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Role of Nanofluids on Heat Transfer Enhancement in Helical Coil Heat Exchangers

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Abstract—*Nanofluids are abeyance of metallic or non-metallic nanoparticles (1-100nm) in base fluid and are synthesized to provide considerable preferences over conventional heat transfer fluids. By improving thermophysical properties of nanofluid, heat transfer characteristics can be increased. This paper depicts a complete review on nanofluids challenges and applications. Forced convective heat transfer with nanofluids in helical coil heat exchanger is also presented and reviewed. Also, challenges on applications of nanofluids has been reviewed and presented. This paper illustrates latest advancements in study of nanofluids, as well as preparation methods, working for heat transfer improvements, and utilization in heat transfer field.*

Keyword*: Nanofluids, Synthesis, Helical Coil heat exchanger*

1. INTRODUCTION

Due to energy disaster and energy dissipation in various industries, heat transfer has been emerged as an utmost crucial and relevant area in engineering sciences i.e. mechatronics , microelectronics, electronic component, power generation, air conditioning, petrochemical, oil gas industry .For enhancing the rate of heat transfer ,addition of solid particles into heat transfer media is a new invention.. In spite of major attention to use suspended millimeter sized particles is that they possess plausible to cause various problems such as clogging, large pressure drop, erosion, settlement of particles, sedimentation of particles [28]. To overwhelm the shortcoming faced by micro/macro sized particles, Choi [1] Argonne National Laboratory USA has dispersed nanosized particles in range of 1-100 nm into base fluids. Reasons for using these nanofluids are superior properties such as long-lasting stability, enhancement in heat transfer, high thermal conductivity; reduce clogging, less energy for pumping the fluid and ultimately reduction in cost. Nanofluids i.e. water, polymer solution, bio-fluids, ethylene glycol and oil, that are the cessation prepared by scattering nanometer-sized solid particles such as metals (Gold, copper, Silver, Iron); carbide ceramics (titanium carbide, silicon carbide); oxide ceramics (copper oxide, aluminum oxide); semiconductor (Titanium oxide); nonmetal includes graphite, single-,double-, or multi-walled carbon nanotubes and composite materials such as nanoparticles core-polymer shell composites.

Nanofluids posses the following benefits [26]: Specific surface area is higher as compared to conventional fluids, large heat transfer surface, decreased particles obstruction, decreased scattering stability accompanying main particles. Also because of Brownian motion miniaturized pumping power is required, hence stronger system miniaturization, fast cooling and heating, superior lubrication to suit the different applications. Except these, they have adjustable properties such as thermal conductivity and varying particles .Due to these applications, nanofluid successively used in lighter and shorter heat exchangers .

2. SYNTHESIS OF NANOFLUIDS

Two methods have been used in production of nanofluid: one step and two step technique. Two step method is superior for preparation of nanofluid. Initially, with the help of chemical or physical method they are produced as dry powder. By utilizing exhaustive magnetic force mixing, ultrasonic stirring, homogenizing and ball milling, high share agitation in second processing step, dispersion of exhaustive nanosized powder will be done into base fluid. By using two step method, suspension of prepared TiO_2 in water will be done by Murshed et al [2].In the one step method, nanoparticles produced and scattered directly into base fluid at the same time. Single step is also called as VEROS (Vacuum Evaporation onto a Running Oil Substrate) a method which was developed by Akoh et al [3].Benefits of such technique is agglomeration of nanoparticles are minimized. Modified VEROS method which was developed by Eastman et al [4].This method includes direct condensation of Cu vapour into nanoparticles by contacting it with flowing low-vapor-pressure liquid (EG).A novel one-step chemical method for preparing copper nanofluids by reducing CuSO4.5H2O with NaH2PO2.H2O in ethylene glycol under microwave radiation was presented by Zhu et al [5].

Their results showed that the properties of nanofluids and reaction rate are the two factors which are affected by insertion of NaH2PO2.H2O and the ratification of microwave irradiation. This method is compatible with only single low vapor pressure fluids [30].

3. APPLICATION OF NANOFLUIDS IN DIFFERENT AREAS

Apart from the initial objective of producing intensified flow and heat transfer with nanofluids, analysis should directed to essential progression heating the water by solar energy ,electronic circuits cooling, engine transmission oil, lowering the temperature of nuclear system, engine cooling, bio medical application, environmental control. Possible field of applications consist of boiler exhaust flue gas recovery, high power laser diode array, drilling and lubrication, in transportation industry, refrigeration (domestic and chillers), lubrication, thermal storage, drug reduction, directed self assembly of nanostructures.

4. HEAT TRANSFER METHODS

Both active and passive methods can be used for enhancing the heat transfer rate. Active enrichment depends upon the augmentation of exterior power to convey about the desired flow adaptation. Active enrichment illustration consists of surface vibration, heat transfer, fluid vibration, and electrostatic field introduction. Passive technique use appropriate geometry or fluid supplement. Passive Enrichment classical examples are disturbed promoters, vortex generators and roughness of surface. However in heat transfer enhancement techniques (active and passive), boosting can be done extremely and lastly pumping cost shift high.

One of passive method which increases heat transfer rate is by using helical coil. Reasons for preferring the passive methods are that they have reduced cost, high running life, manufacturing is simple. Helical coil flow is distinct from straight tube flow due to existence of centrifugal forces. Berger et al [6] stated that a secondary flow produced by centrifugal force, usual to the primary direction of flow, with circulatory effects, that enhance both the rate of heat transfer and friction factor.

5. NANOFLUID CONVECTIVE HEAT TRANSFER IN HELICALLY COILED TUBES

A helical coiled tube heat exchanger consists of flat surfaces pair that is twisted to form the two passages in a counter-flow arrangement. The main advantage of the Spiral heat exchanger is that space is used efficiently. Three main types of flows are there in a spiral heat exchanger: counter-current flow and spiral or cross flow, distributed vapour or spiral flow. Counter-current flow used for liquid-liquid, condensing and gas cooling application; Spiral flow is suitable for gases having low density and distributed flow suitable for sub cooling of both condensate and non-condensate. Various researchers demonstrate the literature review of double helical coil

Narrein et al [7] analysed the effect of rotation of nanofluids on helically coiled tube heat exchanger. In this, nanoparticles (SiO_2, Al_2O_3, ZnO, CuO,) with diameter of particles (25-80nm) and various concentrations are used. The results revealed that as compared to water Al_2O_3, CuO, ZnO nanoparticles can achieve better heat transfer enhancement. Also, flow field results demonstrated that Al_2O_3, ZnO and CuO had lowest pressure drop come after SiO_2 due to difference in densities. Additionally, engine oil had highest pressure drop as compared to water and ethylene glycol.

Gorman et al [8] investigated the fabrication and operating characteristics of uniquely compact helical heat exchanger. Work was done on annealed 316 stainless steel for a particular heat exchanger and this work was found to be suitable. The heat exchanger followed a principle in which tight meshing of two small diameter tubes like that collaboration of tubes surround each other.

Akbaridoust et al [9] numerically and experimentally investigated heat transfer of nanofluid in helically coiled tubes at constant wall temperature. He used dispersion model to find heat transfer. They concluded that in helical tube, heat transfer can be enhanced by using base fluid rather than straight tube.

Bahremand et al. [10] studied experimentally and numerically the pressure drop and convective heat transfer of water-silver and water nanofluids under turbulent flow condition and constant heat flux condition. As compared to straight tubes, micrometer-sized particles enhanced mean axial velocity and suppressed turbulence. Results showed that two-phase approach predicted better results than homogenous model.

Pakdaman et al [11] experimentally investigated the MWCNT pressure drop characteristics in vertically helically coiled tubes under laminar flow regimes. The results showed that pressure drop increases with increases nanoparticles weight concentration and Reynolds number, using of nanofluids and helical coils, pressure drop increases.

Behabadi [12] studied experimentally the nanofluids heat transfer enhancement inside vertically helically coiled tubes under uniform wall temperature condition. They used the 0.1, 0.2, 0.4% weight concentration of nanofluid. The results showed that by utilizing helical coil heat transfer rate can be increased up to 80% than straight tube. Similarly, nusselt number can be increased up to 60%. in helical coil by using nanofluids rather than conventional base fluid.

Wu et al. [13] investigated experimentally convective heat transfer coefficient and pressure drop of alumina/ water nanofluids in double-pipe helically coiled heat exchanger under laminar and turbulent flow condition. They used the weight concentration in range of 0.78% -7.04.According to them, Nanofluid heat transfer enhancement is from 0.37% to3.43% when compared to water according to constant velocity basis. Another effects of nanoparticles such as diffusiophoresis , thermophoersis and brownian motion are insignificant compared to main thermo physical properties of nanofluids.

Arani et. al. [14] experimentally investigated diameter effect on pressure drop and heat transfer performance of Titanium oxide-Water nanofluids (with diameter 10, 20, 30, 50 and volume concentration from 0.01 to 0.02 by volume) with fully developed turbulent flow in horizontal double tube. Their result showed that thermal performance is more for 20 nm nanoparticles diameter nanofluid rather than other particle diameter. Maximum thermal performance factor is found to be 1.9 by synchronic utilization of TiO_2-Water nanofluid with Reynolds number of 47000, diameter size 20 nm, nanofluid with 0.02% volume.

Kumaresan et al. [15] studied experimentally secondary refrigerant based MWCNT convective heat transfer characteristics inside tubular heat exchanger. He used the constant wall temperature and constant heat flux boundary condition. The results showed that enhancement in convective heat transfer coefficient while reduction in reynold number was found. Due to micro convention effects of chaotic movement of carbon nanotubes, MWCNT nanofluid with 0.45 vol. % enhance the thermal conductivity by 19.73% at 40˚ C, while showing enhancement of 159.3% in average convective heat transfer coefficient at same temperature condition. The enhancement in friction factor is negligible at higher velocity and higher temperature for nanofluids with 0.15 vol. % MWCNT.

Huminic et al [16] analysed the heat transfer characteristics of double tube helical heat exchanger using TiO_2 and CuO nanoparticles of diameters 24nm dispersed in water and volume concentration of 0.5-3 vol. % under laminar flow. The results showed that by increasing dean number and mass flow rate, particle concentration, convective heat transfer rate of water as well as nanofluids increase.

Rabienataj et al [17] observed experimentally the investigation of convective heat transfer and friction factor of Al_2O_3/Water nanofluid with Reynolds number and friction factor varied from 5000-20000 and 0-1% by volume in helically corrugated tube. The results showed that by increasing nanofluids concentration the friction factor increases and heat transfer by factor of 3.2.

Asirvathum et al [18] investigated the convective heat transfer of silver-water nanofluids with volume concentration 0.3%-0.9% under laminar, transition, and turbulent flow regimes in horizontal 4.3 mm inner diameter tube-in-tube counter-current heat transfer test section. Experiments showed that convective heat transfer coefficient increased by 28.7% and 69.3% for 0.3% and 0.9% of silver content.

Akbaridoust et al [19] studied experimentally and numerically investigation of nanofluid heat transfer in helically coiled tubes at constant wall temperature using dispersion model under laminar and steady flow condition. The result showed that tubes having great curvature ratio has more enhanced heat transfer. Utilization of base fluid in helical tube with greater curvature compared to use of nanofluid in straight tubes enhanced more heat transfer more effectively.

Hashemi et al [20] investigated experimentally the heat transfer and pressure drop characteristics of CuO-base oil nanofluid flow in horizontally helically coiled tube under constant heat flux .Different weight concentration of nanofluid 0.5%,1%,2% are used. The result showed that, there is maximum heat transfer enhancement of 18.7% and 30.4% is obtained for nanofluid flow with 2% wt concentration compared to base oil flow inside the straight tube and helical tubes. High performance index for base oil is 1.16 inside helical tube at reynold number of 21.9.

Shirsagar et al [21] experimentally studied the manufacture and analysis of tube-in-tube type helical Heat Exchanger with counter current flow with water as nanofluid. When the efficiency of heat exchanger was compared with convention heat exchanger, it was found 15-20% more and experimentally calculated efficiency is 93.33%. For constant flow rate in annulus region, overall heat transfer coefficient increases with increases in inner-coiled tube flow rate. Similarly for constant flow rate in inner-coiled tube, for different flow rate there is increases in overall heat transfer coefficient with increases in annulus regions.

Kannadasan et al [22] investigated the comparison of pressure drop and heat transfer in vertical and horizontal helically coiled heat exchanger by using CuO/water based nanofluids with 0.1&0.2% volume concentrations under turbulent flow condition. The result showed that the nusselt number at 0.1&0.2% in horizontal and vertical position were 36% &45% and 37% & 49% respectively when compared to water in turbulent flow region. The friction factor in horizontal position were found to be 7 % and 21% and in vertical position under 12% and 25% turbulent flow respectively. In turbulent flow,by increasing particle volume concentration friction factor increases.

Huminic et al [23] studied the heat transfer characteristics in double tube helical heat exchangers under laminar flow conditions. They used CuO and TiO_2 nanoparticles with 24nm diameter dispersed in water with volume concentration of 0.5-3% The results revealed that nanofluid heat transfer rate was 14% greater than of pure water, for 2% CuO nanoparticles in water and same mass flow rate in inner tube and Annulus and for case which through inner and outer tubes flow rates, heat transfer rate of water from annulus than through inner tube flowing nanofluids was approximately 19% greater than. By increasing dean number and mass flow rate convective heat transfer coefficient of nanofluids and water increases.

Khairul et al [24] predicted the CuO/Water nanofluids heat transfer performance in spirally corrugated helically coiled heat exchanger. They used fuzzy logic technique for this purpose. They found that with increase in volume concentration enhancement in heat transfer coefficient about 5.90-14.24% when compared to water. According to them the value of friction factor decreases, with increase in the volume flow rate and volume concentration.

Madhesh et al [25] experimentally investigate the rheological characteristics and convective heat transfer of Cu-TiO_2 hybrid nanofluids inside tube in tube counter flow heat exchanger. They used the average size of 55 nm and volume concentration ranging from 0.1%-0.2%.The results show that there is enhancement in heat transfer coefficient, Nusselt number and convective heat transfer, overall 68%, 52%, 49% respectively up to 1% volume concentration. There is decrease in convective heat transfer and nusselts number beyond the volume concentration of 1% and upto 2%. For 2% volume concentration pressure drop and the friction factor of hybrid nanofluids were expected to be 14.9% and 1.7%.

6. CONCLUSION AND FUTURE CHALLENGES

An accurate explanation of best nanofluids investigation for application in heat transfer in helical coil type heat exchangers has being discussed. Almost all work discussed in literature review shows that the heat transfer coefficient is enhanced by dispersing nanoparticles into base fluid. Heat transfer coefficient is also increased with increase in particle concentration, raise in thermal conductivity, and disordered movement of nanoparticles with increase in particle concentration, decreased particle size, increase in Reynolds number of nanofluid, reduction in thermal boundary layer thickness. By using nanofluid in heat transfer works the results demonstrate that our present understanding on nanofluid is quiet limited. Nanofluid community is facing number of challenges ranging from generation, possible application to system understanding big threats for heat transfer application are nanofluids with controlled particle size and morphology. Apart from the effect of thermal conductivity, future investigation should also consider other properties, especially viscosity, wet ability and examine systematically their effect on flow and heat transfer. In order to understand the mechanism of increased flow and thermal behaviors of nanofluids there is insufficient knowledge regarding the chemical physical surface interaction between the nanoparticles and base fluid. Advancement of computer based model of nanofluid phenomenon, hybrid nanofluid, and to forecast convective heat transfer, correlation and models are necessary for future research.

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