

Potential of Nanofluids as Working Fluid for Advances in Heat Transfer Systems

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Abstract—Nanofluids are the key area of interest for many researchers now a day. Recent advancements in nanotechnology have given these new types of heat transfer fluids called nanofluids. Nanofluids are prepared by dispersing and stably suspending nanometer sized solid particles in conventional heat transfer fluids. Past researches have shown that a very small amount of suspending nanoparticles have the potential to enhance the thermo physical, transport and radiative properties of the base fluid. Due to improved properties, better heat transfer performance is obtained in many energy and heat transfer devices as compared to traditional fluids which open the door for a new field of scientific research and innovative applications. The aim of this paper is to present the broad range of nanofluid based potential current and future applications. Some barriers and challenges are also focused for implementing these new class of working fluids. At last future opportunities in nanofluid research are identified and future directions are also given so that the vision of nanofluid can be completed.

Keywords: Nanofluids, Nanoparticles, Heat Transfer enhancement, applications.

1. INTRODUCTION

Nanotechnology provides new opportunities to process and produce materials with average crystallite sizes below 100 nm called nanomaterials. The term “nanomaterials” encompasses a wide range of materials including nanocrystalline materials, nanocomposites, carbon nanotubes and quantum dots. Due to its nanostructural features, nanomaterials exhibit enhanced properties (mechanical, thermal, physical, chemical), phenomenon and processes than conventional materials. In general, there are four types of nanomaterials: Carbon based nanomaterials (eg. carbon nanotubes), Metal based nanomaterials (metal oxides such as aluminium oxides), Dendrimers (nanosized polymers) and Composites (nanosized clays).

When these nanoparticles are suspended in conventional fluids (water, oil, acetone) called “nanofluids”. Nanofluids clearly exhibit improved thermo-physical properties such as thermal conductivity, thermal diffusivity, viscosity and convective heat transfer coefficient. The property change of nanofluids depends on the volumetric fraction of nanoparticles, shape and size of the nanomaterials. Due to novel properties of nanofluid it can be widely used for various heat transfer applications of

engineering including, automotive and air conditioning cooling, solar and power plant, improving diesel generator efficiency, cooling in machining, or and defense and space.

The use of nanofluids will improve the overall properties and heat transfer characteristics of base fluid and overcome the problems of poor suspension stability and channel clogging of milli and micro particles even then the development and applications of nanofluids may be limited by several factors due to use of very small size solid particles with very small concentration. This paper first covers various potential applications of nanofluids then identifies parameters which challenges for the use of nanofluids to various applications and in last suggest directions for future research of nanofluids.

2. BENEFITS OF USE OF NANOFLUIDS

Nanofluids possess the following advantages as compared to conventional fluids which makes them suitable for various applications involving heat exchange.

- i. The suspended nanoparticles increase the surface area and the heat capacity of the fluid due to the very small particle size.
- ii. The suspended Nanoparticles enhance the thermal conductivity which results improvement in efficiency of heat transfer systems.
- iii. Heating within the fluid volume, transfers heat to a small area of fluid and allowing the peak temperature to be located away from surfaces losing heat to the environment.
- iv. The mixing fluctuation and turbulence of the fluid are intensified.
- v. The dispersion of nanoparticles flattens the transverse temperature gradient of the fluid.
- vi. To make suitable for different applications, properties of fluid can be changed by varying concentration of nanoparticles.

3. APPLICATIONS OF NANOFUIDS

Nanofluids can be used in broad range of engineering applications due to their improved heat transfer and energy efficiency in a variety of energy systems. The following section gives a brief idea of different areas of nanofluid applications based on available literatures.

3.1 Applications in Automotive

In automobile arena, nanofluids have potential application as engine coolant, automatic transmission fluid, brake fluid, transmission fluid and greases. The first application in cooling automatic power transmission system done by Tzeng et al show that CuO nanofluids have the best heat transfer performance.

3.1.1 Nanofluid as coolant

The use of nanofluids as coolants would allow for smaller size and better positioning of the radiators. There would be less fluid due to the higher efficiency, coolant pump could be shrunk and truck engines could be operated at higher temperatures allowing for more horsepower. In a study done by Singh et al have shown that the use of nanofluids in radiators can lead to a reduction in the frontal area of the radiator by up to 10%. This reduction in aerodynamic drag can lead to a fuel saving of up to 5%.

3.1.2 Nanofluid in Fuel

It was shown that the combustion of diesel fuel mixed with aqueous aluminum nanofluid increased the total combustion heat while decreasing the concentration of smoke and nitrous oxide in the exhaust emission from the diesel engine. It is due to the high oxidation activity of pure Al which allows for increased decomposition of hydrogen from water during the combustion process.

3.1.3 Nanofluid in Brake Fluids

During the process of braking, the produced heat causes the brake fluid to reach its boiling point, a vapour lock is created that retards the hydraulic system from dispersing the heat caused from braking. It will create a brake malfunction and poses a safety hazard in vehicles. Nanofluids with enhanced characteristics maximize performance in heat transfer as well as remove any safety concerns.

3.2 Applications of nanofluid in Domestic Refrigerator

Now a days, in refrigeration equipment HFC134a is used as a refrigerant. Traditional mineral oil is avoided as a lubricant due to the strong chemical polarity of HFC134a in refrigeration equipment. POE (Polyol-ester) oil as a lubricant also has the problems of flow choking and severe friction in the compressor. So nanoparticles can be used to enhance the working fluid properties and energy efficiency of the refrigerating system associated with reduction in CO₂ emission.

3.3. Industrial Cooling Applications

Routbort et al. employed nanofluids for industrial cooling and showed great energy savings and resulting emission reductions. They showed that replacement of cooling and heating water with nanofluids has the potential to conserve about 300 million kWh of energy for industries. For the electric power industry using nanofluids could save about 3000-9000 million kWh of energy per year which is equivalent to the annual energy consumption of about 50,000-150,000 households. The associated emission reductions would be approximately 5600 million kg of carbon dioxide, 8.6 million kg of nitrogen oxides and 21 million kg of sulfur dioxide.

It was observed that the nanofluids specific heat capacity was enhanced by 50%. Hence, it was concluded that nanofluids have better efficacy in thermal energy storage applications compared to cooling applications.

3.4. Solar Devices

Direct absorption solar collectors have 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. Otanicar et al. demonstrated efficiency improvements of up to 5% in solar thermal collectors by utilizing nanofluids as the absorption mechanism. The experimental and numerical results demonstrate an initial rapid increase in efficiency with volume fraction, followed by a leveling off in efficiency as volume fraction continues to increase.

4. LIMITATIONS OF USING NANOFUIDS

The use of nanofluids seems attractive in a broad range of applications as reported in the previous section. But the development in the area of nanofluid application is hindered by many factors in which long term stability of nanofluid in suspension is major reason. The following are the most pressing issues.

4.1 Poor long term stability of suspension

Long term physical and chemical stability of nanofluids is an important practical issue because of aggregation of nanoparticles due to very strong van der Waals interactions so the suspension is not homogeneous. Physical or chemical methods have been applied to get stable nanofluids such as (i) an addition of surfactant; (ii) surface modification of the suspended particles; (iii) applying strong force on the clusters of the suspended particles. Particles settling must be examined carefully since it may lead to clogging of coolant passages.

4.2 Increased pressure drop and pumping power

Pressure drop development and required pumping power during the flow of coolant determines the efficiency of nanofluid application. It is known that higher density and

viscosity leads to higher pressure drop and pumping power. One of the experimental study calculated 40% increase of pumping power compared to water for a given flow rate.

4.3 High cost of nanofluids

Nanofluids are prepared by either one step or two step methods. Both methods require advanced and sophisticated equipments. This leads to higher production cost of nanofluids. Therefore high cost of nanofluids is drawback of nanofluid applications.

5. FUTURE RESEARCH

As far as for better understanding of nanofluids, further research is needed. Mostly heat transfer depends on Thermal conductivity of nanofluid. The thermal conductivity of nanofluids can be a function of parameters such as particle shape, particle agglomeration etc. therefore future research should be focused on finding out the main parameters affecting the thermal conductivity of nanofluids. Theoretical predictions should be evaluated in terms of agreement with experiments regarding concentration, particle size and temperature dependence. Currently, the available nanoparticles are limited and their specifications are not accurate. The challenging point is to obtain the desirable nanoparticle product. The development of the nanoparticle production technique will be very helpful for the nanofluid research. So in last we can say that low cost, high volume production of stable green nanofluids is one of the most challenging directions for future applied research.

6. CONCLUSION

This paper concluded that nanofluids are important because they can be considered as a potential candidate for numerous applications involving heat transfer and their use will continue to grow. It was also found that the use of nanofluids appears promising, but the development of the field faces several challenges. Nanofluid stability and its production cost are major factors in using nanofluids. The problems of nanoparticle aggregation, settling, and erosion all need to be examined in detail in the applications. We can say that once the science and engineering of nanofluids are fully understood and their full potential researched, they can be reproduced on a large scale and used in many applications.

It is also suggested that further research still has to be done on the synthesis and applications of nanofluids so that they may be applied as more efficient and compact heat transfer systems, maintaining cleaner and healthier environment and unique applications.

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