International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 10 Issue 02, February-2021

Effect of Concentration of Al_2O_3 Nano Particles in Base Fluid on Thermal and Flow Properties to Enhance the Heat Transfer Rate

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***Abstarct*:- Cooling is almost important in industry. It is needed to improve the performance of cooling system. However due to the low thermal conductivity of fluid there will be limitations for the heat transfer characteristics. Nano fluid i.e suspension of nano size particles in the base fluid such as water ,ethylene glycol ,oil and diesel were used as innovative heat transfer fluid for cooling applications because thermal conductivity of the nano fluid is more than the conventional fluid such as water, ethylene glycol ,oil etc. There are many literature surveys available which shows that increase in the thermal conductivity and heat transfer characteristic with increased in concentration of nano particles in base fluid. The aim of this review is to summarize how increased concentration of nano particles increases the thermal conductivity and heat transfer rate. Also about the effect on the thermal and flow properties of nano fluid.**

Keywords: Nano fluid, Al_2O_3, concentration, thermal conductivity, heat transfer rate.

1. INTRODUCTION

Conventional fluid such as water, engine oil, ethylene glycol was used as heat transfer fluid. These fluid having low heat transfer characteristics and affects the performance of the cooling devices like heat exchangers and in many electronics equipments. There

are many researchers going to enhance the heat transfer rate to enhance the efficiency the devices. Hence many authors [1] used the solid particles in size mm in water, engine oil and ethylene glycol to enhance the thermal conductivity and heat transfer characteristics of the fluid. But due to the addition of the mm size particles in water/engine oil/ethylene glycol, sedimentation problems occurs and resulting in the viscosity of the fluid increases. The thermal conductivity of the solid particles are more as compared to the base fluid such as water/engine oil/ethylene glycol etc. Suspension of nano size metal particles in conventional fluid called as nano fluid increases the heat transfer characteristics of the nano fluid and thermal conductivity.

Use of nano size metal particles in water, oil and ethylene glycol which enhance the thermal conductivity and heat transfer characteristic can be used for many engineering heat transfer applications. Nano fluids are suspended nao size particles in the base fluid. The size of the nano particles vary from 1 to 100nm. Nano fluids are not simple liquid solid mixture.

Nano particles which are used to mix in liquid should not react with base fluids and stable for long duration in order to enhance the thermal conductivity and heat transfer characteristics.

Nano fluids have attracted great interest recently because of enhanced thermal conductivity and heat transfer rate [2-6]. This article aims to an overview of the concept of alumina based nano fluids and detailed research about Al_2O_3-water carried out around the world.In this article we discuss the parameters such as thermal conductivity, specific heat, viscosity and temperature of Al_2O_3-water based nano fluid .Also discussed preparation methods of nano fluids.

2. THERMAL CONDUCTIVITY

Thermal conductivity is an important property to increase the heat transfer rate of base fluid . Thermal conductivity of the solid particle (metals) higher than that of the base fluid. Hence thermal conductivity of the suspended particle in the base fluid increases the heat transfer performance. There are different methods used to identify the thermal conductivity of the nano fluids.

i) Temperature oscillation method
ii) Steady state parallel plate method
iii) Transient hot wire method.

The transient hot wire method is extensively used to measure the thermal conductivity of nano fluid which is explained in the literature survey [5].

A. *Preparation of nano fluid.*

i) Single step direct evaporation method
ii) Two step method

B. Thermal conductivity measurement techniques

i) Temperature oscillation method[9-12]
ii) Steady state parallel plate method[8]
iii) Transient hot wire method [1-5]

C. Experimental Result on Thermal Conductivity of Al_2O_3 Based Nano Fluids

Generally

1. Thermal conductivity of nanofluids increases with increasing volume fraction of nanoparticles with decreasing particle size.
2. Shape of the particles also influences the thermal conductivity of the nanofluid.
3. Thermal conductivity of the nanofluid increases with in temperature of basefluid.
4. Browniun motion of the particle, interfacial layer with additives.

3. EFFECT OF VOLUME FRACTION OF NANOPARTICLES ON THERMAL CONDUCTIVITY OF AL_2O_3 BASED NANOFLUID.

1. Volume concentration mostly less than the 5% in all the cases
2. From all the paper the maximum thermal conductivity observed for 4% to 5% volume load. In case of water based nanofluid which increases 30% to 32% increase of thermal conductivity and 30% increase in thermal conductivity in case of ethylene glycol as base fluid
3. H wang [17] for base fluid as water shows 4% enhancement in thermal conductivity of concentration from 0.3 to 1.0, particle size 48 nm at the enhancement ratio of 1.013 to 1.04.

Thermal conductivity enhancement was decreased as concentration increased from 6% to 10%. Sometimes thermal conductivity was increased as concentration increased from 2% to 10% even though particles size almost the same in both cases.

A. Effect of Particle Size on Thermal Conductivity of Al_2O_3 Based Nanofluid.

Particle size also effect to enhance the thermal conductivity of nanofluid. So many researches show that particle size of 150 nm, 35 nm, 28 nm for particular composition (by volume) [1, 7, 8, 11, 14, 16, and 20]. Effect of Base Fluid

1. Water
2. Ethylene glycol
3. Engine oil

TABLE II

Table: Thermal conductivity of base fluid at 20ºC

Base fluid	Thermal conductivity	Temperature ºC
Water	0.598 to 0.6	20
Ethylene glycol	0.25 to 0.26	20
Engine oil	0.13	20
Toluene	0.15	20

Thermal conductivity enhancement of nanofluid in case of poor thermal conductivity fluids is more as compare to the better thermal conductivity of fluid like water. It is encouraging because of the low thermal conductivity fluids involve to enhance the heat transfer rate and thermal conductivity of nanofluids [1, 7, 8, 28].

B. Effect of the Preparation Method on Thermal Conductivity of Al_2O_3 Based Nanofluid.

By referencing the all the author preparation method is also important for different size and volume % to enhance the thermal conductivity of nanofluid. Many authors used two step methods to prepare the nanofluid [1, 7, 8, 15, and 16].

TABLE II

Effect of Two Step Preparation Method to Enhance the Thermal Conductivity

Author	Particlce size in 'nm'	% by Volume	% of increase in thermal conductivity	Temperature in ºC
Masuda	13	4.3	32	32
Masuda	13	3	20	32
Lee	38.4	4.3	10	32
Das	38.4	1 to 4	10	32
Wang	28	5.5	16	32
Xie (using ultrasonic agitation)	60.4	3	12	32
Xie (using ultrasonic agitation)	60.4	5	21	32
Xie, (using magnetic agitation)	60.4	5	21	32
Xie, (using magnetic agitation)	60.4	3.2	14	32

Above table shows that enhancement was more in Xie work as compare to Wang and Das, Lee authors because the author using magnetic agitation and ultrasonic disrupter.

C. Effect of Temperature on Thermal Conductivity of Al_2O_3 Based Nanofluid.

Thermal conductivity of nanofluid is temperature sensitive compare to that of base fluid . the effect of temperature on water based Al_2O_3 nanofluid , that is due to the motion of particle shown by the author Das [7].

Das shows that for Al_2O_3 nanofluid there will 9.4% increase in thermal conductivity 2% composition by volume and 21% enhancement in thermal conductivity for 4% composition by volume. Murshed [20] reported that larger size particles used also enhance the thermal conductivity using Brownian motion of nanoparticles by the addition of surfactant and application of temperature. The author Murshed [20] and Beck [22] also

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 10 Issue 02, February-2021

shows that thermal conductivity depends upon the base fluid behavior.

Thermal conductivity of nanofluid can be measured by different method, they are

i) Temperature oscillation method[9-12]
ii) Steady state parallel plate method[8]
iii) Transient hot wire method [1-5].

Generally thermal conductivity increases with increase in volume fraction, these methods gives different results for water based nanofluids, this may be due to the sedimentation and aggregation of nanoparticles, particle diameter and nanofluid preparation. Steady state parallel plate method is seems to be least affected by the particle sedimentation, thickness of the sample fluid less than the 1mm.

But still research has to be carried out which technique is better for different size, shape, volume fraction of nanofluids to enhance the thermal conductivity [1, 7,8, 23].

D. *Effect of PH on Thermal Conductivity of Al_2O_3 Based Nanofluid.*

Xie [16] conducted experiment for water based Al_2O_3 nanofluid for range of 5 to 124 m^2/g using transient hot wire method were he found that P^H range was 2 to 11.5 and thermal conductivity of suspension particle is greater than base fluid. The enhanced thermal conductivity increases with increase in the difference between the P^H values of aqueous suspension and isoelectric point of the Al_2O_3 particles.

Xie [16] shows that for 60.4 nm size particles and volumetric composition of 1.8% to 5% thermal conductivity observed was 7% to 21%.

E. *Effect of surface active agents on thermal conductivity of water based Al_2O_3 Nanofluid*

TABLE III

Effect of surface active agents on thermal conductivity of water based Al_2O_3 Nan fluid

Author	Base fluid	Size (nm)	% volume	Surfactant	% Increase in thermal conductivity
Wen	Water	48	1.59	Sodium dodecyl benzene surfonate	10
Kole	Water	50	3.5	Oleic acid	10.4
kole	Ethylene glycol	50	5	Oleic acid	12 to 13

4. EXPERIMENTAL RESULTS ON VISCOSITY OF AL_2O_3 BASED NANOFLUID.

Camparing the experimental studies on thermal conductivity of nanofluid , they are limited rheological studies [8].

The author [8] shows that for Al_2O_3 – water based nanofluid and 3% by volume the viscosity increases to 20 to 30% as compare to water. Das [26] shows that viscosity of nanofluid increases with increase % volume and that nanofluid considered to be non newtoniun. As per the study [19] using two step method Al_2O_3 based nanofluid for the percentage of 0.01 to 0.3 without any surfactant at the temperature of 21ºC to 39ºC. Viscosity of Al_2O_3 – water nanofluid significantly decreases with increase in temperature and slightly increases with increase in volume fraction. Measured viscosity of Al_2O_3 – water nanofluid non linear (occurs at low percentage volume concentration below 2%.

As per the author [27] viscosity increases by 83.4% for the volume 5 % of Al_2O_3 – water. As per the author Nguyen [28] of Al_2O_3 water nanofluid for the size of 36nm, 47nm and CuO water nanofluid with 29nm reported that changes in the hysteresis behavior of nanofluid of nanofluid for the percentage volume 1% to 9.4% at temperature 75ºC approximately.

The water based Al_2O_3 nanofluid at 75ºC for the size of 36 nm and 4% volume hysteresis behavior of Al_2O_3 water nanofluid will change on heating and cooling beyond the critical temperature. It is very interesting that hysteresis is predominant only in fluids with higher nanoparticle concentration.

TABLE III

Effect Concentration on Viscosity of Nanofluid

Author	Size (nm)	Base fluid	Viscosity	Percentage of volume
[20]	80	Deionized water	Increase 82%	5%
Wang [8]	28	Distelled water	Increase 86%	5%

A. *Reason for the difference*

1. Difference in size of particle cluster
2. Difference in the dispersion technique.
3. Surfactant

The above information from all the researchers shows that change in the relative velocity at lower concentration was minimal over a temperature. As per the author Xie [24] viscosity of suspended nanoparticles was much larger than the corresponding values predicted by the theoretical one.

And also Kole [25] enhancement ratios of the of the viscosity ration of ethylene glycol based suspension are smaller than those of water based suspensions, indicating that base fluid is also influenced. As per the Kole [25] Al_2O_3 in engine oil demonstrated that there is transition from Newtonian characteristic to non-Newtonian characteristic and viscosity increases with increase in the percent ration of concentration and decreases with increase in temperature. An optimal laoding of is required (perc by volume) in nanofluids so that we can avoid viscosity rise for the application and at the same time increses the rise in the thermal conductivity of the nanofluids. So that more studies is required in this direction.

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5. HEAT TRANSFER CHARACTERISTIC OF AL_2O_3 BASED NANOFLUID.

Heat transfer aspect of the nanofluidstudies by many Author's especially about convection and multiphase heat transfer of nanofluid more critical. Author Pak & Cho [30] and Putra [31] studies the natural convection using **γ-**Al_2O_3 and $TiO_2$with water as base fluid and found that Nusselt number of nanofluid increases with increased concentration and Reynolds Number, and an apparently paradoxical behaviour of heat transfer of nanofluid observed. i.e heat transfer deterioration was observed in the experimental study. That is due to the followings, means depends upon the parameters such as,

1. Particle concentration.
2. Materials of particles.
3. Geometry of the containing cavity.

Haris [32] discussed CuO-water and Al_2O_3-waterin a cylinder at constant wall temperature,increasing the concentration, laminar flow convective heat transfer, he found that at low concentration heat transfer characteristic of both (CuO-water and Al_2O_3-water)are same and close to each other. But increase in the concentration shows that heat transfer ration of the nanofluid to homogenous moduleof Al_2O_3-water increases. Author [33] also studies the laminar flow with forced convection heat transfer of Al_2O_3-water inside circular tube with constant wall temperature and measured the following numbers.

1. Nusselt Number
2. Peclet Number.
3. Reynolds Number.

And the result observed was enhancement of heat transfer characteristic of Al_2O_3nanofluid with increase in concentration.

The author [34] shows that in his experiment for$Al_2O_3$and [ZrO_2] water based nanofluid for turbulent convective heat transfer for various flow ratios i.e Reynolds number 9000<Re<63000. The authors compare the experimental data to prediction made using the traditional single phase convection heat transfer and viscous pressure loss correction for fully developed turbulent flow Dittus-Bolter and Blasius Mac/Adams respectively. The author in his investigation shows that the calculation of Reynolds Number, Nusselt Number and Prandtle number in terms of measured temperature, loading dependent thermal conductivity and viscosity of the nanofluid. Therefore, no abnormal heat transfer enhancement was observed in this study.

Xuan and Li [35] conducted an experiment of Al_2O_3 water based nanofluid in cylinder (tube) to investigate convection heat transfer and flow features. They measured heat transfer coefficient and friction factor. They discussed effect of volume fraction of suspended nanoparticles and Reynolds number on the heat transfer and flow features.

Wen and Ding [24] conducted on experiment of Al_2O_3 – water (deionized water) in copper tube of laminar flow and showed enhancement in convective heat transfer of nanofluid in laminar flow. Enhancement was particularly significant in the entrance region. The reason is that for enhancement are migration of nanoparticle and resulting disturbance of the boundary.

You et al [36] conducted experiment for Al_2O_3 – water nanofluids and measured the CHF (critical heat flux). Further investigated that the critical heat flux of nanofluid increased 3 fold times that of pure water. This is an unprecedented phenomenon. Although in his experiment shows that average size of the bubbles increased and bubble frequency decreased significantly as compare to pure water.

Bang et al [37] studies boiling heat transfer characteristic and pool boiling heat transfer phenomenon for Al_2O_3 – water nanofluids and compare result with pure water. The author shows that poor heat transfer performance of nanofluid in boiling heat transfer due to the deposition of nanoparticles on the surface of plate both in horizontal and vertical pool boiling, surface characteristic will change due to the deposition of nanoparticles, hence CHF has increases.

Das et al [38] studies boiling (pool boiling) in water Al_2O_3 nanofluids in horizontal tube of small diameter and shows that deterioration of heat transfer is less in small narrow tubes as compared to large industrial application tubes which makes less susceptible to local overheating in convective application.

Farajollahi et al [39] studied the water Al_2O_3 and TiO_3/water nanofluid in shell and tube heat exchanger with turbulent flow and shows that at optimum concentration of nanoparticles in water TiO_3/water nanofluid having better heat transfer characteristic than Al_2O_3/ water based nanofluid and optimum concentration of nanoparticles in water exist.

Author also shows that the heat transfer characteristic of Al_2O_3/ water nanofluid increases with increased concentration.

Author [40] studies that alumina based nano fluids used in oscillated heat pipes and shows that better heat transfer rate at 0.9% wt. this is an optimal mass fraction to get maximum heat transfer rate in oscillate heat pipe, and it decreases thermal resistance 0.14ºC/W when power input was 58.8 W at 70% filling ratio and 0.9% mass fraction. Author shows that settlement of nanoparticles take place mainly at evaporater. If change the surface condition at the evaporater which increases the heat transfer heat.

Ho at al [41] conducted experiment for different size closed enclosure (vertical). The solid loading of 0.1% to 4% for the Rayleig number $6.21x10^3$ to $2.56x10^8$, the average heat transfer rate for three enclosures is constant with assessment based on the changes in thermo physical properties of nanofluid formulated.

Author shows that there will be systematic de gradation of heat transfer for volumetric % increases greater than 2% over the entire range of Rayleigh number. Nanofluid contains 0.1% vaolume, heat transfer rate increased to 18% compared with that of pure water in largest enclosure for high Rayleigh number. The enhancement in the heat transfer rate is not only due to changes in thermo physical properties of nanofluid but also other properties.

Nayak et al [42] demonstrated experimentally with Al_2O_3 water based nanofluid instability is suppressed and flow rate decreases as compared to water natural flow rate. The flow instability occurs only in water, the addition of nanoparticles in water suppress the instability and increases the natural circulation of flow rate.

Heat transfer studies of Al_2O_3-water based Nanofluid very important

1. Heat transfer rate increases with increase in volumetric concentration
2. Cost and stability duration of nanofluid is also dependant for the application.

6. APPLICATION OF ALUMINA BASED NANOFLUIDS

Al_2O_3 water/oil can be used

1. To cool automobile engine, welding equipment.
2. High heat flux devices such as power micro tubes and high power laser diode arrays.
3. Al_2O_3 water nanofluid could flow through tinny passages in MEMS to improve its efficiency.
4. Use of nanofluid increases (CHF) critical heat fluxes in forced convection hence it is used in nuclear applications.
5. As per the Author [43] studies, if nanofluid improves the chiller efficiency by 1% saving of 320 billions kWh of electricity or an equivalent of 5.5 million barrels of oil per year.
6. Used in deep drilling applications.
7. For increasing the dielectric strength and life of transformer oil by dispersing nano particles.
8. Nguyen et al [44] experimentally investigated use of nanofluid (Al_2O_3) for cooling microprocessor or other electronics equipments in closed loop.
9. Used to enhance the consider heat transfer and cooling of cooling block convective heat transfer coefficient considering turbulent flow.
10. As per the research use of 6.8% by volume nanoparticles heat transfer coefficient about 40% increases compare to base fluid and also decreases the temperature of system.
11. Experimentally show by You at al [36] for the nanofluid of 36nm – 47nm, 36nm size is most efficient heat transfer rate than 47nm.
12. Experimentally show by You at al [36] shows CHF for pool boiling from a flat square heater immersed in Al_2O_3water based nanofluid in a concentrating range 0 to 0.05 g/l, CHF drastically increases than in pure water which is raising the chip power in electronic components and cooling requirements for space applications.
13. Tzeng et al [45] dispersed CuO and Al_2O_3 nanopartocles and antifoam in engine oil to cool automotive engine for different rpm, it improves heat transfer efficiency and also reduces the temperature of rotary devices.
14. As per author Kulkarni et al [46] Al_2O_3 nanofluid used as a coolent electric generator and also found that the efficiency of waste heat recovery increases for nanofluid due to its superior convective heat transfer coefficient.
15. As per Wu et al [47] observed as potential of Al_2O_3 water nanofluid as a new phase change material for thermal energy storing of cooling system, it reduces the total freezing time 20.5%.
16. Infrared imaging photographs suggest that the freezing rate of nanofluid is enhanced and by only adding 0.2 wt % Al_2O_3 water.
17. Used to cool the transformer it is useful in Navy as well industry (power generation industry) to reduce the size and weight of transformer. It is important because in ever growing demand for greater electricity production necessitates to upgrade transformer on large scale and at the high cost.
18. It can replace the conventional transformer oil with nanofluid (cost saving) it improves the heat transfer properties of the transformer oil shown in the reference paper.

Above all the application shows that Al_2O_3- water based nanofluid having great potential in many applications. However, literature survey shows that application limited to closed loop application but need more research in open loop application.

7. SUMMARY

Al_2O_3 water based nanofluid can be used in many heat transfer application. Most of the nanofluids which are prepared by ultrasonic vibrator are not stable for long time. Researchers therefore have to concentrate on the preparation of nanofluid which should give consistent result and stable for long time. The thermal conductivity and heat transfer characteristic enhancement of Al_2O_3Nanofluidare not consistent for many of the researcher so it may dependent on the.

1. Surfactant.

2. Optimizing PH

3. Temperature for different nanofluid.

4. Surface modification.

Only few literature surveys available to study the enhancement of thermal conductivity by the nanofluid by modification of size, shape and surfactant (acidic, basic of Al_2O_3). But it adverse effect on the heat transfer characteristic of Al_2O_3nanofluid.

In many literature surveys we observe different degrees of enhancement for the same volume fraction. The techniques which are used for measuring thermal conductivity also alter the values. The effect of temperature on the thermal conductivity of nanofluid at lower concentration upto 400K was measured but not yet been reported with experiment dealing with the measurement of the thermal conductivity at lower range temperature, but many research has need to be done effect of temperature (at lower temperature) on the thermal conductivity.

Very few report described the effect of temperature on viscosity at high concentration and hysteresis phenomenon. The researcher has to be concentrating the effect of temperature on nanofluid viscosity at high concentration to study the hysteresis phenomenon (behaviour) of nanofluids. Totally review has summarised the basics of nanofluid, its preparation methods and factors affecting the thermal conductivity enhancement in the Al_2O_3 based nanofluid. It has also identified the areas which require more research for better understanding. The enhancement of thermal conductivity of base fluid will be definite requirement in the future to improve the thermal efficiency of different system.

AKNOLODGEMENT

This review was supported by Dr K Elangovan. We thank our colleagues from Department of Mechanical Engineering, Cambridge Institute of technology, Bangalore, who provided insight and expertise that greatly assisted the research, although they may not agree with all of the interpretations/conclusions of this paper.

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