A Recent Examination on the Performance of Heat Exchangers using Al_2O_3 Nanofluid with Its Thermo Physical Properties

Armstrong. M, Sivasubramanian. M, Selvapalam. N

Abstract*: Heat exchangers are the most significant equipment used in the industrial sites for exchanging the useful energy for many applications. It may be used either for cooling or heating but in the industrial scenario, it mostly used for cooling. In the current research development, the nanoparticles of different high thermal conductivity metals have been prepared and introduced in the low thermal performance base fluids like water, oil, ethylene glycol to enhance its quality of heat absorption in the heat exchangers. In that alumina nanoparticle played a significant role in many research applications and it has good thermal conductivity as a pure fluid. So, in this review work, the recent study of Al_2O_3 nanofluid with its preparation method,A. thermo-physical properties and its performance in varied heat exchangers have been discussed. This would enrich the knowledge and help the researchers who are interested in alumina nanofluid for their experimental works.

***Keywords*— Heat Exchanger Al_2O_3 nanofluid, properties**

I. INTRODUCTION

Heat exchanging devices create the first-rate part in many industrial applications. Because of this, a wide sort of researches is undertaking to decrease the size and cost of the heat transfer equipment with high performance by indulging in diverse invaluable works similar to changing its design, incorporating corrugated structures with the different dimension with different flow configurations and with different heat transferring medium. In power plants, refrigeration plants and in many other industrial sites heat exchangers plays a vital role in increasing the efficiency of the whole system by optimizing the production rate using normal base fluids like water, ethylene glycol, oil etc.. As per the Central Electricity Authority India, the installed coal-based power capacity is expected to reach 248,513 MW by 2026-27 and according to its Electricity Plan, an additional capacity of 51,342 MW is under-development and likely to yield benefits by 2021-22, so the demand for the coal-based power plants is increased due to the rapid growth in the population and its usage in the electrical appliances. This could be solved by utilizing the energy transferring equipment in a better way by reducing the losses and by enhancing its performance by introducing high thermal conductivity base fluids to release or absorb its energy instantly. Many types of research are going on to discover a new nanofluid to satisfy and solve this issue in the heat exchanging process. Because nanofluids are playing wide applications in many industrial fields (2). In that most commonly used nanofluid is alumina-based nanofluids. Since, it provides good thermal properties and high heat exchanging performance with less synthesis cost. In this review paper, the recent development in the preparation and utilization of alumina as a nanofluid in varied heat exchangers and its performance had been discussed.

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***** M. Armstrong

Armstrong M*, Department of Mechanical Engineering, Kalasalingam Academy of Research and Education, Krishnankovil, India. Email: armstrong@klu.ac.in

Sivasubramanian. M, Department of Automobile Engineering, Kalasalingam Academy of Research and Education, Krishnankovil, India Email: m.sivasubramaniana@klu.ac.in.

Selvapalam. N, Department of Chemistry, Kalasalingam Academy of Research and Education, Krishnankovil, India. Email: n.selvapalam@klu.ac.in

A. Aluminum Oxide Nanofluid

Aluminum oxide is a non-metallic compound with the combination of aluminum and oxygen with the chemical formula of Al_2O_3. It is also called alumina. It occurs with a less electrical property but with high thermal conductivity. This property made it be eminent in the application of heat exchangers. Some of the properties of Al_2O_3 are shown in Table 1.

Table 1 Properties of Al_2O_3 Salt

Appearance	Density	Boiling point	Thermal conductivity
White solid	3600 kg/m^3 (5)	2,977 °C	36 W/m. K (5)

B. Preparation of Alumina nanofluid

Alumina nanofluid could be prepared by both single and two-step method. In these methods, the metal oxides provide higher stability by using the two-step method compared to single step methods (15). The two-step method is economic and high production rate with less time duration made it to plays a major contribution and most preparation method in multiple research works. In this method, the alumina nanoparticle is synthesized by different approaches including physical, chemical and biological technique. After the production of nanoparticle, it is well mixed with the base fluids like water, ethylene glycol, oil, etc. with or without adding surfactant. It is well dispersed with the magnetic stirrer and ultrasonic homogenizer for 2 hours (16). The fluid was found stable for three months. The varied time duration in ultrasonic homogenizer were experimented by many authors and got different stability results of particular nanoparticle and its base fluid. In a single step method, the nanoparticle is prepared by direct evaporation and condensation in the base fluid to provide and enhance the stability.

It is of many methods like chemical vapor deposition (CVD) method, the electrical explosion of wire (EEW), Electric discharge machining method, etc. In this CVD methods were used predominantly by many researchers.

II. STABILITY, RHEOLOGICAL AND AGGLOMERATION PROPERTIES

Thermo-physical properties of nanofluid play a significant role in the many industrial applications, especially in the heat transfer application. Since the thermal conductivity and good stability made the nanofluid an effective heat transferring medium (12). For better thermal conductivity, the concentration of the nanoparticle has to be high. But it leads to increased aggregation while applying and the stability got reduced. So these thermo-physical properties had to be tested and engaged with the optimum level. Zeta potential, spectral absorbency and visual inspection are used for the stability investigation of the nanoparticle in the base fluid (12). Osman et al 2019 (11) prepared the alumina nanoparticle and he had used ultrasonicator (Qsonice Q700) with an amplitude of 60% for 20 minutes at 3 s pulse on and 1 s pulse off intervals to enhance the stability of the nanofluid. By measuring the viscosity at 25 °C over 24 hour and visual inspection of one week, he found no agglomeration during his inspection. Hadi Barzegari et al (3) discussed that during the preparation of the alumina nanoparticle in distilled water without using surfactant, the stability was good at 120-minute sonication process compared to 30 minutes. Higher particle volume fraction leads to premature sedimentation during continuous experimentation. M. M. Elias et al (5) studied the thermo-physical properties of the alumina nanofluid and measured the thermal conductivity, density, viscosity, specific heat and stability using different measuring instruments and concluded the results with 25°C to 55°C. Stability of the nanoparticle depends on the volume fraction, shape, size and thermo-physical properties of the nanoparticle and the base fluid. Sedong Kim et al (9) discussed that after Ultrasonic excitation over three different concentrated nanofluids created effective dispersion of nanoparticles in a base fluid compared to the untreated nanofluid which was kept for 7 days. Mohsen Motevasel et al (13) had used magnetic stirrer, ultrasonicator (UIP500, Hielsher Co.) and Zeta potential (Malvern, ZEN 3600) to measure the stability of the nanofluid which shows no sedimentation for 2 days and the Zeta potential value was more than 30 mV which denoted the nanofluid was stable. Modak et al (14) performed two-step method by preparing in Sonicator for 5 h continuously to acquire a more stable and evenly dispersed nano-particle suspension. The thermal conductivity and absolute viscosity of the nanofluids were measured using thermal properties analyzer (KD-2 Pro, Decagon devices) with an accuracy of ±0.5 and viscosity meter (LVDV-II + PRO, Brookfield Digital Viscometer, USA). N. A Usri et al (17) experimentally discussed that the increase in the percentage of ethylene glycol base fluid decreases the thermal conductivity of the nanofluid. The thermal conductivity was measured with KD2 pro thermal analyzer for 13nm alumina nanofluid and attains maximum at 2.0 % volume concentration at 70 °C for all base fluid. Abdul Hamid et al (16) experimentally studied the viscosity of alumina nanofluid with water and ethylene glycol as base fluid with Brookfield LVDV III Ultra Rheometer. He concluded that at 30 to 70 °C, the viscosity of nanofluid was influenced by nanofluid concentration in the base fluid, ethylene glycol concentration and temperature.

III. RESULTS AND DISCUSSION

Hadi Barzegari et al (3) experienced that the convective heat transfer coefficient was increasing with the increase in dean number for both distilled water and nanofluid using Wilson method. The higher result is obtained only in the lower volume fraction of nanofluid at 70°C. The hot fluid temperature creates an impact on the viscosity of the nanofluid, heat transfer rate and particle concentration of the nanoparticle. Mehdi Bahiraei et al (6) discussed the influence of concentration of nanoparticle and Reynolds number over the heat flux, pumping power, overall and convective heat transfer coefficient were studied. He states that in spiral heat exchangers the at 2% concentration, the convective heat transfer coefficient increases about 134.4% with the Reynolds number from 4000 to 11,000 and it augments almost 26.3% with raises of the concentration from 0 to 5% at Reynolds number of 10,000. The pumping power increases when decreasing the hot and cold pipe gap, increase in Reynolds number and concentration. Prabhat Chaurasia et. al (7) experimentally stated that in automobile radiator the influence of Al_2O_3 nanofluid over water as a coolant. In this, the flow rate and air flow rate increases with the heat transfer performance and the heat transfer rate were found the maximum of 44.29% and effectiveness of 40.3% at 0.2% volume fraction at 40 LPH. He concluded that the effectiveness was attained higher with lower flow rates. Amin Shahsavar et al (8) experimentally depicted that, nanoparticle shapes, platelet-shaped gave good heat transfer characteristics and in performance index of the heat exchanger spherical nanoparticle containing nanofluid is higher. Sedong Kim et al (9) stated that as the heat transfer coefficient, Reynolds number and concentration was increased with the decrease in the tube diameter. M. M. Elias et al (5) showed that in a plate heat exchanger, the 60° chevron angle showed better performance in comparison with 30° chevron angle with heat transfer coefficient, the overall heat transfer coefficient and the heat transfer rate 15.14%, 7.8%, and 15.4%, respectively. Nallusamy et.al [10] experimentally stated that the presence of Al_2O_3 nanoparticle in the water as a base fluid increases the nusselt number and overall heat transfer coefficient with 1% volume concentration in shell and tube heat exchanger. Shell and tube heat exchanger provides higher performance with an increase in concentration and higher compared to parallel and counter flow heat exchangers. Sohaib Osman et al 2019 (11) experimentally studied heat transfer enhancement by comparing the laminar, turbulent and transition flow regime in the rectangular channel with one step method nanofluid preparation. In this work, the results he attained that the transition flow in the rectangular channel had 54% heat transfer enhancement compared to the turbulent flow with 11% at 1% concentration with the Reynolds number range of 200–7000. Mohsen Motevasel et al (13) observed that changes in the nanoparticle type had no significant effect on the increase in heat transfer coefficient.

Table 2 Research of alumina nanofluid

Researchers &Year	Nano Fluids Utilized	Base fluids utilized	Particle Size (nm)	Particle Volume Concentration (Vol %)	Preparation method	Heat Exchangers	Result and Discussion
Hadi Barzegaril et al 2019	Al_2O_3	Distilled water	-	0–0.5%	Two-step method	Shell and coil	The volume fraction of 0.016, the flow rate of 3.5 L/min, and a temperature of 70°C gave better result
Sedong Kim et al 2019	Al_2O_3	water	40	0.5%, 1.0% & 2.0%	Two-step method	Small diameter tubes in electronic systems	The heat transfer coefficient at 0.8 mm diameter was about 160 % higher compared to 2.0 mm diameter at the Reynolds number of 1588.
Amin Shahsavar et al 2019	Boehmite alumina	water/ethylene glycol	-	0.5–2.0%	Two-step method	Double-pipe mini channel Heat Exchanger	Platelet-shaped gave good heat transfer characteristics and in performance index of the heat exchanger spherical nanoparticle containing nano, fluid is higher.
Prabhat Chaurasia et. al 2019 (7)	Al_2O_3	Distilled water	50–200	0.1%, 0.15% & 0.2%	Two-step method	Automobile radiator	The heat transfer rate and effectiveness was 44.29% and 40.3% at 0.2% volume fraction at 40 LPH.
Sohaib Osman et al 2019 (12)	Al_2O_3	Water	30	0.3, 0.5 & 1%	One step method	Rectangular channel	Convective heat transfer coefficient was higher in the transition flow regime compare to the turbulent flow regime.
Mehdi Bahiraei et. al 2018 (6)	Al_2O_3	Water	-	0 to 5%	Two-step method	Spiral Heat Exchanger	Overall and convective heat transfer coefficient and heat flux increases with increase in Reynolds number and concentration
Nallusamy et. al 2018 (10)	Al_2O_3	Water	50	1%	Two-step method	Parallel, Counter and Shell and Tube heat exchanger	Shell and tube heat exchanger provides higher performance with an increase in concentration and higher compared to parallel and counter flow heat exchanger.
M.M Elias et. al 2018 (5)	Al_2O_3	Water	30	0 - 0.5%	Two-step method	Plate heat exchanger	Pressure drop increases with the increase in concentration which is the main drawback in the plate heat exchanger. In this 60° chevron angle showed better performance in comparison with 30° chevron angle.
Mohsen Motevasel et al 2018 (13)	Al_2O_3, CuO, SiC	Distilled water	20, 40, 50	0.02 - 0.2%	Two-step method -	Vertical pipe	Heat transfer coefficient of Al2O3, CuO and SiC was not much changed with the same Reynolds number and a new model was proposed for finding local heat transfer coefficient
Modak et al. 2018 (14)	Al_2O_3, aqueous surfactant solution	Pure water	<100	0.15%, 0.6%;100 – 400 ppm	Two-step method	Hot surface	The heat transfer enhancement for Al2O3 nanofluid and aqueous surfactant solution was 140%, 207%, and 117% higher compared to pure water.

IV. CONCLUSION, CHALLENGES AND FUTURE WORK

In this study, we could understand that the thermo-physical properties with the volume concentration of alumina nanoparticle gave a serious impact on the enhancement of heat transfer. These properties are majorly created at the time of preparation of nano fluid with different methods. The following are the summary, challenges and future works of alumina nanofluid production and application.

- The preparation method has to be chosen appropriately, to the proper maintenance of the thermo physical properties. Even though the suitable preparation methods are available, the stability and agglomeration of the nanoparticle in the base fluid is still a non-rectified problem persist in this nano-thermal world.
- During the synthesis of nanoparticle, a chemical method prepared the nanoparticle faster compared to others yet it uses toxic chemicals and it is non-eco-friendly (15). So the eco-friendly biological process has to be determined for active production of alumina nanoparticles.
- Since it is a metal oxide nanoparticle, the two-step method is enough for the preparation with the above-discussed information.
- Increase in concentration of the nanoparticle enhances the convective heat transfer coefficient.
- Convective heat transfer coefficient was better in the transition flow compared to the turbulent flow.
- The heat transfer enhancement was higher when using alumina nanofluid compared to any aqueous alcohol solutions or water.
- According to the comparative study, the Al_2O_3, CuO, SiC nanofluids, the heat transfer coefficient didn't change much with the constant Reynolds number maintained.
- The performance of shell and tube heat exchanger was better compared to the parallel or counterflow heat exchangers.

This recent review study on alumina nanofluid would help the researchers to choose the suitable application, the preparation according to the stability, thermal conductivity, and viscosity of the alumina nanoparticle and the instruments available to measure these different properties. The usage of alumina nano fluid is extended over many decades due to its good properties, easy adoptability to the given application, economic and ease in preparation.

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