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A Comprehensive Analysis of the Synthesis, Properties and Uses of Nanofluid

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Abstract

Nanofluid, which is a suspension of nanoparticles, has the potential to be a heat transfer fluid with a wide range of applications due to its superior thermal conductivity and rheological properties. This article summarises both previous and current research on nanofluid heat transfer improvement. A survey was done on the most recent advancements in readiness and stability improvement. The discussion included thermophysical properties, heat transfer properties of nanofluids and the impact of surfactant, temperature, particle size, shape and other variables on thermal conductivity. The current study proposes potential possibilities through the utilisation of nanofluids. A few challenges and roadblocks were also discussed. The challenges and opportunities for further research were finally covered.

Keywords: *Application, Nanofluid, Preparation, Properties, Stability*

1.0 Introduction

The significance of rapid heat transmission in engineering domains has increased over time. There has been ongoing research to reduce frictional loss, pressure drop and pumping power for heat transfer fluid, as well as to boost thermal conductivity and heat transfer rate. Improved thermal properties are the goal of a novel kind of heat-transfer fluid known as a nanofluid. This is produced by suspending a small amount of nanoparticles in base fluids, like water, ethylene glycol, etc., either with or without the use of stabilisation procedures. A nanoparticle's average size is less than 100nm. The author's 1999 study[1] looked at the thermal conductivity of oxide nanoparticles dispersed in base fluid. Based on ethylene glycol, the author[2] found that copper nanoparticle-containing nanofluids had increased thermal conductivity. The author[3] investigated the heat conductivity of nanotube suspension. The author's book "Nanofluids: Science and Technology" was released in 2007[4]. The author suggested using nanofluid in car cooling systems[5]. A group of twelve European businesses and research facilities called Nano Hex started the biggest investigation into the use of nanofluids[6]. Overheating is a common issue in a wide range of industries, including electronics, manufacturing, heavy machinery and engine operation[7]. There are significant disadvantages of conventional heat-transfer fluids. Nanofluids have improved thermophysical properties which help to alleviate

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some of these limitations[8]. Nanofluids have outstanding thermophysical qualities that make them suitable for use as coolant in many different applications, such as electric generators, transformers, car engines and high-heat flux devices[9]. The development of nanofluids is still hampered by a variety of issues, including stability, a lack of well-understood theoretical models and mechanisms, production complexity, high costs, etc[10]. The primary goal of this study is to help researchers understand the present research gap and recent breakthroughs in nanofluids by a thorough assessment of nanofluids[11].

By significantly enhancing the thermophysical characteristics of conventional heat transfer fluid, nanoparticles raise its thermal conductivity. Among these thermophysical characteristics are density, specific heat, thermal conductivity and dynamic viscosity[12]. The amount of nanoparticles floating in the base fluid determines how much heat transfer is enhanced[13]. The research aims to seek high thermal conductivity metal oxide nanoparticles[14]. Water, ethylene glycol, engine oil and other base fluids are frequently utilised. The Al_2O_3/water nanofluid in the car radiator was investigated[15] and it was observed that it increased the heat by 45% when compared to pure water. By significantly enhancing the thermophysical characteristics of conventional heat transfer fluid, nanoparticles raise its thermal conductivity. Among these thermophysical characteristics are density, specific heat, thermal conductivity and dynamic viscosity[16].

The goal of this research is to obtain highly thermally conductible metal oxide nanoparticles[17]. Commonly used base fluids include water, ethylene glycol and engine oil. A recent examination of the Al_2O_3/water nanofluid in automobile radiators revealed a 45% increase in heat compared to pure water[18]. The significant heat transmission is also believed by many experts to be caused by the Brownian motion of the nanoparticles. According to the author[19], Brownian motion should be included while calculating velocity. The random migration of nanoparticles inside the base fluid causes the thermal boundary layer to shrink[20]. Micro-level convection, Brownian motion and percolation are responsible for the increased heat transport[21]. Moreover, researchers discovered that superior results were obtained when nanoparticles were added to energy storage systems[22]. The current project focuses on improving stability techniques, thermophysical characteristics and heat transmission aspects, as well as closing preparedness gaps. The review research also discusses the possible industries in which nanofluids could prove useful. Lastly, the difficulties and potential avenues for additional research on nanofluids have been discussed.

1.1 Aim and Objectives of Work

The aim and objectives of the present research work are described below:

- To propose potential possibilities through the utilisation of nanofluid.
- To address various challenges and opportunities for further research.

2.0 Preparation of Nanofluid

By mixing nanoparticles into the basic fluid, one can produce nanofluids. Before preparing nanofluids, a good dispersion is necessary. That is why surfactants are occasionally added to nanofluids to make them more stable. Furthermore, nanofluid stability may be enhanced by altering the surface of the dispersed particles and applying a high force to their clusters. One- and two-step physical processes are the two basic techniques for creating nanofluids. The chemical procedure is an additional innovative way to create nanofluids.

2.1 One-Step Process

Certain processes such as drying, storing, transporting and distributing nanoparticles are omitted in this method. Physical Vapour Deposition (PVD) technology is used to directly evaporate and condense nanoparticles in the base fluid to produce stable nanofluid. This process yields pure and homogenous nanoparticles. As a result, there is less nanoparticle buildup. Its main disadvantages are the high cost of the one-step process and the reactants left in the nanofluids. Cu nanofluid was created in one step by the author[23].

2.2 Two-Phase Approach

The most affordable technique for preparing nanofluids on a big scale is this one. A two-step process involves dispersing the nanoparticles into the base liquid and extracting them using various methods to create

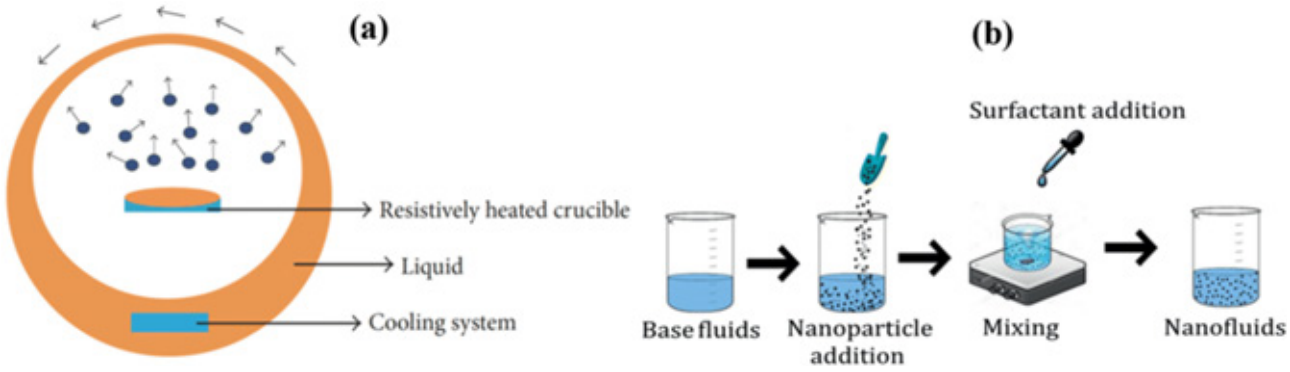


Figure 1. Set up of one-step process and two-phase approach.

the proper nanofluid. This is a large-scale, low-cost production method. The agglomeration of nanoparticles is the primary disadvantage of the two-step approach. The reason for the usage of surfactants is this instability. This is how nanofluid is commercially prepared. When producing nanofluid for study, this method is the one that most researchers opt to employ. The Al_2O_3/water nanofluid was created using two different methods[24].

2.3 Nanofluid Stability

Maintaining the same thermophysical properties of the nanofluid requires stability. There exists a correlation between the van der Waals attraction force and the electrical double-layer repulsive force in nanofluid stability. A stable nanofluid needs to be created when the Vander Waals attractive forces are smaller than the electrical double-layer repulsive force[25,26]. Van der Waals forces are the attraction forces that lead to nanoparticle clustering. Due to their separation and clustering from the base fluid, the separated nanoparticles are drawn to the bottom of the tank by a stronger gravitational force[27]. The electrical double-layer repulsive force, on the other hand, opposes the Van der Waals attractive force, which keeps the particles apart.

3.0 Assessing the Stability of Nanofluids

Consistent thermophysical properties of the nanofluid require stability. To examine the stability of nanofluids, researchers have employed a range of evaluation methods. Listed below are a few popular techniques.

3.1 The Process of Sedimentation Photographs

The photographic approach is another name for this technique. This approach is the simplest to use and doesn't call for any complicated machinery. Gravity is used to analyse particle settling[28]. Due to the extended monitoring of the nanofluid, the process takes time. Using a digital camera, images are taken during this procedure at equal intervals from the nanofluid preparation period[29]. A comparison of these images was used to assess the stability of nanofluids. If there is no sedimentation, it is considered stable. The CuO nanofluid stability was examined by the author[30]. By utilising this technique, some researchers have also discovered other nanofluids, such as Cu/water and kaolinite/water[31,32].

3.2 The Centrifuging Technique

The sedimentation picture method is speedier than centrifugation in this comparison. When there is centrifugal force in addition to gravity, sedimentation occurs more quickly[33]. A centrifuge and dispersion analyser was used to test the stability of grapheme in clean water[34]. Within a polypropylene tube, nanofluid was centrifuged for five, ten and twenty minutes at 6000rpm. Visual inspection of the tube's bottom occurs once centrifugation is complete. Assessing the stability of nanofluid for 20 minutes at 6000rpm produced outstanding results for their inquiry. The same technique was used with Ag/ethanol nanofluid[35]. Sedimentation in the centrifugation process requires a long centrifugation period and assuming the nanofluid is stable, a high rotational speed.

3.3 Zeta Potential

The potential differential between the base fluid and the stern layer of nanoparticles is known as the zeta potential. One common unit of measurement is millivolts. A device known as the Zeta Sizer Nano (ZSN) measures zeta potential, which may be computed using the equation. The Zeta potential value can be used to determine the nanofluid's long- and short-term stability. A larger absolute value of the zeta potential will result in a more stable nanofluid[36]. A greater zeta potential is observed in nanofluids with a lower pH[37]. Zeta potential is one measure that is dependent on pH. Thus, a nanofluid's zeta potential depends on pH. Measurements were used to assess the stability of the K-CNT and Na-CNT nanofluids[38].

3.4 Technique for Electron Microscopy

Nowadays, the majority of researchers combine electron microscopy with other methods. An advanced piece of gear required for this technique is a Transmission Electron Microscopy apparatus, which captures electron micrographs. This camera has a very high resolution for picture capture. If there are any nanoparticle clusters in the image, sedimentation can occur. The author[39] assessed the Cu nano fluid's stability using TEM. The ZnO/glycerol nanofluid's stability was assessed using the same techniques[40]. TEM measurements of a stable nanofluid are shown. Techniques are used to improve the stability of nanofluids[41]. A digital density meter or other density and concentration measurement tools in the laboratory can measure the density of a nanofluid over a range of times with three-digit accuracy[42].

4.0 Uses of Nanofluid

Among other industries, the processing, heavy and microchannel sectors use various heat exchanger types, such as shell and tube, plate type, compact and micro-channel type[43]. Scientists have been putting a lot of effort into replacing conventional heat transfer fluid with nanofluid in an effort to increase the heat exchanger's efficiency[44]. By incorporating multi-walled nanotube particles into the nanofluid studied in the shell and tube-type heat exchanger, the author[45] discovered a remarkable enhancement in heat transmission. TiO_2/water and Al_2O_3/water nanofluids' peclet numbers and nanoparticle volume concentrations were studied in shell and tube-type heat exchangers[46]. According to their findings, nanotechnology's heat transmission coefficient is larger.

A plate heat exchanger's nanofluid was studied using tests and Computational Fluid Dynamics (CFD)[47]. Analysis revealed the improved thermal conductivity of the nanofluid. A dual pipe heat exchanger with silver nanofluid had a higher heat transfer coefficient[48], because of the nanoparticles' higher volume fraction. Additionally, a miniature heat exchanger was studied using nanofluid. A study[49] discovered improved heat transmission. Reclamation of water using nanoparticles is possible in solar heat exchangers. The effectiveness of TiO_2 nanofluid in the milk pasteurisation business was further enhanced by the utilisation of plate heat exchangers[50].

The volume portion of the TiO_2 nanofluid showed a greater rate of heat transmission[51]. Heavy-duty and automotive engines produce a lot of heat. If this extra heat is not quickly released, the engine could be harmed[52]. The most popular coolant for vehicle cooling systems is Ethylene Glycol (EG)-based Heat Transfer Fluid (HTF), which has a volumetric EG-to-water ratio of 60/40 or 50/50. Pure water's freezing point is raised when EG is added. Nanofluid can be utilised to develop efficient and small-sized cooling systems[53].

5.0 Remarks and Upcoming Efforts

The most recent advancements in nanofluid technology to improve heat transfer are presented in the current paper. The paper discusses the creation of nanofluid, as well as its use, thermophysical characteristics, heat transfer characteristics, stability and ways to improve it. To address specific issues of nanofluids, more research is necessary. Below is a prospective study that could be conducted in the future: The cost of preparing nanofluids is high. Therefore, it is imperative to search for cost-effective methods of producing nanofluids. The primary issue with nanofluids is stability, which becomes significant when they are used as heat transfer fluids. Even though there are several ways to increase the stability of nanofluids, additional research is still needed. For many different kinds of nanofluids, the ideal duration for magnetic stirring and sonication has not yet been established. Furthermore, the ideal surfactant concentration is still

unknown. There has been no change made to the mixture of several nanoparticles.

6.0 Conclusion

Nanofluid preparation is expensive. Thus, it is essential to look for ways to produce nanofluids at a reasonable cost. Stability is the main problem with nanofluids, and it becomes important when they are utilized as heat transfer fluids. Though there are several strategies to make nanofluids more stable, further study is still required. The optimal period for sonication and magnetic stirring has not yet been determined for a wide variety of nanofluids. Moreover, it is still unclear what the optimal surfactant concentration is. The mixture of many nanoparticles has not been altered. Thus far, the thermophysical properties and heat transmission properties of the various Nanofluids are not significantly correlated. Further research can be conducted to find new relationships between various nanofluids. They have a wide range of possible applications. Researchers have utilised nanofluid in various fields, including solar absorption, industrial cooling, heat exchangers, nuclear systems and automobile cooling. Nanofluids should not be used in nuclear systems or any other industries without adequate investigation.

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