A Review on Experimental Analysis of Nano-Fluids on Different Heat Exchangers

Sk Abdul Azeez[1], Raffi Mohammed[2], Y. Venkatesh[3]
[1, 2, 3] Dept of Mechanical
[1, 2, 3] Ramachandra college of engineering, Eluru, A.P

Abstract- *In this research studied on different literature survey work forced convection flows of nanofluids consisting of water with nanoparticles Nano-fluids in a horizontal tube with constant wall temperature are investigated numerically. A single-phase model having two-dimensional equations is employed with either constant or temperature dependent properties to study the hydrodynamics and thermal behaviors of the nano-fluid flow. The velocity and temperature vectors are presented in the entrance and fully developed region. The variations of the fluid temperature, local heat transfer coefficient and pressure drop along tube length are shown in the paper which is surveyed by the different researchers studies. Effects of nanoparticles concentration and heat transfer coefficient are presented. Numerical results show the heat transfer enhancement due to presence of the nanoparticles in the fluid in accordance with the results of the experimental study used for the validation process of the numerical model.*

Keywords- Heat exchangers, Nano-fluids, particle size

I. INTRODUCTION

Heat exchanger is a device in which the heat transfer takes place by using Nano fluid. In this the working fluid is Nano fluid (Al_2O_3 and SiO_2). Nano fluid is made by the suspending Nano particles in the fluid like water, ethylene glycol and oil, hydrocarbons, fluorocarbons etc.

1.1 Introduction to Nano fluid

Nano-fluids are dilute liquid suspended Nano-particles which have only one critical dimension smaller than~100nm. Much research work has been made in the past decade to this new type of material because of its high rated properties and behavior associated with heat transfer. . The thermal behavior of Nano fluids could provide a basis for an huge innovation for heat transfer, which is a major importance to number of industrial sectors including transportation, power generation, micro manufacturing, thermal therapy for cancer treatment, chemical and metallurgical sectors, as well as heating, cooling, ventilation and air-conditioning. Nano fluids are also important for the production of Nano structured materials for the engineering of complex fluids, as well as for cleaning oil from surfaces due to their excellent wetting and spreading behavior.

1.1.2 History of Nano fluid

The twenty-first century is an era of technological development and has already seen many changes in almost every industry. The introduction of Nanoscience and technology is based on the famous phrase" There's Plenty of Room at the Bottom" by the Nobel Prize-winning physicist Richard Feynman in 1959.Feynman proposed this concept using a set of conventional-sized robot arms to construct a replica of themselves but one-tenth the original size the nusing that new set of arms to manufacture an even smaller set until the molecular scale is reached.Low thermal conductivity of process of fluids hinders high compactness and effectiveness of heat exchangers, although a variety of techniques is applied to enhance heat transfer. Improvement of the thermal properties of energy transmission of fluids may become a trick of augmenting heat transfer. An innovative way of improving the thermal conductivities of fluids is to suspend small solid particles in the fluids. Various types of powders such as metallic, non-metallic and polymeric particles can be added into fluids to form slurries. The thermal conductivities of fluids with suspended particles are expected to be higher than that of common fluids. An industrial application test was carried out by Liu et al. and Ahuja in which the effect of particle volumetric loading, size, and flow rate on the slurry pressure drop and heat transfer behavior was investigated. In conventional cases, the suspended particles are of µm or even mm dimensions. Such large particles may cause some severe problems such as abrasion and clogging. Therefore, fluids with suspended large particles have little practical application in heat transfer enhancement. Application of nanoparticles provides an effective way of improving heat transfer characteristics of fluids (Eastman et al., 1997). Particles <100 nm in diameter exhibit propertiesdifferent from those of conventional solids. Compared with micron-sized particles, Nano phase 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. Choi is the first who used the term Nano fluids to refer to the fluids with suspended nanoparticles. Some preliminary experimental results (Eastman et al., 1997) showed that increase in thermal conductivity of approximately 60% can be obtained for the Nano fluid consisting of water and 5 vol% CuoNanoparticles. By suspending Nano phase particles in heating or cooling of fluids, the heat transfer performance of the fluid can be significantly improved. The main reasons may be listed as follows: 1.The suspended nanoparticles increase the surface area and the heat capacity of the fluid. 2. The suspended nanoparticles increase the effective (or apparent) thermal conductivity of the fluid. 3. The interaction and collision among particles, fluid and the flow passage surface are intensified. 4. The mixing fluctuation and turbulence of the fluid are intensified. 5. The dispersion of nanoparticles flattens the transverse temperature gradient of the fluid.

1.1.3 Types of Nano fluid

There are different types of Nano fluids basicallyAl_2O_3 + water, Cuo + water, Tio + water.Out of these we are going to use Al_2O_3 +water and SiO_2+water as our Nano fluid in heat exchanger.

1.1.4 Regarding Nano fluid

Heat conduction mechanisms in Nano fluid

Nano fluid is nothing but fluid particles which are less than even a micron(nearly 10-9 times smaller) indiameter and highly reactive and efficient material which can be used to increase factor like rate of reaction, thermal conductivity of any metal or material, they are that much reactive and strong.Kolinskypresented four possible methods inNano fluids which may contribute to thermal conduction.

(a) Brownian motion of Nano particles.
(b) Liquid layering at the liquid/particle interface.
(c) Ballistic nature of heat transport in Nanoparticles.
(d) Nano particle clustering in Nano fluids.

The Brownian motion of Nano particle are too slow to transfer heat through a Nano fluid. This mechanism works well only when the particle clustering has both the positive and negative effects of thermal conductivity which is obtained indirectly through convection.

1.1.5 Thermal Conductivity of (Al2O3 + water)Nano fluid

Nano fluids clearly exhibit improved thermo-physical properties such as thermal conductivity, thermal diffusivity, viscosity and convective heat transfer coefficient. The property change of Nano fluids depends on the volumetric fraction of nanoparticles, shape and size of the nanomaterial's as shown by Yang et al. (2005). The result demonstrates that the thermal conductivity increment is least for the water-based Nano fluids compared with the other Nano fluids. This result is quiteen couraging as heat transfer enhancement is often most required when poorer heat transfer fluids are involved. Thus indicates that the thermal conductivity increment for the poorer heat transfer fluids compared to the fluids with better thermal conductivity such as water. Thermal conductivity of Nano fluid by suspending particles is shown in table.

	Materials	Thermal conductivity(w/mk)
Metallic materials	Copper	401
	Silver	429
Nonmetallic materials	Silicon	148
	alumina	40
Carbon	Carbon Nano tubes	2000
Base fluids	Water	0.613
	Ethylene glycol	0.253
	Engine oil	0,145
Nano fluids	Water/Al_2O_3	0.629
	Ethylene glycol/ Al_2O_3	0.278
	Engine glycol-Water/Al2O3	0.382
	Water/TiO2	0.682
	Water/ Cuo	0.619

1.1.6 APPLICATION OF NANOFLUIDS

Nano fluids can be used to improve heat transfer and energy efficiency in a variety of thermal systems. Much of the work in the field of Nano fluids is being done in national laboratories and academia and is at a stage beyond discovery research. Recently, the number of companies that see the potential of Nano fluid technology and are in active development work for specific industrial applications is increasing. In the transportation industry, GM and Ford, among others, have ongoing Nano fluid research projects.

1.1.6.1 AUTOMOTIVE

In automobile area, Nano fluids has potential application in engine coolant, automatic transmission fluid, brake fluid, gear lubrication, transmission fluid, engine oil and greases. The first application in cooling automatic power transmission system done by Senthilrajaetal.

1.1.6.2 COOLANT

The use of Nano fluids 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 Siddur has shown that the use of Nano fluids in radiators may 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%.

1.1.6.3 FUEL

It was shown that the combustion of diesel fuel mixed with aqueous aluminum Nano fluid 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.

1.1.6.4 BRAKE FLUIDS

During the process of braking, the produced heat causes the brake fluid to reach its boiling point, a vapor 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. Nano fluids with enhanced characteristics maximize performance in heat transfer as well as remove any safety concerns.

1.1.6.5 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. Polio-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.

Sheng shuninvestigated the performance of the refrigerator using HFC134a and POE oil as the base data and then compared using HFC134a and mineral oil, and with different nanoparticles of TiO2 and Al2O3 with the same and different mass fractions with HFC134a for the same tests.

1.1.6.6 INDUSTRIAL COOLING

Outburst et al. Employed Nano fluids for industrial cooling and showed great energy savings and resulting emission reductions. They showed that replacement of cooling and heating water with Nano fluids has the potential to conserve about 300 million kWh of energy for industries. For the electric power industry using Nano fluids 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.

In the Defense Advanced Projects demonstrated cooling enhancement by ~ 8-30% using Nano fluids in compact heat exchangers. The Nano fluids were found to precipitate Nano fins on the heater surface and there augment the heat flux. The nanoparticles used in this study were ex-foliated graphite and multi-walled carbon nanotubes (MWCNT). It was observed that the Nano fluids specific heat capacity was enhanced by 50%. Hence, it was concluded that Nano fluids have better efficacy in thermal energy storage applications compared to cooling applications.

1.1.6.7 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 demonstrated efficiency improvements of up to 5% in solar thermal collectors by utilizing Nano fluids 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. For domestic hot water system, Golden and Otanicar 2009 resulted that the Nano fluid based solar collector has a slightly longer payback period but at the end of its useful life has the same economic savings as a conventional solar collector. The Nano fluid based solar collector has a lower embodied energy 9% and approximately 3% higher levels of pollution offsets than a conventional collector.

1.1.7 LIMITATIONS OF USING NANO FLUIDS

The use of Nano fluids seems attractive in a broad range of applications as reported in the previous section. But the development in the area of Nano fluid application is hindered by following limitations

1.1.8 POOR LONG TERM STABILITY OF SUSPENSION

Long term physical and chemical stability of Nano fluids is an important practical issue because of aggregation of nanoparticles due to very strong Vander walls interactions so the suspension is not homogeneous. Physical or chemical methods have been applied to get stable Nano fluids 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. Lee and Choi found that Al2O3 Nano fluids kept after 30 days exhibit some settlement compared to fresh Nano fluids. Particles settling must be examined carefully since it may lead to clogging of coolant passages.

1.1.9 INCREASED PRESSURE DROP AND PUMPING POWER

Pressure drop development and required pumping power during the flow of coolant determines the efficiency of Nano fluid application. It is known that higher density and viscosity leads to higher pressure drop and pumping power. There are many studies showing significant increase of Nano fluids pressure drop compared to base fluid. One of the experimental study by Choi calculated 40% increase of pumping power compared to water for a given flow rate.

1.1.10 LOWER SPECIFIC HEAT

An ideal heat transfer fluid should possess higher value of specific heat so the fluid can exchange more heat. Previous studies show that Nano fluids exhibit lower specific heat than base fluid. It limits the use of Nano fluids application.

1.1.11 HIGH COST OF NANO FLUIDS

Nano fluids are prepared by either one step or two step methods. Both methods require advanced and sophisticated equipment's. This leads to higher production cost of Nano fluids. Therefore high cost of Nano fluids is drawback of Nano fluid applications

II. LITERATURE REVIEW

Thermal conductivity is an important parameter in enhancing the heat transfer performance of a base fluid. Since the thermal conductivity of solid metals is higher than that of fluids, the suspended particles are expected to increase the thermal conductivity and heat transfer performance. Many researchers have reported experimental studies on the thermal conductivity of Nano fluids. The temperature oscillation method, steady state parallel plate method and transient hot-wire method have been employed to measure the thermal conductivity of Nano fluids. However, the transient hot-wire method has been extensively used by many researchers. A detailed review on different techniques for measurement of thermal conductivity of Nano fluids is available in literatures.

2.1Thermal conductivity of Al_2O_3Nano fluid

Aluminum oxide (Al_2O_3) and Silicon oxide (SiO_2) is the most common nanoparticle used by many researchers in their experimental works. Many efforts have been made to study the thermal conductivity of Nano fluids. The summary of experimental studies on the thermal conductivity of Al_2O_3 and SiO_2 -based Nano fluids. Generally, thermal conductivity of the Nano fluids increases with increasing volume fraction of nanoparticles; with decreasing particle size, the shape of particles can also influence the thermal conductivity of Nano fluids, temperature, Brownian motion of the particle, interfacial layer, and with the additives.

2.2Effect of particle size on thermal conductivity of Al_2O_3 and SiO_2 Nano Fluid

The effect of particle size on thermal conductivity of Al_2O_3 and SiO_2-based Nano fluids the particles used were in the range of 13 to 150 nm. Alumina 25 nm and SiO_2 25 nm in water resulted in thermal conductivity enhancement in the range of 2% to 10% in two studies but up to 21% in another study. The thermal conductivity enhancement for the Nano fluids with 25 nm particles was lying in between that of 38.4 and 60.4 nm, which cannot be explained. Mushed observed higher enhancement with 80- and 150-nm-sized particles at 1 vol. % compared to the Nano fluids with 2.5 vol. % of 28-nm particles in ethylene glycol-based Al_2O_3 Nano fluids. The authors have demonstrated that 80-nm particles showed higher thermal conductivity enhancement at 1 vol.% compared to similar data reported earlier **Xie** used 15- and 60.4-nm-sized particles, observed higher thermal conductivity enhancement for larger nanoparticles in ethylene glycol-based Nano fluids. The results cited here do not correlate the size effect of nanoparticles in thermal conductivity enhancement.

2.3 Effect of particle size on thermal conductivity of water+ Al_2O_3 and SiO_2 Nano fluids:

13 nm, 25 nm, 28 nm, 36 nm, 38.4 nm, 38.4 nm, 40 nm, 48 nm, 60.4 nm, 80 nm, 150 nm.

2.4 Effect of base fluids on thermal conductivity of Nano fluids

The thermal conductivity enhancement is least for the water-based Nano fluids compared with other Nano fluids.

This result is encouraging because heat transfer enhancement is often most needed when poorer heat transfer fluids are involved. The enhancement in the case of PO is 38% at 5 vol. % compared to that of 20% at 4 vol. % TO in contrast to 10.8% enhancement with the same volume fraction of nanoparticles in water. By many researches proved that thermal conductivity enhancement for the poorer heat transfer fluids is good compared to the fluids with better thermal conductivity such as water.

2.5 Effect of preparation methods on thermal conductivity of AL2O3

Thermal conductivities of the nanoparticle fluid mixture were first reported by Masuda.The mean diameter of the particles used in their experiments was 13 nm, and the particles dispersed in water by using a high-speed shearing dispenser ≈ 20,000 rpm. The authors reported a 32.4% increase in thermal conductivity for the volume fraction of 4.3 vol. % against 20% for 3 vol. %Nano alumina. However, the experiment was carried out at a higher room temperature of approximately 32°C, which is higher than most other researchers' reported data at room temperature ranging from 21°C to 28°C. Further, the authors used a high-speed dispenser with addition of HCl and NaOH to the fluids so that electrostatic repulsive forces among the particles kept the powder well dispersed. Lee dispersed 38.4-nm-sized Al_2O_3 nanoparticles in water and ethylene glycol by using polyethylene container and shaken thoroughly to ensure a homogeneous suspension for producing stable suspension. The authors observed an increase of only 10% at the 4.3 vol. % and 8% for the 3% load. The same enhancement was observed by Das for the particle size of 38.4 nm and for the particle load between 1% and 4%. Wang dispersed 28-nm-sized Al_2O_3 nanoparticles in different base fluids and prepared Nano fluids by mechanical blending, coating particles with polymers and filtration method. The thermal conductivity enhancement was 16% for 5.5 vol. % and 12% for 3% volume faction. In the case of Xianthe researchers used 60.4-nm-sized Al_2O_3 dispersed in water and prepared stable solution by adjusting ph. The nanoparticles are de agglomerated by using an ultrasonic disrupter after mixing with a base fluid and were homogenized by using magnetic force agitation. The enhancement observed was 21% for 5% volume fraction and 14% at 3.2% volume fraction.

2.6 Effect of temperature of thermal conductivity of AL2O3 and SiO_2 Nano fluid

The thermal conductivity of Nano fluids is temperature sensitive compared to that of base fluids. The Different groups measured thermal conductivity at different temperatures. **Das *et al*.** varied temperatures in the range of 21°C to 51°C demonstrating an enhancement of 2% to 10.8% for the particle load of 2 vol. % and observed thermal conductivity enhancement of 9.4% as compared to 24.3% for 4 vol. % solids. The authors suggested that strong temperature dependence of Nano fluid thermal conductivity is due to the motion of the particles. The larger sized particles used by Mushed resulted in enhancement similar to that reported earlier indicating that the enhancement is due to the intensification of the Brownian motion of the nanoparticles by addition of a surfactant and the application of temperature. The general trend in of increased thermal conductivity enhancement with increased temperature is not in line with a very early report of Masuda.

2.7 Thermal conductivity of AL2O3 and SiO_2 Nano fluids measured by using different techniques

The thermal conductivity measurement of Al_2O_3 and SiO_2 water-based Nano fluid measured by different techniques. A trend shows that thermal conductivity increased with the increase in volume fraction. The thermal conductivity data in the case of Oh *et al*. were in well agreement with that reported by **Wang *et al*.** Which, however, was higher than the results of **Lee *et al***. and **Das *et al*.** For similar Nano fluids but measured by different techniques. The reason for this discrepancy during the measurement may be due to the sedimentation and aggregation of nanoparticles, particle diameter, and Nano fluid preparation. In comparing the thermal conductivity measurement techniques, the steady state parallel plate method seems to be least affected by the particle sedimentation since the thickness of the loaded sample fluid is less than 1 mm. The transient hot-wire method can be affected by the sedimentation of the Nano fluids. Non-homogeneous nanoparticle concentration in the direction of gravity can give rise to temperature gradient within the vertical hot wire, which may be a source of measurement errors. This is also true for the temperature oscillation techniqueit is not clear how these techniques will behave for a stable Nano fluid which does not at all sediment during the measurement. Therefore, it is essential to produce Nano fluids which can be stable for long periods of time without any noticeable sedimentation.

2.8 Heat transfer charachristics of AL2O3 and SiO_2 Nano fluid

While heat transfer aspects of suspensions are important in applications in general, the aspect of natural convection in multiphase emulsions becomes more critical during storage and special phenomena such as melting of clathrate, which is used for storing coldness by releasing latent heat, separates out as organic liquid and an emulsion of hydro fluorocarbon dispersed in water

Pak and Cho studied the heat transfer enhancement in a circular tube, using γ-Al_2O_3 and TiO_2 nanoparticle fluid mixtures as the flowing medium. They observed an increase in the Nusselt number with the increasing volume fraction and Reynolds number. **Putra *et al.*** studied the natural convection of Nano fluids inside horizontal cylinder heated from one end and cooled from the other. An apparently paradoxical behavior of heat transfer deterioration was observed in the experimental study. The nature of this deterioration and its dependence on parameters such as particle concentration, material of the particles, and geometry of the containing cavity was investigated. The fluid characters are distinct from that of common slurries.

In some investigations CuO and Al_2O_3 oxide nanoparticles in water as base fluid in different concentrations, and the laminar flow convective heat transfer through circular tube with constant wall temperature boundary condition were examined. The experimental results obtained for CuO+water and Al_2O_3+water Nano fluids indicate that heat transfer coefficient ratios for Nano fluid to homogeneous model in low concentrations are close to each other, but by increasing the volume fraction, higher heat transfer enhancement for Al_2O_3+water was observed. The same authors worked on laminar flow forced convection heat transfer of Al_2O_3+water Nano fluid inside a circular tube with constant wall temperature and measured the Nusselt numbers for different nanoparticle concentrations as well as various Peclet and Reynolds numbers. Experimental results emphasized the enhancement of heat transfer due to the presence of nanoparticles in the fluid. Heat transfer coefficient increased by increasing the concentration of nanoparticles in Nano fluid. The turbulent convective heat transfer behavior of alumina (Al_2O_3) and zirconia (ZrO_2) nanoparticle dispersions in water is investigated experimentally in a flow loop with a horizontal tube test section at various flow rates ($9{,}000 < Re < 63{,}000$) .The experimental data were compared to predictions made using the traditional single phase convective heat transfer and viscous pressure loss correlations for fully developed turbulent flow, Dittos Boelter, and Blasius MacAdams, respectively. It was shown that if the measured temperature and loading dependent thermal conductivities and viscosities of the Nano fluids are used in calculating the Reynolds, Prandtl, and Nusselt numbers, the existing correlations accurately reproduce the convective heat transfer and viscous pressure loss behavior in tubes. Therefore, no abnormal heat transfer enhancement was observed in this study.

Xuan and Li conducted an experiment to investigate convective heat transfer and flow features of the Nano fluid in a tube. Both the convective heat transfer coefficient and friction factor of the sample Nano fluids for the turbulent flow were measured, respectively. The effects of such factors as the volume fraction of suspended nanoparticles and the Reynolds number on the heat transfer and flow features are discussed in detail. Wen and Ding reported an experimental work on the convective heat transfer of Nano fluids, made of γ-Al_2O_3 nanoparticles and DIW, flowing through a copper tube in the laminar flow regime. The results showed considerable enhancement of convective heat transfer using the Nano fluids; the enhancement was particularly significant in the entrance region, and was much higher than that solely due to the enhancement on thermal conduction. The possible reasons for the enhancement are migration of nanoparticles and the resulting disturbance of the boundary layer.

You *et al*. Measured the critical heat flux (CHF) in the pool boiling of Al_2O_3+water Nano fluids. They discovered an unprecedented phenomenon a threefold increase in CHF over that of pure water. The average size of departing bubbles increased, and the bubble frequency decreased significantly in Nano fluids when compared with those in pure water. Bangstudied boiling heat transfer characteristics of Al_2O_3+based Nano fluids. Pool boiling heat transfer coefficients and phenomena of Nano fluids are compared with those of pure water, which are acquired on a smooth horizontal flat surface. The experimental results showed that these Nano fluids have poor heat transfer performance compared to pure water in natural convection and nucleate boiling. On the other hand, CHF has been enhanced in not only horizontal but also vertical pool boiling. This is related to a change of surface characteristics by the deposition of nanoparticles.

Experimental study conducted by Das on pool boiling in water+Al_2O_3 Nano fluids on horizontal tubes of small diameter revealed that the deterioration in performance in boiling is less in narrow tubes compared to that in large industrial tubes which makes it less susceptible to local overheating in convective application. Recently, FarajollahiMeasured heat transfer characteristics of γ-Al_2O_3+water and TiO_2+water Nano fluids in a shell and tube heat exchanger under turbulent flow condition. It was reported that by adding nanoparticles to the base fluid, significant enhancement of heat transfer characteristics was observed. For both Nano fluids, two different optimum nanoparticle concentrations exist. A comparison of the heat transfer behavior of two Nano fluids indicates that at a certain Peclet number, the heat transfer characteristics of TiO_2+water Nano fluid at its optimum nanoparticle concentration are greater than those of γ-Al_2O_3+water Nano fluid while γ-Al_2O_3+water Nano fluid possesses better heat transfer behavior at higher nanoparticle concentrations. In another recent study, it was demonstrated that the alumina Nano fluids significantly improved the thermal performance of an oscillating heat pipe, with an optimal mass fraction of 0.9 wt. % for maximal heat transfer enhancement. Compared with pure water, the maximal thermal resistance was decreased by 0.14°C/W. when the power input was 58.8 W at 70% filling ratio and 0.9% mass fraction. The authors observed that the nanoparticle settlement mainly took place at the evaporator. The change of surface condition at the evaporator due to nanoparticle settlement was found to be the major reason for the enhanced thermal performance of the alumina Nano fluid-charged oscillating heat pipe.

Recently conducted an experiment on natural convection of heat transfer of a Nano fluid in vertical square enclosures of different sizes, in the solid loading range of 0.1 to 4 vol. % noted the Rayleigh's number varying in the range of 6.21×10^3 to 2.56×10^8. The experimental result for the average heat transfer rate across the three enclosures appeared generally consistent with the assessment based on the changes in thermo physical properties of the Nano fluid formulated, showing systematic heat transfer degradation for the Nano fluid containing nanoparticles volume fraction ≥2 vol. % over the entire range of the Rayleigh's number considered. The Nano fluid containing 0.1 vol. %, a heat transfer enhancement of 18% compared with that of water, was found to arise in the largest enclosure at sufficiently high Rayleigh's number. The authors suggested that such enhancement is not only due to the relative changes in thermo physical properties of the Nano fluid containing low particle fraction, other factors may come into play.

Although addition of local losses may suppress instabilities, however, it is accompanied by a significant flow reduction which is detrimental to the natural circulation heat removal capability. Nayak demonstrated experimentally, with Al_2O_3 Nano fluids, not only the flow instabilities are suppressed but also the natural circulation flow rate is enhanced. The increase in steady natural circulation flow rate due to addition of nanoparticles is found to be a function of its concentration in water. The flow instabilities are found to occur with water alone only during a sudden power addition from cold condition, step increase in power, and step decrease in power (step back conditions). With a small concentration of Al_2O_3 Nano fluids, these instabilities are found to be suppressed significantly.

The heat transfer studies on alumina based Nano fluids can give rise to the possibility of their use in actual applications. However, cost of such fluids is a major concern *vis-à-vis* the stability duration of such fluids in ideal condition. Further, the effect of acids and bases or surfactants used for stabilization of nanoparticles in actual applications needs to be studied in detail.

Calvin H. Li *et a.l* investigated on volume fraction at 2%, 4%, 6% and 10% of CuO and Al2O3 nano particles of diameters ranging from 29nm to 36nm in size with temperature ranging from 27.5oC to 34oC. The result of experimental values showed enhancement in the effectiveness of CuO at 6% volume concentration and Al2O3 at 10% volume concentration by1.52 times and 1.3 times respectively at 34oC temperature of the nano fluid. It was also reported from the results that as the temperature increases the *k* increases and also shows that there is an optimum volume fraction or volume concentration to give stirring effect in the fluid which increases the rate of heat transfer.

Q.Z. Xue compared their results with Choi *et al.* and HC model and also with four other models. The investigation reported, Choi *et al.* conducted on volume concentration 1% having nano particles of carbon nano tube suspended in oil. An enhancement by 160% has been found whereas this was greater than 10% predicted by HC model and four other models. The volume concentration used by them is 1% carbon nano tube particles suspended in oil as well and this reports 19.6% enhancement which is again greater than HC model prediction. It was observed in this paper that the *k* of nano fluid is very much dependent on the selection of base fluid. The experimental data showed higher enhancement percentage than all the models and even when compared with the theoretical data higher enhancement have been found but it lies within a reasonable range covered by models.

Hrishikesh E. Patel performed experimentally and measure temperature with Transient Hot Wire (THO) and Temperature Oscillation (TO) equipment. Nanoparticles of Aluminum oxide and Copper(II) oxide were dispersed in water, ethylene glycol andtransformer oil. The averaged surface area sizes were categorized into 11nm, 45nm, and150nm. The results obtained shows that the metallic nanofluid gives higher enhancements. A Review on “The Recent Development in Enhancing the Thermal Conductivity in Nanofluids”than oxide nanofluids. It was also observed by the researcher that the *k* is higher at lower volume fraction.

E.V Timofeeva measured the intensity by Dynamic Light Scattering (DLS)technology. The researchers in this paper investigated on nanoparticles of Alumina suspended in base fluids water and ethylene glycol. The results showed that the nanoparticles are highly agglomerated and it varies with time and age. The results also show an enhancement in the rate of *k* due to agglomeration of nanoparticles. RaviPrasher were assumed the particles shape to be spherical. The results showed that there was a change in thermal conductivity due to aggregation in nanofluid; it was also observed that the micro-convective effect occurs due to BM in the nanofluids. This investigation shows that there is an enhancement in the *k* due to increase in aggregation.

Junemo Koo*et al.* studied the movement of nanoparticles in the base fluid. The researcher also discussed the effects of BM, thermophoresis, and osmophoresis on *k*. The paper defines BM as random movement of microscopic particles in base fluid. Thermophoresis is defined as phenomena in which the nanoparticles experiences movement in base fluid due to difference in temperature gradient whereas, osmophoresis can be explained as a phenomenon in which the nanoparticles experiences movement due to difference in temperature gradient as well as pressure difference. It was reported from the paper that the particles arriving from higher temperature have greater momentum than one at lower temperature this is due to the change in density, this difference in momentum showed that particles have different energy level at different temperatures. As observed from results, BM showed the greatest enhancement in *k* than thermophoresis and osmophoresis. This paper concludes with a statement reporting that the BM effect on *k* decreases if the particle size decreases whereas, thermophoresis and osmophoresis is independent of the size of the nanoparticles.

Ravi Prasher*et al.* neglected the impact of layering whereas, effects of three other mechanisms for energy transfer are taken into consideration and they are 'translational BM ,interparticle potential, and convection due to BM. Nanoparticles of Aluminum oxide and Copper(II) oxide were dispersed in water and ethylene glycol. It was reported that the simple single-sphere BM results in greater enhancement in *k* than **MG model**. In this paper, it isobserved that even at very small volume fraction the particles experience the interactionAli JarrarJaffri, MohdWaheedBhat, GauravVyas, Abhinav Kumar and Raja SekharDondapati between them. The results showed that the induced convection due to BM as well as by MGmodel.

P. Bhattacharya*et al.* have observed the use of alumina-ethylene glycol and CuO ethylene glycol as nanofluids. In their study they have worked on a very different technique of computation known as Brownian dynamics simulation, it has been reported that the technique was economical than the molecular dynamics. Brownian dynamics can be explained in such away that the Newton's equation of motion is replaced by the Langevin's equation (Brownian dynamics). It is also observed that the Brownian dynamics simulation resulted in high accuracy comparatively. The researchers varied the number of particles such as 32, 108 and256 in the fluid. They also performed three different simulations of duration's 100, 1000 and10,000-time steps and this resulted that the duration of 100-time steps at 300K was more economical than the other two durations. This paper concluded as a result of the simulation resulting within 3% of experimental data for alumina-ethylene glycol and for CuO-ethylene glycol resembles very much with the experimental data.

Junemoo Koo and Clement Kleinstreuer focused on effects of particle size, volume fraction, and temperature. They also considered properties of the base fluid and compared It with the results of different studies. It was reported that there are strong relation and dependency of effective *k* on temperature and material of the particle. The study validates that for given heat flux, the temperature gradient changes due to varying ***k*** which majorly depends on volume fraction, particle size, particle material and temperature. It is observed that the BM is more effective at a higher temperature. The study concluded that with an opinion for improving the accuracy of effective *k* model by collecting more experimental data.

III. CONCLUSION

After studying all these literature surveys the better way to do experimental analysis by using different heat exchangers to design the pipes of the experimental setups should be created a turbulent flow through the pipes and the selection of nano particles / materials, nano particle size and the methods of preparation of nano –fluids without having more frictional losses in pipes.

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