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Effect of MWCNT/Water Nanofluid on Heat Transfer Enhancement in a Shell-and-coiled Tube Exchanger using CFD

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ABSTRACT

The nanoparticles have stronger characteristic of heat transfer such as high thermal conductivity, increased stability and homogeneity, along with negligible blockage in flow paths due to its limited scale and wide area. These advantages inspired the researchers to conduct heat transfer experiments. In this investigation, the heat transfer and pressure drop of the shell and coiled tube heat exchanger handling MWCNT/water nanofluids have been analyzed by the computational software ANSYS 17.0 version. The MWCNT/water nanofluids at 0.05%, 0.1%, 0.3% and 0.5% volume concentrations have been taken for this investigation. The major factors like volume concentrations of nanofluids and flow rate are considered for predicting the heat transfer rate and pressure drop. The simulation data was compared with the experimental data. It is studied that the heat transfer rate and pressure drop increase with increasing volume concentrations of MWCNT/water nanofluids. It is found that the overall heat transfer coefficient of MWCNT/water nanofluids is found to be 18%, 22%, 27% and 32% at 0.05%, 0.1%, 0.3% and 0.5% volume concentrations respectively higher than that of water at the volume flow rate range of 1–3.LPM, while the pressure drop due to MWCNT/water nanofluids may be expected more than 5%, 7%, 10% and 13 % for 0.05%, 0.1%, 0.3% and 0.5% volume concentrations respectively higher than that of water.

KEYWORDS: *Nanotechnology, Volume concentration of nanoparticle, Shell and helically coiled tube, MWCNT /water nanofluids, Computational fluid dynamics, Pressure drop, Thermal conductivity, overall heat transfer coefficient*

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I. INTRODUCTION

In a range of industrial fields, such as electronics, the transport industry, chemical industries, the power plant, air conditioning, food processing and the nuclear reactors, the traditionally used fluids of heat transfer such as water, propylene glycol, oil, gear oil, paraffin, and ethylene glycol are widely used for heat transfer. In the literature, there are various active and passive methods, which help improve traditional fluid heat transfer properties [1–7]. But the heat transfer improvement has hit a bottleneck through these techniques. The traditional fluids used to transfer heat are poorly thermal; these are thus the principal barriers to the creation of future energy efficient heat exchangers. In order to solve this problem, new, advanced heat transfer fluids need to be produced which can have improved heat transfer properties.

Compared to fluids, solid materials have enhanced thermal properties. In order to determine their thermal properties, researchers suggested the suspension of solid particles into conventional heat transfer fluids. These dispersed solid particles measuring millimetres or microns in the base fluid change the Thermophysical properties of the base fluids which ultimately lead to an improvement in heat transfer [8].

Nevertheless, their use is hampered by severe problems, such as suspension stabilization, blockage, pipe corrosion and increasing pressure drops. Nanometer-sized particles will now be produced with the rapid development of material technology. Nanoparticles in the base fluid (Water, Ethylene, Glycol, Oil, etc.) provide a suspension of this nanometer (10^{-9} m) (metallic and non-metallic) nanoparticles. The nanoparticles have stronger characteristic of heat transfer such as high thermal conductivity, increased stability and homogeneity, along with negligible blockage in flow paths due to its limited scale and wide area [10]. These advantages inspired the researchers to conduct heat transfer experiments that took various nanofluids, i.e. nanoparticles and base fluids, in different combinations.

Nanoparticles such as Al_2O_3, TiO_2, CuO, SiO_2, Fe_2O_3, and Fe_3O_4 have been utilised by researchers in the field. The reasons for this analysis are that very few publications on the convective heat transfer with CNT nanofluids are published. This work presents an investigation on the convective heat transfer characteristics of MWCNT/water nanofluids in a shell and tube heat exchanger.

1.1. Helical Coil Heat Exchanger

Flow via helical coils has gained a great deal of interest as helical coils are commonly used in many commercial heat transfer applications including heat exchangers. Helical coil heat exchangers are small in size and have a wide area per unit volume for heat transfer. Inside the channels, fluid circulating into helical coils causes secondary flow. This secondary flow has a major potential to improve the heat transfer rate due to fluid mixing. The function of tube diameter and helical coil diameter is the strength of secondary flow established inside the tube. The study of flow through helical coils is of primary importance since helical coils have substantially improved heat transfer rates.

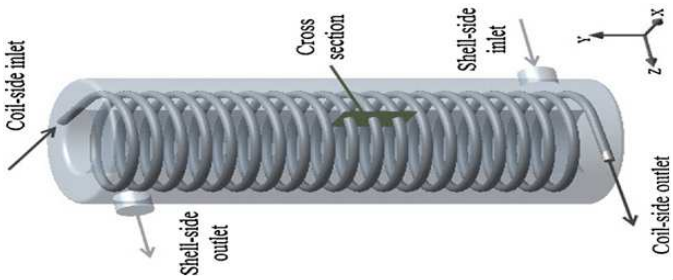

Figure 1 Shell and helical coiled tube Heat Exchanger

II. LITERATURE REVIEW

As the need for more effective heat transfer systems grows, researchers have been using various heat transfer improvement techniques since the mid-1950s. The substantial growth in the number of research publications devoted to this topic has demonstrated, to date, a substantial improvement in the importance of heat transfer technology.

A significant amount of theoretical as well as empirical and quantitative study has been carried out to improve the transfer of heat. A brief review of the related literature is described in this chapter to show the degree of work already published in the open literature on the development of the heat transfer by the application of nano fluids, and use of Shell and coiled tube heat exchanger.

2.1. Previous work

Owing to the heat transfer properties of nanoparticles, industries such as solar synthesis, gas sensing, biological sensing, pharmaceutical, nuclear reactors, the petroleum industry, etc. have followed the idea of using nanoparticles in their respective fields to boost the heat transfer performance of regular fluids. Thermal conductivity is increased by the inclusion of nanoparticles as technically demonstrated by **Choi et al. (2001)** [11].

Masuda et al. (1993) and **Minsta et al. (2009)** have shown that the incorporation of a limited volume of nano-particles < 5 per cent › has resulted in a major increase (10-50 per cent) in the thermal conductivity of simple fluids [12,13].

Kim et al. (2007) examined the critical role of nanofluids in the field of nuclear physics. Proven nanofluids will increase the efficiency of any water-cooled nuclear device system. Possible uses include pressurized water reactor, main coolant, standby protection devices, acceleration targets, plasma diverters, and so on [14, 15].

From **Jackson's (2007)** point of view, the critical heat flux may be increased by producing a controlled surface from nanofluid deposition. The use of nanofluid will increase the in-vessel retention capability of nuclear reactors by as much as 40% [16].

Dean (2008) suggested that the helically coiled tubes are better than straight tubes in view of heat transfer rate as the coiled tube forms strong secondary flow and named the vortex as Dean vortex. Dean found that the secondary flow in coiled tubes (Dean Vortex) is a function of Reynolds number and the d/D ratio [17].

Dean (2009) investigated the steady-state condition of incompressible fluid flow through the helically coiled tubes. He reported that the mass flow rate decreases with respect to the coil ratio [18].

Naphon et al. (2012) reported that the heat transfer characteristics of the coiled tube heat exchanger with respect to the Dean number produces better heat transfer coefficients with nominal pressure drop when compared with straight tubes. They suggested that the coiled tube heat exchanger is highly efficient for transferring heat [19].

Narrein and Mohammed (2014) critically reviewed the important aspects of nanofluids such as types of nanofluids at different base material and base fluid, Thermophysical properties, heat and flow behavior, limitations of nanofluids and applications of nanofluids in helical coil tube heat exchanger. They observed that the use of nanofluids in helically coiled tube heat exchanger leads to the penalty of pressure drop. They proposed the use of nanofluids in industrial applications in real situation need more understanding [20].

Alywaell (2015) carried out the CFD analysis to investigate the effect of nanofluids on heat and flow behavior in a double helically coiled tube with $Al2O3$/water nanofluids. The heat transfer coefficient is improved by increasing the nanofluid volume concentrations with the pressure drop increased up to 2% [21].

Davood et al. (2016) a shell and coiled tube heat exchanger is experimentally studied in which a helical wire has been placed inside the helically coiled tube as a turbulator. The fabrication method of helically coiled tube which contains turbulator and also the effects of turbulator on thermal and frictional characteristics of heat exchanger are presented in this paper. Experiments were performed in two main modes. In first mode, the fluid of coiled tube was water and in second mode the fluid of coiled tube was air. Each mode was studied for both empty coiled tube (without turbulator) and with turbulator under different fluid flow rates. The fluid of shell side was hot water for all cases. Findings showed that this type of turbulator can be employed in coiled tubes which significantly increased the overall heat transfer coefficient and obviously pressure drop [22].

Bahiraei et al. (2018) critically reviewed the recent research works on the use of nanofluids in heat exchangers. They summarized the recent investigation on the application of nanofluids in plate heat exchanger, double pipe heat exchanger, shell and tube heat exchanger and compact heat exchanger. They also revealed the challenges and opportunities for future research on nanofluids. Finally they summarized that the most of the researchers numerically examined the effect of nanofluids and compared the effect of conventional fluids on the heat transfer rate. Most of the research reports concluded that the heat transfer rate is augmented by increasing particle concentration and Reynolds number [23].

2.2. Problem Formulation

In many heat exchangers, the above investigators examined a variety of aspects of nanofluids and different approaches for the use of nanofluids to improve heat transfer rates. In many scientific papers, the research focuses on increasing the potency of nanofluid. However, some papers focus on nanofluid, and its effect, performance, heat transfer and overall heat transfer coefficient. Findings show that nanofluids have greater rises in heat transfer than standard base fluids such as water, oil etc.

It is also studied from the literature review that most of the experimental works on shell and helically coiled tube heat exchanger have been done by using oxide nanofluids. Very little works have been done on shell and helically coiled tube heat exchanger by using MWCNT/water nanofluids with CFD software. Therefore this investigation deals with the thermal and flow behavior of shell and helically coiled tube heat exchanger handling MWCNT/water nanofluids at four different volume concentrations.

2.3. Research Objectives

In this analysis, the thermal characteristics of a MWCNT/water nanofluid in a shell and coiled tube heat exchanger was investigated using a 3-dimensional numerical (3-D) simulation. This investigation deals with handling MWCNT/water nanofluids at four different volume concentrations. The simulation programme ANSYS 17.0 was used for study of the heat transfer physiognomies of a shell and coiled tube heat exchanger with a MWCNT/water nanofluid.

The main objectives of the present work are as follows:

- To analyze the thermal characteristics of shell and coiled tube heat exchanger using MWCNT/water nanofluid.
- To develop shell and coiled tube heat exchanger model and validation on CFD model will be carried out with comparison of previous experimental model.
- Effect of MWCNT/water nanofluid in shell and coiled tube heat exchanger, thermal characteristics is analyzed by parameters such as the Nusselt number, Heat transfer rate, and Overall heat transfer coefficient.
- Calculating the effects of various volume concentrations of MWCNT nanoparticles present in the nanofluid and their effects on heat transfer.
- Calculating the effects of flow rate variation in the performance of the shell and coiled tube heat exchanger.

III. CALCULATION INVOLVED

Two separate statistical formulas are typically used to calculate the heat transmitted through the heat exchanger: the logarithmic mean temperature difference (LMTD) and the number of transfer units (NTU). Considering that all the temperatures of the inlets and outlets were collected numerically, it is more useful to add the LMTD in this work. It is possible to quantify the overall thermal conductance of counter flow heat exchangers as:

$$UA = \frac{\dot{Q}}{\Delta T_{LMTD}}$$

Where,

$$\Delta T_{LMTD} = \frac{\theta_1 - \theta_2}{ln\left(\frac{\theta_1}{\theta_2}\right)}$$

In addition, where $\theta_1$and θ_2 differences is given by:

$$\theta_1 = T_{hot,in} - T_{cold,out}$$
$$\theta_2 = T_{hot,out} - T_{cold,in}$$

The hot and cold subscripts refer to the hot and cold divisions, respectively. The heat rate for each stream,$\dot{Q}$ can, therefore, be calculated from:

Heat transfer rate for hot fluid (J/s):

$$\mathrm{Q_{hot}} = \mathrm{\dot{m}_{hot}} \times \mathrm{c_{p,hot}} \times (\mathrm{T_{in}} - \mathrm{T_{out}})_{\mathrm{hot}}$$

Heat transfer rate for cold fluid (J/s):

$$\mathrm{Q_{cold}} = \mathrm{\dot{m}_{cold}} \times \mathrm{c_{p,cold}} \times (\mathrm{T_{out}} - \mathrm{T_{in}})_{\mathrm{cold}}$$

The average temperature for both cold and hot branches given:

$$T_{Avg.,hot} = \frac{T_{hot,out} + T_{hot,in}}{2}$$
$$T_{Avg.,cold} = \frac{T_{cold,out} + T_{cold,in}}{2}$$

The ***average Nusselt number*** (Nū), estimates the output of a heat exchanger and can be determined on the basis of the following equation:

$$\overline{Nu} = \frac{\bar{h}D_h}{K_a}$$

Where $D_h$is the inlet's hydraulic diameter, h is the standard heat transfer coefficient and K_a is the coolant fluid thermal conductivity.

Mass flow rate (Kg/s):

$\dot{m} = \dot{\rho} AV$

IV. METHODOLOGY

4.1. Computational Fluid Dynamics

CFD is a computer-efficient, numerical analysis-based method of heat - transfer research. CFD simplifies many experimental method problems and offers comprehensive characterization of 3-dimensional flow fields in the heat exchanger.

CFD simulations can be divided into three major steps:

- **Pre-processing** (description of the region of interest, generation of mesh numbers, definition of initial and boundary conditions, mathematical modelling and description of numerical schemes);

- **Solving of simulations** (numeric solution of the transport equations system);
- **Post-processing** (processing and analysis of results).

4.2. The steps of the study

- Firstly we design the shell and coiled tube heat exchanger on Workbench of ANSYS 17.0 Software.
- After designing the model it is transferred to ANSYS for CFD analysis.
- Meshing of model and Name selection is done on CFD pre-processor.
- The boundary conditions are applied on the model and numerical solutions are calculated by using solver.
- The finite volume method is used in solving the problem.
- The solution is calculated by giving iterations to the mathematical and energy equations applied on model.
- The results can be visualized in the form contours and graphs by CFD post processor.
- Applying formulas for calculating heat transfer coefficient, Nusselt Number of shell and coiled tube heat exchanger.
- Result analysis.

V. Geometry Setup and Modelling

5.1. Geometrical specification of shell and coiled tube heat exchanger

The geometry of shell and coiled tube heat exchanger using nanofluids performing the simulation study is taken from the one of the research scholar's **Davood et al. (2016)** with exact dimensions.

Table 1 Geometrical specification of shell

Length(mm)	Thickness (mm)	Inner diameter (mm)
400	2	110

Table 2 Geometrical specification of coiled tube

Turns	Pitch (mm)	Coil diameter (mm)	Tube inner diameter (mm)
9.5	30	60	6

5.2. Solid Model of shell and coiled tube heat exchanger

The solid model of the shell and coiled tube heat exchanger is created in design modular of ANSYS 17.0.

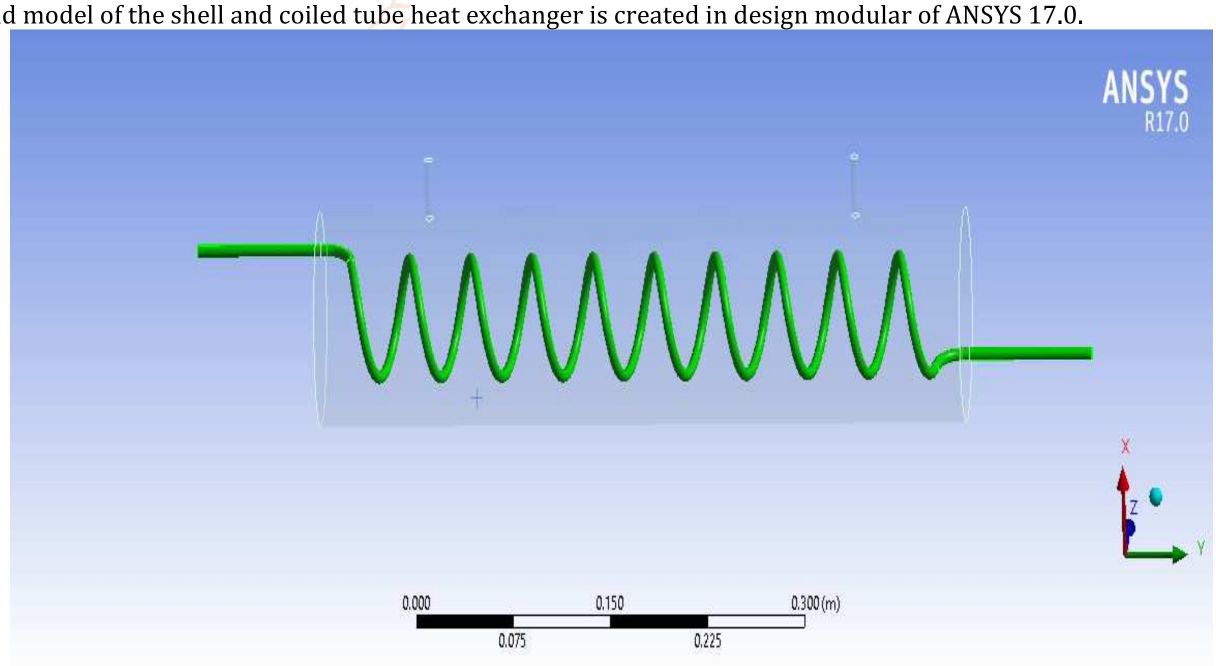

Figure 2 Geometry of shell and coiled tube heat exchanger

5.3. Meshing

The modeling of the test section is meshed with ANSYS 17.0. The coarser meshing is created throughout the effective length of the tube. Fig. 5.6 represents the meshing of shell and coiled tube heat exchanger used in this CFD analysis. The meshing contains the collaborated cells for triangular and quadrilateral expressions at boundary conditions. Much effort is given to the structured hexahedral cells. The smooth meshing is created, edges, as well as regions of temperature and pressure constraints, meshed.

Table 3 Details of Meshing

Domain	Nodes	Elements
Cold_fluid	389108	340938
Hot_fluid	4327200	327825
Inner_pipe	183624	100533
Outer_pipe	253576	139872
All domains	1263508	909168

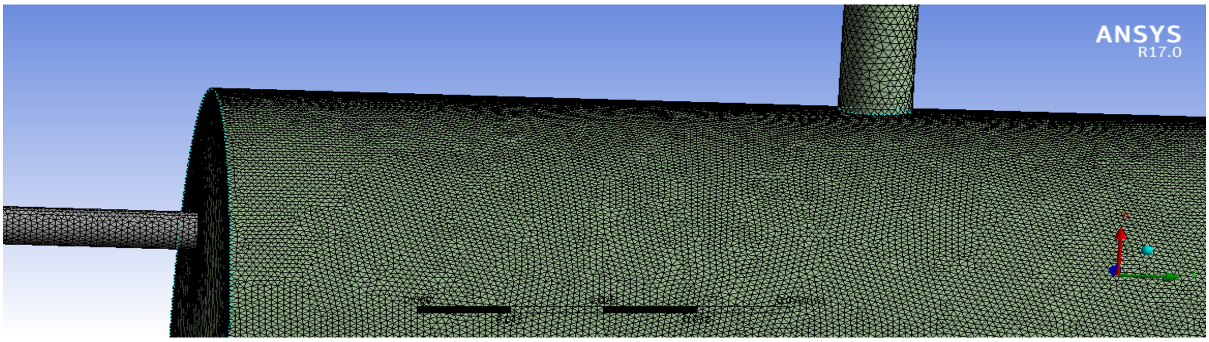

Figure 3 Mesh structure of shell and coiled tube heat exchanger.

5.4. Model Selection and Numerical Simulation

To enhance the simulation accuracy of the current three-dimensional and steady analysis, the governing equations are discretized with the SIMPLE pressure-velocity coupling algorithm with the finite volume formulation. In addition, the second-order upwind scheme have been used for momentum, turbulent kinetic energy, turbulent dissipation rate and energy, while the Presto system is used for pressure.

No-slip condition is applied to all solid walls, and as near-wall treatment, standard wall functions are implemented. The fluids were therefore assumed to be incompressible and the thickness of the tube, heat dissipation from the shell's outer surfaces and radiation were insignificant.

The k-epsilon model is chosen for this analysis as the k-epsilon model predicts well far from the boundaries (wall) and k-omega model predicts well near wall. Continuity, energy and Navier Stokes equations are used to find the conditions for flowing fluid in the helically coiled tube with Eqs.

Mass:

$$\frac{\partial(\rho u_i)}{\partial x_i} = 0$$

Momentum:

$$\frac{\partial(\rho u_i u_k)}{\partial x_i} = \frac{\partial\left(\mu \frac{\partial u_k}{\partial x_i}\right)}{\partial x_i} - \frac{\partial p}{\partial x_k}$$

Energy Equation:

$$\frac{\partial(\rho u_i t)}{\partial x_i} = \frac{\partial\left(\frac{K}{C_p}\frac{\partial t}{\partial x_i}\right)}{\partial x_i}$$

In this project, k- ε model of renormalization group (RNG) was introduced since the estimation of near-wall flows and flows can be enhanced with a high streamline curvature. In the enhanced RNG k- ε model wall thermal effect equations, the thermal effect parameter was chosen.

Turbulent kinetic energy:

$$\frac{\partial(\rho K)}{\partial t} + \frac{\partial(\rho u_i K)}{\partial x_i} = \frac{\partial\left(\alpha_k \mu_{eff} \frac{\partial k}{\partial x_j}\right)}{\partial x_j} + G_k + \rho\varepsilon$$

Turbulent energy dissipation:

$$\frac{\partial(\rho \epsilon)}{\partial t} + \frac{\partial(\rho u_i \varepsilon)}{\partial x_i} = \frac{\partial\left(\alpha_\varepsilon \mu_{eff} \frac{\partial \varepsilon}{\partial x_j}\right)}{\partial x_j} + C_{1\varepsilon}\frac{\varepsilon}{k}G_k + C_{2\varepsilon}\rho\frac{\varepsilon^2}{k}$$

Where, G_k represents the generation of turbulent kinetic energy due to the mean velocity gradient.

$$\mu_{eff} = \mu + \mu_t$$

$$\mu_t = C_u \rho \frac{k^2}{\varepsilon}$$

The empirical constants for the RNG k-ε model are allotted as following:

$C_{1\varepsilon} = 1.42$

$C_{2\varepsilon} = 1.68$

$\alpha_\varepsilon = 1.39$

The following are the consideration for this CFD analysis:

- The MWCNT/water nanofluids are incompressible fluid and single phase fluid.
- The effect of radiation and net convection are neglected.
- The Thermophysical properties are not temperature dependent.
- Uniform dispersion nanoparticles.
- The flow is hydro dynamic.

5.5. Thermophysical properties

In order to generate nanofluids, the MWCNT nanoparticles were dispersed in distilled water at 0.05, 0.1, 0.3 and 0.5 wt. percent before conducting the analysis. At the mean bulk temperature the thermophysical properties of nanofluids were measured. Density, specific heat, viscosity and thermal conductivity values were determined by means of equations:

$$\rho_{nf} = \emptyset\, \rho_p + (1-\emptyset)\rho_{bf}$$

$$\left(\rho c_p\right)_{nf} = \emptyset\left(\rho c_p\right)_p + (1-\emptyset)\left(\rho c_p\right)_{bf}$$

$$\mu_{nf} = (1 + 2.5\,\emptyset)\mu_{bf}$$

$$K_{nf} = \frac{2K_{bf} + K_p + 2\emptyset\left(K_p - K_{bf}\right)}{2K_{bf} + K_p - \emptyset\left(K_p - K_{bf}\right)} K_{bf}$$

Table 4 Thermophysical properties of distilled water and MWCNT nanoparticles at 18 °C

Substance/nanoparticles	Density (kg/m³)	Thermal conductivity (W/m-K)	Specific heat (kJ/kg-K)	Viscosity (kg/m-s)
Distilled water	1000	0.62	4.187	0.000798
MWCNT	2100	3000	0.702	-----------

Table 5 Thermophysical properties of nanofluids at different concentrations

Nanofluids	Wt.%	Density (kg/m³)	Thermal conductivity (W/m-K)	Specific heat (J/kg-K)	Viscosity (kg/m-s)
MWCNT/water	0.05	1026.2	0.6653	4017.3	0.00084548
MWCNT/water	0.1	1052.4	0.7129	3856.0	0.00089295
MWCNT/water	0.3	1156.9	0.9293	3284.6	0.0011
MWCNT/water	0.5	1261.3	1.1990	2808.8	0.0013

Table 6 Thermophysical properties of materials for coiled tube and shell

Material	Density (kg/m³)	Thermal conductivity (W/m-K)	Specific heat (J/kg-K)
Coiled Tube **(Aluminium)**	2800	200	900
Shell **(PVC)**	1440	0.18	1005

5.6. Boundary Conditions

The discrete flow domain has been defined under sufficient limits. Inlets were allocated the flow rate requirements, while pressure outlet limits were allocated for outlets. The surfaces of the heat exchanger is regarded as normal wall limits. The interior walls were fitted with couplings of thermal walls. Table 5.7. Consolidates the restricting constraints on operating heat exchanger fluids.

Table 7 Details of boundary conditions

Constraints	Range/standards
Coiled tube fluid	Cold fluid (MWCNT/water nanofluids)
Flow rate of MWCNT/water nanofluids	1-3 LPM
Inlet temperature of coiled tube fluid	16 °C
Volume concentration of nanofluid	0.05, 0.1,0.3, and 0.5 %
Shell side fluid	Hot fluid (Water)
Flow rate of hot water	5 LPM
Inlet temperature of Shell side fluid	40 °C

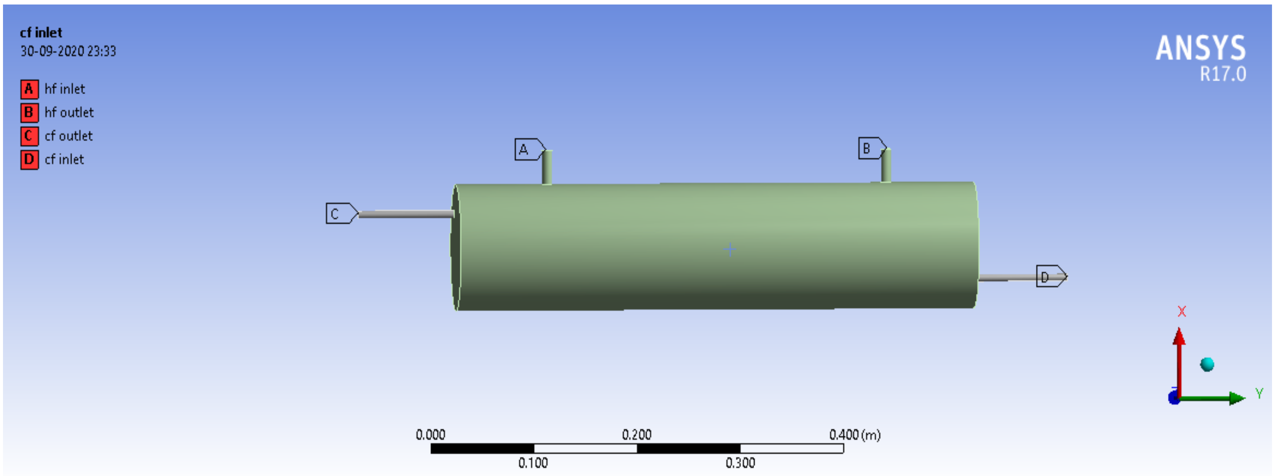

Figure 4 Name selection indicating the inlet and outlet of hot and cold fluid of shell and coil tube heat exchanger

VI. RESULTS AND DISCUSSIONS

This section is aimed at evaluating the shell and coiled tube heat exchanger thermal performance using MWCNT/water nanofluids at different concentration and different volume flow rate. The variations in the overall heat transfer coefficient, Effectiveness and Pressure drop are measured at different concentration and different volume flow rate in order to research the performance of the shell and coiled tube heat exchanger using MWCNT/water nanofluids subject to flow.

6.1. Validation of numerical computations

In this analysis, the validation of CFD data is carried out with the experimental data proposed by **Davood et al. (2016) [22]** who conducted an experimental test on convective heat transfer and flow behavior of shell and coiled tube heat exchanger in the volume flow rate of cold fluid i.e. water at 1-3 LPM and hot fluid i.e. water at 5 LPM.

Table 8 Shows the hot stream and cold stream test conditions

Cold fluid i.e. water Volume flow rate (in LPM)	Cold fluid inlet temperature (in ˚C)	Hot fluid i.e. water Volume flow rate (in LPM)	Hot fluid inlet temperature (in ˚C)
1, 1.5, 2, 2.5, and 3	18	5	40

The values of overall heat transfer coefficient, Effectiveness and Pressure drop calculated from the CFD modeling on the basis value obtained were compared with the values obtained from the experimental work performed by **Davood et al. (2016) [22].**

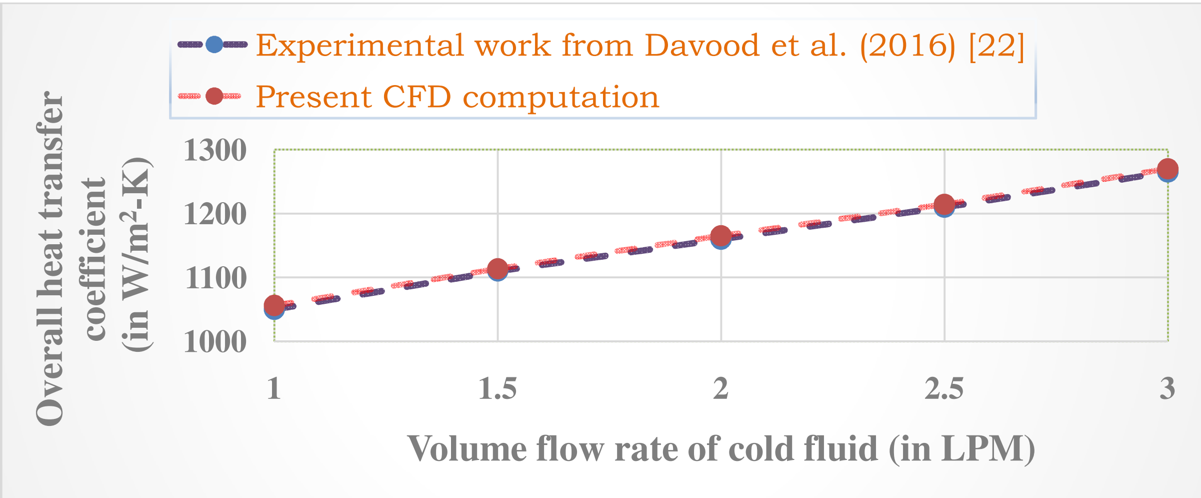

Figure 5 Overall heat transfer coefficient values calculated from the CFD modeling compared with the values obtained from the experimental work performed by Davood et al. (2016) [22] for shell and coiled tube heat exchanger

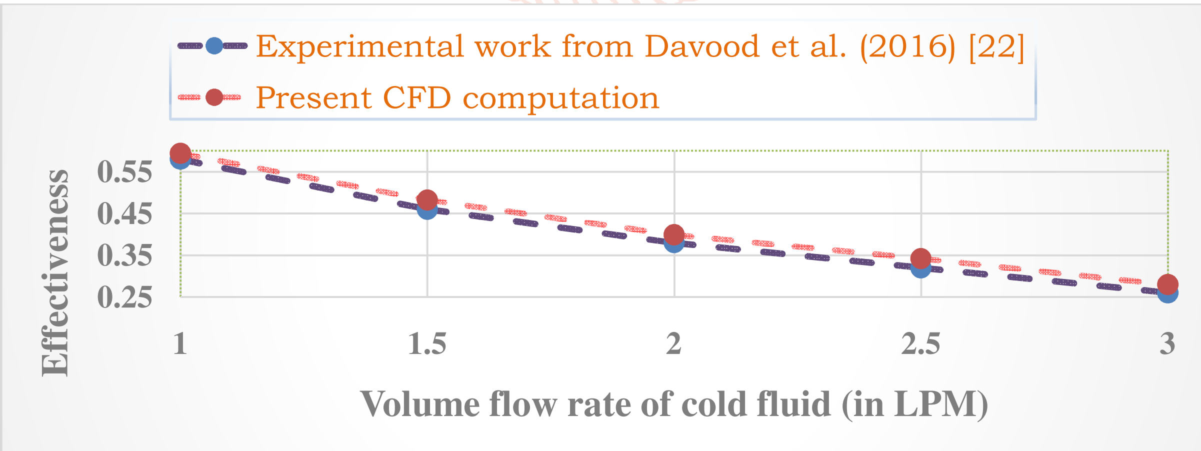

Figure 6 Effectiveness values calculated from the CFD modeling compared with the values obtained from the experimental work performed by Davood et al. (2016) [22] for shell and coiled tube heat exchanger

Indeed, the amount of $(\dot{m}c)_{min}$ calculated with coil side flow rate (because coil side flow rate is less than shell side flow rate for all points of this case). The increment rate of denominator is more than the increment rate of nominator and the result is descending behavior of this case.

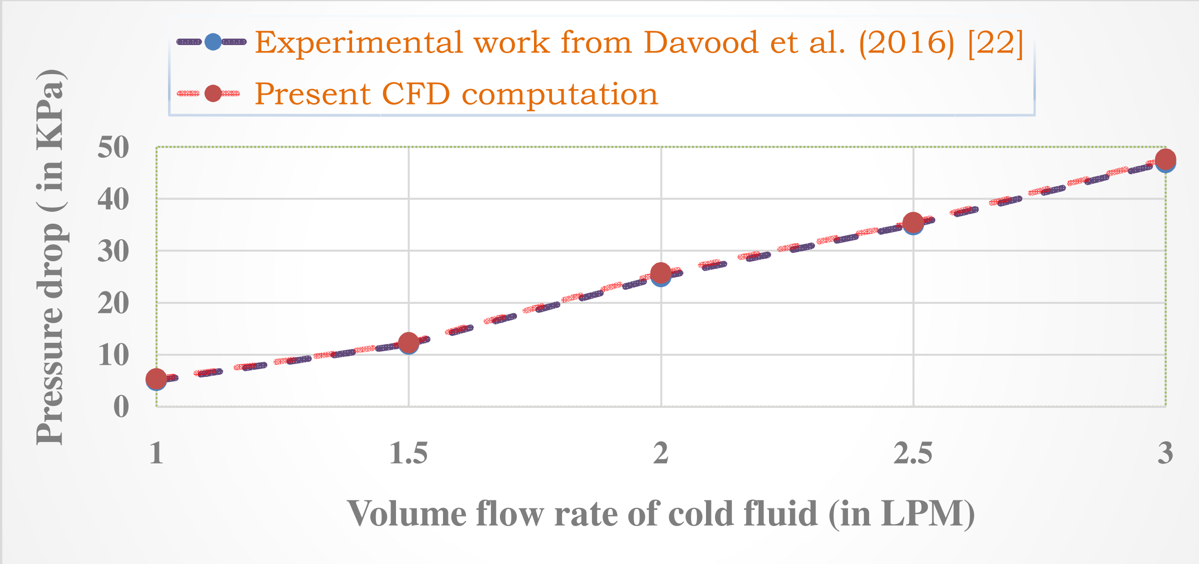

Figure 7 Pressure drop values calculated from the CFD modeling compared with the values obtained from the experimental work performed by Davood et al. (2016) [22] for shell and coiled tube heat exchanger

In the current work, the computations were performed under the same conditions as the experiment [22], and comparisons of the overall heat transfer coefficient, Effectiveness and Pressure drop with those of experimental data were conducted for the validation of the model. Comparing the numerical results with the experimental data, it is noted that their variation tendencies are qualitatively consistent. These demonstrate that the numerical model has reasonable accuracy on the prediction of overall heat transfer coefficient, Effectiveness and Pressure drop.

6.2. Effect of suspension of MWCNT nano-particles in the cold fluid i.e. water of shell and coiled tube heat exchanger

From the numerical results and experimental data it is seen that variation tendencies in the values of overall heat transfer coefficient, Effectiveness and Pressure drop are qualitatively consistent. So, to analyzing the effect of suspension of MWCNT nanoparticles in the cold fluid to enhance thermal augmentation, we take four volume concentration of nanofluid i.e. 0.05, 0.1, 0.3, and 0.5 %. The boundary conditions were same as considered during the analysis of water in shell and coiled tube heat exchanger. The thermal properties of nano fluids is mention in chapter 5, for calculating the effect of different nano particles on overall heat transfer coefficient, Effectiveness and Pressure drop.

Table 9 Comparison of Thermal conductivity values for Conventional fluid i.e. Water and Nanofluid i.e. MWCNT/water at different concentration

Working fluid	Thermal conductivity (in W/m-k)
Water	0.62
0.05 % MWCNT	0.6653
0.1 % MWCNT	0.7129
0.3 % MWCNT	0.9293
0.5 % MWCNT	1.1990

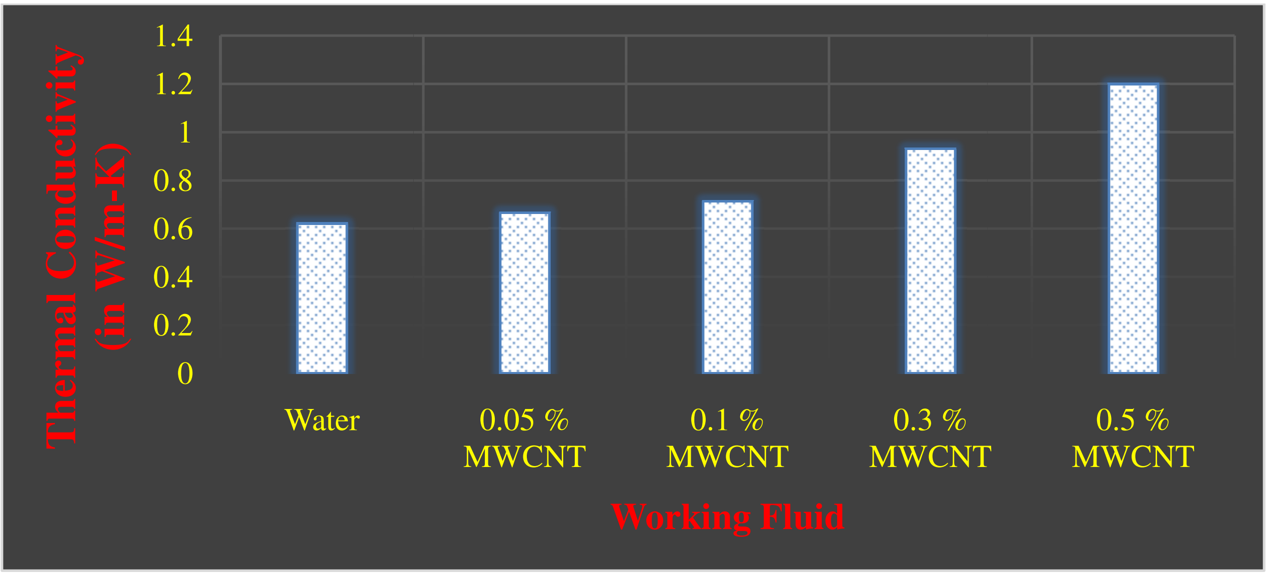

Figure 8 Thermal conductivity values for Conventional fluid i.e. Water and Nanofluid i.e. MWCNT/water at different concentration

It is studied that the thermal conductivity increases with increasing nanofluids volume concentrations. The 0.5 % MWCNT gives higher thermal conductivity than water and nanoparticles at other concentration.

Table 10 Comparison of overall heat transfer coefficient values for Conventional fluid i.e. Water and Nanofluid i.e. MWCNT/water of different concentration at different flow rate

Volume flow rate (in LPM)	Overall heat transfer coefficient (in W/m²-K)				
	Water	0.05 % MWCNT	0.1 % MWCNT	0.3 % MWCNT	0.5 % MWCNT
1	1050	1057.93	1062.73	1075.74	1085.4
1.5	1110	1132.98	1153.54	1169.62	1178.72
2	1160	1185.36	1203.29	1259.04	1277.81
2.5	1210	1236.81	1255.02	1302.68	1325.68
3	1265	1292.44	1311.78	1359.53	1371.63

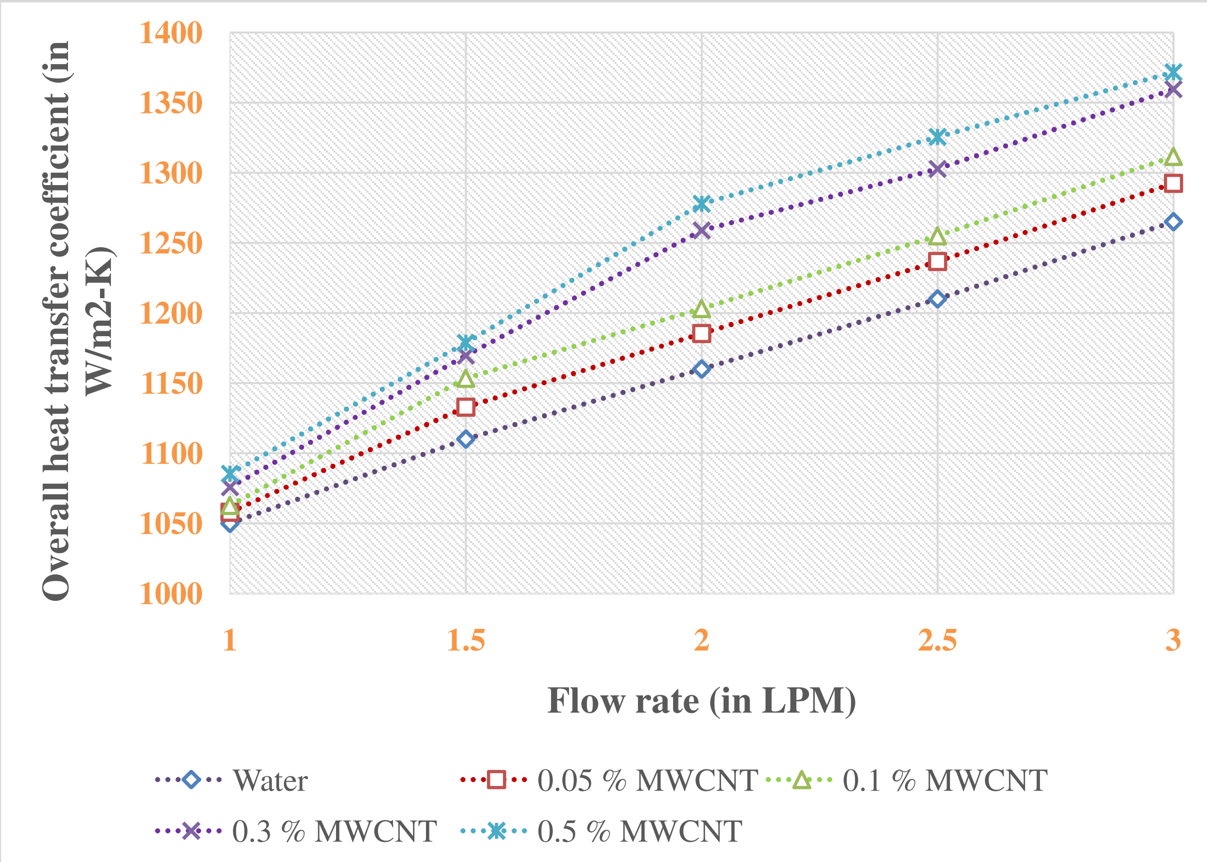

Figure 9 Overall heat transfer coefficient values for Conventional fluid i.e. Water and Nanofluid i.e. MWCNT/water of different concentration at different flow rate

Table 11 Comparison of Pressure drop values for Conventional fluid i.e. Water and Nanofluid i.e. MWCNT/water of different concentration at different flow rate

Volume flow rate (in LPM)	Pressure drop (in KPa)				
	Water	0.05 % MWCNT	0.1 % MWCNT	0.3 % MWCNT	0.5 % MWCNT
1	5	7.45	9.81	11.43	15.67
1.5	12	14.51	16.73	18.49	22.98
2	25	27.39	30.56	31.87	35.52
2.5	35	37.96	41.53	42.84	49.49
3	47	49.41	52.71	54.39	60.17

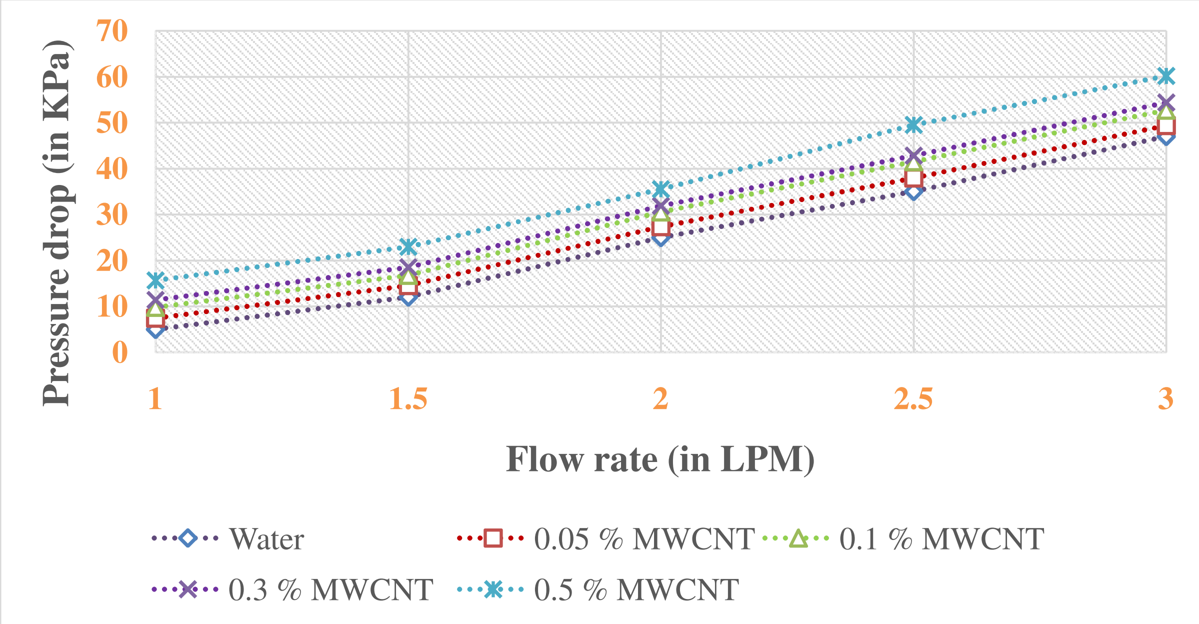

Figure 10 Pressure drop values for Conventional fluid i.e. Water and Nanofluid i.e. MWCNT/water of different concentration at different flow rate.

VII. CONCLUSIONS

This CFD research explores the impact on the performance of shell and coiled tube heat exchanger from MWCNT / water nanofluid flow. The MWCNT / water nanofluids with four volume concentrations of nanoparticles (i.e. 0.05, 0.1, 0.3, and 0.5 percent) were used. A strong agreement has been seen in the comparison of the findings of this research with the existing experimental results of the literature. The effect of MWCNT / water nanofluid were measured and observed to influence the heat transfer and flow of fluids in a hell and coiled tube heat exchanger. The following conclusions can be drawn based on the provided results:

- The Overall heat transfer coefficient of MWCNT/water nanofluids is found to be 18%, 22%, 27% and 32% at 0.05%, 0.1%, 0.3% and 0.5% volume concentrations respectively higher than that of water at the volume flow rate range of 1–3.LPM This is simply because of the higher thermal conductivity of nanofluids and intensification of secondary flow formation leading to lower the residence time dispersion of nanoparticles and base fluids. This lower residence time dispersion is resulting better mixing of the fluid and nanoparticles. Apart from this the Brownian motion of MWCNT contributes a little to enhance the heat transfer.
- It is studied that the pressure drop increases with increasing nanofluids volume concentrations. The 0.5 % nanofluid gives higher pressure drop than water and nanofluid with other below concentration. This is simply because of improved viscosity when particle volume concentrations are increased.
- It is studied that the application 0.5% MWCNT/water nanofluids in helically coiled tube, the secondary flow generation becomes very strong and the MWCNT s are thrown out towards the coiled tube wall and resulting higher pressure drop than water.
- The higher pressure drop due to MWCNT/water nanofluids may be expected more than 5%, 7%, 10% and 13 % for 0.05%, 0.1%, 0.3% and 0.5% volume concentrations respectively higher than that of water when the nanofluids are passing through in the coiled tube with the same entry temperature. This is because of the effect of temperature on viscosity.
- These enhancements in overall heat transfer coefficient and pressure drop are due to the improved higher thermal conductivity of nanofluids and generating stronger secondary flow.

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