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Heat Transfer Analysis of Cone Helically Coiled Heat Exchanger with Nano Fluid Using CFD

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Abstract:

Coiled tube configurations is widely used in industries like power plants, nuclear reactors, refrigeration and air conditioning, heat recovery system, chemical processing and food industries. The coiled tube is of two types alike helical coil and spiral coiled tube. The flow pattern in helical coiled tube is complicated due to the formation of secondary flows induced by the centrifugal force. Secondary flow provides better thermal contact between the surface of the tube and fluids due to the creation of vertex and resulting the mixture of fluid which improve the temperature gradient. This study investigates the heat transfer of cone helically coiled tube heat exchanger using (Multi wall carbon nano tube) MWCNT/water nanofluids by varying pitch size of the tubes. The MWCNT/water nanofluids 0.5% particle volume concentrations were used. From the pressure and temperature contours it was found that along the outer side of the pipes the velocity and pressure values were higher in comparison to the inner values. It may be concluded that by increasing pitch size of cone helically coiled heat exchanger, the heat transfer rate increases as Nusselt no. and Overall heat transfer increases.

Keyword: Numerical analysis, MWCNT /water nanofluids, Computational fluid dynamics, Pressure drop, Thermal conductivity, Nanofluid viscosity, Pitch size.

I. Introduction:

The performance of the heat exchanger is enhanced by improving the heat transfer coefficient and this enhancement, in addition, reduces the heat exchangers size which is the crucial requirement in meeting out the cooling demand. In general heat transfer enhancement techniques can be grouped into active and passive techniques. The active technique needs external forces and passive group needs a special surface geometric face or fluids additives and various tube insert. Coiled tube configuration is widely used in industries such as power plants, nuclear reactors, refrigeration and air-conditioning systems, heat recovery systems, chemical processing, and pharmaceutical industries and so on. The coiled tube is of two types namely helical coiled and spiral coiled tube. As reported by Dean [1], the centrifugal force induces the generation of secondary flow which makes proper mixing of fluids particles in a helically coiled tube that improves the physical contact between the tube area and the fluids. This also provides better mixing of the fluids which results in the improvement of the temperature gradient.

The thermal conductivity of heating or cooling of fluids is very important property for the development of energy efficient heat transfer equipment. Meanwhile, all the processes involving heat transfer, the thermal conductivity of the fluid is one of the basic and most important parameter taken into account in designing and controlling the processes. Nanofluids are engineered colloids which are made of a base fluid and nanoparticles of (1-100) nm. It has been found by many researchers that the nanofluids provide higher thermal conductivity compared to base fluids. Its value increases with the increase in particle concentration, temperature, particle size, dispersion and stability. Nevertheless, it is expected that other factors like density, viscosity, and specific heat are also responsible for the convective heat transfer enhancement of nanofluids. Nanofluids are having high thermal conductivity and high heat transfer coefficient compared to single phase fluids.

Heat transfer and separation of fluid flow in annular channel occurred due to change in pressure gradient caused by an increase or decrease of cross-sectional area of annular channel. Fluid flow in annular channels can be found in several heat exchange devices, such as heat exchangers, nuclear reactors, evaporators, condensers, etc. Generally, many experimental and numerical studies are concerned with the phenomena of separation and reattachment flow.

A nanofluid is prepared by dispersing particles of metal or metal oxide with sizes ranges from 0-70 nm, in a base liquid such as water. The purpose of using nanofluids is to achieve higher values of heat transfer coefficient compared with that of the base liquid. This is achieved by the dispersion of solid particles, which have higher thermal conductivity than the base liquid. There are many engineering applications that can benefit from the use of nanofluids, for example absorption refrigeration, micro electromechanical systems, lubrication of automotive systems, coolant in machining, automobile radiator cooling, solar water heating, heat exchangers, several medical applications, nuclear reactors, and in several aerospace applications. Recent advances in material technology have made it possible to produce innovative heat transfer fluids by suspending nanometer-sized particles in base fluids, which could change the transport and thermal properties of the liquids. Nanofluids represent solid-liquid composite materials consisting of solid nanoparticles with sizes no larger than 100 nm suspended in liquid. This study presents the work undertaken by various investigators and the possible impact of nanofluids on the enhancement of heat transfer in the near future.

Large volume of studies devoted to characterization of individual thermo-physical properties of nanofluids, such as thermal conductivity, viscosity, and agglomeration of nanoparticles, has been summarized in a number of review articles.

Evaluation of cooling efficiency, i.e., ability to remove heat from the heat source, includes assessing flow regime-dependent contributions from thermal conductivity, viscosity, specific heat, and density of the fluid and also depends on the applied flow regime. The studies devoted to evaluation of the heat transfer performance of nanofluids are scarce and inconclusive compared to the studies on the thermo-physical properties of various nanofluids indicating a significant gap between fundamental research and practical applications of nanofluids for thermal management.

II. Computational Fluid Dynamics

CFD is useful for studying fluid flow, heat transfer; chemical reactions etc. by solving mathematical equations with the help of numerical analysis. CFD resolve the entire system in small cells and apply governing equations on these discrete elements to find numerical solutions regarding pressure distribution, temperature gradients. This software can also build a virtual prototype of the system or device before can be apply to real-world physics to the model, and the software will provide with images and data, which predict the performance of that design. More recently the methods have been applied to the design of internal combustion engine, combustion chambers of gas turbine and furnaces, also fluid flows and heat transfer in heat exchanger. The development in the CFD field provides a capability comparable to other Computer Aided Engineering (CAE) tools such as stress analysis codes.

Fig 1. Cone helically coiled tube

The analysis is performed on a cone helical coil heat exchanger with the specifications as mentioned below.

Cone coil angle (θ)	8 degree
Cone inner tube diameter (di)	0.08 cm
Cone outer tube diameter (do)	0.1 cm
Diameter of the shell	11.4 cm
Effective length of the coil	500 mm
Pitch of the coil	1.8, 2.0, 2.2 cm
Calming section length	11 cm
Cone coil diameter	6.4 cm
Number of turns	18

Table 1. Specifications of cone coiled helical tube heat exchanger

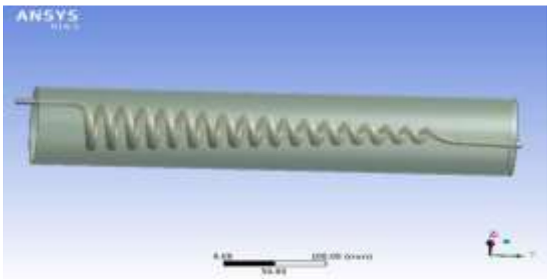

Fig 2. Geometrical model of heat exchanger

Grid Independence is the term used to designate the enhancement of results by using successively smaller cell sizes for the calculations. A calculation should reach the correct result so the mesh becomes smaller; hence the term is known as grid Independence. The ordinary CFD technique is, to start from coarse mesh and gradually improve it until the changes detected in the values are smaller than a pre-defined acceptable error. There are 2 problems with this. Firstly, it can be quite difficult with other CFD software to gain even in a single coarse mesh resulting for some problems. Secondly, refining a mesh by a factor two or above can lead to take more time. This is clearly offensive for software intended to be used as an engineering tool design operating to constricted production limits. In addition to that the other issues have added significantly to the perception of CFD as an extremely difficult, time consuming and hence costly methodology.

III. RESULTS AND DISCUSSION

Fig 3. describes the Dean versus the overall heat transfer coefficient. It is seen that the overall heat transfer coefficient increases with increasing the Dean number and pitch.

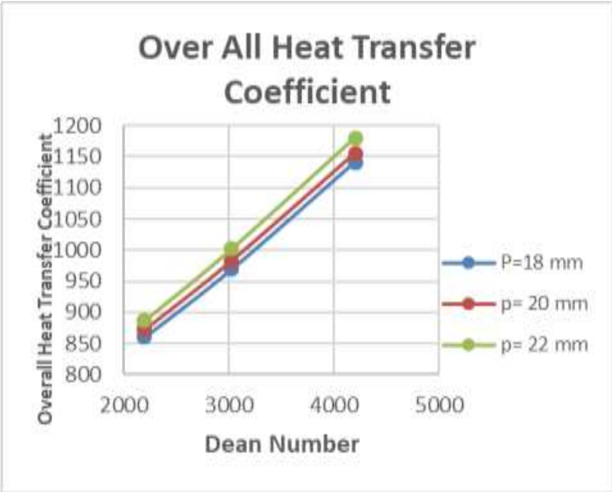

Fig 3. Overall Heat Transfer

The maximum overall heat transfer coefficient is 52% at 0.5% nanofluid in the Dean number 4200. The overall heat transfer coefficient is the effect of conduction and convection mode in the heat exchanger.

In particular the inner heat transfer is highly effective due to stronger convection current between MWCNTs and water. This leaves to improve more convective heat transfer.

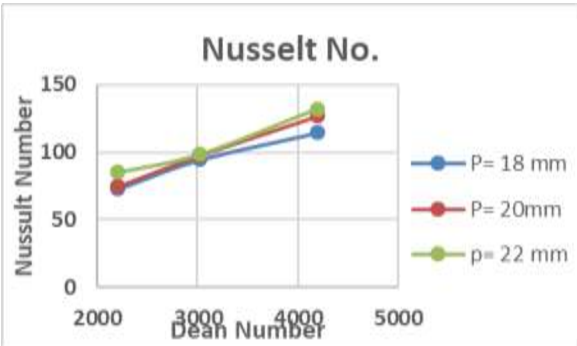

Fig 4: Effect on Nusselt No.

It is seen that the Nusselt number is enhanced by changing Dean Number and pitch size. The improvement is because of the thorough mixing of water particles and CNTs, this also may be the contribution Brownian motion of

the CNTs. Moreover, the random movement of MWCNT disturbs the boundary layer formation and the formation of secondary flows are intensified. The Nusselt number is directly proportional to the inner heat transfer coefficient and therefore Nusselt number increases with increase the heat transfer coefficient.

Conclusion:

- In this paper, the turbulent flow (2200 < De < 4200) heat transfer characteristics of cone helically coiled tube with MWCNT/water nanofluid at 0.5% particle volume concentration and pitch size variation were studied through CFD. It is found that the maximum overall heat transfer coefficient of nanofluids is approximately 50% higher than the water at 0.5% nanofluid in the Dean number 4200 when compared to water It is found that the maximum Nusselt number for pitch=22 mm is 14.91% higher than the pitch=18mm in the Dean number 4200.

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