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# A Review on Heat Transfer Enhancement In Heat Exchangers by Using Nanofluids

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*Abstract*—**In daily life we come across many examples of heat transfer. Heat transfer is the energy interaction due to a temperature difference in a media. A heat exchanger is an equipment that is used to transfer heat from one fluid to another, usually through a separating wall. Heat exchangers are employed for different applications such as steam power plants, chemical processing plants, building heating, air conditioning, refrigeration systems, etc. In the field of engineering heat transfer enhancement is a major factor in thedesign of heat exchangers. Heat transfer enhancement in heat exchangers is done by using nanofluids. Nanofluids are the fluids in which nano-sized metallic powders( such as $Al_2O_3$ $TiO_2$, MgO, CuO..etc) are suspended in base fluids( such as water, ethylene glycol, and engine oil..etc). This paper reviews the recent developments in the field of heat transfer enhancement of various types of heat exchangers by using various nanofluids.**

*Keywords*—**Heat transfer, heat exchangers, heat transfer enhancement, nanoparticles, nanofluids, thermal conductivity, overall heat transfer coefficient.**

## 1. INTRODUCTION

A wide variety of industrial processes involve the transfer of heat energy. Throughout any industrial facility, heat must be added, removed, or moved from one process stream to another and it has become a major task for industrial necessity. These processes provide a source for energy recovery and process fluid heating/cooling.

The enhancement of heat transfer (either heating or cooling) in a process may lead to savings in energy, decrease in process time, increase in thermal rating and improvement in the working life of the equipment. Some processes are even affected qualitatively by the action of enhanced heat transfer. The development of high-performance thermal systems for heat transfer enhancement has become popular nowadays. So far work has been performed to gain an understanding of the heat transfer performance for their practical application to heat transfer enhancement. Thus the advent of high heat flow processes has created a significant demand for new technologies to enhance heat transfer. There are some methods to improve heat transfer rate such as utilization of extended surfaces, application of vibration to the heat transfer surfaces and usage of micro-channels. Enhancement of heat transfer can also be improved by increasing the thermal conductivity of the base fluid. Generally used heat transfer fluids such as water, ethylene glycol, and engine oil have relatively low thermal conductivities when compared to solids. Solids having high thermal conductivity are made into small particles and thendispersed into the base fluid hence increasing the thermal conductivity of that base fluid. Nanofluids are one of the nanotechnology applications created by suspending nanoparticles (1-100nm) of high thermal conductivity materials into the base fluid (water,ethylene glycol, engine oil) to improve the overall thermal conductivity and the convective heat transfer characteristics of the base fluid. Nanoparticles shapes are either spherical or cylindrical.

Many industries make use of heat exchangers for heat transfer. A heat exchanger is an equipment that is used to transfer heat from one fluid to another, usually through a separating wall.

Heat exchangers are classified in many ways. Some important classifications are as follows:-

i) According to the direction of flow
ii) According to the type of heat transfer
iii) According to surface compactness
iv) According to construction
v) According to the number of fluids

Heat transfer enhancement in a heat exchanger is done by using nanofluid as one of the operating media in the heat exchanger. Because ofthe use of nanofluid in the heat exchanger there will be anenhancement in the overall heat transfer coefficient of the heat exchanger.

## 2.NANOFLUID PREPARATION METHODS

Two methods are used for preparing nanofluids. They are:-

**2.1Single-Step Method:**This method involves preparation of nanoparticles, combining and synthesis of the nanofluid. Nanoparticles are prepared by either physical or chemical process. In this method, dispersion of nanoparticles, drying, storage, and transportation are avoided, therefore, nanoparticles agglomeration is minimized and fluids stability is increased. However, this method is used only for low vapor pressure fluids.

**2.2 Two-Step Method**: In this method, the first step is the production of nanoparticles and the second step is the dispersion of the produced nanoparticles into the base fluid. The two-step method is advantageous when mass production of nanofluids is considered, as at present, nanoparticles are produced in large quantities by making useof of inert gas condensation . The main disadvantage of the two-step technique is that the nanoparticles form clusters during the

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preparation of the nanofluid which prevents the properdispersion of nanoparticles inside the base fluid .

### 3. LITERATURE REVIEW

Heat exchangers are used in many industrial applications. But by using conventional fluids in heat exchangers the heat transfer rate is less. Many researchers are done experimental and theoretical studies over the heat exchangers by using different nanofluids to enhance the heat transfer rate in heat exchangers.Some of the recent research in this field include:-

**V. Murali Krishna[1]:**In this study, ZnO nanoparticles were prepared by using the sol-gel technique. The raw material was passed through different stages such as dissolving, preparation of the solution, formation of the gel, filtration and drying to get the nano-sized particles. Sintering was performed to remove the liquid traces completely from nanoparticles. The ZnO-water nanofluid has been prepared at different volumetric concentrations. The experiments were conducted on a concentric heat exchanger to study the heat transfer rates of ZnO-water nanofluid for different flow rates and for different volume fractions of nanoparticles in the base fluid. The experimental results were compared with those of the base fluid. The nano-fluid properties were evaluated with correlations available in the literature to find the theoretical heat transfer coefficients.

**P. Gunnasegaran..et.al [2]:** In this study, applications of nanofluids in compact heat exchangers were presented. Normally in compact heat exchangers base fluids such as water or oil are used. But in this study nanofluids were used in place of the regular base fluid. From this work, it was observed that the enhancement of heat transfer in the compact heat exchanger occurs due to the usage of EG-diamond and EG-$SiO_2$.

**Reza Aghayari..et.al [3]:** In this paperthe enhancement of heat transfer coefficient and Nusselt number of a nanofluid containing nanoparticles ($\gamma$-$Al_2O_3$) with a particle size of 20nm and volume fraction of 0.1%–0.3% (V/V) was conducted. Effect of temperature and concentration of nanoparticles on Nusselt number changes and heat transfer coefficient in a double pipe heat exchanger with counter turbulent flow wasinvestigated. Comparison of experimental results with valid theoretical data based on semi-empirical equations shows an acceptable agreement. Experimental results show a considerable increase in heat transfer coefficient and Nusselt number up to 19–24%respectively. Also, it has been observed that the heat transfer coefficient increases with the operating temperature and concentration of nanoparticles.

**T.Srinivas..et.al [4]:** This paper attempted a study on forced convective heat transfercarried out in an agitated shell and helical coil heat exchanger using CuO/water nanofluid. Experiments were carried out at various concentrations of CuO nanoparticles in water(0.3, 0.6, 1, 1.5, and 2% wt.), stirrer speeds ( 500, 1000 and 1500 rpm) and shell-side fluid ( heating medium ) temperatures (40, 45 and $50^0$C). Water was used as the coil-side fluid, and studies were conducted at different values of Dean numbers (flow rates). Enhancement in heat transfer due to the use of nanofluid had reported in terms of heat transfer rate.

**M.Hasanuzzaman..et.al[5]:**The effectiveness of a heat exchanger depends on the convection heat transfercoefficient of the fluid. Convective heat transfer coefficient of water, Cu-water, Al-water, $Al_2O_3$-water and$TiO_2$-water of 2% nanoparticle concentration werecalculated for a counterflow heat exchanger. It was found that the convective heat transfer coefficient of Cu-water, Al-water, $Al_2O_3$- water and $TiO_2$-water nanofluids are 81 %, 63%, 66%, and 64% higher compared to pure water respectively. It was found that overall heat transfer coefficients of Cu- water, Al-water, $Al_2O_3$-water, and $TiO_2$-water nanofluids were 23%, 20%, 21 %, and 20% higher compared to pure water respectively.**Manoj.V..et.al [6]:** Nanoparticles in a conventional fluid, called nanofluids have been the subject of interesting studies in the research field since the discovery of the anomalous thermal behavior of these fluids. The enhancement in thermal conductivity of this fluid in small particle concentration was surprising. This article presented the heat transfer enhancement using $Al_2O_3$-water nanofluid in a spiral plate heat exchanger experimentally and the results were compared to that of a conventional fluid. Also, numerical analysis was performed by considering the presence and absence of Brownian motion.

**Dr. ZenaK.Kadhim..et.al [7]:** Experimental investigations were carried out in this paper to study the enhancement of heat transfer characteristics for cross-flow low integral finned tube heat exchanger by using (MgO) nanofluid. The study includes designing and manufacturing a test section from Pyrex glass having dimensions (250x 500x 1200) mm. The setup consisted of a single copper tube with eight passes. The low integral finned tube had (19 mm)inner diameter, (21 mm) root diameter and (24 mm) outer diameter. The fin height was (1.5 mm), thickness (1 mm) and the pitch (2 mm). Air was used as a cooling fluid passing across the test tube with a range of velocities (1, 2, 3 and 4) m/sec. The inner side flow rates with a range of (2, 3, 4, 5 and 6) L/min. for water and for nanofluid. The fluid temperaturesat the inlet of the test tube were (50, 60, 70, $80^0$C). Magnesium Oxide (MgO) nanoparticle powder with (40 nm) diameter was dispersed in distilled water with different volume concentrations (0.15, 0.35, 0.55, and 0.75) % by volume is used to prepare the nanofluid. The results showed an increase in thermal conductivity and density of fluid when using nanofluid. The results also showed an enhancement in heat transfer characteristics whenusing the nanofluid.

**Kulwant Dhankar..et.al [8]:** In many industries, such as power generation, chemical production, transportation, microelectronics and air conditioning, conventional heat transfer fluids such as water, mineral oil, and ethylene glycol are used. However, the heat transfer efficiency decreases because of their low thermal conductivities. It has been found byresearchers that the heat transfer rates (efficiency) of these conventional fluids can be amplified (increased) by the suspension of metallic nanoparticles. The suspended metallic nanoparticles can change the heat transfercharacteristics of the base fluid.The nanoparticles used are Cu, Ag, $Al_2O_3$, and $TiO_2$. Nowadays the experiments are conducted in concentric tube heat exchangers to study the heat transfer rates of $Al_2O_3$ -water nanofluids for variant flow rates. This review sum ups the development of nanofluids and gives the broad range of current and future applications in different fields like nuclear

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reactors, transportation, electrical energy, magnetic, mechanical, solar absorption and biomedical fields. However, there are some barricades and challenges that had been foundin industrial applications.

**KiranShivade..et.al [9]:**The demand for more powerful engines in smaller hood spaces has created a problemof insufficient rates of heat dissipation in cross-flow heat exchanger (automotive radiators). Upwards of 33% of the energy generated by the engine throughcombustion is lost in heat. To minimize the stress on the engine as a result of heatgeneration, automotive radiators must be redesigned to be more compact while stillmaintaining high levels of heat transfer performance. Base fluids (water, ethyleneglycol, and glycerol) have been used as conventional coolants in cross-flow heatexchanger (automobile radiator) for many years; however, these offered low thermalconductivity, which has prompted researchers to find fluids that offer higher thermalconductivity compared to that of conventional coolants. Nanofluids have beenconsidered as a new-type heat transfer fluid because of their substantial increase inliquid thermal conductivity, liquid viscosity, and heat transfer coefficient. Proposed work concentrates on developing the experimental system to investigate the heat transfer enhancement of cross-flow heat exchanger with hybrid nanofluids as a coolantand its CFD analysis.

**Nitin Jaju..et.al [10]:** A heat exchanger is a device that is used for thermal energy exchange. It may be within the solid or solid-fluid interface or within the gas itself having a temperature gradient. The heat exchanger that has good efficiency and an economic running cost is considered vital from an industrial point of view. The study involved conducting experiments focused on enhancing the heat transfer rate. This paper proposedthat the research and practical work done on tube heat exchanger by using nanofluids which was a heat transfer augmentation technique.

**4. Discussion :**From the literature review the following observations are identified.

- Experiment conducted on concentric heat exchanger with ZnO-water nanofluid for heat transfer enhancement[1].
- Experiment conducted on compact heat exchanger with EG-diamond and EG-$SiO_2$ for heat transfer enhancement [2].
- Experiment conducted on double pipe heat exchanger with counter turbulent flow with ($\gamma$-$Al_2O_3$) a particle size of 20nm and volume fraction of 0.1%–0.3% (V/V) for heat transfer enhancement[3].
- Experiment conducted on agitated shell and helical coil heat exchanger by using CuO/water nanofluid for heat transfer enhancement[4].
- Experiment conducted on counter-flow heat exchanger with , Cu-water, Al-water, $Al_2O_3$-water and$TiO_2$-water of 2% nanoparticle concentration for evaluation of convective heat transfer coefficient[5].
- Experiment conducted on spiral-plate heat exchanger with $Al_2O_3$-water nanofluid for heat transfer enhancement[6].
- Experiment conducted on cross-flow low integral finned tube heat exchanger by using (MgO) nanofluid for heat transfer enhancement[7].
- Experiment conducted onconcentric tube heat exchangers to study the heat transfer rates of $Al_2O_3$ -water nanofluids for variant flow rates for heat transfer enhancement[8].
- Experiment conducted on cross-flow heat exchanger with hybrid nanofluids as a coolantand its CFD analysis for heat transfer enhancement[9].
- Experiment was conducted on shell and tube heat exchanger with a nanofluid of $Al_2O_3$-water for heat transfer enhancement[10].

**5. Conclusion :** Research has been carried out on concentric tube, compact heat exchanger, double pipe, shell and helical coil heat exchanger,counter-flow, spiral plate, cross-flow low integral finned tube heat exchanger, concentric tube heat exchangers, cross-flow heat exchanger, shell and tube, with ZnO-water,EG-$SiO_2$,$\gamma$-$Al_2O_3$-water , CuO-water, $Al_2O_3$-water, $TiO_2$-water, MgO-water and Hybrid water nanofluid respectively for heat transfer enhancement. Cross-flow compact heat exchangers have more surface area then other type of heat exchangers due to which the heat transfer rate is more. In future research can be on cross-flow compact heat exchangers because of its better features for effective heat transfer enhancement.

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