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Review on thermal analysis of helical coil heat exchanger using nanofluid

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Abstract: The motivation behind review is to summarize the recent developments on convective heat transfer along with pressure drop in shell and helical coil heat exchanger using Nano fluids as working liquid. The Nano fluid is a mixture of nano sized practical such as metal oxide in conventional base fluids like ethylene glycol, DI water. The researchers have concentrated more on forced convective heat transfer under laminar and turbulent flow condition. In this paper we are going to review the published paper on experimental investigations of forced convective heat transfer and pressure drop of Nano-fluids. The vast majority of the researcher has distinguished a little rise in pressure drop with utilization of Nano- fluids in helical coil heat exchanger. We can see massive difference in Nusselt number by adding small percentage of nanoparticles concentration in base fluid for both the flow condition.

***Index Terms* - Reynolds number, dean number, overall heat transfer coefficient, Nusselt number, thermal conductivity.**

I. Introduction

To enhance heat transfer rate there are more than fifteen heat transfer enhancement techniques. The above techniques are be broadly classified into active, passive and compound techniques. Active techniques are those which require additional power such as electricity, acoustic field and surface vibration to enhance heat transfer rate, whereas in case of Passive techniques, which do not require any additional power for the enhancing heat transfer rate .In compound technique it is a combination of both active and passive technique.

Active Techniques

Mechanical Aids: It consists of stirring the fluid or rotating the surfaces by mechanical means. In Surface Vibration Low or high frequency surface vibrations devices such as piezoelectric device are used to enhance single phase heat transfer. Fluid Vibration is a type of vibration in which enhancement is due to the pulsation of fluid in heat exchangers. Electrostatic Fields can be created in the form of electric or magnetic fields or a combination of the two forms of DC or AC sources, which can be applied in heat exchange systems involving dielectric fluids. An electrostatic field produced by either direct current or alternating current, is used for dielectric fluids, to cause proper bulk mixing of the fluid in the vicinity of the heat transfer surface. The electric field applied to the dielectric fluid imposes a body force on the fluid, which influences the fluid motion.

Suction involves vapor removal in the nucleate or film boiling, or fluid withdrawal through a porous heated surface. This technique is applicable to only the single phase fluids. Jet Impingement involves spraying a liquid on the hot surface; it spreads as a thin film and gets evaporated.

Passive Techniques

Extended Surfaces is the most common approach to enhance the heat transfer by increasing the surfaces area and the recent developments are capable of producing desirable geometry with high precision. Rough Surfaces are the

surface modifications that promote turbulence in the flow field in the wall region, primarily in single phase flows, without increase in the surface area. Inserts are one that is placed into the flow channel, to improve the energy transport at the heated surface indirectly. The inserts mix the main flow without affecting the main flow significantly, in addition to that in the wall region. Swirl Flow Devices include a number of geometrical arrangements or tube inserts for a forced flow that create a rotating or secondary flow. Helical vane inserts and twisted tape inserts are some examples of swirl flow devices. One of the most important passive techniques to augment the heat transfer is the use of vortex generators. Coating of the Surfaces in hydrophilic coating promotes the condensate drainage on the evaporator fins, by reducing the wet air pressure drop. The temperature drop across a laminar condensate film depends on the condensate thermal resistance and such capillary assisted film thinning reduces the resistance. Additives for base fluid Additives for the single phase liquids may be solid particles or gas bubbles. Now-a-days, high conductive nano-sized metallic particles are of considerable interest, to increase the thermal conductivity of the heat transfer fluid. Additives for Gases Solid additives are frequently used in the fluidized beds, which involve heat transfer between a bundle of tubes and a fluidized gas-solids medium. The enhancement ratio for a gas solid suspension flowing inside a tube is found to be 3.5 times higher than the base case. The Solid additives are glass, sand, zinc, graphite, aluminum oxide etc., and the liquid additives generally refer to water droplets, added to the air stream. The wetted heat transfer surface facilitates evaporation from the water film surface into the air stream.

HELICAL COILED HEAT EXCHANGER

Thermal load removal is a great concern in many industries including power plants, production and chemical process, transportation and electronics. For several years, the efforts have been put to enhance heat transfer, reduce heat transfer time and minimize size of heat exchanger and finally increase energy and fuel efficiencies. One of the most critical challenges faced by the scientists is the necessity to increase the heat fluxes and reduce the size of the heat exchangers. Among the different heat exchangers, the helical coiled heat exchangers receive much attention, because of the additional momentum and energy transportation by cross-sectional convection due to co-existence of centrifugal force. The centrifugal force causes a secondary flow normal to the primary direction of flow with circulatory effects that provides proper mixing to augment the heat transfer rate than that in the straight tubes. The experimental studies showed that the helical coil heat exchangers possess high thermal performance, though there is an increase in pressure drop across the helical section. Higher heat transfer rate results with appreciable reduction in surface area that leads to high compactness. Hence, the use of helical geometry is considered as one of the most important passive technique to enhance the heat transfer rate between the fluids and it can be useful to develop the energy efficient systems for various industrial applications.

The thermo physical properties such as thermal conductivity, viscosity, specific heat and density of base fluids and nanofluid are measured by conducting experiments. Earlier studies reported that nanofluid properties vary with temperature and the particle volume concentration in the base fluid.

The thermal conductivities of nanofluids are comparatively higher than those of base fluids. Properties of nanofluids can be advantageously altered to make them suitable particularly in heat transfer applications.

For this study secondary data has been collected. From the website of KSE the monthly stock prices for the sample firms are obtained from Jan 2010 to Dec 2014. And from the website of SBP the data for the macroeconomic variables are collected for the period of five years. The time series monthly data is collected on stock prices for sample firmsand relative macroeconomic variables for the period of 5 years. The data collection period is ranging from January 2010 to Dec 2014. Monthly prices of KSE -100 Index is taken from yahoo finance.

II. LITERATURE REVIEW ON NANOFLUID PROPERTIES

A novel idea of two-phase fluid i.e., a liquid with nano particles present in it is conceived and this fluid mixture is expected to give high thermal conductivity. Nano particles of metals and metal oxides dispersed in any conventional heat transfer fluids show higher thermal conductivities when compared to the thermal conductivities of pure liquids. In the last 100 years, a number of theoretical and experimental studies were undertaken on the properties of liquid suspensions containing milli or micro sized particles.

THERMAL CONDUCTIVITY

In 1995, Choi stated for the first time that addition a nanoparticles into a base fluid could increase the thermal conductivity of the fluid[2]. The thermal conductivity of the fluids can be increased by adding these metal oxides innanoscale into the base fluid. Nowadays hybrid nanofluis haven used to enhance the thermal conductivity. Presence of solid particles inside the deionized water,

due to the Brownian motion, accounts for the enhancement in thermal conductivity of the mixture[3]. Overall asnanoparticles concentration increases it enhance the thermal conductivity of the deionized water, when they are dispersed into the water.

Maxwell equation

$$K_{nf} = \frac{K_v + (n-1)K_w - \varphi(n-1)(K_w - K_v)K_w}{K_v + (n-1)K_w + \varphi(K_w - K_V)}$$

VISCOSITY

It is one of the important property of nanofluid which indicates the resistance to flow of the fluid. As the viscosity increases, the power required for pumping and therefore the energy consumption of the pump increases[2]. Many researchers have studied on the performance of viscosity under various flow and temperature condition. The researchers have given various correlation to find out viscosity of nanofluid. Viscosity of the silver/water nanofluid influence the Brownian motion and fluid dynamics of the nanofluid [3]. As temperature increases the viscosity of the nanofluid decrease.

viscosity correlation proposed by (Einstein)

$$\mu_{nf} = \mu_w + (123\varphi^2 + 7.3\,\varphi + 1)$$

DENSITY

The density of fluid is defined as the ratio of mass and volume. Volume of the fluid is temperature dependent in case of fluid. [2]. This is mainly due to the presence of the nanoparticles inside the bulk of fluid which increases the mass of the unit volume of nanofluids[3].Increasing the concentration of nanoparticles not only enhances the densityof nanofluid but also intensifies the scale formation of the particles. Therefore, depending on the application of the nanofluid, concentration should be optimized[3].

(Pak and Cho) $$\rho_{nf} = \varphi.\rho_p + (1-\varphi).\rho_p$$

SPECIFIC HEAT TRANSFER

According to these studies, the addition of nanoparticles leads to a reduction in the specific heat of nanofluids. It should be mentioned that the decrease and increase of this property has a strong dependence on the base fluid. However, the reduction of the specific heat of the fluid by the addition of nanoparticles has been reported in mostcases[2].

(Xuan and Roetzel) $$(\rho C_p)_{nf} = \varphi(\rho C_p)_p + (1-\varphi)(\rho C_p)_w$$

Author	Base Fluid	Nano particle	Flow regime	Observation
P. Rathnakumar et al. (9)	Water	CNT	Turbulent	The utilization of helical louvered pole embeds in plain cylinder causes strengthening in heat move with critical increment in pressure drop. The Nusselt number for the cylinder fitted with helical louvered pole embeds is higher contrasted with the plain cylinder for a given Reynolds number. The Nusselt number increments with increment in Reynolds number and nanoparticle focus.
Ahmad Hajatzadeh Pordanjani et al. (2)	Water, EG, etc	Ag, CNT,Tio2,Cuo	Laminar & turbulent	As in case of laminar flow, the convection heat transfer coefficient has been increased by increasing the concentration of nano particle in base fluid The volume part of nanoparticles Increases prompts a decrease in the heat capacity of nanofluids.
Maryam Nakhjavani et al. (3)	Di- water	Ag	-	Silver nanoparticle when scattered in deionized water indicated an estimated improvement of 45% over the base liquid for thermal conductivity, which suggested on this reality that silver/water nanofluid offers an extraordinary potential for cooling applications.
Shajahan Mohamed Iqbal (4)	Water	Zro2	laminar	Results uncovered that the warmth move rate are higher than that of base liquid DI Water, this is because of the expansion in warm conductivity of zirconia nanoparticles introduced in the DI Water. Thermo physical properties like Thermal conductivity and viscosity, of the nanofluids are indicated eminent enlargement with expanded volume fixation.
Bahrehmand et al. (5)	Water	Al2O3	Turbulent	The mean warmth move rate increment with volume centralization of nanofluid 0.2% and 0.3% with increment 14% and 18% individually. Loop side increment nanofluid focus ,shell side and in general warmth move coefficient improvement. The weight drop increment with increment Dean number with higher volume centralization of nanofluid.
Gabriela huminic et al. (6)	Water	Cuo TiO2	Laminar	For 2 %Cuo volume concentrartion tube in tube helical coil the maximum effectiveness was 91% were as for 2% TiO2 volume concentrartion the effectiveness is 80%.
Allahyar et al. (7)	Water	Al2O3 / Ag (hybrid)	Laminar	The greatest pace of warmth move can be obtained by utilizing the composite nanofluid at a grouping of 0.4 vol% which is 31.58% higher than that of the refined water.

Khoshavaght-Aliabadi et al. (8)	Water	Cuo	Laminar	PEC, HCT-I which has the littlest curl distance across shows the best presentation among other contemplated HMTs. The most extreme PEC is discovered to be 2.24 for 0.3% Cu–water nanofluid through HMT-I at Reynolds number of 1985.
Wu Zan et al. (9)	Water	MWCNT	Laminar	Viscosity and thermal conductivity increase with weight concentration of nanaofluid. At 1% of Weight concentration, the relative viscosity is 9.56 and 1.04 for thermal conductivity
Siamak Mirfendereski et al. (10)	Water	Ag	Laminar	heat transfer in helical coil by using naono fluid has increased by 2.5 - 3.8%. As the pressure drop increases with curvature ratio's 0.04778 at 0.03% volume concentration of nanofluid.
Srinivas et al. (11)	Water	Cuo	Laminar	The heat transfer was 32.7% maximum at 2% wt concentration for dean number 3700. The effect of sittrrer speed is less compared weight concentration of nanofluid.
Milad Rakhsha et al. (12)	Water	Cuo	Turbulent	For two phase media i.e nanofluid shows the pressure drop in a range of 14-16% and heat transfer coefficient is increased about 16 - 17% respectively.
Mukesh kumar et al. (13)	Water	Al2O3	Laminar	The nusselt number is increased by 30% at 0.8 % of volume concentration for dean number of 2650. The pressure drop is increased by 9% at 0.8 % of volume concentration.
Siamak Mirfendereski et al. (14)	Water	Ag	Laminar	Comparing the both the methods of enhancing heat transfer helical coil has more influence on thermal and hydrodynamic flow than the use of Ag nanofluid which enhance the heat transfer coefficient by 3.5 – 3.8%.
Mukesh kumar et al. (15)	Water	Al2O3	Laminar	It is found that for 0.8% of volume fraction of nanofluid the nusselt number has increased by 42% and there is deviation of 7.5% from the predicted nusselt number to experimental value. The pressure has been reduced by 20% for the same concentration.
Kahani et al. (16)	Water	Al2O3	Laminar	By decreasing the bend proportion or expanding the pitch curl prompts increase the warmth move rate i.e nusselt number is increased from 15.51% to 51.58%
Aly et al. (17)	Water	Al2O3	Turbulent	The warmth move coefficient increments by expanding the curl breadth and nanoparticles volume fixation. Besides, the erosion factor increments with the expansion in the ebb and flow proportion also, nearly there is no weight drop reduction with expanding the nanoparticles volume focus up to 2%.
Khairul et al. (18)	Water	Cuo, Al2O3 & Zno	Turbulent	Decrease in entropy and increase in heat transfer coefficient with increase volume rate for Cuo at 3%volume concentration is 6.14% and 7.14% respectively.
Fakoor Pakdaman et al. (19)	Heat transfer oil	MWCNT	Laminar	As Reynolds number and nanoparticle weight concentration increases pressure drop also increase up to 20% and found maximum at Re = 1800.
Akhavan Behabadi et al. (20)	Heat transfer oil	MWCNT	Laminar	Heat transfer is comparatively more in helical coil heat exchanger than straight tube heat exchanger. Heat transfer coefficient is increased by 80% to that of base fluid 45%. Nusselt number increased upto 45% as a result of using nanofluid instead of the base fluid .
Mohammed et al. (21)	Water	Cuo	Laminar	As helix span is diminishes the warmth move can be improved by expanding the inward cylinder measurement and diminishing annulus breadth. As the helix range is decreased weight drop has been expanded.

III. EXPERIMENTAL PROCEDURE

The most common experimental setup is as shown in the fig:1. It consists of two reservoirs, one for hot fluid and one for cold fluid, two separate pump for each reservoir. Mass flow rate, temperature and pressure are measured using rotameter, temperature sensor, and u-Tube manometer respectively at test section . The helical coil surface is maintained at constant temperature by passing the hot fluid. The test section is well insulated to reduce the heat loss to the surrounding. Cold water/ nanofluid is allowed to flow over the helical coil. Standard operating procedure is to run the experiment and readings have been noted down. The following equation has been used to estimate the rate of heat transfer.

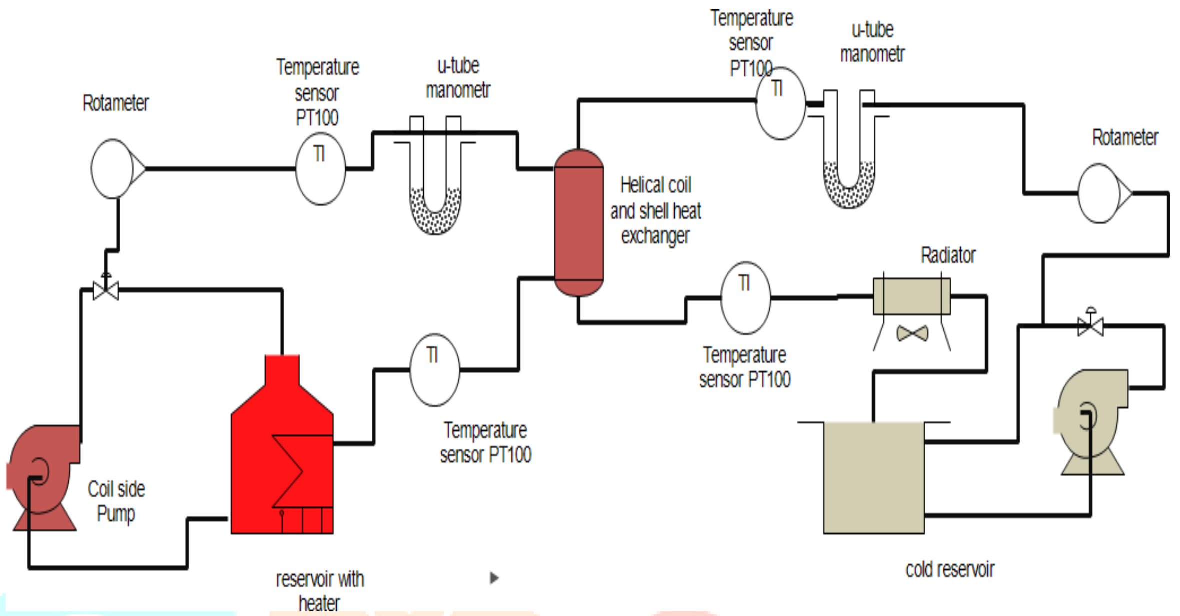

Fig:01 Experimental setup

Data Reduction

Analysis of heat exchanger is carried out using the following equation

Heat absorbed by cold water $Q_c = m_c \times Cp_c \times (T_{in} - T_{out})$

Heat rejected by hot water $Q_h = m_h \times Cp_h \times (T_{in} - T_{out})$

Area $A = \pi dl$

LMTD $\mathrm{LMTD} = \frac{(\mathrm{Thi-Tci})-(\mathrm{Tho-Tco})}{\ln\frac{(\mathrm{Thi-Tci})}{(\mathrm{Tho-Tci})}}$

Over all heat transfer coefficient $Q = U * A * \mathrm{LMTD}$

Reynolds number $\mathrm{Re} = \frac{4m}{\pi * d * \mu}$

Dean number $\mathrm{De} = \mathrm{Re}\sqrt{\frac{d}{D}}$

Nusselt number $\mathrm{Nu} = \frac{h*d}{k}$

Pressure Drop $\Delta p = \rho * g * h$

Friction Factor $f = \frac{\Delta p}{\left(\frac{1}{2}\right)\rho v^2\left(\frac{D}{L}\right)}$

Thermal Performance Factor $\eta = \left(\frac{\left(\frac{Nu_{nf}}{Nu_w}\right)}{\left(\frac{f_{nf}}{f_w}\right)^{\left(\frac{1}{3}\right)}}\right) * \delta^{0.003}$

IV. Conclusion

Literature survey on experimental studies of Convective heat transfer and pressure drop in Shell and Helical Coiled Tube heat exchanger under laminar and turbulent flow condition shows significant improvement in heat transfer, as the concentration of nano particle increases in base fluid. Different researches has used different nano particle such as Ag-water, Al2O3- water , Sio2-water, Cuo -water, TiO2 -water, MWCNT-water and Zro2- water among them Ag-water nano fluid has highest thermal conductivity and heat transfer coefficient is comparably high. Based on position vertical has higher heat transfer rate compared to horizontal one. The heat transfer coefficient and pressure drop increase with increase in Dean Number is shown in results. Few experimental studies disclose that increase in pitch coil and decrease in curvature ratio, increases the heat transfer rate.

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