HEAT TRANSFER ENHANCEMENT USING VARIOUS NANO FLUIDS –A REVIEW

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Abstract

Heat exchanger plays a very important role in modern industry. To improve the heat transfer rate the new innovative fluid is introduced called Nanofluid to improve the overall heat transfer. Nano fluid is Nano meter sized particle such as metal, oxide, and carbide etc., dispersed into base heat transfer fluid. This review paper is on the preparation of the nanofluids. Comparison of the past research on Nanofluids. Applications of the Nanofluids. Thermal conductivity is affected by the following parameters like shape, size, clustering, collision, porous layer, melting point of nanoparticle etc., controlling this type of parameters to increase the thermal conductivity of Nano fluid.

Keywords: Nano fluid; thermal conductivity; heat transfer rate; Heat exchanger.

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1. INTRODUCTION

A Nano fluid is a fluid contain Nano metre size metal particle, called Nanoparticles. These Nanofluids are engineering colloidal suspension of nanoparticle in base fluid by different methods. Nanoparticle used in Nano fluids are typically made of metals, oxides, carbides or carbon Nano tube. Common Nano particles are, Al_2O_3, CuO, TiO_2, CeO_2 and SiO_2. Base fluids include water, ethylene glycol and oil. Synthesis and stability of nanofluids are the two very primary requirements to study nanofluids [1]

2.CLASSIFICATION OF NANO PARTICALS

Nano particles are broadly divided into various categories depending on their morphology, size and chemical properties.[2]

2.1. Carbon-based Nano particle

Fullerenes and Carbon Nanotubes (CNTs) represent two major classes of carbon-based Nano particles Fullerenes contain nanomaterial that are made of globular hollow cage such as allotropic forms of carbon. These materials possess arranged pentagonal and hexagonal carbon units, while each carbon is sp^2 hybridized. CNTs are elongated, tubular structure, 1–2 nm in diameter. These can be predicted as metallic or semiconducting reliant on their diameter telicity. These are structurally resembling to graphite sheet rolling upon itself. The rolled sheets can be single, double or many walls and therefore they named as single-walled (SWNTs), double-walled (DWNTs) or multi-walled carbon nanotubes (MWNTs)

2.2. Metal Nano particles

Metal Nano particles are purely made of the metals precursors. Due to well-known localized surface plasmon resonance (LSPR) characteristics, these Nano particles possess unique optoelectrical properties. Nano particles of the alkali and noble metals i.e. Cu, Ag and Au have a broad absorption band in the visible zone of the electromagnetic solar spectrum.

2.3. Ceramics Nano particles

Ceramics Nano particles are inorganic non-metallic solids, synthesized via heat and successive cooling. They can be found in amorphous, polycrystalline, dense, porous or hollow forms. Therefore, these Nano particles are getting great attention of researchers due to their use in applications such as catalysis, photocatalysis, photodegradation of dyes, and imaging applications.

2.4. Semiconductor Nano particles

Semiconductor materials possess properties between metals and non-metals and Semiconductor Nano particles possess wide bandgaps and therefore showed significant alteration in their properties with bandgap tuning. Therefore, they are very important materials in photocatalysis, photo optics and electronic devices.

2.5. Polymeric Nano particles

These are normally organic based Nano particles and, they are mostly nanospheres or noncapsular shaped. The former are matrix particles whose overall mass is generally solid and the other molecules are adsorbed at the outer boundary of the spherical surface.

3. APPLICATION OF NANO FLUIDS

Nano fluid can be used to cool automobile engine and welding equipment and cool high heat flux device such as high-power microwave tube, and high-power laser diode array. [3]

Some common applications are:

- Solar water heating
- Refrigeration
- Defence and space application
- Thermal storage
- Engine transmission oil
- Boiler exhaust flue gas recovery
- Cooling of electronic circuit
- Nuclear cooling system

- Bio-medical application
- Drilling and lubrication
- Engine cooling

4. SYNTHESIS OF NANO PARTICLES

Various methods of preparing nanomaterials including Gas Condensation, Vacuum Deposition and Vaporization, Chemical Vapor Deposition (CVD) and Chemical Vapor Condensation (CVC), Mechanical Attrition, Chemical Precipitation, Sol-Gel Techniques, Electrodeposition.[4]

4.1 Gas Condensation

Gas condensation was the technique used to synthesize nanocrystalline metals and alloys. In this technique, a metallic material is vaporized using Joule heated refractory crucibles or electron beam evaporation devices as source for thermal evaporation. At atmosphere of 1-50 m bar. In gas evaporation, a high residual gas pressure causes the formation of ultra-fine particles size of particles are 100 nm.

4.2Chemical Vapor Deposition (CVD)

In CVD process solid is deposited on a heated surface via a chemical reaction from the vapor or gas phase. In thermal CVD the reaction is activated by a high temperature above 900ºC. A Setup includes of gas supply system, deposition chamber and an exhaust system.

There are different CVD methods.

- In plasma CVD, the reaction is activated by plasma at temperatures between 300 and 700°C.
- In laser CVD, pyrolysis occurs when laser thermal energy heats an absorbing substrate
- In photo-laser CVD, the chemical reaction is induced by ultra violet radiation which break the chemical bond in the reactant molecules. In this process, the reaction is photon activated and deposition occurs at room temperature

SiC/Si_3N are the composite powder was prepared by CVD using SiH_4, CH_4, WF_6 and H_2 as a source of gas at 1400°C.(A1.2)

4.3 Chemical Vapor Condensation (CVC)

Chemical vapor condensation (CVC) was developed in Germany in 1994. It involves pyrolysis of vapours of metal organic precursors in a reduced pressure atmosphere. Particles of ZrO_2, Y_2O_3 and Nano whiskers have been produced by CVC method. A metal organic precursor is introduced in the hot zone of the reactor using mass flow controller. (A1.2)[4]

4.4 Mechanical Attrition

Mechanical attrition produces its nanostructures by the structural decomposition of coarser grained structures as a result of plastic deformation. Elemental powders of Al and β-SiC were prepared in a high energy ball mill. Mechanical alloying process can be carried out at room temperature. The process can be performed on both high energy mills, centrifugal type mill and vibratory type mill, and low energy tumbling mill. (A1.2)[4]

High energy mills include:

- Attrition Ball Mill.
- Planetary Ball Mill
- Vibrating Ball Mill
- Low Energy Tumbling Mill
- High Energy Ball Mill

5. PREPARATION OF NANOFLUIDS (A1.3)[1]

5.1 Two-Step Method. (A1.4)[5]

Two-step method is the most widely used method for preparing nanofluids. Nanoparticles used in this method are first produced as dry powders by chemical or physical methods. Then, the nanosized powder will be dispersed into a fluid in the second processing step with the help of intensive magnetic force agitation, ultrasonic agitation, high-shear mixing, homogenizing, and ball milling. Lee et al. [6], Wang et al. [7] used two-step method to produce alumina nanofluids [1] Two step method is the most economic method to produce Nanofluids in large scale, because Nano powder Synthesis is techniques have already been established in industrial production levels. Due to the high surface area and surface activity, nanoparticles have the tendency to aggregate. functionality of the surfactants under high temperature is also a big concern, especially for high-temperature applications.

5.2 One-Step Method(A1.4)[5]

To reduce the agglomeration of nanoparticles, Akoh et al. [8]developed a single-step direct evaporation method. This process is familiar as VEROS (Vacuum Evaporation onto a Running Oil Substrate). But it was difficult to separate nanoparticles form fluids. Eastman et al. [9]developed a modified VEROS technique, [1] Eastman et al. developed a one-step physical vapor condensation method to prepare Cu/ethylene glycol nanofluids [10]. The one-step process consists of simultaneously making and dispersing the particles in the fluid. In this method, the processes of drying, storage, transportation, and dispersion of nanoparticles are avoided, so the agglomeration of nanoparticles is minimized. One-step physical method cannot synthesize nanofluids in large scale, and the cost is also high, so the one-step chemical method is developing rapidly. Zhu et al. presented a novel one-step chemical method for preparing copper nanofluids by reducing $CuSO_4\,5H_2O$ with $NaH_2PO_2\,H_2O$ in ethylene glycol under microwave irradiation [11]. there are some disadvantages for one-step method. The most important one is that the residual reactants are left in the nanofluids due to incomplete reaction or stabilization. It is difficult to elucidate the nanoparticle effect without eliminating this impurity effect.

5.3. Other Methods

Wei et al. developed a continuous flow microfluidic microreactor to synthesize copper nanofluids. By this method, copper nanofluids can be continuously synthesized, and their microstructure and properties can be varied by adjusting parameters such as reactant concentration, flow rate, and additive. CuO nanofluids with high solid volume fraction can be synthesized through a novel precursor transformation method with the help of ultrasonic and microwave irradiation [R7] [12]. Phase transfer method is also applied for preparing stable kerosene based Fe_3O_4 Nanofluids. Oleic acid is successfully grafted onto the surface of Fe_3O_4 nanoparticles by chemisorbed mode, which lets Fe_3O_4 nanoparticles have good compatibility with kerosene [R8] [13]. The preparation of nanofluids with controllable microstructure is one of the key issues. It is well known that the properties of nanofluids strongly depend on the structure and shape of nanomaterials. The recent research shows that nanofluids synthesized by chemical solution method have both higher conductivity enhancement and better stability than those produced by the other methods [R9] [14]. This method is distinguished from the others by its controllability. The nanofluid microstructure can be varied[5]

6. STABILITY OF NANOFLUIDS

Nanofluids can lose their potential to transfer heat due to their proneness to coagulation.it is important to evaluate stability of Nano fluid.[1]

6.1. Methods for evaluating the Stability Nanofluids

6.1.1. Zeta potential analysis

Zeta potential is the potential difference between the dispersion medium and the stationary layer of fluid attached to the particle. The zeta potential indicates the degree of repulsion between adjacent, similarly charged particles in dispersion. So, colloids with high zeta potential (negative or positive) are electrically stabilized while colloids with low zeta potentials tend to coagulate or flocculate. Nanofluids with zeta potential from 40-60 mV are believed to have excellent stability. Kim et al. [15] used zeta potential analysis for Au nanofluids and found out standing stability. Zhu et al. [16]measured the zeta potential of Alumina-water based nanofluids under different pH values and different concentrations.

6.1.2. Sedimentation method

Sedimentation method is the most elementary method for evaluation of nanofluids [17]. An external force field is applied to start the sedimentation of nanoparticles in the nanofluids. The weight of sediment or the volume of sediment indicates the stability of nanofluids. Nanofluids are generally considered to be stable if the concentration of the supernatant particles remains constant with time. Zhu et al. [18] used the principle of sedimentation method in his own experimental setup to measure the stability of graphite suspension. Use of camera has proven to be a suitable aid to capture sedimentation photographs for observing the stability of Nanofluids [19]. Waiting time for capturing photos links up with quality of nanofluids during preparation and well use of applied methods to make a stable nanofluids. Wei et al. captured photographs of their samples within 24 hours after preparation. Wang et al. followed the path for testing sedimentation of alumina-water nanofluid. [20]

6.1.3. Centrifugation method

Sedimentation method is very time consuming as it requires a long period of observation. So, centrifugation method is developed for stability evaluation. Sing et al. [R16] [21] used centrifugation method to evaluate the stability of silver Nanofluid prepared by reducing $AgNO_3$ and selecting PVP as the stabilizer. An excellent stability of silver nanofluids was found due to the protective role of PVP because it decelerates the agglomeration of particles by steric effect.

6.1.4. Spectral analysis method

Spectral analysis via UV- vis spectrophotometer is another useful way to evaluate stability of Nanofluids. The advantage over other methods that UV-vis spectroscopy gives quantitative results corresponding to concentration of nanofluids. Hwang et al. [R17] [22]analysed the stability of MWNT Nanofluids by measuring the UV-vis absorption of MWNT at different sediment time. The above three methods can be used all together to complete the stability evaluation process. For example, Li et al. [R18] [23] performed zeta potential analysis, absorbency and sedimentation photography for copper nanofluids under different pH values, different dispersion types and different concentrations.

6.1.5. 3ω Method

In this method, stability of suspensions can be evaluated considering thermal conductivity growth caused by the nanoparticle sedimentation in a wide nanoparticle volume fraction range [R19].[24] A new literature has found using this method to check the stability of nanofluids [R20]. [25]

6.1.6. Electron microscopy and light scattering methods

Measurement of particle size distribution by microscopy and light scattering techniques are two general methods for observing particle aggregation. Very high-resolution microscope such as TEM and SEM are applied to capture the digital image of nanoparticles, known as electron micrograph. Figure 1 and 2 shows TEM and SEM photographs of CuO Nano particles respectively and Figure 3 & 4 shows TEM photos of dispersed Al_2O_3 and TiO_2.Cryogenic electron microscopy can be used for the same purpose if the microstructure of nanofluids is not changed during cryoation [42]. Light scattering technique can also be used for the study of complex nanosuspensions.

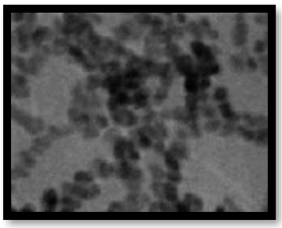

FIG.1 TEM of CuO Nano Particles.[43]

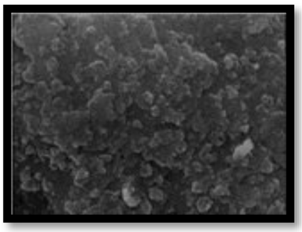

FIG.2.SEM of CuO Nano Particles.[44]

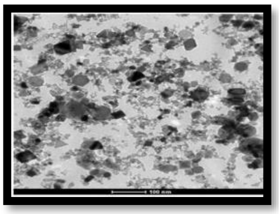

FIG.3.TEM of dispersed Al_2O_3 Nanoparticles in Water.[45]

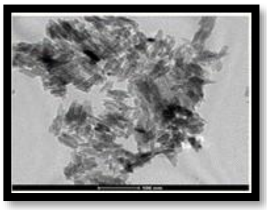

FIG.3.TEM of dispersed TiO_2 Nanoparticles in Water.[45]

6. STABILITY MECHANISMS

Stability which is the most crucial issue can be hampered by particle aggregation. Aggregation of nanoparticles is due to the sum of attractive and repulsive forces between particles. If attractive forces prevail over repulsive one then particle aggregate in clusters. Therefore, enhancement of repulsive forces over attractive forces can prevent particle aggregation and ensure stability. Enhancement can be done by two mechanisms: electrostatic stabilization and steric stabilization.

6.1. Electrostatic stabilization

Existence of an electric charge on the surfaces of particles is a major source of kinetic stability. Electrostatic stabilization occurs by adsorption of ions to the electrophilic metal surface Adsorption creates an electrical double/multi-layer which results in a Columbic repulsion force between the nanoclusters. Electrostatic stabilization is a pH sensitive method and of limited use.

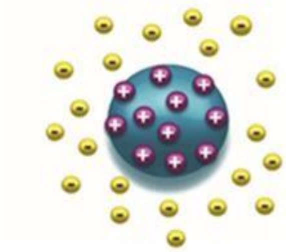

FIG 1. Electrostatic stabilization(A1.4) [5]

6.2. Steric stabilization.

Stabilization of nanoparticles is achieved by attaching macromolecules such as polymers or surfactants to the surfaces of the Particles. The stabilization is due to the large adsorbents which provide steric barrier to prevent particles coming close to each other. For example, stability of graphite nanofluids is due the protective role of PVP as it prevents the agglomeration of nanoparticles due to steric effect [R13].[18]

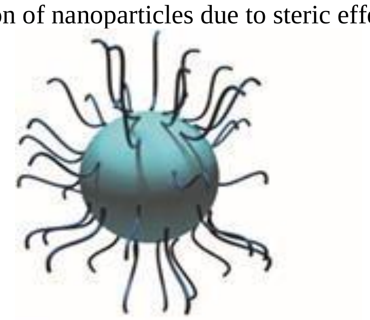

FIG 2. Steric stabilization(A1.4)[5]

7. THERMAL AND PHYSICAL PROPERTIES OF THE NANOFLUIDS

7.1. Volume Fraction.

The volume fraction (φ) is the percentage of volume of nanoparticles to the mixture volume of base fluid (water) with nanoparticles.[31]

$$\varphi = \frac{\langle \frac{W_p}{\rho_p} \rangle}{\langle \frac{W_b}{\rho_b} + \frac{W_p}{\rho_p} \rangle} \times 100 \qquad \textbf{1.1}$$

7.2. Density.

The density of nanofluid can be calculated using Pak and Cho correlations.

$$P_{nf} = (1\text{-}\varphi)\ \rho_{bf} + \rho_p \qquad \textbf{1.2}$$

where $\rho_{nf}$is the density of the nanofluid, $\emptyset$ is the particles volume concentration, $\rho_f$is the density of the base fluid and $\rho_p$is the density of the nanoparticles.[40]

7.3. Specific Heat

The specific heat is calculated from Xuan and Roetzelas following

$$P_{nf}\,(Cp)_{nf} = (1\text{-}\varphi)\ \rho_{bf}\,(Cp)_{bf} + \varphi\ (Cp)_p\rho_p \qquad \textbf{1.3}$$

Where, $(Cp)_{nf}$ is the specific heat of nanofluid, $(Cp)_{bf}$ is the specific heat of base fluid (water), $(Cp)_p$ is the specific heat of nanoparticles (Al_2O_3). [47]

7.4. Thermal conductivity

The thermal conductivity of nanofluid can be calculated from Maxwell following expression $K_{nf.}$

$$\frac{K_{nf}}{K_b} = \frac{K_p + 2K_b - 2(K_b - K_p)\varphi}{K_p + 2K_b + (K_b - K_p)\varphi} \qquad \textbf{1.4}$$

Where, K_{nf} the thermal conductivity of nanofluid, K_{bf} is the thermal conductivity of base fluid (water), K_p is the thermal conductivity of nanoparticles (Al_2O_3).[46]

7.5. Viscosity

The viscosity of nanofluids less than 5% concentration can calculated using Drew and Pass man correlation.

$$\mu_{nf} = (1 + 2.5\ \varphi)\ \mu_w \qquad \textbf{1.5}$$

Where, μ_{nf} is the viscosity of nanofluid, μ_w is the viscosity of water. [48]

Property	Density ρ (kg/m^3)	Heat Capacity Cp (J/kg K)	Thermal Conductivity k (W/mK)
Water	992	4182	0.618
Al_2O_3	3900	779	40
CuO	6310	550.5	32.9
TiO_2	4250	686.2	8.9538
CeO_2	1008	4046	0.662
SiO_2	1001	130	0.620

Table 1. Thermophysical Properties of Nanoparticles and base fluid[34],[49]

8. LITERATURE SURVEY

[8.1] Reza Aghayari et al: Investigated the enhancement of heat transfer co-efficient and Nusselt number of a Nanofluid in double pipe is of steel tube with the inner diameter of 14mm, outer diameter of 16mm, and thickness of 2mm. aluminium oxide (Al_2O_3) predisposed in water, with an average particle size of 20nm for volume fraction of 0.1%–0.3%. Heat transfer coefficient and Nusselt number of the nanofluid increase from 15 to 20% compared to the base fluid according to the comparison on the basis of fixed Reynolds number.[26]

[8.2]. S. Senthilraja and KCK. Vijayakumar: Investigated the heat transfer coefficient of CuO/Water nanofluid. The heat transfer coefficient of the CuO/water was measured with the help of double pipe heat exchanger. The outer pipe of the test section is made of Galvanized Iron, 33.2mm outside diameter and 27.8mm inner diameter with a heat exchange length of 1m. The inner tube is made from smooth copper tubing with 9.53mm outer diameter and 8.13mm inner diameter and 1.5m length. The nanofluid was prepared by dispersing a CuO Nano particle in deionized water. Nominal diameter of Nano particle is 27nm.Experimental investigation is performed by taking volume concentrations 0.1 &0.3 vol.% at room temperature. Convective heat transfer coefficient and Nusselt number of nanofluids were increased compared to base fluid (water). The enhancement of nanofluid is increase with the increasing particle volume concentration.[27]

[8.3]. S.Senthilraja et al: Investigated heat transfer enhancement with and without electric field for Test section of 1000mm long horizontal double pipe heat exchanger where The inner tube is made from copper material with an outer diameter of 9.53mm and an inner diameter of 8.13mm while the outer tube is made from PP (poly propylene) material with an outer diameter of 33.9mm and an inner diameter of 27.8mm. CuO nanoparticles of about 27nm diameter were used in study. The volumetric concentration varies from 0.05-0.15 vol%. CuO/water Nano fluid gives the higher heat transfer co efficient and convective heat transfer co efficient increase with an increasing Reynold numbers. The convective heat transfer efficient of the nanofluid was increased up to the volume fraction of 0.15% after that it decreases because of deposition of Nano particles in pipe surface. Also increasing the supplied voltage results in higher heat transfer rate. [28]

[8.4].K.Vijaya Kumar Reddy et al: Investigated The double pipe heat exchanger The inner pipe is made of mild steel inside diameter of 0.625 inch and outside diameter of 0.815 inch the outer tube made of standard 1.5 inch steel pipe. The unit is composed of 2 sections in series. ZnO, MgO and CuO Nano fluids are with 0.05% and 0.1% volume concentrations. Nanoparticles are prepared with high energy high revolutionary Ball Mill. The Enhancement ratio of the overall heat transfer coefficient is 1.622 For 0.01% CuO overall heat transfer coefficient at mass flow rate of 0.0727 kg/s the amount of the overall heat transfer coefficient of the nanofluid is 62% greater than that of base fluid. The maximum enhancement ratio of Nusselt number 1.599 For 0.01% volume concentration at mass flow rate of 0.0727 kg/Nusselt number of the Nano fluid is 59% greater than that water.[29]

[8.5]. V. Murali Krishna: Investigated Heat Transfer Enhancement in a Concentric Tube Heat Exchanger under Forced Convection Conditions. The inner tube is made of copper and the outer tube is made of stainless steel. The two-step method is used for preparation of Nanofluid. In first step ZnO nanoparticles are prepared by using sol-gel technique after that in second step Nanofluids at different volumetric concentrations 0.1 to 0.5% is prepared by using probe sonicator. For the stability of nanoparticles 10% surfactant is added to the nanofluid. The Overall heat transfer coefficient nanofluid is increase with the increasing particle volume concentration. The overall heat transfer coefficient is increased by 11% with volume fraction of 0.5 % of ZnO nanoparticles compared with water. [30]

[8.6]. Dr. Zena K. Kadhim et al: The enhancement of heat transfer characteristics of finned tube heat exchanger with dimensions of 250 mm width,500mmheight and 1200 mm length. The single copper tube with eight passes. The low integral finned tube with 19 mm inner diameter, 21 mm root diameter and 24 mm outer diameter. The fin height is 1.5 mm, thickness is 1 mm and the pitch is 2 mm using MgO Nano fluid. Diameter of MgO nanoparticle is 40 nm. Nano fluid is prepared with distilled water as base fluid with volume concentrations of 0.15, 0.35, 0.55, and 0.75 % by volume. The heat dissipation rate is increase with the increase of nanoparticle concentration in the water, the maximum percentage of enhancement was 15.85%, achieved at 0.75% nanoparticle concentration. The air side heat transfer coefficient is increase with the increase with nanoparticle concentration in the base fluid, the maximum percentage of enhancement was 19.23% over the base fluid, occurs at 0.75% Nanoparticle concentration. Increasing the nanoparticle concentration, the thermal conductivity and, Also, it's increase the density and viscosity, whereas specific heat is decreased. over the base fluid. [31]

[8.7]. M Siva eswara rao et al: Investigated the Heat transfer rate of Nano fluids in a Shell and Tube Heat exchanger. Shell and tube heat exchanger 670 mm long consists and brass material. In this tube diameter 7.54 mm and wall thickness 1.96 mm and tube long 610mm consists of 20 tubes and the surface area of heat exchanger is 0.289 m^2. Al_2O_3/water

Nanofluid of prepared at volume concentrations of 0.13%, 0.27%, 0.4% and 0.53% with two step method. In first step Alumina Nano particles are prepared by using chemicals with the help of Sol-Gel method. In second step Particles are dispersed in distilled water by using sonicator. In counter flow heat transfer rate is higher than parallel flow condition. Highest heat transfer rate is calculated for counter flow condition at 0.53% volume concentration. The overall heat transfer rate of Nano fluid is more than two times increases than that of base liquid. [32]

[8.8]. Jaafar Albadr et al: Studied Heat transfer through shell and tube heat exchanger using Al_2O_3 nanofluid at different concentrations. The shell and tube heat exchanger is made of stainless steel.it is 248 mm long consisting of 37 tubes. The tube diameter is 2.4 mm with a tube wall thickness of 0.25 mm, The heat transfer area of $0.05m^2$ .The diameter of Al_2O_3 Nano particle is 30 nm. Nano Fluid is prepared of 0.3, 0.5, 0.7, 1 and 2 % volume concentrations.it is observed that Dispersion of the nanoparticles into the distilled water increases the thermal conductivity and viscosity. At a particle volume concentration of 2% the use of Al_2O_3/water nanofluid gives significantly higher heat transfer. The overall heat transfer coefficient of the nanofluid is 57% greater than that of distilled water. Also, Friction factor increases with the increase in particle volume concentration. This is because of the increase in the viscosity of the nanofluid and it means that the nanofluid incur little penalty in pressure drop. [40]

[8.9]. Dadui Guerrieri et al:-Investigated Shell and tube heat exchangers using nanofluids. Numerical analysis is performed in the Mathcad 14 software to check better heat transfer for water and ethylene glycol base Nanofluid.
Al_2O_3 and CuO Nano particles with concentration of 0.05 to 0.15% is studied. The result show that the propylene glycol based nanofluids have low thermal conductivity compared to water based Nanofluids. Reduction in effective length of the heat exchanger is increase with increasing concentration of Nano particles for both Al_2O_3 and CuO. The maximum reduction of 22.7% is found at 0.15% Al_2O_3 with ethylene glycol base Fluid.[50]

[8.10].Arun Kumar Tiwari investigated thermal performance of shell and tube heat exchanger using Nanofluids. The diameter of Al_2O_3 nanoparticle is taken as 44 nm. Nanoparticle volume fraction was augmented from 0.5% to 3% for water based Al_2O_3 Nanofluid. Mathematically at constant mass flow rate NTU increases by around 9% but there is drop in specific heat capacity of around 10.4%. The effectiveness of heat exchanger increases by almost 6.2% due to increase in percentage volume concentration from 0.5% to 3%. The heat transfer inside the tubes in shell and tube heat exchanger increases by using Al_2O_3/water nanofluid due to increase in heat transfer properties and hence the effectiveness of heat exchanger also increases. [51]

[8.11].Abazar Vahdat Azad and Nader Vahdat Azad investigated the effect of nanofluid in reduction of the overall cost of heat exchanger, the overall cost-objective function-including investment and operational costs of the heat exchanger is minimized using the genetic algorithm. volume ratio of 0.01–0.07% The maximum Nusselt number is obtained for Reynolds number of 50,000 at 0.07 vol% of nanoparticles alumina nanofluid. kern and Nano fluid optimize diameter are 0.016m and 0.0123m respectively. The genetic algorithm was used for optimization of the objective function. Over 185% increase in tube side heat transfer coefficient allows reduction of heat exchanger length and fluid velocity and thereby pressure drop up to 94%. The total cost of the optimized heat exchanger was reduced by 55.19% as compared with that designed by conventional methods. The shell and tube exchanger in the presence of nanofluid provides less pressure drop, higher heat transfer coefficients, lower heat transfer surface area and lower investment and operational costs as compared with the exchanger designed by conventional methods. [52]

[8.12].Monika R. Kohale and Shrikrushna P.Chincholkar: Investigated a radiator for increasing cooling performance comparing with water consists 36 vertical tubes with circular cross section with diameter of 8 mm. The Al_2O_3/water is with volumetric concentration 0.1, 0.2 and 0.3 vol%. Increasing the flow rate of working fluid enhances the heat transfer coefficient for both pure water and nanofluid. The degree of the heat transfer enhancement depends on the amount of nanoparticle added to pure water on volumetric concentration. [33]

[8.13].M.Sabeel Khan and T.Dil: Investigated the heat transfer enhancement in automobile radiator. The nanofluids are used for investigation are CuO, Al_2O_3 and $TiO_2$with volumetric concentration 0.05, 0.1, 0.15 and 0.2 vol%. Larger the concentration of the CuO nanoparticles in base fluid higher is the heat transfer rate of CuO/water Nanofluid. One of the reason of better heat transfer is Viscosity of the water Nanofluid than the other two Nanofluids and therefor the velocity of CuO /Water nanofluids decreases. This allows the nanofluid to take more time on the heated surface and thus absorbs more heat from this surface in comparison to other two nanofluids. The velocity of nanofluid decreases with increasing magnetic field strength and concentration factor of Nano particles. [34]

[8.14].Navid Bozorgan et al: Studied Application of CuO-Water Nanofluid in Automotive Diesel Engine Radiator. This radiator consists of 644 brass flat tubes and 346 continuous copper fins. Fin thickness is 0.01 cm, Hydraulic diameter is 0. 351cm.The CuO-water nanofluid at different volume fractions 0.1% & 2% was studied under turbulent flow conditions.it is observed from simulation results indicate that the overall heat transfer coefficient of nanofluid is greater than water the overall heat transfer coefficient and pumping power are approximately 10% and 23.8% more than that of base fluid for given conditions, respectively. And therefore, the total heat transfer area of the radiator can be reduced.[35]

[8.15]. K.P. Vasudevan Nambeesan et al: Investigated the heat transfer enhancement in automobile radiator using Al_2O_3/water–ethylene glycol nanofluid coolants. The radiator is a commercial aluminium plate fin type automobile radiator of size 517 mm × 380 mm × 24 mm. Two proportions of water–EG mixture are used in the experiments to study the effect of EG 90:10, and 80:20. A constant volume fraction of 0.1% of nanoparticles is used in all the experiments. The investigation suggest that the addition of Nanoparticles enhances the heat transfer performance of the coolant. Nanofluid with 0.1% of Al2O3 in the 80:20 water–EG mixture showed an improvement of 37%. This implies that for the same temperature change there will be an increase in heat transfer by 37%.[36]

[8.16]. Tushar Gaidhane and Sameer Bhosale:-Investigated CFD Analysis and Experimental of Heat Transfer Enhancement of CFHX With Hybrid Nanofluid as a Coolant. The dimension used for analysis in ANSYS 14.5 are Diameter of the tube is 2mm Spacing is 5 mm and Length of the tube is 250mm.Hybrid Nanofluid is prepared of Fe_2O_3+CuO at 0.5%, 1.0% and 1.5% volume concentration. In the experimental investigation, at a volume concentration of 1.5%, the use of Hybrid Nanofluid increases convective heat transfer coefficient up to 41% and overall heat transfer coefficient up to 21% than that of conventional coolant at same flow conditions. [37]

[8.17].Hsien-Hung Ting and Shuhn-Shyurng Hou:-Investigated Laminar Convective Heat transfer for Al_2O_3/Water Nanofluids Flowing through a Square Cross-Section Duct with a constant Heat Flux. Dimension used in analysis is 1m long Duct with a square cross section of $1cm^2$.The Al_2O_3 Nano particles of diameter of 25nm is used. Volumetric concentration of 0.2, 0.5,1.5 and 2.5 vol% are investigated. From the investigation found that the heat transfer coefficient of Al_2O_3/Water Nanofluid is increased by 25.5% at a particle concentration of 2.5 vol. % compared with that of pure water. [38]

[8.18].S. Zeinali Heris et al Investigated Convective Heat Transfer Through Square Duct Under Uniform Heat Flux using CuO/water Nanofluid. Duct was manufactured using copper paper. Duct has a square cross-section area of 1 cm^2 and 0.4mm thickness. the hydraulic diameter is 1cm and the total length is 100cm.The mean diameter of CuO Nano particles were 30-50nm.Nanofluids with different concentrations of CuO Nano particles including 0.1%,0.2%,0.5%,0.8%,1.0% and 1.5% volume fractions in distilled water were prepared.it was found that the enhancement achieved by over the base fluid while experiments give maximum enhancement of 20.7%. Heat transfer rate increase with increasing concentration. Thermal conductivity. Also, Nanofluid flow through square duct has benefits of both low pressure drops. [39]

[8.19].Nur Irmawati and H.A. Mohammed: - Investigated mixed convection in a horizontal rectangular duct using Al_2O_3 Nanofluid. The results covered Rayleigh number range of 2×10^6 to 2×10^7 and Reynolds number range of 100 to 1100. . It is observed that the Nusselt number increases as Rayleigh number increases as the buoyancy force increases. It is also observed that Nusselt number increases with increasing Reynolds number. This is because of forced convection is dominant on the heat transfer process. Friction factor increases as Reynolds Number Increases because of forced convection is dominant on the heat transfer process[40]

[8.20] Kashif Ali et al: -Studied how the external magnetic field influences the flow and thermal characteristics of Nanofluid inside a vertical square duct. Water-based nanofluids containing silver nanoparticles. the spectral method and the finite difference method (FDM) is used investigation is observed that Re is more sensitive to Nanoparticle volume fraction parameter for the smaller values. Raleigh number remarkably reduces the fluid velocity and in the middle of the duct. Nusselt number is found to be almost a linear function of the nanoparticle volume fraction parameter, for different values of the Raleigh number and the magnetic parameter.[53]

8. SUMMARY OF LITREATURE REVIEW:

8.1. Literature review on double pipe heat exchanger

Author	Heat exchanger	Nano particles/ base fluid	Observation
Aghayari [26]	Double pipe heat exchanger	0.1–0.3% (γ-AL_2O_3)/ Water	Increase of 15 to 20% in Heat transfer coefficient and Nusselt number
Senthilraja [27]	Double pipe heat exchanger	0.1%&0.3% CuO/Water	Convective heat transfer coefficient and Nusselt number of nanofluids were increased
Senthilraja [28]	Double pipe heat exchanger	0.05–0.15% CuO/Water	Heat transfer efficient of the nanofluid was increased up to the volume fraction of 0.15% after that it decreases because of deposition of Nano particles
K.Vijaya [29]	Double pipe heat exchanger	0.05%&0.1% ZnO, MgO and CuO / Water	CuO has better heat transfer rate then ZnO and MgO
V. Murali [30]	Concentric Tube Heat Exchanger	0.1-0.5% ZnO/Water	The overall heat transfer coefficient is increased by 11% with volume

			fraction of 0.5 % of ZnO nanoparticles compared with water
Dr. Zena [31]	Integral Finned tube heat exchanger	0.15–0.75% MgO/Water	The maximum percentage of enhancement was 19.23% over the base fluid, occurs at 0.75% nanoparticle concentration.

8.2. Literature review on Shell and Tube Heat exchanger

Author	Heat exchanger	Nano particles/ base fluid	Observation
M siva [32]	Shell and Tube Heat exchanger	0.13–0.53% Al_2O_3/ Water	Highest heat transfer rate is calculated for counter flow condition at 0.53% volume concentration
Jaafar [41]	shell and tube heat exchanger	0.3-2% Al_2O_3/Water	At a particle volume concentration of 2% maximum over all heat transfer co efficient is achieved.
Dadui **[50]**	shell and tube heat exchanger	0.05-0.15% Al_2O_3 and CuO /Water & EG.	The maximum reduction of 22.7% of length of heat exchanger is found at 0.15% Al_2O_3 with ethylene glycol base Fluid.
Arun Kumar **[51]**	shell and tube heat exchanger	0.05–0.15% Al_2O_3/Water	The effectiveness of heat exchanger increases by almost 6.2% with increase in volume concentration from 0.5% to 3%.
Abazar [52]	shell and tube heat exchanger	0.01–0.07% Al_2O_3/Water	The reduction of heat exchanger length and fluid velocity and there by pressure drop found up to 94%.

8.2. Literature review on Radiator

Author	Heat exchanger	Nano particles/ base fluid	Observation
Monika [33]	Radiator	0.1–0.3% Al_2O_3/ Water	Increasing the flow rate of working fluid enhances the heat transfer coefficient for both pure water and nanofluid
M.Sabeel [34]	Radiator	0.05–0.2% CuO, Al_2O_3 and TiO_2/ Water	CuO Nano particles have a much higher heat transfer rate than Al_2O_3/water and TiO2water Nanofluids
Navid [35]	Radiator	0.1–0.2% CuO / Water	The overall heat transfer coefficient is approximately 10% more than that of base fluid.
K.P. Vasudevan [36]	Radiator	0.1% Al_2O_3/ Water-EG ,90:10 and 80:20 by Volume	For Nanofluid with 0.1% Al_2O_3 of in the 80:20 water–EG mixture enhance heat transfer 37%
Tushar [37]	Radiator	0.5–1.5% Fe_2O_3+CuO/ Water	In the experimental investigation at 1.5% the use of Hybrid Nanofluid increases overall heat transfer coefficient up to 21%.

8.2. Literature review on Duct

Author	Heat exchanger	Nano particles/ base fluid	Observation
Hsien [38]	Square Cross-Section Duct	0.2–2.5%Al_2O_3/ Water	The heat transfer coefficient of Al_2O_3-Waternanoflui d is increased by 25.5% at a concentration of 2.5%.

S. Zeinali [38]	Square Duct	0.1–1.5% CuO/ Water	From experiments maximum enhancement of 20.7% is found compare to base fluid
Nur [40]	Rectangular Duct	Al_2O_3/ Water	It is observed that the Nusselt number increases as Rayleigh number increases.
Kashif **[53]**	Square duct	Silver/Water	It is observed that Re is more sensitive to Nanoparticle volume fraction parameter for the smaller values

9. DISCUSSION

Different experimental investigation related to heat transfer enhancement and it's affecting factors by using Al_2O_3, CuO, TiO_2, ZnO, MgO and SiC. Amongst all CuO and Al_2O_3 are frequently used for higher thermal conductivity, but many type of nanoparticle using to enhance the heat transfer rate at different application, and discussed many factors affecting the heat transfer rate of Nano fluid. For Preparation of Nano fluid two steps method is widely used. Mixing is important for enhancement of heat transfer rate. Ultrasonic mixture is suitable for enhance thermal conductivity of nanoparticle, Thermal conductivity increase with increase in concentration.

10. CONCLUSIONS

- Heat transfer rate increases with increasing concentration of nanoparticle.
- Dispersion of the Nano particles into the base fluid increases the average heat transfer coefficient with the increase in the flow rate of fluid.
- Heat transfer rate is directly proportional to the Reynolds number.
- The fine grade of Nano particles increases the heat transfer rate but it's having poor stability.
- One-step synthesis method is that nanoparticle agglomeration is minimized.
- One step method can produce limited amount of nanofluid.
- Two step method is mostly for Nano Fluid Preparation because of cost effeteness.
- The Fluid Prepared from Two Step Method is less stable compare to one step method.
- Surfactants improve the stability of the Nanofluid but Chemical properties may change.
- Increasing the supplied voltage results in higher heat transfer rate in double pipe heat exchanger.
- Increasing concentration also increase the density and viscosity, whereas decreasing the specific heat.
- Concentration of nanoparticles increases the pressure drop of Nano fluid.
- Heat transfer rate is higher in counter flow compare to parallel flow.

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