A REVIEW- USE OF NANOFLUID IN TUBE IN TUBE HEAT EXCHANGER TO INCREASE HEAT TRANSFER RATE

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***Abstract*: Heat exchangers are used to transfer heat from one medium to another. To increase the heat transfer rate or heat transfer per unit surface area fluid having high specific heat and thermal conductivity were used to increase heat transfer. Using nanofluid is one of the ways to increase heat transfer rate. Researcher using nanofluids has progressed rapidly since its enhanced thermal conductivity was first reported about a decade ago, though much controversy and inconsistency have been reported, and insufficient understanding of the formulation and mechanism of nanofluids further limits their applications. This work presents a critical review of research on heat transfer applications of nanofluids with the aim of identifying the limiting factors so as to push forward their further development.**

***Keywords*: heat exchanger, nanofluid, optimization, heat transfer rate, flow behavior**

1. Introduction

A Heat exchanger is a thermal device which is used for the heat transfer between two fluids by the convection and conduction. Conduction takes place between the one part of the fluid and between the wall of the heat exchanger and convection is taking place between two fluids flow. In the heat exchanger, the fluid may be direct or indirect contact. The fluid is separated by a wall

The heat exchanger may be classified in different criteria

I. **Parallel flow heat exchanger**-In this type of heat exchanger both fluid flow in the same direction i.e. cold and hot fluid. Parallel flow heat exchanger is generally maintaining constant wall temperature.
II. **Counter flow heat exchanger**-one fluid flows opposite to the direction of other fluid flow. They are most effective due to less variation in mean temperature, i.e. the temperature variation in counter flow heat exchanger may be idealized as one dimensional. Counter flow heat exchanger exhibit thermodynamically superior to any other flow arrangement
III. **Cross-flow heat exchanger**- when the fluid flow takes place perpendicular to each other known as cross-flow heat exchanger and they are further classified as (a) mixed cross-flow heat exchanger, in mixed flow fluid is mixed as shown in figure 2 and (b) unmixed cross-flow heat exchanger, in unmixed flow fluid does not mix to each other.

In the recent years' number of researchers and experimental studies are conducted to research the feasible result and unrevealed mechanism of skyrocketing thermal physical phenomenon in convective heat transfer thanks to the utilization of nanoparticles in numerous base fluids.In the previous years, a number of researchers and experimental studies have been conducted to investigate the possible effect and underlying mechanism of increasing thermal conductivity in convective heat transfer due to the use of nanoparticles in different base fluids.

Use of nanofluids is still lacking in real life applications due to contradictory results amongst researchers and lack of theoretical understanding. There are few experimental studies about the effect of nanofluids in double tube heat exchanger at very low volume concentration and especially the effect of constant wall temperature which occurs during the condensation of steam. Even few researchers have mentioned the effect of variation in temperature on nanofluids heat transfer while conducting the experiment using double tube heat exchanger. In this paper, double tube heat exchanger is used to develop the experiment, including the setup of the heat exchanger, preparation of measurement techniques, and calibration of equipment and collection of data. Governing equations are discussed which are being used to calculate the data from the experiment. All the results of the experiment are calculated and analyzed to show by using nanofluid how significant change in heat transfer can be achieved. Convective heat transfer coefficient and Nusselt number are used as the main indicator to prove the results. The researchresults provide significant references for the application of nanofluid in heat exchangers.

2. Existing research work

Many researchers have optimized the different process parameters of heat exchanger using nano fluids as a working fluid to increase heat transfer rate. Different types of nano particles were used at different proportion to increase heat transfer some of the research work is conclude here.

Masuda et al. [1]1993 The thermal conductivity of metal compared to the fluid is much higher, with that information they started the measurement of thermal conductivity of nanoparticles. They have shown experimentally that the thermal conductivity of nanofluid with Al_2O_3 particles at a volume concentration of 4.3% can increase the thermal conductivity of base fluid water by 30%.the relation between the estimated and experimental measured conductivities is satisfactory. But at that time, no credit given to that experimental research due to the problem arises in production.

Choi et al. [2] 1995the resulting “nanofluids” are expected to exhibit high thermal conductivity of nanofluidswith copper nanophase material are give new era of research and also we get the one more benefits of nanofluids will reduce the heat exchanger pumping power. They were conclude that the concept of nanofluids is an innovative idea and get feasibility of high thermal conductivity of fluids and the potential benefits of nanofluid with copper nanophase particles have been estimated. They find that the reduction in heat exchanger pumping power, he found that for two times increase in heat transfer, the pumping power with conventional fluid should be increased by a factor of 10, however if nanofluid are used then thermal conductivity is increased by three times of conventional fluid without increase in pumping power.

Lee et.al. [3] 1999 They deals with the measurement of thermal conductivity of various metal oxide nanoparticles, apart from aluminium oxide they also deal with copper oxide. They measured the thermal conductivity of four oxide nanofluid i.e. aluminium oxide in water, aluminium oxide in ethylene glycol, copper oxide in water and copper oxide in ethylene glycol by a transient hot-wire method.The experimental result shows that these nanofluidswhich contain nanoparticles in small amount have higher thermal conductivity with respect to the base fluid. They also compared the result with Hamilton and Crosser model and suggest that not only particle shape but particle size also dominant in enhancing the thermal conductivity of nanofluids.

Xuan et.al [4] 2000 The main aim of this paper is, a procedure for making a nanofluid which is a consisting of nanoparticles powders and a base liquid.. In this paper for measuring the thermal conductivity, the hot-wire apparatus is used. The nanofluids with suspended copper nanophase powders are used for the investigate the thermal conductivity.Some properties such as the volume concentration, dimensions, shapes and characteristicsof the nanoparticles are discussed.. In this experiment, For the water base, CuO nanoparticles suspension nanofluid the thermal conductivity enhance by 24% to 78% when the volume concentration of nanoparticles varies from 2.5% to 7.5%.

Xhang et al. [5] 2006thermal diffusivity is important properties of nanofluid which tell us about the how fast heat transfer is take place compare to heat absorbed. The effective thermal conductivity and thermal diffusivityof Au/toluene, Al_2O_3/water, and CNT/water nanofluids have been measured accurately for various volume concentrationand temperatures. They found that the effectivethermal conductivity and thermal diffusivity increase with an increase in the particle concentration. The effective thermal conductivities of nanofluidshave not shown any anomalous enhancements. All of themeasured values at lower volume fractions agree well with those predicted by the numerical equation for the spherical particlesand by the unit-cell model equation of Yamada and Ota forthe CNFs.

Heris et al. [6] 2006they deal with the experimental investigation of convective heat transfer of Al_2O_3/water nanofluid in a circular tube. The main aim of the experiment to compare the rate of heat transfer with and without nanofluids in circular tube and flow is laminar with constant wall temperature. In this experiment the nanofluid flow in the circular tube with constant wall temperature for laminar flow with variation in Reynolds number and Peclet number they conclude that increase in thermal conductivity is not the single reason for heat transfer enhancement in the nanofluid. Dispersion and chaotic movement of nanoparticles, particle migration and Brownian motion have also participated in heat transfer enhancement. Particle motion and interaction, especially in higher Peclet number may cause the change in flow structure and lead to augmented heat transfer due to the presence of nanoparticles.

Duangthongsuket.al [7]2009 Apart from heat transfer enhancement, the pressure drop a special property to analyze in nanofluids. An experimental investigation on TiO_2-water nanofluid in a double-tube counter flow heat exchanger for examining the heat transfer enhancement and pressure drop characteristics. In this experimental study on the forced convection heat transfer and flow characteristics of nanofluid in which water act as a base fluid and we used Titanium oxide nanoparticles to creating nanofluid with 0.20% volume concentration of $TiO_{2.}$ The analysis shows that heat transfer coefficient is increased by about 6-11% compare to base fluid water only, and also conclude that the heat transfer coefficient increases with increase in mass flow rate of the hot water and nanofluid, and increase with a decrease in nanofluid temperature and inlet temperature of hot fluid does not have significant effect on heat transfer coefficient of nanofluid.

Chandrasekar et al. [8] 2010 Aluminum oxide nanoparticles of diameter 43 nanometer with concentration vary from 0.33% to 5% at room temperature with water as a base fluid was used for the investigation. For theoretical investigation of nanofluid viscosity, they are used a various model to investigate the thermal conductivity and viscosity of the material and for measuring thermal conductivity practically of nanofluid they were used KD2 pro thermal properties analyzer and for measuring the viscosity of nanofluid used Cone and plate assembly. After the investigation of aluminium oxide water base nanofluid they conclude that the thermal conductivity of aluminium oxide-water nanofluid varies linearly with increase in concentration of nanoparticles but in case of viscosity, it varies nonlinearly when the volumetric concentration of nanoparticles is greater than 5% and for concentration 3 to 5% it shows the Newtonian fluid property.

Naiket.al [9] 2010 They investigate on copper oxide nanoparticles in propylene glycol-water (60:40 by volume) nanofluid in the range of 0.25, 0.10, 0.40, 0.80 and 1.2% concentration. After the experiment with various concentration nanofluid with the different temperature range, they conclude that the increase in thermal conductivity ranges from 10.9% to 43% with temperature ranges from

25^0C to 65^0C for the nanofluid with 1.2% concentration. The best part of the investigation is that the thermal conductivity increases with both increases in the concentration of nanoparticles and with the increase in temperature of nanofluid.

Saidur et al. [10] 2011 To investigate the behavior of nanofluid,related to viscosity and pumping power, examine the performance of nanoparticles in the refrigeration system and lubricating oil. Due to their remarkable improvement in their heat transfer rate, After they examine various result in the literatures, it has been found that nano refrigerants have a greater reliability on temperature-dependent thermal conductivity at very low particle concentrations than conventional refrigerant. Experimental result show that HFC134a and mineral oil with TiO2 nanoparticles works normally and safely in the refrigerator with better performance. The power required of the HFC134a refrigerant usingmineral oil and nanoparticles mixture as lubricant saved 26.1% energy with 0.1% weight concentration of TiO_2nanoparticles compared to the HFC134a and POE oil system. Ithas been found that the thermal conductivities of nano refrigerants are greater than traditional refrigerants.

Kamyar et al. [11] 2012 used the computational fluid dynamics to investigate the properties of nanofluid. With the help of experimental result we validate the result with software system and after validating the result we get the more result related to the property of nanofluid with two-phase system. From the previous result, in this article shows that from a numerical point of view, nanofluids achieve an important improvement in the heat transfer performance, which is in a better result with experimental works.

Mohammad et al. [12] 2012. Two different louvered strip insert arrangements (forward and backward) are used in this study with a Reynolds number varies from 10,000 to 50,000. The effects of various louvered strip slant angles and pitches are also examined. Four different types of nanoparticles, Al_2O_3, CuO,SiO_2andZnO with different volume concentrationvaries from 1% to 4% and different nanoparticlesdiameters in the range of 20 nm to 50 nm, dispersed in a water. The numerical results indicate that the forward louvered strip arrangement can enhance the heat transfer by approximately 367% to 411% at the highest slant angle of α=30° and lowest pitch of S=30 mm. The maximal skin friction coefficient of the enhanced tube is around 10 times than that of the smooth tube and the value of performance evaluation criterion (PEC) lies in the range of 1.28–1.56. It is found that SiO_2nanofluid has the highest Nusseltnumber value, followed by Al_2O_3, ZnO, and CuO while pure water has the lowest Nusselt number.

Kabeel et al.[13] 2013 In this study, an experimental test loop has been constructed to study the PHE thermal characteristics; heat transfer coefficient, effectiveness, transmitted power and pressure drop at different concentrated volume fractions of AL_2O_3nano-material (1-4%) in pure liquid water as a base fluid. The maximum increase in heat transfer coefficient is reached 13% for a nanofluidconcentration of 4% vol. However, the increase in heat transfer coefficient is up to 13% under anuncertainty of 9.8%, at constant Renault number. If it is compared at constant flow rate, this marginalenhancement will be further reduced. So the application of nanofluidsas a strong potential forenhancing the heat transfer in the corrugated PHE is doubtful for the current study.

Naseema et al. [14] 2017heat transfer in the heat exchanger by using nanofluid, the heat transfer increases with increase in the concentration of nanoparticles. They investigate the heat transfer enhancement in the heat exchanger with different nanoparticles with same base fluid. They used aluminium oxide, copper oxide nanofluid with different concentrations in a water-based fluid. They also examine the rate of heat dissipation by changing Renolds number. They experimentally found that the rate of heat transfer is more in case of aluminium oxide compare to copper oxide up to volume concentration of 3%. For the 0.1% volume concentration of Al_2O_3, the heat transfer coefficient is 182 W/m^2-k compare to base fluid water heat transfer coefficient of 140W/m^2-k i.e., overall heat transfer coefficient is increased by 1.305 times that mean increase by 30%.

Han et al. [15] 2017 They examine the rate of heat transfer with 0.25% and 0.5% by volume concentration at various inlet temperatures. After the experiment they analyze that by using different concentration of Al_2O_3 that include 0.25% and 0.5% by volume concentration with Renolds number varies from 20000 to 60000 maximum increase in heat transfer coefficient is about 9.7% and 19.6% respectively at 40^0C, and with same volumetric concentration and also Renolds number varies from 20000 to 60000 the maximum increase in heat transfer coefficient is about 15% and 29% for volume concentration 0.25% and 0.5% respectively at 50^0C. Comparing the result at 40^0C and 50^0 with the volume concentration of 0.25% and 0.50%, the increase in heat transfer coefficient is about 5.3% and 9.4% respectively., by using nanofluid the Nusselt number also increases about 8.5% and 17% at the volumetric concentration of 0.25% and 0.50% respectively.

4. Conclusion

- A critical review of the state-of-the-art nanofluids research for heat transfer application was conducted in this work, which showed that our current understanding on nanofluids is still quite limited.
- There are a number of challenges facing the nanofluids community ranging from formulation, practical application to mechanism understanding.
- Engineering suitable nanofluids with controlled particle size and morphology for heat transfer applications is still a big challenge.
- The current uncertainties on the content of nanofluids, including both solid phase and liquid phase, could be one of the main reasons responsible for the controversy and inconsistency reported.
- Besides thermal conductivity effect, future research should consider other properties, especially viscosity and wettability, and examine systematically their influence on flow and heat transfer.
- An in-depth understanding of the interactions between particles, stabilizers, the suspending liquid and the heating surface will be important for applications.

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