NANO FLUIDS PREPARATION METHODS AND ITS EFFECTS ON HEAT TRANSFER-A REVIEW

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ABSTRACT: *Nano fluids are used for increasing thermal properties in heat transfer equipment like heat exchangers, radiators etc. This paper investigates the heat transfer rate of Nano fluids using a shell and tube heat exchanger in single and multi-tubes under turbulent flow condition by a forced convection mode. Alumina Nanoparticles are prepared by using Sol-Gel method. Heat transfer rate increases with decreasing particle size. Nanofluid is a suspension of nanoparticles which is promising heat transfer fluid in the heat transfer enhancement having a plethora of applications because of its superior thermal conductivity and rheological properties. This paper points out the previous studies and recent progress in the improvement of heat transfer using nanofluid. The recent progresses on preparation and enhancement of stability were reviewed. Thermophysical, heat transfer characteristics of nano fluid and different factors such as particle size, shape, surfactant, temperature, etc. on thermal conductivity were presented. The present study reveals potential applications by utilizing nano fluid such as heat exchanger, transportation cooling, refrigeration, electronic equipment cooling, transformer oil, industrial cooling, nuclear system, machining operation, solar energy and desalination, defense, etc. Few barriers and challenges were also addressed. Finally, the challenges and further research opportunities were presented.*

Keywords: Nano fluids, Preparation, Thermophysical properties, Application

1.0 Introduction

Nanofluids have become increasingly closer to an engineering reality starting from their initial vision originated more than decades ago [1]. In the last ten years, there has been more attention paid to enhance the convective heat transfer performance of nanofluids [2], due to the recognition in practical applications of nanofluids. Heat exchangers are widely used in many engineering applications, for example, applications in power production industry, chemical industry, food industry, environmental engineering, waste heat recovery, air conditioning, and refrigeration. For decades, efforts have been made to enhance heat transfer of heat exchangers, reduce the heat transfer time and finally improve energy utilization efficiency. These efforts commonly include passive and active methods such as creating turbulence, extending the exchange surface or the use of a fluid with higher thermophysical properties [3]. The characteristics of flow and heat transfer in microchannels and microtubes have also attracted much attention of researchers because of the rapid developments of micro-electromechanical systems (MEMS) and micro total analysis system. These developments have great impacts on the microelectronic cooling techniques, the micro heat exchanger, bioengineering, human genome project, medicine engineering etc [4]. This aim of this review article is to summarize the heat transfer enhancement potential of nanofluids both experimental and numerical work and on the effect of the concentration and diameter of nanoparticles and the shape of cross-sectional tubes.

2.0 Application of nanoparticles:

an effective way of improving heat transfer characteristics of fluids Particles different from those of conventional solids. Compared with micron-sized particles, nanophase powders have much larger relative surface areas and a great potential for heat transfer enhancement. Some researchers tried to suspend nanoparticles into fluids to form high effective heat transfer fluids

By suspending nanophase particles in heating or cooling fluids, the heat transfer performance of the fluid can be significantly improved. The main reasons may be listed as follows:

- The suspended nanoparticles increase the surface area and the heat capacity of the fluid.
- The suspended nanoparticles increase the effective (or apparent) thermal conductivity of the fluid.
- The interaction and collision among particles, fluid and the flow passage surface are intensified.

3.0 Literature review

Leong et al. [5] used copper nanofluids and ethylene glycol as base fluid in an automotive cooling system. They observed an increase in the heat transfer coefficient compared to the base fluid. Their results showed that with 2% volume concentration the heat transfer increases of 3.8% considering the Reynolds number of 6000 and 5000 for air and coolant, respectively. They have also given some indications on the reduction of the frontal surface. Hussein et al. [6] examined the increase of heat transfer by using nanoparticles of TiO2 and SiO2 in pure water under laminar flow conditions. The volumetric flow rate, the inlet temperature and the volume concentration of the nanofluids are between 2-8 LPM, 60-80 °C and 1-2% respectively. It was observed that the Nusselt number increased significantly with the flow velocity and slightly with the inlet temperature and the volumetric concentration of the particles. In the experimental work of Subhedar [7] focused on the global heat transfer coefficient of Al2O3 nanoparticles and water mono ethylene glycol (MEG), used as refrigerant in a car radiator under laminar flow conditions. The experimental setup developed is similar to the automotive cooling system. The nanofluid used was prepared by a two-step method, using ultrasound for the correct dispersion of Al2O3 nanoparticles, with a diameter of 20 nm, in the mixture of water and MEG (with volumetric proportion of 50:50). The experimental study showed that the use of nanofluid improves the global heat transfer coefficient compared to the base fluid. It has been observed that the increase of the volumetric concentration of nanoparticles from 0% to 8%, also increases the overall heat transfer coefficient. The increase of the inlet temperature from 65 °C to 85 °C. Finally, it was found that the nanofluid with a volumetric concentration of 2% of Al2O3 allows a reduction of the heat exchanger surface of the 36.69%. Bozorgan et al. [8] carried out a numerical analysis on an application of CuO-water nanofluid in automotive diesel engine radiator. The results showed that for the nanofluid at 2% volume concentration circulating through the flat tubes while the automotive speed is 70 km/hr, the overall heat transfer coefficient and pumping power are approximately 10% and 23.8% more than that of base fluid for given conditions, respectively. An experimental study was accomplished by Hwa Ming Nieh [9]. An alumina (Al2O3) and titania (TiO2) nano-coolant (NC) were used to enhance the heat dissipation performance of an air-cooled radiator. The experimental results showed that the heat dissipation capacity and the efficiency factor of the nanofluid are higher than ethylene glycol, and that the nanofluid with TiO2 is more efficient than one with Al2O3 according to most of the experimental data. Gulhane and Chincholkar [10] carried out an experimental study on the application of water based Al2O3 nanofluid at lower concentrations in a car radiator. The results showed that the heat transfer coefficient enhances with an increase in particle concentration, flow rate, and inlet temperature of coolant and the maximum increase in heat transfer coefficient is 45.87 % compared to pure water. Ray and Das [11] compared three different nanofluids containing aluminum oxide nanoparticles, copper oxide and silicon oxide in the same base fluid, a mixture of ethylene glycol and water with a mass ratio of 60:40, used as a refrigerant in the car radiator. They observed that a nanofluid with a volumetric concentration of 1% of nanoparticles has better properties than those with higher concentrations: there was a 35.3% reduction of the pumping power and 7.4% of the heat transfer surface using an Al2O3 nanofluid. CuO nanofluid showed a slightly lower improvement, with a reduction of the pumping power and heat transfer surface of 33.1% and 7.2%, respectively. Finally, the SiO2 nanofluid showed lower performance, but still allowed to reduce the pumping power of 26.2% and the surface of 5.2%. Ali et al. [12] added ZnO nanoparticles in the base fluid with different volumetric concentrations (1%, 8%, 2% and 3%). The flow rate of the fluid was varied in a range between 7 and 11 LPM (liters per minute), the Reynolds number range was 17,500-27,600. The nanofluids showed an increase in heat transfer compared to the base fluid for all the concentrations examined. The maximum increase observed was 46% compared to the base fluid with a volumetric concentration of 2%. Increasing the volumetric concentration to 3%, it is noted that the heat transfer decreased. Besides, by varying the inlet temperature from 45 °C to 55 °C showed an increase in heat transfer velocity up to 4%. Moghaieb et al. [13] carried out an experimental analysis on the Al2O3 nanofluid and water, used in a cooling system of a car engine. The authors studied the convective heat transfer of the nanofluid with different diameters of nanoparticles (21-37 nm). The results showed that the convective heat transfer coefficient is directly proportional to the flow velocity and inversely proportional to its temperature. The heat transfer is 78.67% higher compared the traditional fluid in a car radiator, considering a volumetric concentration of nanoparticles of 1%. In the study of Elbadawy [14] two nanofluids (Al2O3/water and CuO/water) flowing in a flat tube of radiator investigated numerically to evaluate thermal and flow performance. They achieved a significant reduction in the radiator volume due to marked improvement in the heat transfer performance, while the required pumping power is found to be a function of Reynolds number and Nano fluid concentration ratio. The increase in the heat transfer coefficient reached 45% and 38% for Al2O3/water and CuO, respectively compared to the values of pure water. The optimum nanoparticle volume concentration which gives a moderate heat transfer enhancement with moderate pumping power increase is investigated an approximately found to be 4.5% for both Nano fluids. Harsh et al. [15] presented an experimental work on heat transfer using nanofluid as coolants in engine. Ethylene-glycol water solution was taken as a base fluid for nanoparticle dispersion. The analysis carried out with flow rate of 4,6,7 LPM and the air flow rate inside the duct was kept constant at 4.9 m/s. Results shows that there is an improvement of 24.5% in the overall heat transfer coefficient and there was also an increase of 13.9% in the heat transfer rate compared to the base fluid (80:20 Water: EG solution)

4.0 Preparation of nano fluid

Nano fluids are prepared by dispersing nanoparticles in the base fluid good dispersion is prerequisite for the application of nano fluid. Hence surfactants are used sometimes which enhance the stability of nano fluids. Besides, surface modification of the dispersed particles and application of strong force on the clusters of the dispersed nanoparticles may increase the stability of nano fluids. There are two fundamental methods to prepare nano fluids which are one step and two-step physical. Chemical process is another emerging technology in preparation of nano fluids. The percentage of volumetric concentration is calculated from the Eq.

$$\text{Volume concentration}, \phi = \left[\frac{\frac{W_{np}}{\rho_{np}}}{\frac{W_{np}}{\rho_{np}} + \frac{W_{bf}}{\rho_{bf}}} \right] \times 100 \qquad (1)$$

where W_{np} is weight of nanoparticles, W_{bf} is weight of base fluid, ρ_{np} is density of nanofuid, and W_{bf} is density of the base fluid

4.1 One-step method: In this method, some processes are avoided like drying, storage, transportation, and dispersion of nanoparticles. Stable nano fluid is prepared by Physical Vapor Deposition (PVD) technique in which direct evaporation and condensation of nanoparticles are carried in the base fluid. Pure and uniform nanoparticles are produced by this method. Hence accumulation of nanoparticles is reduced. The main drawbacks of one- step method is that the residual reactants are left in the nanofluids and also the cost is high. Zhu et al. [16] prepared Cu nanofluid one-step method.

4.2 Two-step method:

This is the most economic method for large scale preparation of nanofluid. In two-step method, the nanoparticles are obtained by different methods and then these nanoparticles are dispersed into the base liquid for the desired nanofluid. This production process is inexpensive and massive. The main drawback of two- step method is aggregation of nanoparticles. Because of instability, surfactant is used. This is the commercial method to prepare nanofluid. Most of the researchers prefer this method in preparation of nanofluid for research. Zhu et al. [29] used two step methods to prepare Al_2O_3/water nanofluid. Figure 1 demonstrates the two-step method.

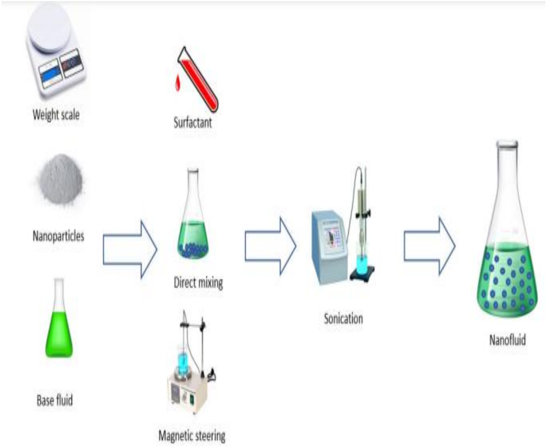

Figure 1 Two-step method

4.3 Stability of nanofluid:

It is important to get the same thermophysical properties. Stability of nanofluid is related to electrical double layer repulsive force and Van der Waals attractive force. Electrical Double Layer Repulsive Force (EDLRF) must be higher than the Vander Waals attractive forces to get stable nanofluid. Van der Waals attractive forces between nanoparticles causes to get clustered because of attraction forces. If this force is high, nanoparticles get separated from base fluid and these clustered nanoparticles settle down at the bottom of vessel because of gravitational force. On the other hand, EDLRF acts as opposite to Van der Waals attractive force which separates the particles from each other. Figure 2 demonstrates the sedimentation of Al_2O_3 nanoparticles without stabilizer at different time from the preparation of nanofluid.

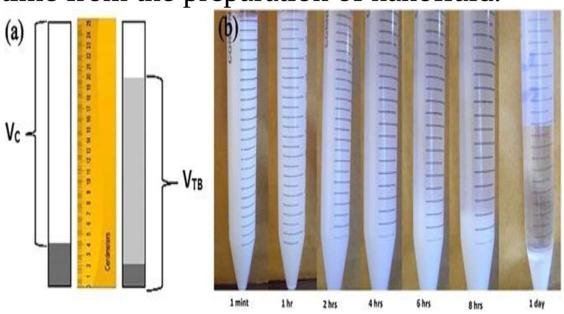

Figure 2 Sedimentation of Al_2O_3 nanoparticles without stabilizer

5.0 Techniques of enhancing nanofluid:

stability Density of nanofluid over different time can be measured with three-digit accuracy by laboratory density and concentration measurement device such as digital density meter. A circulating fluid temperature bath is used to maintain and measure the density of the specimen of nanofluid at different temperatures. But calibration and a benchmark test are required before measuring the desired nanofluid. Some researchers used Anton-Paar digital density meter to measure the density of different nanofluid [17, 18]. Different methods have been developed in enhancing nanofluid stability. Addition of dispersant, and sonication are the notable methods. Addition of dispersant is the most economical method.

5.1 Dispersant:

Addition of dispersants or surfactants is the common method in enhancing the stability of nanofluid which prevents the agglomeration of nanoparticles by reducing the surface tension of the base fluid. But excess use of dispersant may deteriorate the thermophysical properties of nanofluid including decrease in thermal conductivity as well as degradation of chemical stability [19]. Hence, dispersant should be used in optimum quantity. Surfactants chemically consists of two portions, hydrophilic polar head group and a long-chain hydrocarbons called hydrophobic tail. Some common dispersants are Sodium dodecyl benzene sulfonate (SDBS), Gum arabic, Sodium dodecyl sulphate (SDS), Polyvinyl prolidone (PVP), Dodecyl trimethylammonium bromide (DTAB), Oleic Acid (OA), etc.

5.2 Magnetic stirring: Magnetic stirrer is employed in laboratory which use rotating magnetic field to increase the homogeneity of nanofluid by reducing sediment. Generally, two knobs are present in a magnetic stirrer or magnetic mixer, left knob and right knob. Stirring rate is controlled by the left knob. On three other hands, heating is controlled by the right knob. Magnetic stirring technique is used by some researcher before sonication [20]. used magnetic stirring to prepare TiO2 nanofluid.

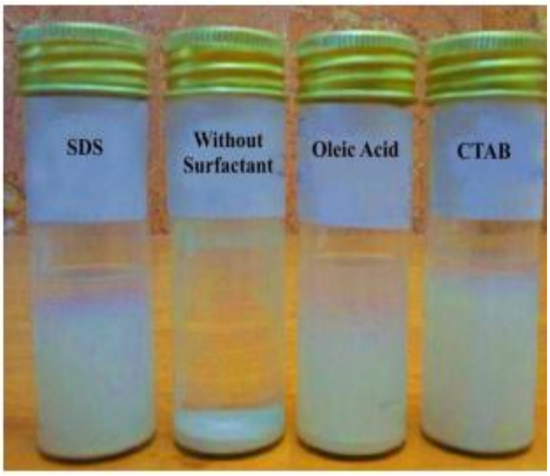

Fig. 4 Effect of surfactant on Mg(OH)2 / water nanofluid (after 45days)

5.3 Sonication: This method gives better dispersion which has less probability of particle agglomeration than magnetic stirring. Ultrasonic waves are applied in sonication method through the nanofluid. Sonication helps to make more homogenized suspension. To provide uniform dispersion, sonication is better than magnetic stirrer. Two types of sonicates are available, bath type and probe type. Probe type sonication gives better performance than bath type sonication. The agglomerated nanoparticles are subjected to vibration by the ultrasonic waves when sonication is applied. The cavitation bubbles grow until critical state which are generated during sonication. The hot spots are created which are combination of very high local pressure and temperature. The hot-spots are generated during the critical state.

6.0 Conclusions and future scope

The present study presents recent developments of nanofluid in heat transfer enhancement. The study extends to the preparation of nanofluid, stability of nanofluid, enhancing the stability of nanofluid, thermophysical properties, heat transfer characteristics, application. Nanofluid has some challenges for which further research should be conducted.

Preparation of nanofluid is costly. Hence, efforts are required to identify cost-effective techniques for the nanofluid preparation.

- Stability is the main challenge of nanofluid which is crucial in the application as heat transfer fluid. More researches are required though some techniques are adopted in enhancing stability of nanofluid.
- The optimum time of sonication and magnetic stirring is not determined yet for different types of nanofluid. Moreover, optimum concentration of surfactant is not determined yet.
- The combination of different nanoparticles is not yet touched. Hence, effort can be made to find out the thermophysical properties of hybrid Nano fluid.

The development of correlations of friction factor and heat transfer through tubes with nanofluids. Therefore, further studies are needed to develop a generalized hydrodynamic and heat transfer characteristic correlation for nanofluid in a tube. Additionally, a comparison among tube shapes for use in a car radiator can be performed experimentally and numerically. The more research in nanofluids which will define their future in the field of heat transfer is expected to grow at a faster pace in the coming future.

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