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A Review on Performance of Heat Exchanger using Nanofluids

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Abstract-The nanofluid is advanced type of fluid which is made up of colloidal suspensions of nanoparticle used as heat transfer fluid in different type of heat exchanger and other cooling purpose in industry as well as automobile. From the current review, it can be seen that nanofluids clearly exhibit enhanced thermal conductivity, which goes up with increasing volumetric fraction of nanoparticle. This paper focuses on presenting the broad range of current and future applications that involve nanofluids, emphasizing their improved heat transfer properties that are controllable and the specific characteristics that these nanofluids possess that make them suitable for such applications.

Keyword- *Nanofluid, Plate fin Heat exchanger, double pipe heat exchanger, heat transfer properties.*

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I. INTRODUCTION

A. HEAT EXCHANGER

Heat exchanger is device which is used to transfer heat from hot fluid to cold fluid. Heat exchanger is device built for efficient heat transfer and acquires compact size. So heat exchanger finds several industrial and engineering applications. The typical application involves heating or cooling of fluid stream of concern and evaporation or condensation of single or multi component fluid stream. In other application, the objective may be to recover or reject heat, or sterilize, pasteurize, fractionate, distill, concentrate, crystallize, or control a process fluid. Heat exchangers play an increasingly important role in the field of energy conservation. So it is necessary to improve performance of heat exchanger by designing the component and on enhancing the thermal potential of working fluid.

B. NANOFLUID

Nanofluids are the new generation heat transfer fluids for various industrial and automotive applications because of their excellent thermal performance and the word was which was coined at Argonne National Laboratory of USA by Choi in 1995, which showed that the conventional liquid thermal performance could be remarkably improved using nanoparticle. Nanofluids can be used for a wide variety of engineering applications like transportation, electronics, medical, food, defense, nuclear, space, and manufacturing of many types. Magnetic nanoparticle in bio-fluids can be used for medical applications as drug delivery vehicles, providing new cancer treatment technique. Using nanofluids in heat transfer applications will provide a number of potential advantages, such as better long-term stability, miniaturized heat exchangers, Improved heat transfer, reduced heat transfer fluid inventory, little penalty in pressure drop, and can have significantly greater thermal conductivity. As a result, these offer an opportunity for engineers to develop highly compact and effective heat transfer equipments.

II. PREPARATION OF NANOFLUID

Nanofluids are prepared by mixing nanoparticle with fluids is first done by Stephen U.S. Choi. Since then, there has been rapid development in the synthesis techniques for nanofluids. There are two techniques to prepare nanofluids for the study or research which are the single-step or the two step-methods. In *Two-step process* first nanoparticle are produced as a dry powder, typically by inert gas condensation. The second step involves dispersion of dry nanoparticle powder into a base fluid, like water, oil or ethylene glycol. The advantage of two-step process is that the inert gas condensation technique has been scaled up to commercial nanopowder production. A deficiency of this method is the tendency of nanopowder to agglomerate during storage and dispersion in the base fluids, particularly with heavier metallic nanoparticle. *A single-step* approach is emerging as a powerful method for growing nanostructures of different metals, semiconductors, non-metals and hybrid system. Laser ablation is another much sought, single-step technique that simultaneously makes and disperses nanoparticle directly in the base fluids. A variety of nanofluids has been prepared by laser ablation method by ablating solid metals, semiconductors, which are submerged in the base fluid. By creating the nanofluid in this way, stable nanofluids resulted without using any property-changing dispersants.

III. LITERATURE REVIEW I

F.S. Javadi et al. [10] calculated the Al_2O_3, TiO_2, SiO_2 nanofluids on the plate fin heat exchanger.

In this plate fin heat exchanger is taken which has various applications such as air conditioners, petrochemical processes, gas liquefiers, oil and gas processing, automobile radiators, waste heat recovery, aeronautical and cryogenic

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system. This study is focused on increasing the heat transfer rate and minimizing the pressure drop.

Properties of nanofluid:-

Properties	SiO2	TiO2	Al2O3
ρ	2220	4157	3970
C_p	745	710	765
K	1.38	8.4	36

Heat capacity of base fluid is 1043 J/kgK and Prandtl number of hot and cold fluid is 0.74767 and 0.75, respectively.

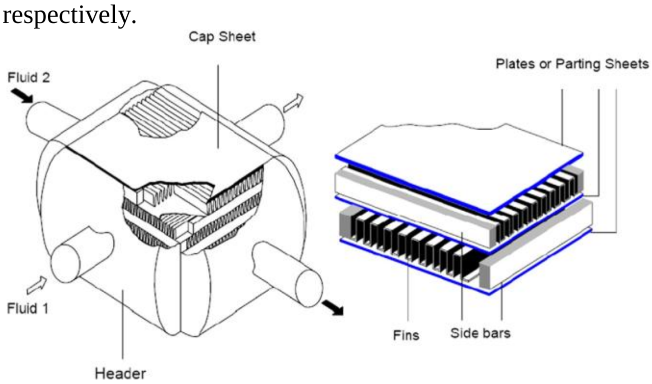

Fig.1 Plate fin heat exchanger[10]

In this experiment several comprising graph are found. This graph depend upon the concentration of nanoparticle in nanofluid. Thermal conductivity, pressure drop, heat transfer rate are parameter is varies with the concentration of nanoparticle. Following graph show the result after calculation.

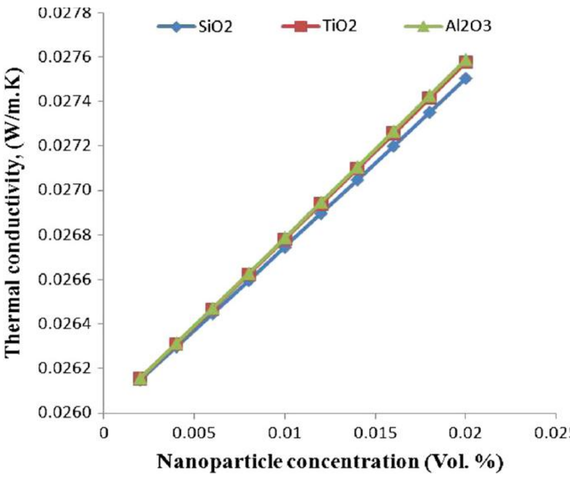

Fig 2. . The thermal conductivity at different volume fraction[10]

This thermal conducticity is calculate by

$$k_{nf} = \left[\frac{kn+2kf+2\phi(kn-kf)}{kn+2kf+\phi(kn-kf)}\right]k_f$$

where,

$$\phi = \frac{\frac{mn}{\rho n}}{\frac{mn}{\rho n}+\frac{mf}{\rho f}}$$

This graph shows that comparison between the thermal conductivity of nanofluids with nanoparticle volume fraction. The thermal conductivity of TiO2 and Al2O3-Nanofluid are almost same and it is more than thermal conductivity of SiO2 nanofluid. In fact, the graph show that thermal conductivity increases by increasing the nanoparticle volume fraction in basefluid.

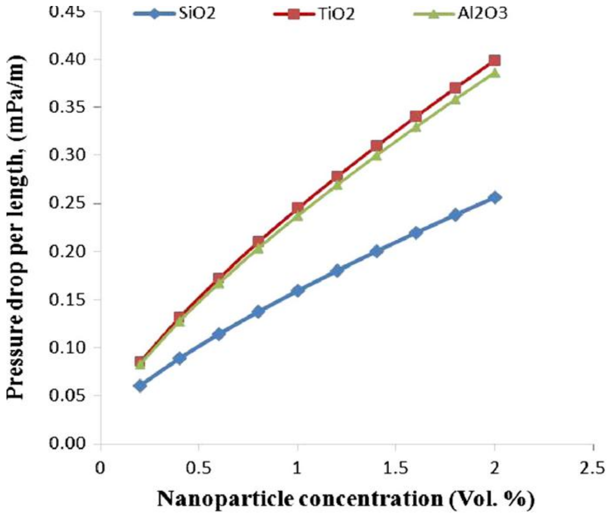

Fig 3..Pressure drop per unit length for different nanofluids[10]

This pressure drop can be calculated as

$$p = \frac{4FLG^2}{2\rho D}$$

Where F=frictional factor & G=mass velocity

From above obtained graph, it can be seen that the lowest pressure drop occurs by applying SiO2 nanoparticle, while using TiO2 and Al2O3 nanoparticle result in remarkable higher pressure drop. It is shown that higher pressure drop is obtained with higher volume concentration of nanofluid.

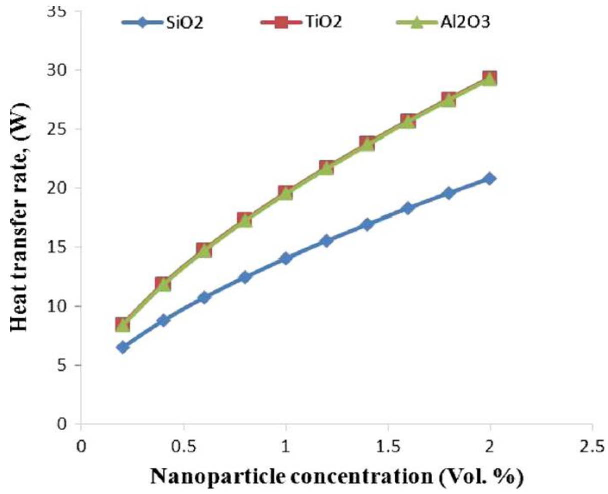

Fig 4. Heat transfer rate of plate fin heat exchanger with different nanofluids[10]

From above graph it is seen that the highest heat transfer rate is obtained for TiO2 and Al2O3 nanofluids whereas the SiO2 show the lowest heat transfer rate. This is because that TiO2 has higher density and Al2O3 has higher specific heat. Therefore they have almost similar effect on the rate of heat transfer. The heat transfer rate for TiO2 and Al2O3 nanofluid is 30% greater than the SiO2.

Conclusion from literature review I

The thermal conductivity of the base fluid increases by adding nanoparticle. The increment of thermal conductivity by adding TiO2 and Al2O3 was almost the same and it was higher than SiO2.

1. The heat transfer characteristics of a plate fin heat exchanger increases with increasing the volume concentration of nanoparticle.
2. Al2O3 nanofluid suggest as the best nanofluid for plate fin heat exchanger as it posses higher thermal conductivity and lower pressure drop respect to TiO2.

IV. LITERATURE REVIEW II

Calvin H. Li et al.[12] checked the effect size of nanoparticle on effective thermal conductivity of Al2O3-water nanofluid.

In this paper the author checked whether the thermal conductivity of nanofluid is increases or decreases with changing volume concentration and critical dimension of nanoparticle in nanofluid . He used a steady-state method was used to evaluate the effective thermal conductivity of Al_2O_3/distilled water nanofluids with nanoparticle diameters of 36 and 47 nm. Tests were conducted over a temperature range of 27–37 °C.

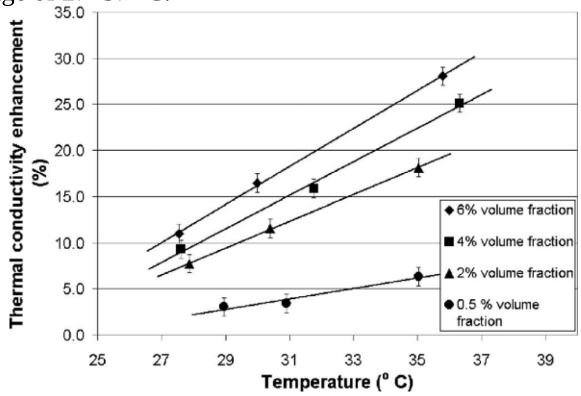

Fig 5. Temperature vs thermal conductivity at different volume fraction[12]

From this graph it is clearly shown that the thermal conductivity is increases with increasing the volume fraction and temperature. The highest enhancement is for 6% of volume fraction at 37°C.

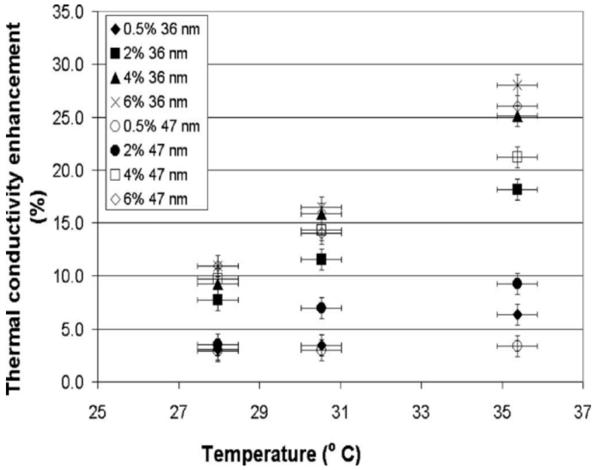

Fig 6. Temperature vs thermal conductivity at different volume fraction of 36nm and 47nm nano size particle.[12]

From this graph it is seen that the thermal conductivity is increases with volume fraction but decreases with increasing dimension of nanoparticle.

Conclusion from literature review II

1. Thermal conductivity is increases with increasing volume fraction in nanofluid.
2. Thermal conductivity is less for the higher dimension nanoparticle in nanofluid.

V. LITERATURE REVIEW III

Sr No	Author Name	Nanofluid Used	% Volume Concentration of Nanofluid	Type of Heat Exchanger	Enhancement in Heat Transfer Coefficient
1	Mukeshkumar P.C et al. [1]	Al2O3/Water 45-50 nm	0.4 % and 0.8%	Shell and helically coiled heat exchanger	4-8 % Higher at 0.4 % 5-9 Percent Higher at 0.8 Percent
2	Elsayed et al. [3]	Al2O3/Water	3 %Volume Fraction of Nanofluid	Helically coiled tube	Increased by 60 Percent
3	Elias et al. [2]	Water/Ethylene Glycol	0 to 1 %	Shell and tube heat exchanger	for Cylindrical Shape 2.4% Higher At 1 % concentration
4	Maddah et al.[4]	Al2O3/Water 20-22 nm	0.2 and 1 Percent	Horizontal double pipe heat exchanger	Increased by 12 to 52 %
5	Senthilraja et al. [5]	CuO/Water 27 nm	1% and 3 %	Double pipe heat exchanger	Greater with 0.3 % Volume Concentration
6	El-Maghlany et al.[7]	CuO/Water	1 to 3%	Shell and tube heat exchanger	Heat transfer in the NTU is 51.4% increased And while the pressure drop increases by 136%.

Conclusion From Literature Review III

1. The heat transfer coefficient is continuously increased with introducing the nanofluid in heat exchanger. The heat transfer coefficient is highest at the higher concentration of nanoparticle.
2. The size of nanoparticle varies from 9-45 nm different for different nanofluid.
3. Efficiency of heat exchanger is varies by factors like temperature flow rate, concentration of nanofluid, size of heat exchange

VI. FUTURE SCOPE

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 drag. 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.

Brake and Other Vehicular Nanofluid:-As vehicle aerodynamics is improved and drag forces are reduced, there is a higher demand for braking systems with higher and more efficient heat dissipation mechanisms and properties such as brake nanofluid. A vehicle's kinetic energy is dispersed through the heat produced during the process of braking and this is transmitted Through out the brake fluid in the hydraulic braking system. If the 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. Such an occurrence will in turn will cause a brake malfunction and poses a safety hazard in vehicles. Since brake oil is easily affected by the heat generated from braking, nanofluids with enhanced characteristics maximize performance in heat transfer as well as remove any safety concerns.

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