NANOFLUIDS WITH RECENT APPLICATION & FUTURE TRENDS

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ABSTRACT
This paper provides an overview of enhanced properties of nanofluids which are used in plethora of engineering applications ranging from use in automotive industry to medical arena to use in power plant cooling systems. In addition , it also highlights future work and possibilities. The novel concept of nanofluids in the spring of 1993, talented and studious thermal scientists and engineers in the rapidly growing nanofluids community have made scientific breakthrough not only in discovering unexpected thermal properties of nanofluids , but also in proposing new mechanisms behind enhanced thermal properties of nanofluids. As a result , this research topic of nanofluids has been receiving increasing attention worldwide.

Keywords: Nanotechnology , nanoparticles, hybrid nanofluids , base fluids , thermal conductivity.

INTRODUCTION
Nanofluids (nanoparticle fluid suspensions) is the term coined by Choi (1995) to describe this new class of nanotechnology-based heat transfer fluids that exhibit thermal properties superior to those of their host fluids or conventional particle fluid suspensions. Nanofluid technology, a new interdisciplinary field of great importance where nanoscience, nanotechnology, and thermal engineering meet, has developed largely over the past decade. The goal of nanofluids is to achieve the highest possible thermal properties at the smallest possible concentrations (preferably < 1% by volume) by uniform dispersion and stable suspension of nanoparticles (preferably < 10 nm) in host fluids. To achieve this goal it is vital to understand how nanoparticles enhance energy transport in liquids.

Nanofluid is a fluid containing nanometer sizes particles, called nanoparticles. These fluids are engineered colloidal suspensions of nanoparticles in a base fluid. The nanoparticles used in nanofluids are typically made of metals, oxides, carbides, or carbon nanotubes. Common base fluids include water, ethylene glycol and oil. From previous investigation, nanofluids have been found to possess enhanced thermophysical properties such as thermal conductivity, thermal diffusivity, viscosity and convective heat transfer coefficients compared to those of base fluids like oil or water.

Nanofluids have novel properties that make them potentially useful in many applications in heat transfer, including microelectronics, fuel cells, pharmaceutical processes, and hybrid-powered engines, engine cooling/vehicle thermal management, domestic refrigerator, chiller, heat exchanger, nuclear reactor coolant, in grinding, machining, in space technology, defense and ships, and in boiler flue gas temperature reduction. They exhibit enhanced thermal conductivity and the convective heat transfer coefficient compared to the base fluid. From the current review, it can be seen that nanofluids clearly exhibit enhanced thermal conductivity, which goes up with increasing volumetric fraction of nanoparticles. It is important to do more research so as to ascertain the effects of these factors on the thermal conductivity of wide range of nanofluid.In recent years

,nanofluids have attracted more and more attention .The main driving force for nanofluids research lies in a wide range of application .[2]

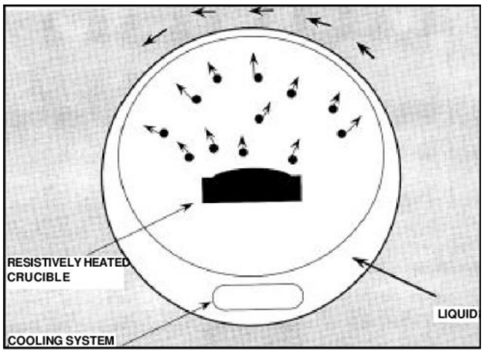

Figure 1 : Schematic diagram of Nanofluid

2. METHODS OF PREPARATION OF NANOFLUIDS

The preparation of nanofluids is not just a simple process of mixing the nanoparticles into the base fluid. To get nanofluids with homogeneously dispersed nanoparticles, stabilization and proper mixing are required under certain environment conditions. There are many methods used for the preparation of nanofluids, which can be further classified into two primary classes:

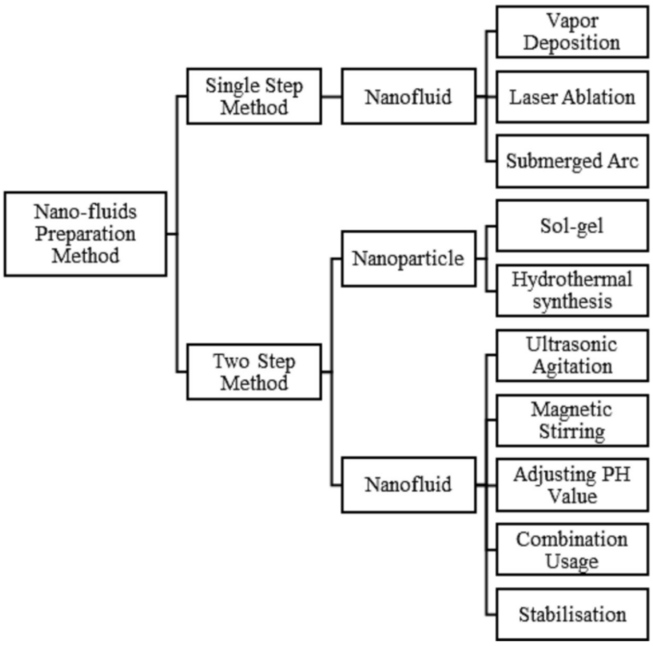

Figure 2: Methods of preparation of Nanofluids

2.1 One-step method

A one step method and system for producing nanofluids by a nanoparticle source evaporation and deposition of the evaporant into a base fluid. The base fluid such as oil or ethylene glycol is placed in a rotating cylindrical drum having an adjustable heater -boat - evaporator and heat exchanger cooler apparatus. As the drum rotates ,a thin liquid layer is formed on the inside surface of drum . An insulated heater - boat - evaporator having an evaporant material (nanomaterial source) placed within its evaporator is adjustably positioned near a portion of the rotating thin liquid layer , the evaporant material being heated thereby evaporating a portion of the evaporant material and forming nanoparticles , the nanoparticles absorbed by the liquid film to form nanofluid.

The one-step process is simultaneously making and dispersing the particles in the base fluids which could be reduced to the agglomeration of nanomaterials. This method makes the nanofluids more stable with a limitation of the high cost of the process. [1,2,3,13]

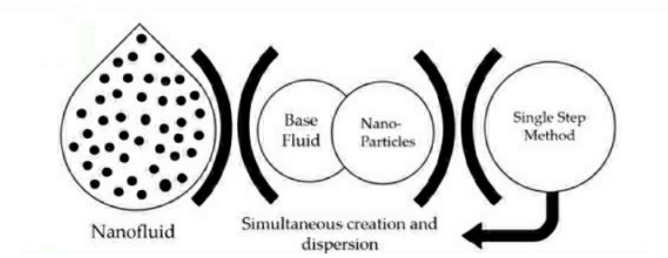

Figure 2.1 : One-Step Method

2.2 Two-step method

A two step method is the most widely used method for preparing nanofluids. Nanoparticles, nanofibres, nanotubes, or other nanomaterials used in this method are first produced as dry powders by chemical or physical methods. Then, the nanosized powder will be dispersed into a fluid in the second processing step with the help of intensive magnetic force agitation, ultrasonic agitation, high-shear mixing, homogenizing, and ball milling. Two-step method is the most economic method to produce nanofluids in large scale, because nanopowder synthesis techniques have already been scaled up to industrial production levels, Due to the high surface and surface activity , nanoparticles have the tendency to aggregate . The important technique to enhance the stability of nanoparticles in fluid is the use of surfactants. However, the functionality of the surfactants under high temperature is also a big concern , especially for high temperature applications.[3]

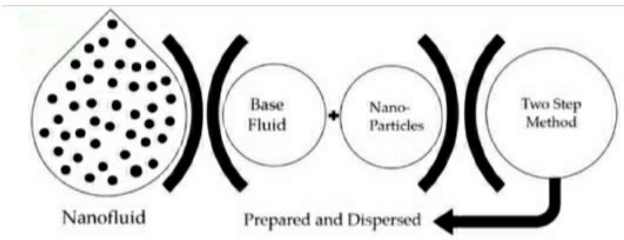

Figure 2.2 : Two-Step Method

TYPES OF NANOFLUIDS

Nanofluids which is a term used to describe fluids containing dispersed particles of nanoscale , can be formed from nanoparticles of single element (e.g. Cu,Fe and Ag), single element oxid (e.g.CuO, Cu_2O , Al_2O_3 and TiO_2)alloys (e.g Cu-Zn ,Fe-Ni, and Ag-Cu) multielement oxides(e.g. $CuZnFe_4O_4$, $NiFe_2O_4$ and $ZnFe_2O_4$)metal carbides (e.g SiC ,B_4C and ZrC) metal nitrides (e.g. SiN, TiN and AlN)and carbon particles (e.g. graphite , carbon nanotubes and diamond)suspended in water , ethanol ,EG , Oil and refrigerants. They can be classified into two main categories :single material nanofluids and hybrid nanofluids.[11,13,14]

3.1 Single material nanofluids

This category of nanofluid was first proposed by Choi, in 1995, and is considered as the conventional form of nanofluids used, where a single type of nanoparticles is used to produce the suspension via different preparation methods. It was reported by many authors that nanofluids of such category are superior in performance, due to having much more favorable thermophysical properties than their basefluid.

3.2 Hybrid nanofluids

Hybrid nanofluids are an advanced category of nanofluids which are made of a combination of more than one type of nanoparticles suspended in a basefluid. This type of fluid was first studied experimentally by Jana et al., in 2007, in order to enhance the fluid thermal conductivity beyond that of a conventional single material type nanofluid. In their study, Cu nanoparticles, carbon nanotubes (CNTs), and Au nanoparticles dispersed in water, as well as their hybrids (CNT-Cu/H_2O and CNT-Au/H_2O) were examined. The results showed that the thermal conductivity of Cu/H_2O nanofluids was the highest among the tested samples and increased linearly with the rise of particle concentration. Nevertheless, the stability of the CNT-Cu/H_2O nanofluid achieved a longer settling time than the other types of nanofluids. This enables the fluid to conserve its thermal conductivity much longer before degrading. [9,10]

PROPERTIES

1) Thermal Conductivity
2) Viscosity
3) Convective Heat Transfer
4) Density
5) Specific Heat

CHARACTERIZATION OF NANOFLUIDS

Nanofluids are characterized by the following technique: SEM, TEM, XRD FT-IR, DLS, TGA and Zeta potential analysis. [9,8,13]

Important analysis for nanofluids

1) DLS analysis estimates the average dispersed size of nanoparticles in base liquid.
2) TGA: study the influence of heating and melting on thermal stabilities of nanoparticles.
3) Zeta potential value is related to the stability of nanoparticle dispersion in base fluid.

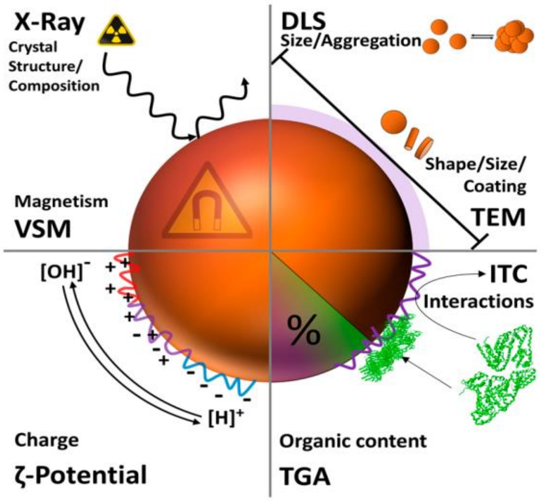

Figure 3 : Characterization of Nanofluids

ADVANTAGES OF NANOFLUIDS

1) High specific surface area and therefore more heat transfer surface between particles and fluids.
2) High dispersion stability with predominant Brownian motion of particles.
3) Reduced pumping power as compared to pure liquid to achieve equivalent heat transfer intensification.
4) Reduced particle clogging as compared to conventional slurries, thus promoting system miniaturization.
5) Adjustable properties, including thermal conductivity and surface wettability, by varying particle concentration to suit different applications.

APPLICATIONS

In this section, the focus will be on the application of nanofluids. Nanofluids are used in several industries such as automobile sector, biomedical sector and energy industry. Specific application include coolants, nanofluids as vehicle brake fluids and shock absorbers, nanodrug , cancer therapy , solar cells , solar absorption , energy storage , nanofluids in heat exchanger , space and defence .In following section , the role of nanofluids in these applications is discussed in detail.

Figure 4 : Application of Nanofluids

7.1 Application of Nanofluids in Automobile

Engine oils, automatic transmission fluids, coolants, lubricants, and other synthetic high-temperature heat transfer fluids found in conventional truck thermal systems-radiators, engines, heating, ventilation and air-conditioning(HVAC)- have inherently poor heat transfer properties. These could benefit from the high thermal conductivity offered by nanofluids that resulted from addition of nanoparticles. [11, 13]

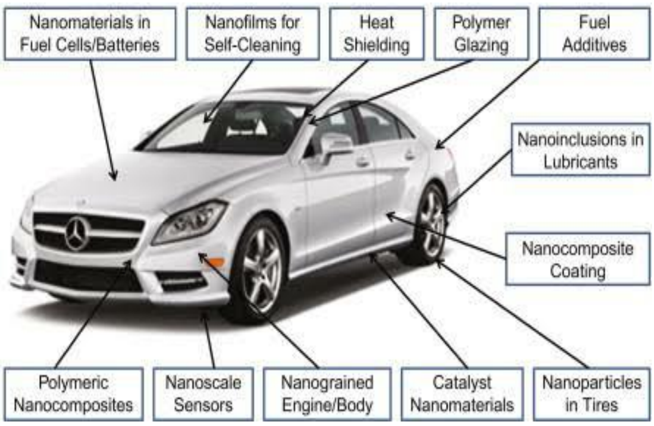

Figure 5 : Application of Nanofluids in Automobile

7.1.1 Nanofluid Coolant

In looking for ways to improve the aerodynamic designs of vehicles, and subsequently the fuel economy, manufacturers must reduce the amount of energy needed to overcome wind resistance on the road. At high speeds, approximately 65% of the total energy output from a truck is expended in overcoming the aerodynamic drug. This fact is partly due to the large radiator in front of the engine positioned to maximize the cooling effect of oncoming air. The use of nanofluids as coolants would allow for smaller size and better positioning of the radiators. Owing to the fact that there would be less fluid due to the higher efficiency, coolant pumps could be shrunk and truck engines could be operated at higher temperatures allowing for more horsepower while still meeting stringent emission standards.[10,11]

Future engines that are designed using nanofluids cooling properties would be able to run at more optimal temperature allowing for increased power output. With a nanofluids engine, components would be smaller and weigh less allowing for better gas mileage, saving consumers money and resulting in fewer emissions for a cleaner environment.

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7.1.2 Nanofluids as Vehicular brake fluids

A vehicle's kinetic energy is dispersed through the heat produced during the process of braking and this is transmitted throughout the brake fluid in the hydraulic braking system, and now, there is a higher demand for the properties of brake oils. Copper-oxide and aluminum-oxide based brake nanofluids were manufactured using the arc-submerged nanoparticle synthesis system and the plasma charging arc system, respectively. The two kinds of nanofluids both have enhanced properties such as a higher boiling point, higher viscosity, and a higher conductivity than that of traditional brake fluid. By yielding a higher boiling point, conductivity, and viscosity, the nanofluid brake oil will reduce the occurrence of vapour-lock and offer increased safety while driving.[10,11,13]

7.1.3 Shock Absorbers

Shock absorbers provide the comfortable ride in vehicles ranging from sports cars to pickup trucks Modern automobiles are well equipped with hydraulic shock absorbers to absorb unwanted vibration during travel. Nanofluids can also be used in such a kind of equipment. The researchers prepared a special kind of fluid by suspending magnetic nanoparticles with the base fluid. The above prepared fluid is known as Magneto Rheological nanofluid. Depending on the size of the nanoparticles, the magnetic fluid may be able to change its viscosity proportion to the strength of the magnetic field applied to it. Shock absorbers based on magnetic fluids are used in the modern automobiles like " Audi Le mans Quattro". Energy is derived from the electronic control system and the on board computer adjusts the shock absorber based on the information provided by the sensors.[12,13]

7.2 Application of Nanofluids in biomedical

According to the nanofluid definition , all of the nanoparticles containing suspensions or nanosuspensions were considered and application of such fluids in drug delivery and biomedical treatment are reviewed in this section .[14]

7.2.1 Drug delivery

The main purpose of the design of a drug delivery system is to release the drug in a controlled manner at the desired site. First studies in drug delivery systems were about drug release kinetics , pH and temperature sensitivity ,polymers , nasal delivery and oral drug .The use of nanofluid is drug delivery systems is one of the topics , which has been considered by many researchers in recent years to provide some benefits like being suitable for accurate delivery to target cells,increased therapeutic properties and safety ,decreased toxicity and biocompatibility[14]. Regarding the development of a nanofluid formulation for drug delivery , the system must afford drug loading and release characteristics , prolonged shelf life and biocompatibility . One of the most important matters with nanofluidic drugs is the charge of NPs in the fluid . The surface charge of fundamental biological particles in blood is almost negative and the inner walls of blood vessels are negatively charged and inner walls of blood pressure negatively charged . Thus , they repulse each other and blood cells do not agglomerate in the vessel . Therefore, commonly , the therapeutic particles must be negatively charged to prevent aggregation .
[7,8]

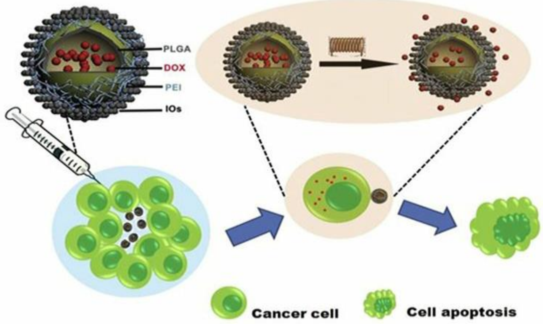

Figure 6 : Role of nanofluids in Drug Delivery

7.2.2 Cancer Therapeutics

There is a new initiative which takes advantage of several properties of certain nanofluids to use in cancer imaging and drug delivery . This initiative involves the use of iron based nanoparticles as delivery vehicles for drugs or radiation in cancer patients. Magnetic nanofluids are to be used to guide the particles up the bloodstream to a tumor with magnets .It will allow doctors to deliver high local doses of drugs or radiation without damaging nearby health tissue ,which is a significant side effect of traditional cancer treatment methods. In addition,magnetic nanoparticles are more adhesive to tumor cells than non-malignant cells and they absorb much more power than microparticles in alternating current magnetic fields tolerable in humans ; they make excellent candidates for cancer therapy .[15,16]

7.2.3 Nano Cryosurgery

Cryosurgery is a procedure that uses freezing to destroy undesired tissues. This therapy is becoming popular because of its important clinical advantages Although it still cannot be regarded as a routine method of cancer treatment , cryosurgery is quickly becoming an alternative to traditional therapies.[14]

Simulations were performed by Yan and Liu on the combined phase change bioheat transfer problems in a single cell level and its surrounding tissues , to explicate the difference of transient temperature response between conventional and nano cryosurgery .According to theoretical interpretation and existing experimental measurements, intentional loading of nanoparticles with high thermal conductivity into target tissues can reduce the final temperature , increasing the maximum freezing rate and enlarge the ice volume obtained in the absence of nanoparticles. Additionally , introduction of nanofluid enhanced freezing could also make conventional cryosurgery more flexible in many aspects such as artificially interfering in the size ,shape ,image and direction of ice ball formation . The concept of nano cryosurgery may offer new opportunities for future tumor treatment
[17].

7.3 Application of nanofluids in Solar

Nanofluids based direct solar collectors are solar thermal collectors where nano particles in a liquid medium can scatter and absorb solar radiation. They have recently received interest to efficiently distribute solar energy.[14]

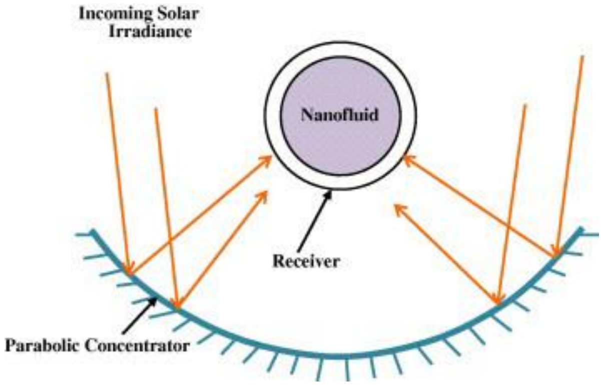

Figure 7 : Nanofluids in solar Collector

7.3.1 Solar Stills

A lot of research is carried out on solar stills and different methods are invented to improve their efficiency. In recent times, Gnanadason et al. stated that solar stills efficiency can be increased by using nanofluids. They examined the effects of a single basin solar still by adding carbon nanotubes to the water. Their results showed that the efficiency improved by 50% with addition of nanofluids.[2,3]. However, they have not mentioned the exact amount of nanofluids added to the water for the solar still. As the cost of nanofluid is so high, the economic capability should be considered. It is also suggested that solar stills efficiency can be improved by adding dyes in fluid. Nijmeh et al. concluded that solar stills efficiency increases by 29% by adding violet dye to the water, which is remarkable. It can be used to minimize the production of greenhouse gas emissions from the production of fresh water.[,14]

7.3.2 Solar cells

Efficiency of solar cells can be improved by cooling them. Nanofluids can be used as a solution for this problem. Elmir et al. numerically simulate the cooling of a solar cell by forced convection in the presence of a nanofluid. They considered the solar panel as an inclined cavity and solved the equations in the Cartesian coordinate system. They used Al_2O_3 and water nanofluid for analysis purposes. The thermal conductivity and viscosity of the nanofluid are calculated using the models of Brinkman and Wasp respectively. They concluded that the average Nusselt number increases by use of nanofluids which leads to the improving the rate of cooling. But in whole analyses they did not consider the thermal conductivity and viscosity of nanofluid. [17,18]

7.4 Application of Nanofluids in Electronics

7.4.1 Cooling of Microchips

A principal limitation on developing smaller microchips is the rapid heat dissipation . However ,nanofluids can be used for liquid cooling of computer processors due to their high thermal conductivity .[14] It is predicted that the next generation of computer chips will produce localized heat flux over 10 MW/m^2, with the total power exceeding 300W. In combination with thin evaporation , the thin film evaporation , the nanofluid oscillating heat pipe (OHP)cooling system will be able to remove heat fluxes over 10MW/m^2 and serve as the next generation cooling device that will be able to handle the heat dissipation coming from new technology.[20]

7.4.2 Microscale Fluidic Application

The manipulation of small volumes of liquid is necessary in fluidic digital display devices , optical devices and microelectromechanical systems (MEMS) such as lab-on-chips analysis systems. This can be done by electrowetting or reducing the contact angle by an applied voltage , the small volumes of liquid .Vafaei et al. discovered that nanofluids are effective in engineering the wettability of surface and possibly of surface tension.[14,21]

7.5 Application of Nanofluids in space and defence

Due to the restriction of space, energy and weight in space stations and aircraft , there is a strong demand for high efficient cooling systems with smaller size .You et al. and Vassalo et al. have reported order of magnitude increases in the critical flux in pool boiling with nanofluids compared to the base fluid alone.Further research of nanofluids will lead to the development of next generation of cooling devices that incorporate nanofluids for ultrahigh -heat-flux electronic systems , presenting the possibility of raising chip power in electronics components or simplifying cooling requirements for space applications .[14]

As a number of military devices and systems require high heat flux cooling to the level of tons of MW/m^2. At this level, the cooling of military devices and system is vital for the reliable operation.Nanofluids with high critical heat fluxes have the potential to provide the required cooling in such applications as well as in other military systems , including military vehicles , submarines and high power in space and defence fields , where power density is high and the components should be smaller and weight is less.[14]

7.6 Application of Nanofluids in Refrigeration

Nanofluids can also be used in air conditioning and refrigeration systems. The negative environmental effect of using chlorofluorocarbons along with hydrofluorocarbons has propelled research into alternative refrigerants. Traditionally, vapor compression refrigeration systems (VCRSs) are used in the cooling industry; however, the major drawback to this system is the large compressor power requirement. An alternative heat-powered absorption refrigeration system (VARS) has been developed, although the coefficient of performance (COP) of these systems is still below those of the VCRS. Nanoparticles have been used to create new refrigerants known as nanorefrigerant which can improve the COP of both the VARS and VCRS and decrease the compression work of the VCRS.[22]

7.7 Application of Nanofluids in Heat Exchangers

Heat transfer equipment is extensively used in all aspects of engineering applications, such as HVAC systems, refrigeration systems, automobile radiators, electronics devices, process industries, etc. Numerous scientific researches have been carried out in the past few decades to discover a suitable heat transfer fluid to design more compact heat exchangers with excellent thermal efficiency. Nanotechnology offers a novel approach in intensifying the heat transfer characteristics by utilizing the higher thermal conductivity of solid nanoparticles. In recent years heat transfer augmentation achieved immense momentum due to the increased demand for energy consumption optimization in a great deal of industrial and engineering equipment, such as compact heat exchangers.[19,23]

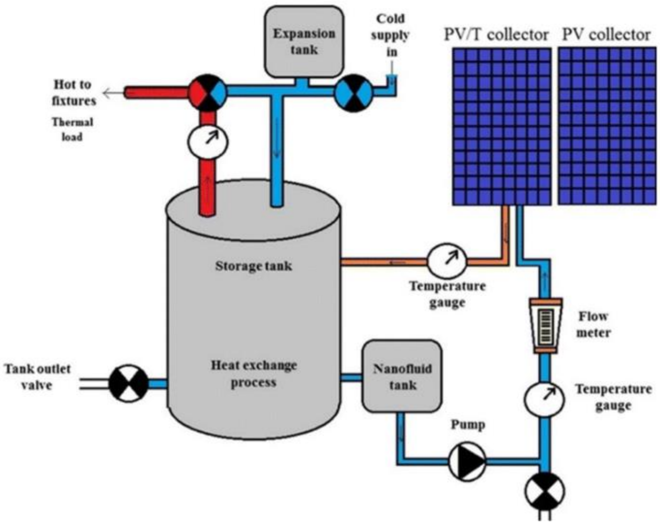

Figure 8: Heat exchange process

7.8 Application of Nanofluids as Nuclear Reactor

The use of nanofluids as a coolant in nuclear reactors is a very promising application because nanofluids can be highly effective in cooling over heated surfaces in emergency situations. There are a few concerns regarding the loss of nanoparticles through the boiling vapour and regarding the safety measures for the disposal of nanofluid. Despite the concerns that we have, application of nanofluids in nuclear reactors is a promising future application. [11]

8. FUTURE SCOPE AND NEW FRONTIERS

Nanofluids have a variety of applications as of now and many more are expected in the future. The main area of research should probably be directed towards inventing efficient energy transport methods using nanofluids. The rate of heat transfer is mainly dependent on the thermal conductivity of nanofluid. The effect of particle shape, particle agglomeration on the thermal conductivity of nanoparticles should be thoroughly researched for inventing efficient energy transport mechanisms. There are concerns regarding the safety in the use and production of nanofluids currently and these are also areas of future research. Nanofluids present a novel method for extracting energy from the core of the earth. Nanofluid particles could also aid in developing micro chips of smaller size. Smaller microchips could lead to better computers. Nanofluids could also help in targeted drug delivery, and will help the pharmaceutical industry to make big leaps and bounds. Improvement of thermal conductivity of nanofluids could also help to make better automobile engines. Nanofluid technology can only be harnessed by inventing non-toxic or biodegradable nanoparticles. [24,13]

The research effort to produce and characterize the behavior of nanofluids will consist of the following main tasks.

1) Nanophase metal powders will be produced in the existing state of the art gas condensation preparation system at ANL. The particle size and agglomeration behavior of nanophase powders in liquids will be studied.
2) Technology for production of nanoparticle suspensions will be developed and the stability ,dispersion and rheological /transport properties of these nanofluids will be investigated .
3) Practical investigations will be investigated.

4) Develop nanofluids that are environment friendly and wear resistant.
5) Use of new efficient , minimum global warming potential and eco-friendly fluids and refrigerants.
6) Use of dielectric liquid in microchannels enables direct contact of working liquid with electronics.
7) More improved theoretical understanding of complex nanofluids will even provide broader impact.
8) Development of computer based models of phenomena including physical and chemical interactions between nanoparticles and base fluid molecules.
9) Development of new experimental methods for characterizing nanofluids in the lab and in nature.
10) Besides the above work possibilities, the nanofluids also can be used in:

A. Solar cooling systems
B. photovoltaic systems
C. solar absorption refrigeration system

Both technical and economical advancements in nanofluids are still going on and this trend has strong potential in facilitating greater development of nanofluids.[25,26]

FUTURE CHALLENGES

The use of nanofluids in a wide variety of applications appears promising, but the development of the field is hindered by :

1) The lack of agreement between results obtained in different laboratories
2) The often poor characterization of the suspensions
3) The lack of theoretical understanding of the mechanisms responsible for the observed changes in properties.[26,27]

CONCLUSION

In this paper, the goal was to present an overview of the recent developments in the field of nanofluids. Preparation,characteristics and applications of nanofluids have been discussed in detail. Nanofluids are important because they can be used in numerous applications involving heat transfer, and other applications such as in detergency. Colloids which are also nanofluids have been used in the biomedical field for a long time, and their use will continue to grow. Future research still has to be done on the synthesis and applications of nanofluids so that they may be applied as predicted. Nevertheless, there have been many discoveries and improvements identified about the characteristics of nanofluids in the surveyed applications and we are a step closer to developing systems that are more efficient and smaller, thus rendering the environment cleaner and healthier.

Many researchers are still going on in this field for better futuristic scope of nanofluids in industries and will define the future of nanofluids with better results.

REFERENCES

1) Stephen U. S. Choi, Nanofluid Technology:current status and future research,Vol no. 1,pp 1-3, 1998
2) V. Trisakti and S. Wongwises, “Critical review of heat transfer characteristics of nanofluids,” Renewable and Sustainable Energy Reviews, vol. 11, no. 3, pp. 512–523, 2007.
3) Yu W, Huaqing XA. Review on nano-fluids: Preparation, stability mechanisms, and applications. Journal of Nanomaterials. 2012;2012:435873. 17p
4) S. Özerinç, S. Kakaç, and A. G. YazIcIoğlu, “Enhanced thermal conductivity of nanofluids: a state-of-the-art review,” Microfluidics and Nanofluidics, vol. 8, no. 2, pp. 145–170, 2010.
5) S. Özerinç, S. Kakaç, and A. G. YazIcIoğlu, “Enhanced thermal conductivity of nanofluids: a state-of-the-art review,” Microfluidics and Nanofluidics, vol. 8, no. 2, pp. 145–170, 2010.
6) S. Özerinç, S. Kakaç, and A. G. YazIcIoğlu, “Enhanced thermal conductivity of nanofluids: a state-of-the-art review,” Microfluidics and Nanofluidics, vol. 8, no. 2, pp. 145–170, 2010.
7) M. Arruebo, R. Fernández-Pacheco, M. R. Ibarra, and J. Santamaría, “Magnetic nanoparticles for drug delivery,” Nano Today, vol. 2, no. 3, pp. 22–32, 2007.
8) A. Vonarbourg, C. Passirani, P. Saulnier, and J. P. Benoit, “Parameters influencing the stealthiness of colloidal drug delivery systems,” Biomaterials, vol. 27, no. 24, pp. 4356–4373, 2006.

9) T. P. Otanicar, P. E. Phelan, R. S. Prasher, G. Rosengarten, and R. A. Taylor, "Nanofluid-based direct absorption solar collector," Journal of Renewable and Sustainable Energy, vol. 2, no. 3, Article ID 033102, 13 pages, 2010.
10) Yu, W., France, D. M., Routbort, J. L., and Choi, S. U. S. , "Review and comparison of nanofluid thermal conductivity and heat transfer enhancements," Heat Transfer Engineering, vol. 29, no. 5, pp. 432–460, 2008
11) Chopkar, M., Das, P. K., and Manna, I. , "Synthesis and characterization of nanofluid for advanced heat transfer applications," Scripta Materialia, vol. 55, no. 6, pp. 549–552, 2006.
12) J. Kim, Y. T. Kang, and C. K. Choi, "Soret and Dufour effects on convective instabilities in binary nanofluids for absorption application," International Journal of Refrigeration, vol. 30, no. 2, pp. 323–328, 2007.
13) Kaufui V. Wong, Omar De Leon "Applications of Nanofluids: Current and Future",vol 2,pg 5,2009
14) A. R. Prasad, Sumer Singh, Harish Nagar, A review on Nanofluids:Properties and applications, International journal of advanced research and innovative ideas in Education, Vol-3, no. 3,pp.70-76, 2017
15) Ovsianikov, A., Chichkov, B., Mente, P., Monteiro-Riviere, N. A., Doraiswamy, A., and Narayan, R. J. , "Two photon polymerization of polymer-ceramic hybrid materials for transdermal drug delivery," International Journal of Applied Ceramic Technology, vol. 4, no. 1, pp. 22–29, 2007.
16) Labhasetwar, V. , and Leslie-Pelecky, D. L. , Biomedical Applications of Nanotechnology, New York, NY, USA John Wiley & Sons. 2007.
17) Bica, D., Vékás, L., Avdeev, M. V., "Sterically stabilized water based magnetic fluids: synthesis, structure and properties," Journal of Magnetism and Magnetic Materials, vol. 311, no. 1, pp. 17–21, 2007.
18) G. Paul, M. Chopkar, I. Manna, and P. K. Das, "Techniques for measuring the thermal conductivity of nanofluids: a review," Renewable and Sustainable Energy Reviews, vol. 14, p. 1913, 2010.
19) BENGT SUNDEN and Zen Wu, Performance of heat exchangers using Nanofluids, Heat transfer enhancement with Nanofluids, vol-7, pg 353-355, 2015
20) Ma, H. B., Wilson, C., Yu, Q., Park, K., Choi, U. S., and Tirumala, M. , "An experimental investigation of heat transport capability in a nanofluid oscillating heat pipe," Journal of Heat Transfer, vol. 128, no. 11, pp. 1213–1216, 2006.
21) Vafaei, S., Borca-Tasciuc, T., Podowski, M. Z., Purkayastha, A., Ramanath, G., and Ajayan, P. M. , "Effect of nanoparticles on sessile droplet contact angle," Nanotechnology, vol. 17, no. 10, pp. 2523–2527, 2006.
22) Choi, S. U. S., Zhang, Z. G., and Keblinski, P. , Nalwa, H. S. , "Nanofluids," Encyclopedia of Nanoscience and Nanotechnology, vol. 6, Los Angeles, Calif, USA American Scientific pp. 757–737, 2004.
23) Khairul, M.A., Alim, M.A., Mahbubul, I.M., Saidur, R., Hepbasli, A., Hossain, A.: Heat transfer performance and exergy analyses of a corrugated plate heat exchanger using metal oxide nanofluids. Int. Commun. Heat Mass Transf. 50, 8–14 (2014)
24)]ee, J., Mudawar, I.: Assessment of the effectiveness of nanoflu-ids for single-phase and two-phase heat transfer in micro-chan-nels. Int. J. Heat Mass Transf. 50, 452–463 (2007)
25) Sizochenko, N., Syzochenko, M., Gajewicz, A., Leszczynski, J., Puzyn, T.: Predicting physical properties of nanofluids by com-putational modeling. J. Phys. Chem. C 121, 1910–1917 (2017)
26) Sreelakshmi K R, Aswathy S Nair, Vidhya K M,Saranya T R, An overview of recent Nanofluid research, International research journal of pharmacy, vol-13, pp 80-84, 2014
27) Rahman saidur, Kin Yuen Leong, Haneen mohammad, A review on application and challenges of Nanofluids, Renewable and sustainable energy reviews 15(3) :1646-1668, 2011.