanofluids

A stable ethylene glycol-based silicon-multiwalled carbon nanotubes nanofluid with mass fraction ranging from 0.01% to 1% was prepared to evaluate the unique properties of nanomaterials, stability of nanofluid, optical properties and photothermal conversion properties [10].

IV. PROPERTIES OF NANOFLUIDS.

In this section properties such as thermal conductivity, density, viscosity, specific heat and specific heat of nanofluid prepared by previous researcher have been discussed in detail.

A. Thermal conductivity

Hybrid nanofluid prepared by using graphene nanoplatelets and titanium oxide with base fluid as mixture of distilled water and ethylene glycol resulted increasing thermal conductivity for all the samples. The maximum and average deviation for thermal conductivity was 3.12% and 2.57% [2]. Work on Al_2O_3 nanofluid for 0.5 Vol.% of nanoparticles was done and reported that thermal conductivity was enhanced accordingly with the intensification of temperature. Brownian motion of nanoparticles increases due to higher nanofluid temperature and enhanced the thermal conductivity [4]. With increase in temperature the thermal conductivity of titanium nanoparticle with distilled water is varied linearly [5]. Mesoporous silica modified by copper nanoparticle hybrid nanofluid shows the increased thermal conductivity of 24.24% when compared with base fluid at a temperature of 50°C and at concentration of 0.075% [13]. Increase in oxide nanofluid volume fraction shows increased thermal conductivity particularly larger in ethylene glycol with CuO nanofluid when compared with water CuO nanofluid [15]. It is reported that graphene nanoplatelets-sliver hybrid nanofluid exhibits increase in thermal conductivity with increase in temperature as well as increase in particle concentration [17].

B. Viscosity

For graphene nanoplatelets and titanium oxide with base fluid as mixture of distilled water and ethylene glycol, the average deviation of prepared hybrid nanofluid was 1.68%. It was reported that the prepared hybrid nanofluid obeys Newtonian fluids [2]. It was reported that the working fluid is also a significant factor that influence the thermal performance of flat late collector. Al_2O_3 water nanofluids at a nanoparticle concentration of 0.1% exhibits a thermal enhancement of 2.16% in the collector. While reduction in thermal performance was reported for hybrid nanofluid of 1.79% [3]. Viscosity of nanofluid significantly decreases with increase in temperature from 10°C to 50°C for Al_2O_3 nanofluid for 0.5 Vol.% of nanoparticles. The reason is due to weakening of inter particle adhesion forces with the increase of temperature [4]. With increase in temperature the viscosity of titanium nanoparticle with distilled water is fell within the stated accuracy of the viscometer [5]. Viscosity of pure water at different temperature was measured and compared with the ASHRAE handbook, shows that the measured viscosity is validated at all temperature. Graphene-SiO_2/water hybrid nanofluid at 25°C exhibits decrease in viscosity with increase in shear rate while increase the viscosity with increase in concentration of nanofluid from 0.05% to 1% and also when compared to pure water [6]. Viscosity was found to be decrease with increase in temperature for different nanofluid. However, for water the viscosity was found to be declined slightly and validated with the ASHRAE data handbook [9]. With increment in particle volume fraction viscosity of all types of nanofluids gradually increases which is due to formation of clusters and internal viscous stress in the fluid, with the addition of nanoparticles in the base fluid. CuO/water based nanofluid shows highest viscosity at each fraction when compared to Al_2O_3-TiO_2/water hybrid nanofluid [12].

C. Heat transfer coefficient

Greater enhancement of heat transfer coefficient was observed for Al_2O_3 -water nanofluid and Al_2O_3/Fe-water nanofluid nearly 72% and 56% when compared with its base fluid respectively [3]. Heat transfer coefficient for Al_2O_3-carbon nanotube/distilled water shows the highest value when compared to water and Al_2O_3 nanofluid. When inlet temperature increases the heat transfer coefficient also increase for different fluids [8]. Over all heat transfer coefficient increase with increase in nanofluid flow rate. However, for CNT/water nanofluid result in enhanced heat transfer when compared to water at two different heat section [18]. The suspended copper/water nanofluid can remarkably improve heat transfer behaviors of the base fluid and heat transfer coefficient increase with increase in volume fraction of nanoparticles [19].

D. Density

It was reported that density of Al_2O_3 nanofluid for 0.5 Vol.% of nanoparticles increased with increasing ultrasonication duration this is due to at lower ultrasonication period, nanoparticles are not well dispersed [4]. Ternary hybrid nanofluid shows increased density with increase in volume fraction of nanofluid for Al_2O_3-TiO_2-CuO/water base [12]. It was reported that increase in particle concentration density of graphene nanoplatelet-sliver hybrid nanofluid also increase at constant temperature while density decrease with increase in temperature at constant particle concentration [17].

E. Specific heat

Decrease in specific heat capacity with increase in volume concentration for different nanofluid. When compared to hybrid nanofluid the mono nanofluid shows increased specific heat capacity for the same concentration. Increase in volume concentration of ZnO hybrid nanofluid resulted in decrease in specific heat capacity at constant temperature of 25°C [9].

V. CONCLUSION

Critical review on synthesis, types and properties of nanofluid was discussed in details based on the previous researcher findings. Increase in temperature result in enhanced thermal conductivity for all the nanofluid while viscosity was decreases with increase in shear rate. Two step synthesis process is preferrable then single step process for preparation of nanofluid which is due to control over the volume concentration of nanofluid. Performance of mono nanofluid is comparatively lower that that of hybrid nanofluid with respect to thermal properties. When concentration of nanofluid increases the viscosity was found to be decline. However, viscosity of nanofluid can be improved for lower temperature when compared to higher temperature. Validation of nanofluid may be done by using ASHRAE hand book.

VI. FUTURE WORK

The base fluid maybe prepared by using water and ethylene glycol with equal proportion. For the prepared base fluid Al_2O_3 and graphene nanoparticles can be added to prepare hybrid nanofluid. Another set of hybrid nanofluid can be prepared using titanium oxide and zinc oxide with the same combination of base fluid. Further, comparison can be made on the prepared hybrid nanofluid.

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