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Heat Transfer Enhancement in Heat Exchanger by using Nano Fluid: a Review

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Abstract: *Heat exchangers are playing a vital role in many engineering applications like petrochemical plants , power cycles ,automobile ,building ,electronic sectors etc. To intensify heat transfer with minimum pumping power innovative heat transfer fluids called nanofluid have become the major area of research now a days .Recently stable homogeneous graphene nanoplatelet (GNP) nanofluid is studied for maximum heat transfer rate alongwith different nanofluids. This review paper focuses on previous work comprising performance of heat exchangers using nanofluids experimentally as well as numerically for different flow rates and different volume concentrations. The results show variation in overall heat transfer coefficient ratio and pressure drop ratio for different nanofluids. Secondly it gives an idea about applications of nanofluids in heat exchangers alongwith usefullness of nanofluids based on experimental and numerical investigations. The review of previous works by reasearchers suggests that nanofluids have great potential in augmentation of heat transfer of a heat exchanger. There is a wide scope on perfomance of heat exchanger and applications of nanofluid in the comming years.*
Keywords: *Heat exchanger, heat transfer, Nano fluid, overall heat transfer coefficient*

I. Introduction

Heat exchanger is a device which transfers heat from hot fluid to cold fluid. Nano fluid is used as a cold fluid in heat exchanger which considered as a three phase fluid i.e. solid phase (nanoparticles), liquid phase (base fluid), and interfacial phase therefore it increases the rate of heat transfer and efficiency of heat exchanger as well. In many field like Automobiles, boilers, cooling towers, and cogeneration systems use of nanofluid has become one of the emerging topics discussed due to its favorable characteristics in thermal and electrical conductivity. The colloidal mixture of Nano particles of size 1 to 100nm are dispersed in water by different methods and to monitor the stability of nanofluid samples photo capturing technique was utilized. Nanofluid is prepared either by one-step or two-step method. In one-step method nanoparticles are synthesized in base fluid by using chemical methods. In case of two step method nanoparticles are firstly prepared in powder form by physical or chemical methods like laser ablation and sol- gel processing. Nano fluid stability and concentrations are characterized for best results. The study of heat transfer enhancement and flow characteristics of nano fluid aims at various parameters like overall heat transfer coefficient ratio verses coolant volume flow rate, heat transfer coefficient verses coolant volume flow rate, pressure drop verses coolant volume flow rate[1].

II. Literature Review

Albadr et al. [1] experimentally studied horizontal shell and tube heat exchanger for forced convective heat transfer and flow characteristics of a counter flow under turbulent flow conditions for water as base fluid and different volume concentrations of Al_2O_3 nanofluid. They found that nanoparticles dissolved in distilled water not only increases thermal conductivity but also viscosity of the nanofluid. Friction factor increases with the increase in volume concentration of nanoparticle. Particle volume concentration of 2% the use of Aluminum oxide nanofluid gives significantly higher heat transfer characteristics.Farajollahi et al. [2] Used shell and tube heat exchanger for comparative investigation of Al_2O_3 and TiO_2 water nanofluid.They studied that at different nanoparticle concentrations the heat transfer enhancements of both nanofluids are different. TiO_2/water and ɣ-Al_2O_3/water nanofluids has better heat transfer at higher volume concentrations, respectively.Tiwari et al. [3] investigated experimentally to optimize particle volume fractions depends on a high heat transfer rate, convective heat transfer coefficient, also overall heat transfer coefficient, effectiveness and performance index. They gives result that the optimum volume conc. of Al_2O_3, CeO_2, SiO_2 and TiO_2 nanoparticles in water were 0.75, 1.0, 0.75 and 1.25 vol.%, for maximum heat transfer rate, overall heat transfer coefficient, convective heat transfer coefficient and effectiveness, respectively. El-Maghlany et al. [4]experimentally investigated the thermal behavior of horizontal double tube heat exchanger having counter flow. Due to availability of high surface area for heat transfer, there is enhancement in overall heat transfer coefficient. They observed that availability of nanofluid and the rotation of inner pipe effectively increase the heat transfer rate however, On account of rotational speed of the inner pipe, pressure drop increases significantly.Vermahmoudi et al. [5] experimentally investigated by considering laminar flow conditions, overall heat transfer coefficient of water based iron oxide nanofluid has been measured in compact air cooled heat exchanger. The concentrations range of 0.15%, 0.4% and 0.65 vol.% of stabilized Fe_2O_3/water nanofluid have been examined with different flow rates in the range of 0.2–0.5m^3/h. The result shows that when nanofluid inlet temperature increases from 50 to 80 °C, the overall heat transfer coefficient reduced due to the large increase in the LMTD with gradually increasing nanofluid temperature difference. Javadi et al. [6] studied SiO_2, TiO_2 and Al_2O_3 nanofluids were passed in a plate heat exchanger and the behavior on thermo physical properties and heat transfer characteristics are compared with the base fluid. They concluded that the increasing nanoparticle's volume concentration, Prandtl number goes on decreasing. At 0.2% volume concentration maximum Prandtl number occurred which is equal to 0.406, 0.415,and 0.382 for Al_2O_3, SiO_2, and TiO_2 nanofluids, respectively. Mare et al. [7] studied experimentally of two types of nanofluids for their thermal performances for comparision. The first nanoparticles used alumina oxide dispersed in water and the other one is aqueous suspensions of nanotubes of carbons. They found that for the same Reynolds number an improvement of convective heat transfer coefficient in laminar mode is about 42% and 50% for N1 and N2 respectively when compared with pure water. Suresh et al. [8] investigated experimentally thermal characteristics of Al_2O_3/water and CuO/water nanofluids in transition flow in helical screw tape inserted in straight circular duct. Thermal performance analysis is mainly depends on the constant pumping power criteria , helical screw tape inserts give better thermal performance when used with CuO/water nanofluid than with Al_2O_3/water nanofluid. They concluded that CuO/water nanofluid is more efficient and gives better enhancement in heat transfer compared to Al_2O_3/water nanofluid. Tiwari et al. [9]experimentally investigated the performance of the plate heat exchanger have been studied using different nanofluids (CeO_2, Al_2O_3, TiO_2 and SiO_2) for best overall heat transfer rate at different volume flow rates and specific range of concentrations. They gives result that at the lower volume concentrations TiO_2 and CeO_2 nanoparticles possesses better heat transfer characteristics and at the higher volume concentrations Al_2O_3 and SiO_2 nanoparticles at the higher volume concentrations are more effective. Sarafraz et al. [10] investigate experimentally the heat transfer coefficient and pressure drop characteristics of carbon nanotube water-based nanofluids inside the double pipe heat exchanger. They observed that presence of carbon nanotubes inside the deionized water can enhance the thermal conductivity of nanofluid up to 56% for wt.% = 0.3. Labib et al. [11] studied numerically convective heat transfer of Aluminum oxide nanoparticle into two different base fluids . They gives result that heat transfer coefficient enhancement appears to be more for using Ethylene Glycol as a base fluid than water. Tiwari et al. [12] experimentally investigated the heat transfer and pressure drop characteristics in a chevron-type corrugated plate heat exchanger using CeO_2/water nanofluid as the coolant. Their result indicate that the convective heat transfer coefficient increases with increase in nanoparticle volume concentration (up to optimum value), volume flow rate of the heating fluid and coolant volume flow rate, and decrease in nanofluid temperature. Aliabadi et al. [13] studied numerically convective heat transfer coefficient in the vortex-generator plate-fin channels copper-base deionized water nanofluid with laminar and steady-state flow, and validate their results by CFD method. They gives outcome that the better prediction of nanofluids flow inside the tested channel at the studied range. The average deviation between the experimental data and the CFD results based on this model for 0.1, 0.2, and 0.3% wt. nanofluids was about 4.2%, 3.1%, and 1.4%, respectively.

III. Dispersed Nanoparticles In Base Fluid

The Fig.1 shows the image of dried GNP suspensions with different specific surface areas. For the GNPs, the sheet-like structure with a lateral size at the micrometer length scale has been well captured as shown in Figure [14]. Figs.2,4,5,6 shows TEM images of dispersed SiO_2 ,CeO_2 ,Al_2O_3 ,TiO_2 . A TEM is use to find exact size of the nanoparticles shown in Figs 2,4,5,6 [3]. Fig.3 The Copper-nanoparticles are shown in the dispersed form, photo presented taken by(TEM). Cu-nanoparticles have a spherical in shape & their size diameters have a normal distribution in a range from 63 to 100 nm [4].

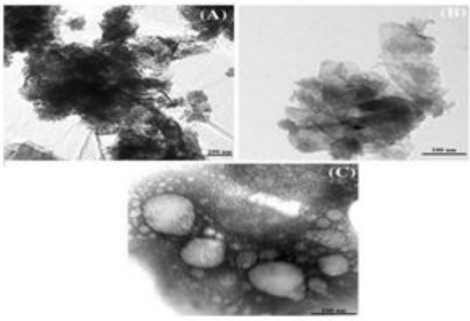

Fig.1: (TEM photographs of GNP nanoparticles. GNP 300, (B) GNP 500, and (C) GNP 750.[14]

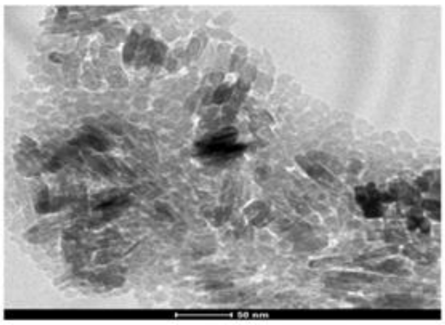

Fig.2: (TEM of dispersed SiO_2 Nano particles in water).[3]

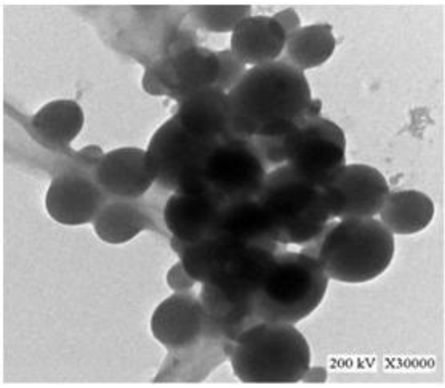

Fig.3: TEM photograph of Cu-nanoparticles[4]

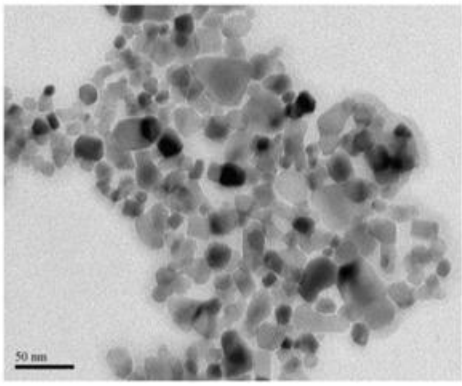

Fig.4: TEM photograph of dispersed CeO_2 nanoparticles in water.[3]

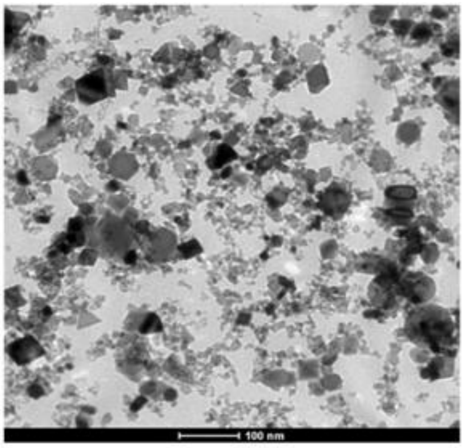

Fig.5: TEM photograph of dispersed Al_2O_3 Nano particles in water.[3]

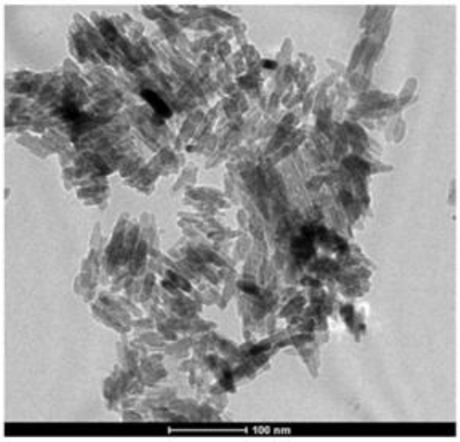

Fig.6: TEM photograph of dispersed TiO_2 nanoparticles in water.[3]

IV. Results And Discussion

Table 1 provides the properties of nanofluids and base fluid. From this study thermal conductivity, density, viscosity of CeO_2 is greater than Al_2O_3,TiO_2,SiO_2. Heat capacity of SiO_2 is greater than Al_2O_3,TiO_2,CeO_2. Table 2 shows experimental results done by various researchers. Heat transfer rate is maximum at higher concentration ensure a high-quality product, diagrams and lettering MUST be either computer-drafted or drawn using India ink.

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Table 1. Thermophysical Properties of nanofluid and base fluid

Property	Water	CeO_2	Al_2O_3	TiO_2	SiO_2
Thermal Conductivity k (W/mK)	0.618	0.662	0.642	0.627	0.620
Viscosity μ (mPas)	0.62	0.68	0.67	0.66	0.68
Density ρ (kg/m^3)	992	1008	1002	1003	1001
Heat Capacity C_p (J/kg K)	4182	4046	4110	104	130

Table 2. Experimental Result

Author	Base fluid	Nano particle material	Volume concentration	Remark
Albadr et al. [1]	Water	Al_2O_3	0.3 to 2%	1.The maximum augmentation ratio is 1.596 at 0.0125 L/s 2.Nusselt number is 62.6% greater than that of distilled water.
Farajollahi et al. [2]	Water	γ-Al_2O_3 TiO_2	0.3 to 2%	Augmentation of heat transfer of γ-Al_2O_3 and TiO_2 has same.
Tiwari et al. [3]	Water	CeO_2, Al_2O_3,SiO_2,TiO_2	0.75 to 1.25%	Optimum concentration depends on base fluid, Materials of the nanoparticle, temperature and volume flow rate.
El-Maghlany et al. [4]	Water	Cu	1 to 3%	Heat transfer in the NTU is 51.4% increased and the effectiveness enhanced by 30.7% while the pressure drop increases by 136%.
Vermahmoudi et al.[5]	Water	Fe_2O_3	0.15 to 0.65	Heat transfer enhancement due to inlet temperature of nanofluid is increase 116%. 0.65% concentration increase heat transfer coefficient about 13% and heat transfer rate up to 11.5%.
Javadi et al. [6]	Water	SiO_2, TiO_2 and Al_2O_3	0.382 to 0.415%	The enhancement of thermal conductivity by adding TiO_2 and Al_2O_3 was almost the same and it was higher than SiO_2.

V. Conclusion

In this paper, experimental and numerical investigation of different researchers from previous work on heat transfer enhancement of heat exchangers by using different nanofluid has been reviewed for wide range of Reynolds number and nanoparticle concentrations.

1. Heat exchangers used were plate heat exchanger, shell and tube type, and double pipe heat exchanger. Heat transfer rate in plate heat exchanger is more than in shell and tube heat exchanger with minimum pressure drop.
2. The overall heat transfer augmentation ratio in the range of 1.22 to 1.596.heat transfer enhancement goes in increasing with increasing nanoparticle volume concentration.
3. Nanofluids used were CeO_2 , Al_2O_3 ,TiO_2 ,SiO_2,Fe_2O_3. The nanoparticle concentration varies from 0.3 to 3%.
4. Nanoparticle size varies from 9 to 10 nm for CNT and 30 to 37 nm for other nanofluids.
5. Nanofluids are more efficient as compare to other base fluids.
6. Efficiency of heat exchanger is varies by factors like temperature flow rate, concentration of nanofluid, size of heat exchanger.

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