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Review on Applications of Nano fluids in Refrigeration System

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Abstract— **Sustainable energy and development demands would be the subjects of human development that were always closely researched. Technological development and progress in the design of models would solve the clean energy problem. The new innovation in nano-based technology in the past decades has been widely applauded for its approach towards reducing the consumption of energy with its applications on several heat transfer systems including solar collectors, heat exchangers, thermal storage systems, electronic cooling and so on. The study highlights the effectiveness of thermal physical properties of nanoparticles such as high thermal conductivity, dynamic viscosity, increased stability and homogeneous particles, as well as reduced energy use. Various simulation program are observed for nanoparticles such as (Cu, Al2O3, CuO, TiO2) showing promising results with different nanoparticles size and volume fraction. The trend advantages of nanoparticles over conventional cooling are good for heat transfer and high thermal conductivity with a very low concentration of particles. Thus, the challenges and leading examples of nano-fluids in the future would be more concerned with energy needs.**

Keywords — Nanoparticles, thermal conductivity, volume fraction, heat transfer enhancement

I. Introduction

With growing demand for progressive technology for better heat transfer fluids, which also has an economic advantage, the new technological developments would be explored. Modern nanotechnology offers an advantage to efficient energy growth. Nanoparticles are the latest type of heat transfer fluid engineered in conventional heat transfer fluids by nanometer-sized particles. The refrigerant-based nanofluid in nano particles improves the rate of heat transfer and reduces energy consumption. These nanoparticles are usually less than (50-100) nm suspended inside a coolant, usually metal or oxide, that improves fluid conductivity to improve cooling. Example: - Ethylene glycol- copper Nano fluids, Water- copper oxide, Aluminium oxide disperse in R141b/ R134a refrigerant and many more [8,9]. Recent few publications point to the tremendous rates of heat transfer and conductivity increase in these Nano-particle-based fluids (1-3). This demonstrates that it is very cost-effective than conventional coolants with a potential to reduce energy consumption and G.W.P. They are targeted at an increase in thermal capacity and a decrease of particle volume (Fig.1). They are generally prepared by two methods: -

a. Firstly, through a direct process of evaporation, which produces nano particles and at the same time disperses them into the coolant fluid base.
b. The nano particles are then produced separately and then distributable into the basic fluids.

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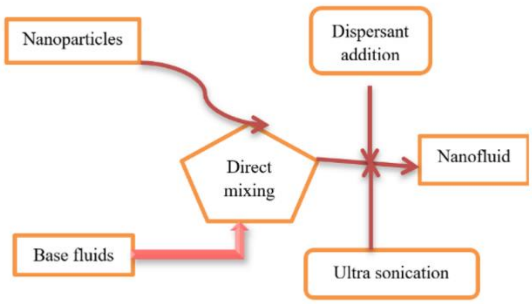

Figure 1: Preparation of Nanofluids [1]

A. Advantages of Nano fluids as studied

i. The heat transfer range between particles and fluids is wider.
ii. Higher stability of dispersion.
iii. Low pumping power due to potential energy saving.
iv. Particles are minimally obstructed that promote system miniaturization.
v. Better conductivity rate for thermal use.
vi. Better surface wettability.
vii. Fluid homogeneity is attained.

This paper increases the number of studies on nanofluids for use in cooling. It could certainly be a vital asset in the development of refrigeration. In addition, efforts have been made to maximize Nano's output with a higher heat transfer rate, but the limited resources and the technology inhibits it. The challenges for Nano fluids however are still mongering, but their advantages and application in various useful fields can be found.

In their review Sreelakshmy K.R, et al.[1] illustrate that nanoparts can be used in several applications as thermal enhancements fluids more effectively. While their procurement and development may cost far more than usual value, overall efficiency is significantly higher than basic fluids. The development of nanotechnology provides a sustainable and ecological energy access solution. In addition to the improvement of heat in industrial applications, it could also be advantageous for the drug industry because in various difficult operations it would improve the targeted medicinal products delivery possible.

In their studies on Al2O3 and R134a nanorefrigerant, R. Saidur, et al [2] concludes. The study shows that heating increases the volume of nanoparticles. The proportion shows an increase of about 0,1-0,4% over the base fluid in 1.013%. Increasing temperatures also reduce the nanoparticle-based fluid viscosity and density.

The development of nanoparticles in the conventional V.C.R system was researched by Raghu Ande et al. [3]. In R134a the concentration of CuO as a nanopart shows inflation in the COP of the cycle of about 16.7 percent and a reduction of 13.7 percent in energy consumption. The diffusiveness of nanofluid over base fluid proves to be economical.

The Duke A.M. et al.[4] studied the heating of nanofluid enhancement in a double-wall reactor experimentally. The CUO and Al2O3 nanoparticles are promising for an enrichment of nanofluid leading properties with concentrations of up to 0.3% and 0.4% respectively. The Copper Oxide increased13%, and aluminum oxide increased by approximately 11.7% over basic fluids. He concludes that for aluminum oxide the lower pressure drop is greater than copper oxide since Al2O3 (20nm) is smaller than copper oxide (40nm) which increased the aluminum oxide viscosity.

Hisham Saed et al [5] studied the improvement of typical cooling system performance with Al2O3 coolant. He concludes that the heat transfer rate for 0.01% and 0.02% of the volume increased by 6.7% respectively and 21.4%. COP also increased respectively by 3.33% and 12% for a larger proportion of the base fluid nanoparticle. In addition, the energy consumption has decreased by 1.6% and 3.3% respectively, improving the system performance.

The effect on nanoparticles in refrigeration was numerically studied by Hsien-Hung Ting et al.[6]. The nanofluids Al2O3/water show an increasing heating rate and the number of Nusselt. In comparison with the basic fluid of the traditional system, conductivity increased by 25.5% at 2.5%.

Bi S. Bi S. et al., [7] studied the domestic cooling performance of nanofluids based on coolant TiO2-R600a. The 0.1% and 0.5% transcalence concentrations increased respectively by 12.4% and 16.5%. It also shows a 20 percent decrease in energy consumption with increased freezing capacity.

Pravesh K. et al .[8] investigated experimentally nanofluids based on (R134a-Al2O3) with a volume fraction of 0.25% and 0.5%. The survey shows the increase in heat transfer respectively by 5.54% and 9.52%. The use of nanofluids in the cooling system also reduced the power consumption by about 4.35% and 14.7 percent.

Hafez E.A., et al [9] A study of nano article CuO on a system R134a VCR concluded that the thermal coefficient increased up to 0.5% with a heat flux range of 10-40 kW/m2 using CuO nanoparticles with proportion 0.0-0.2-0.3-0.5% and particle size 15-70nm.

The effects of SiO2 nano-oil in the system VCR were investigated by Nilesh S. et al. [10]. The nanoproduct was continuously suspended. The content ratio of1%,2%, 5% of the base fluids of nanoparts increases the system's COP by7.61%, 14.06% and 11.09% respectively over basic fluids. This shows its benefits and performance compared to regular methods.

The thermal behavior of magnetized fluids and nanofluids was reviewed by Rahim, I Ismail et al. [11]. He concluded, by using these fluids even at room temperature, that the thermal behavior was increased by chance. The conductivity range from 0.43 W/m-K to 0.56 W/m-K increased by the use of traditional nanotechnology.

The stability and density of methanol-based TiO2 nanofluids were investigated by R.M.Mostafizur et al.[12]. He summarized his findings by increasing the volume of the nanofluid density and increasing the conductivity density. At a concentration of 0.6 per cent at 20 oC, about 2.4 percent density bounces.

S.A. Fadhilah et al. [13] have studied the characteristics of nano refrigerants experimentally and are proportionate directly to their proportion of volume. The conductivity properties in CuO are further enhanced by 5 percent with the volume concentration increases. Moreover, the increase in volume content in the case of R134-a by 5% improves heating properties by 23.7%. Increasing nanofluid conduction by conventional heating fluids by 42.43 percent also revealed positive results.

The effect of nanoparticles using a heat exchanger was numerically described by Kaya H. et al. [14]. They concluded that the use of water-based nanoparticles improves thermal properties more effectively. The use of water-CuO, Water-TiO2, water-Al2O3 overall improves the application of heat exchangers to heating by approximately 13.76%, 1,56%, 1,32%, respectively.

The effect of TiO2 nanopart in ammonia absorption cooling system was explored by Jiang et al. [15]. It was deduced that with an ammonia-based cooling volume share of0.1%,0.3%,0.5%, ammonia-based cooling of19%,27%, and an increase of the COP of the system, respectively were investigated. This is how ammonia-based cooling system COP improving is based strongly on CuO Nanoparticles' volume percentage.

The presence of CuO, ZnO and Al2O3 in the refrigeration compression system was assessed by Jeyakumar et al[16]. [16]. The presence of CuO, ZnO and Al2O3 in the refrigeration compression system was assessed by Jeyakumar et al [16]. [16]. In the R134 - a coolant in 0,06% - these particules were dispersed, 0,08%, 0,1%. The results were positive, with an improvement in CuO and Al2O3respectively by 12.45% and by 3.65% in the COP. Also, energy utilization decreased by approximately 1.35%, respectively by 0.6% with CuO, Al2O3. The results were positive, with an improvement in CuO and Al2O3 respectively by 12.45% and by 3.65% in the COP. Also, energy utilization decreased by approximately1.35%, respectively by 0.6% with CuO, Al2O3.

S. Rambhad et al. [26] performed the regeneration of the composite desiccant dehumidifier by parabolic trough solar collector, using circular coil inserts to enhance heat transfer.

Vednath P. Kalbande et al. [27] reviewed the performance of the solar collector for the Nanofluids based thermal storage System.

II. Objectives

We should prioritize applications of nanofluids in different heating applications to improve the existing advanced technology. The research and analysis required the most effective and thorough. In various industrial and pharmaceutical works we need to give maximum testing for use in nanoflows as our best alternative in increasing the application. Our current system could certainly be reinforced by nanotechnology used as heat fluids in various areas.

Based on the studied data of nanoparticles their features are listed below (Table 2).

TABLE I

THERMAL CONDUCTIVITIES AT 300K [18]

Suspended Particles/ Base fluids.	Thermal conductivity k (W/m-K)
CIP	80.6
TiO_2	8.14
CuO	17.56
Al_2O_3	40
Al	241
Cu	405
Silicon Oil	0.136
Deionized water	0.612
Ethylene glycol	0.265
Engine oil	0.154

The above feature clearly demonstrates that, by using nanofluids in various applications, we can achieve the desired conduction result. Therefore, we see that the improvement in conductivity is not only a myth. We can make progress on next-generation sustainable development technology (Fig.2).

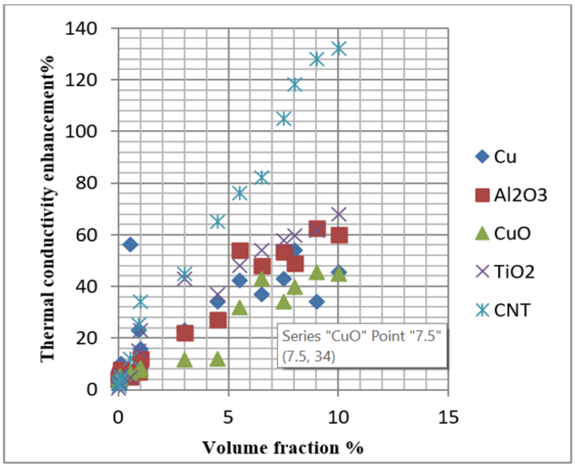

Figure 2: Thermal conductivity ratio to volume concentration of Nanofluids

III. Properties Of Nanofluids

It has been practiced for a long time to include small solid particles in a foundation fluid to increase the thermal conductance for the suspension [17]. Viscosity, specific heat, thermal conductivity and stability are the properties of nanofluids. These properties play a major role in nanofluid preparation. The following are the properties:

A. Viscosity

Although the literature about heat convection in nanofluids is limited compared with thermal conductivity, there are very diverse and worthy results and approaches in this area. The comprehension of the problems of convection however is strictly linked to nanofluid viscosity [18].

B. Specific Heat

A differential scanning calorimeter (DSC) model DSC1 measured the specific heat for each nano fluid (Mettler Toledo, USA). The calculation of the heat capacities is based on the DIN (DIN51007), and is carried out according to the following sequence: 5 minute isothermal at 25 0C, 25oC to 95oC dynamic at 10 0C/min and 5 minute isothermal at 95 0°C. [24].

C. Thermal Conductivity Of Nanofluids

A KD2 Pro conductmeter was used to measure the thermal conductivity of all nanofluid (Decagon Devices Inc.). The KD2 Pro is a commercial instrument that uses transient hot cable techniques to measure the thermal conductivity. The characteristics of nanofluids are superior to conventional heat transfer fluids. One reason is that nanofluid thermal conductivity increases noticeably with the suspended particles. Nanofluid's thermal conductivity is highly dependent upon the volume of the nanoparticles. A sophisticated theory for predicting a thermal conductivity of nanfluids has not yet been developed, even though the apparent conductivity of the two-phase blend is determined by semi-empirical correlation. Based on an effective thermal conductivity definition for a two-component mixture [25].

D. Stability Of Nanofluids

The stability of nanofluids is analyzed by evolving the amount of light dispersed from an incident laser beam by the nanofluid. The tests were performed with the Turbiscan Lab Expert (Formulaction SA, France). This system consists of a pulsed near-infrared illumination source and a detector which measures the sample-dispersed light. The rear dispersion profiles were achieved throughout the height cell for every nanofluid. The measurements were performed at different time intervals for the analysis of the stability of nanofluids up to a total time of 48 hours.

IV. Applications Of Nanofluids

Due to their better heat transfer and energy efficiency in a variety of thermal systems the nanofluids can be used in a broad range of engineering applications.

A. Heat Transfer Intensification

The potential for nanofluids in thermal transfer applications has become increasingly attractive since the nanofluid concept was first introduced about a decade ago. There have been reviews of several aspects of nanofluids, which included preparation and characterization, thermal conductivity measurement techniques, theory and model, thermophysical properties, and convective heat transfer [19].

a. Electronic Applications

The higher density of the chips makes heat dissipation more difficult due to the design of compact electronic components. Advanced electronic equipment confronts thermal management challenges from the high level of heat production and the reduction of available heat removal surfaces. So, for smooth working of advanced electronic appliances, the reliable thermal management system is vital. Generally speaking, there are two ways to improve electronic equipment heat recovery. One of these is to find the optimum cooling geometry; the other is to increase the capacity of heat transfer. The coefficients for convective heat transfer compared to basic fluids are predicated on nanofluids with higher thermal conducting rates. Recent research has shown that the thermal conductivity of a refrigerant can increase nanofluids' thermal transference coefficient. Jang and Choi have developed a new cooler combined nano-fluid heat sink [20].

b. Transportation

Nanofluids can improve the cooling rates for cars and heavy duty engines by increasing efficiency, reducing weights and lowering the complexity of thermal systems. Improved refrigeration rates for cars and trucks can be used to retrieve more heat from the same-sized cooling systems from higher power engines. Alternatively, compact cooling systems with less and lighter radiators are beneficial to design. The high performance and high fuel saving of cars and trucks in turn are advantageous. Due to its low pressurization, ethylene glycol-based nanofluids attracted a great deal of attention as a low-pressure motor-coolant in the application compared with a 50/50 ethylene glycol-water blend [21].

c. Industrial Cooling Applications

Nanofluid applications in industrial refrigeration lead to a great reduction in energy efficiency and emissions. For the US industry, substitutes of nanofluid cooling and heating water can conserve 1 trillion Btu of energy [22]. The US electricity industry could save some Btu 10-30 billion annually (equivalent to the annual energy consumption of approximately 50,000–150,000 homes) by using nanofluids in closed-loop refreshing cycles. The emission reductions associated with this would amount to about 5.6 million tons of carbon dioxide, 8600 tons of nitrogen oxides and 21 000 tons of sulphur dioxide. [23].

V. Future Scope

Nanofluids have a wide range of applications to boost trends in future development. Nanofluids can be very successful as a replacement not only for an effective energy supply for the next generation but also their progressive and effective use. The conduction rate in nanofluids depends basically on their thermal conductivity, concentration of particles, form and size. The nanoparticles in these areas should be researched extensively for maximum output. There are many concerns about the safety of nanofluid production and transportation, which are concerns in future. In the unknown sector, nanofluid technology, such as extraction of energy from the earth's core, nuclear cooling systems, microchip design and production support, can be explored. The potential is high in the treatment by the pharmaceutical industry of deadly diseases and drug production as a cure. In the production of motor vehicles, an increase in an effective heat conductivity rate could also lead. We can therefore say that the efficient production of non-toxic and biodegradable nanoparticles can harness this prestigious technology.

VI. Conclusion

The enhancement of nanofluid conductivity makes it vital for future demands for energy. To that end, we need advanced technology to enhance nanofluid efforts. In addition, it is necessary to understand the basic properties of nanoparticles.

- The heat transfer rate has been found to be directly proportional to the number of Reynolds and the number of peclet of nanofluids.
- Spherical nanoparticles with an increased heat transfer rate over other particles of form.
- Increasing the number of nanoparticles reduces the heat transfer rate per unit volume by decreasing the area.
- Several studies indicate that the use of nano coolant over conventional cooling systems can increase heat transfer by up to 20% to 65%.
- The efficiency of cooling, by using 0.1 percent mass fraction of TiO2 nanoparticles over conventional HFC134a chills and POE oil system, was found to be 26 percent better.
- The use of Al2O3 nanoparticles approximately (0.1% wt.) with 60% R134a also improves thermal transmission rates. Energy consumption decreased by 2.4% and performance coefficients improved by 4.4%.

Nanotechnology is still not fully realized and can be used only through further research and development. There are still several problems in the development of a smaller and more efficient system with its synthesis and demand. The future is based on the correct and efficient use of nanofluids to achieve a more clean and healthy society in terms of performance.

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