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Numerical Study On Thermal Performance Of TiO_2 Nano Fluid In An Heat Exchanger

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Abstract

The rate of heat transfer and the size of the equipment play an important role in the current situation, irrespective of the type of industry and the type of process in which the heat exchanger is been employed i.e. in modern world each and every person is looking for the heat exchangers which possess higher efficiency (greater rate of heat transfer) & which occupies less space.

The regular shell and tube heat exchanger (STHE) is been employed in most of the places but the engineers always apply hard work & knowledge for discovering the new things which is better than the present one. One such type of invention in enhancement technique is the use of helical coil in the STHE where the straight tubes are replaced with helically coiled tubes. Hot and cold fluids are made to pass through shell and coil side respectively or in the reverse manner. The heat transfer takes place between these fluids.

According to the experimental results and literature survey, helically coiled tubes possess better heat exchanger qualities than the conventional double pipe and the STHE. Because of the helical coil geometry, when the fluid is made to flow through it, the fluid (primary flow) due to the geometry gains a centrifugal force, the pitch and helix angle of the coil governs the torsion and this force intern generates a secondary flow, which is the main reason for the increase in the rate of heat transfer.

Even though there is noticeable change in the rate of heat transfer because of the change in the geometry but the rate can be further increased by replacing water with titanium oxide–water based nano-fluid. Addition of nano sized particle in the base fluid, say water which possess lower thermal conductivity. The nanoparticles which generally possess higher thermal conductivity than the base fluid & hence there is increase in rate being observed.

LITERATURE SURVEY

We have made after writing overview throughout my task. The ideas clarified in every paper are considered as a kind of perspective all through the undertaking furthermore which will upgrade nature of the work. The accompanying creators distributed papers are as per the following.

(i) Literature survey on "Shell and tube heat exchanger".

"B Farajollahi etal". [1] in there experimental study, they have used two different nanoparticles namely γ-Al2O3 and TiO2 and these nanoparticles are been suspended an common base fluid i.e. water. And in there study, under turbulent flow condition in the shell & tube HE , heat transfer characteristics were studied. The effect of various parameters like the concentration of the nanoparticle, the type of the nanoparticle and the peclet number etc on the heat transfer characteristics were studied. As the result of the study, they have observed that the addition of the particles to the base fluid, there is noticeable increase in the thermal properties of the fluid. They found out that there exist an optimum concentration at which the thermal transport properties are found to be maximum.

It was observed that at optimum concentration, heat transfer characteristics of TiO2/ water based nanofluid is more dominant than γ-Al2O3/ water based nanofluid for a given peclet number. And also at higher concentrations, γ-Al2O3/ water based nanofluid possess greater thermal properties than the other.

“Roghayeh Lotfi etal”.[2] in there experimental stud of horizontally placed STHE, the enhancement of the heat transfer is achieved by a multi-walled carbon nano tub(MWNT)/water based

Objective and Methodology

As discussed earlier, the main aim of any engineer is find out the efficient method to remove the heat from the system with minimum changes in the present system, and also effort are being made to minimize the size of the equipment.

To full fill the above requirement, in our study ‘I’ have modified structurally the system by replacing the straight tubes with an helically coiled tube, the helically coiled tubes are as shown in the fig(1). below.

Selection of material plays an important role, as the material is subjected to two different types of fluids at different operating condition of pressure, temperature, and chemical composition, a material which possess chemical stability, and at the same time as it is used for heat transfer application the material should be a good conductor of heat, and hence generally copper is used in this application. The second modification made in the system is replacing cold water with an TiO_2, water based nano fluid, as explained earlier as the thermal conductivity of the nano sized particles which are dispersed in the base fluid (water) is higher than the base fluid (career fluid), and hence there by increase in rate of heat transfer is observed. The concentration of the nano fluid is changed and results are been plotted.

nano fluid, & physical MWNT are obtained by catalytic chemical vapor deposition process over the magnesium oxide nano crystal or Co–Mo nano crystal. Three stage methods were employed to improve the stability of the tube. The tubes were made hydropilic by inserting an functional group of COOH. And it was experimentally found that there is increased in heat transfer rate in the presence of MWNT in accordance with the base fluid.

Fig(1). **TiO_2** nano particle.

Nanoparticles: Nano particles are those particles whose size varies from 1 to 100 nano meter in size and hence it is termed as nano particles. The production of nano particle is carried out in different methods as follows,

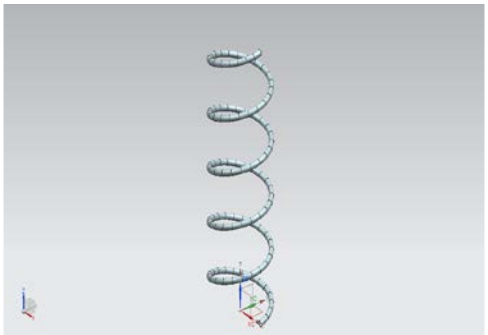
(i) Attrition: In this method the solid metals are grinded in to fine sized particles in the ball mills.

(ii) Pyrolysis: In this method a liquid or gas is made to pass through an atomizer at an high pressure an then burned, the soot which is been produced is air clarified and the oxides are recovered from the soot.

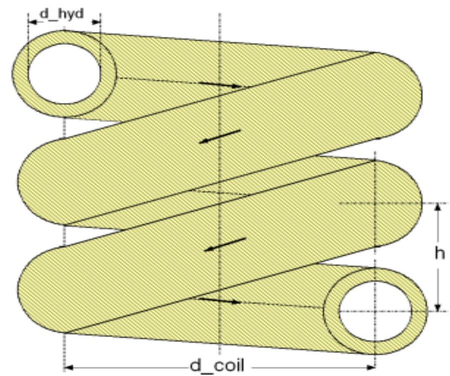
(iii)
(iv)
(v)

(vi)

(vii) Thermal synthesis: In this method metallic powder is subjected to thermal plasma where the temperature will be in the order of 10,000k, & hence it will result in vaporization of the powdered metals, and at the exit region cooling of the plasma is carried out as the plasma has vapors present in it, resulting in the formation of nanoparticles. etc.



Fig(2) Solid model



Fig(3) Coil Description

Methodology for any numerical simulation using an software package remains the same which includes the following main things.

(1) Data collection.

(2) Pre Processing

(3) Processing

(4) Post processing

The CFD software package works on the principle of the basic three laws and it is represented in the form of partial differential equations. The laws are as follows,

(i) Conservation of mass : it is given by the continuity equation in both integral and differential form as follows,

(a)

$$\int_{cs} \rho V \, dA + \frac{\partial}{\partial t} \int_{cv} \rho \, dA = 0$$

(b)

$$\frac{\partial \rho}{\partial t} + \frac{\partial(\rho.u)}{\partial x} + \frac{\partial(\rho.v)}{\partial y} + \frac{\partial(\rho.w)}{\partial z} = 0$$

(ii) Conservation of momentum: it is based on the principle of Newton's second law of motion F = ma.

The Conservation of momentum is represented by Navier-Stokes Equations,

$$\rho\frac{\partial u}{\partial t} + \rho u\frac{\partial u}{\partial x} + \rho v\frac{\partial u}{\partial y} + \rho w\frac{\partial u}{\partial z} = \rho g_x - \frac{\partial p}{\partial x} + \mu\frac{\partial^2 u}{\partial x^2} + \mu\frac{\partial^2 u}{\partial y^2} + \mu\frac{\partial^2 u}{\partial z^2}$$

$$\rho\frac{\partial v}{\partial t} + \rho u\frac{\partial v}{\partial x} + \rho v\frac{\partial v}{\partial y} + \rho w\frac{\partial v}{\partial z} = \rho g_y - \frac{\partial p}{\partial y} + \mu\frac{\partial^2 v}{\partial x^2} + \mu\frac{\partial^2 v}{\partial y^2} + \mu\frac{\partial^2 v}{\partial z^2}$$

$$\rho\frac{\partial w}{\partial t} + \rho u\frac{\partial w}{\partial x} + \rho v\frac{\partial w}{\partial y} + \rho w\frac{\partial w}{\partial z} = \rho g_z - \frac{\partial p}{\partial z} + \mu\frac{\partial^2 w}{\partial x^2} + \mu\frac{\partial^2 w}{\partial y^2} + \mu\frac{\partial^2 w}{\partial z^2}$$

(i) The conservation of momentum:

$$\frac{\partial}{\partial t}\left(\rho e + \frac{1}{2}\rho v^2\right) + \frac{\partial}{\partial x}\left(\rho u e + \frac{1}{2}\rho u v^2\right) + \frac{\partial}{\partial y}\left(\rho v e + \frac{1}{2}\rho v v^2\right) + \frac{\partial}{\partial z}\left(\rho w e + \frac{1}{2}\rho w v^2\right) =$$

$$k\left(\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} + \frac{\partial^2 T}{\partial xz^2}\right) - \left(u\frac{\partial p}{\partial x} + v\frac{\partial p}{\partial y} + w\frac{\partial p}{\partial z}\right) +$$

$$\mu\left[u\frac{\partial^2 u}{\partial x^2} + \frac{\partial}{\partial x}\left(v\frac{\partial v}{\partial x} + w\frac{\partial w}{\partial x}\right) + v\frac{\partial^2 u}{\partial y^2} + \frac{\partial}{\partial y}\left(u\frac{\partial u}{\partial y} + w\frac{\partial w}{\partial y}\right) + w\frac{\partial^2 u}{\partial z^2} + \frac{\partial}{\partial z}\left(u\frac{\partial u}{\partial z} + v\frac{\partial v}{\partial z}\right)\right]$$

$$+2\mu\left[\frac{\partial^2 u}{\partial x^2} + \frac{\partial u}{\partial y}\frac{\partial v}{\partial x} + \frac{\partial^2 v}{\partial y^2} + \frac{\partial v}{\partial z}\frac{\partial w}{\partial y} + \frac{\partial^2 w}{\partial z^2} + \frac{\partial w}{\partial x}\frac{\partial u}{\partial z}\right] + \rho u g_x + \rho v g_y + \rho w g_z$$

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Results and discussion:

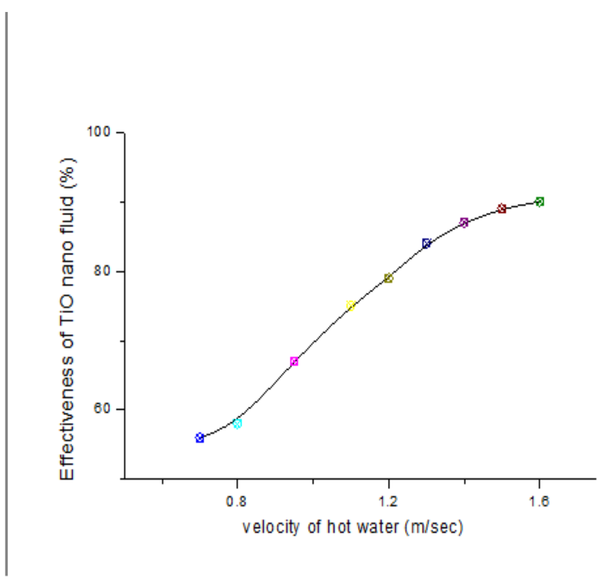
The following graphical representation gives the better understanding for TiO_2 nano-fluid used as an working fluid. There are various graphs plotted which gives the relation among them.

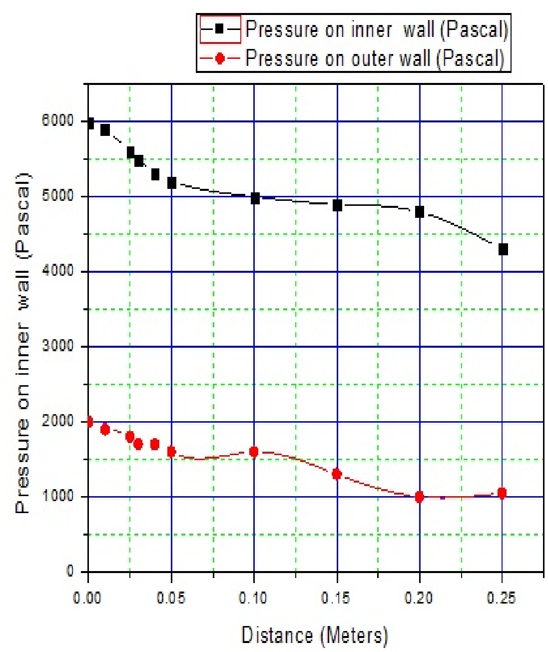
(i) The first graph gives the information regarding how there is an increasing in the effective ness of the H.E using TiO_2 nanofluid as the working fluid. This increase in effectiveness is due to mainly two reasons the first one is due to the use of the helical coil and the other is due to the use of nano sized particle. In helical coil due to its geometry the fluid flow sets up an secondary flow (just similar to the vortex) which increases the rate of heat transfer. They sure of nano size particle increase the thermal capacity of the fluid.

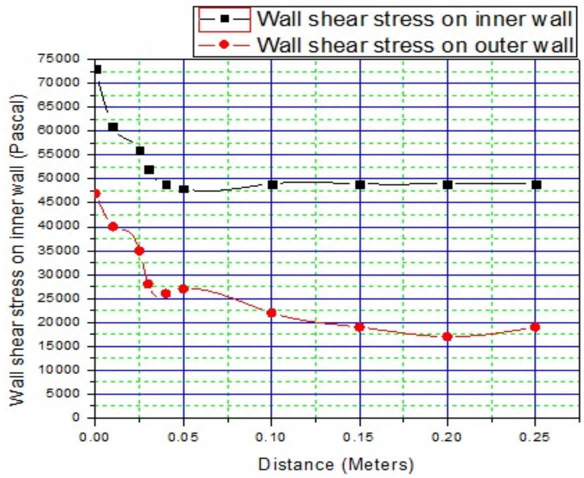
(ii) In the second graph the variation of pressure is clearly shown along the length i.e. is pressure decreases along the length of the coil due to the geometry.

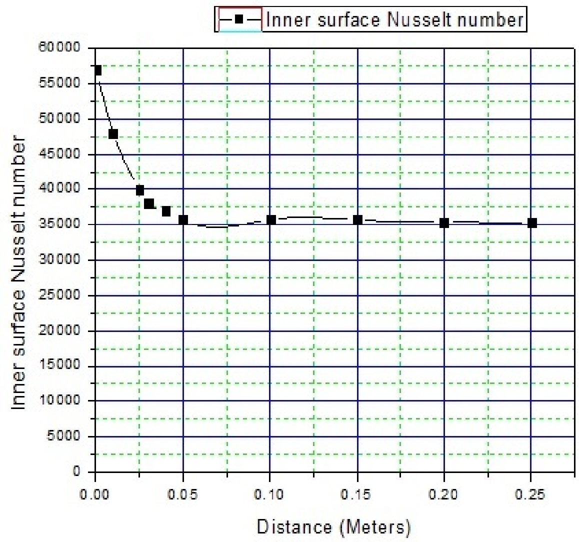
(iii) In the third graph the wall shear stress acting on both inner and outer wall of H.E is shown.

(iv) And finally the variation of inner surface Nusselt number along the length is plotted.









CONCLUSIONS AND SCOPE OF FUTURE WORK

Conclusion: It has been observed from the numerical analysis that the use of TiO_2 nano fluid in an helically coiled H.E increases the efficiency of the equipment considerably when compared with water as a working fluid in the same setup.

Scope of future work: Various alterations can be made to the present system for increasing the performance of the equipment is as follows,

(1) By changing the dimensions of the helical coil i.e. coil diameter, pitch, tube diameter etc.
(2) By changing the type of material used the heat exchanger coil and also by changing the type nano particle used.
(3) Baffles can be placed along the length for regulating the fluid flow when an helical coil is placed in a tubular H.E. etc.

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