HEAT TRANSFER ANALYSIS FOR SHELL AND HELICAL COIL HEAT EXCHANGER HAVING NANO-FLUID

Avinash Pandey[*1], Vishwajeet Kureel[*2]

[*1]Research Scholar, Department Of Mechanical Engineering, GRKIST, Jabalpur, India.

[*2]Asst Prof., Department Of Mechanical Engineering, GRKIST, Jabalpur, India.

ABSTRACT

In this paper circular cross-sectional double tube with a different number of turns and outside diameters keeping a constant helix angle was employed with a comparison of a circular cross-section straight tube in a double pipe heat exchanger. The number of turns varies from 1 to 7, keeping the helix angle and total length of the tube constant to examine the effect on heat transfer performance. The aim of this study is "To investigate the heat transfer rate with structural modification of double pipe helically shaped heat exchanger by changing the helical geometry i.e., number of turns and outside helical dia using different ionic liquid different weight percentage." The investigation was performed on water and Io-nano fluid containing boron nitride nanoparticles at various mass fractions. The number of turns ranged between 1 to 7. Because the pitch is shorter than the diameter, more than 7 spins are still not conceivable.

Keywords: Helix Angle, Heat Transfer Performance, Double Pipe Helically Shaped Heat Exchanger, Boron Nitride, Nanoparticles, FEA, Etc.

I. INTRODUCTION

1.1 General

The heat exchanger must seek out new and inventive methods of enhancing the heat transfer mechanism due to the always-growing need for high performance and decreased size. Numerous researchers created various surfaces with corrugations, dimples, and wavy channels to improve heat transfer mechanisms. The heat exchangers' design and shape must be changed for these completely novel procedures to work, which increases expense and complexity. Instead of altering the geometry of the heat exchanger, researchers have suggested that adding some solid particles to the base fluid will boost the working fluid's ability to transfer heat more effectively. Over the past few years, the use of nanofluids to enhance heat transmission has attracted a lot of attention.

1.2 Heat Exchangers

A thermal device called a heat exchanger transfers heat from one fluid stream to another (or to more than one fluid stream). The energy contained in one fluid must be transferred from one fluid to another using process equipment. A heat exchanger is a mechanical device that converts thermal energy from a hotter fluid to a colder fluid.

In other ways, heat exchangers ensure that two fluids of varying temperatures effectively exchange heat while preventing the fluids from mixing due to a dividing wall. The term "heat exchanger" is technically a misnomer. Perhaps a heat transfer might be a better one to use.

In design, a wide range of heat exchangers is frequently employed. Each form of heat exchanger includes drawbacks and advantages.

Large organizations, chemical plants, cooling and refrigeration systems, thermal energy storage, biochemical facilities, aerospace radiators, thermal power stations, and the household sector are only a few examples of applications. The latter category includes refrigerators and room air conditioners. For a single unit, capacity ranges from a few hundred watts (as with chillers in photography processing equipment) to 500 MW or more (as in the case of condensers of thermal power plants). Numerous designs have evolved as a natural outcome of the broad range of performance and usage.

II. LITERATURE REVIEW

An approach for designing rectangular channel counter flow micro heat exchangers was tried to present by Saha and Baelmans et al. (2014). They described a 1-D model for rectangular microchannel counter-flow heat

exchangers as well as a CFD model. Their research provides the optimal plate dimensions as well as empirical studies for rectangular microchannel counterflow heat exchangers with an efficiency ranging from 0.6 to 1. Several articles had also investigated double-pipe heat exchangers with nanofluids.

Chun et al. (2008) investigated the effect of nanoparticles, specifically alumina nanoparticles and transformer oil, on a convective heat transfer coefficient in a laminar double-pipe heat exchanger. According to the findings, increasing the solid quantity of nanoparticles in the fluid increased the average heat transfer coefficient.

Zarringhalamet et al. (2016) investigated the convection heat transfer coefficient of water/CuO nanofluid with various volume fractions of turbulent flow using a counter flow double pipe heat exchanger. They found that by increasing the Re no. and vol. fraction of nanoparticles by 4% increased the convection heat transfer coefficient to 57%.

Hemmat Esfe et al. (2014) conducted another experiment in which they examined nanofluids inside a double-pipe heat exchanger in a turbulent regime. They studied the heat transfer attributes and pressure drop of COOH-functionalized double-walled carbon nanotube (DWCNTs)/water nanofluid and found that, when compared to the base fluid, the convection heat transfer coefficient was enhanced by 25% while only 0.4 vol% Related to normal DWCNTs were used. Abbasian Arani and Amani et al. investigated the diameter effect on heat transfer performance, the pressure drop of TiO2-Water nanofluid on convection heat transfer, and the pressure drop inside a counter flow double pipe heat exchanger (2016). Their findings demonstrated that the Nu no. did not go up when the diameter of the particles was reduced as compared to the base fluid. Furthermore, their research shows that volume concentration, and pressure declines in the Re no. range, and the maximum Nu numbers are all attained with nanofluids with particle sizes of 18 nm or smaller. The use of nanofluid in heat exchangers has the potential to significantly improve performance, according to recent literature.

A computational analysis of the high thermal behavior in a double-pipe heat exchanger equipped with open-cell porous foam was done by Xue Chen et al. in 2019. To simulate the flow and thermal transport inside the foam regions while taking into account the coupling effects between the inner and annular spaces, the Forchheimer-extended Darcy equation and the local thermal non-equilibrium model are used. In the modeling procedure, the influence of solid wall thick is taken into account together with the temperature and heat flux continuity conditions at the porous-solid interface. The P1 technique is used to calculate the thermal radiation transfer when simulating a counter-flow heat exchanger. While the hot fluid moves through the circumferential gap, the cool fluid moves through the inlet. It is possible to anticipate the temperature distribution, pressure drop, efficiency of the heat exchanger, and overall efficiency. Studied are the effects of thermal radiation, foam structural characteristics, and heat exchanger size. As a result of thermal radiation, the thermal exchange between the two fluid sides is encouraged, according to the results.

III.   METHODOLOGY

Finite Element Analysis

ANSYS Workbench 18.0 is used for Finite element analysis. In ANSYS software Computational Fluid Dynamics (CFD) is used as a platform for the study.

Mathematical Background

The flow is governed by the continuity equation, the energy equation and Navier-Stokes momentum equations. Transport of mass, energy and momentum occur through convective flow and diffusion of molecules and turbulent eddies. All equations are set up over a control volume where i; j; k = 1; 2; 3 correspond to the three dimensions

The continuity equation defines the conservation of mass and is inscribed as in equation

$$\partial p/\partial t + (\partial pU_1)/(\partial x_1) + (\partial pU_2)/(\partial x_2) + (\partial pU_3)/(\partial x_3) = 0 \qquad\qquad .... (3.1)$$

$$\partial p/\partial t + (\partial pU_i)/(\partial x_i) = 0, i = 1,2,3 \qquad\qquad .... (3.2)$$

The momentum equation in tensor notation for a Newtonian fluid can be written as

$$\partial U_i/\partial t + U_j\,\partial U_i/\partial x_j = -1/\rho\;\partial p/(\partial x_i) + \vartheta\,\partial/(\partial x_j)(\partial U_i/\partial x_j + (\partial U_j)/(\partial x_i)) + g_i$$
$$........... (3.3)$$

Equation 3.3 can be written in different forms for constant density and viscosity, in addition to gravity, there can be further external sources that may affect the acceleration of fluid e.g. electrical and magnetic fields. Strictly it is the momentum equations that form the Navier-Stokes equations but sometimes the continuity and momentum equations together are called the Navier-Stokes equations. The Navier-Stokes equations are limited to macroscopic conditions.
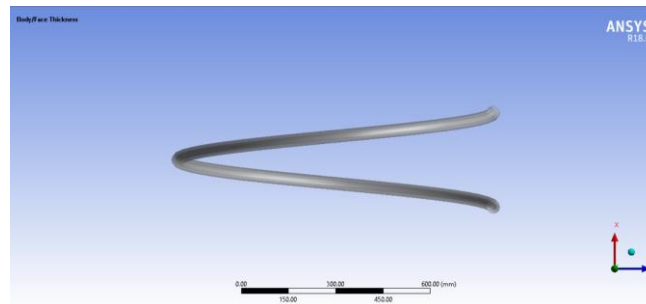
CFD Analysis

Computational fluid dynamic study of the system starts with building desired geometry and mesh for modelling the domain. Generally, geometry is simplified for the CFD studies. Meshing is the discretization of the domain into small volumes where the equations are solved by the help of iterative methods. Modelling starts with defining the boundary and initial conditions for the domain and leads to modelling the entire system domain. Finally, it is followed by the analysis of the results.

Geometry

The ANSYS workbench design modular has a designed heat exchanger layout. The planar asymmetry helps to simplify geometry. Concentric tubes on a counter-current heat exchanger with a helical form are taken into account for the study. The heat exchanger's shape and parameters are shown in turn in Figure 3.1
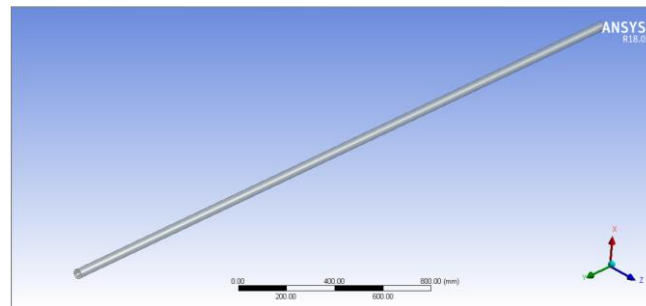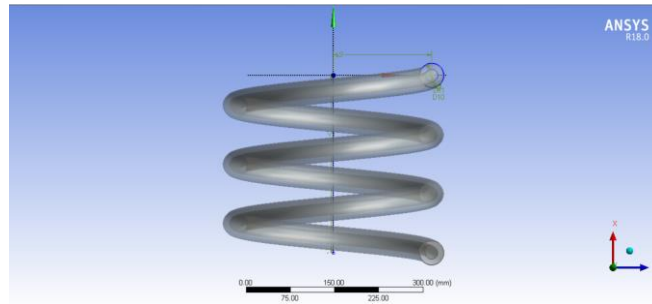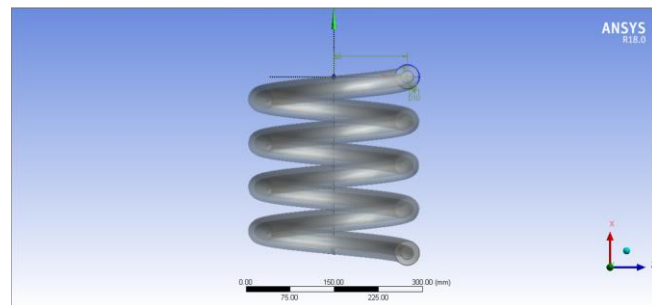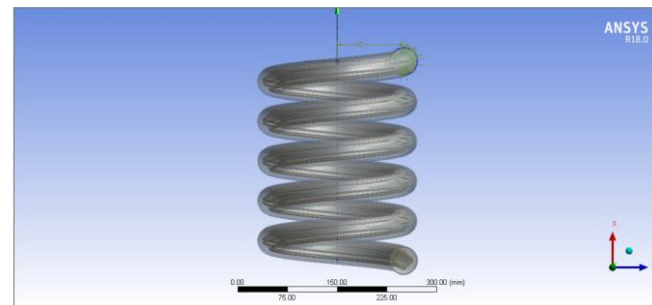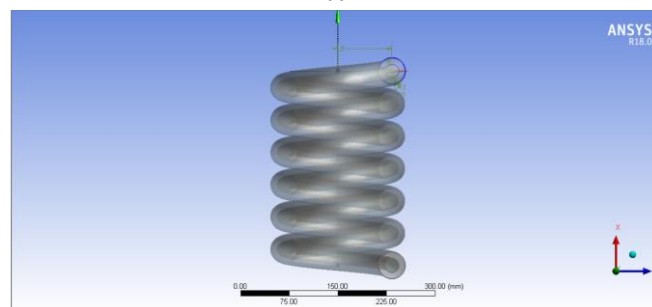

(a)

(b)
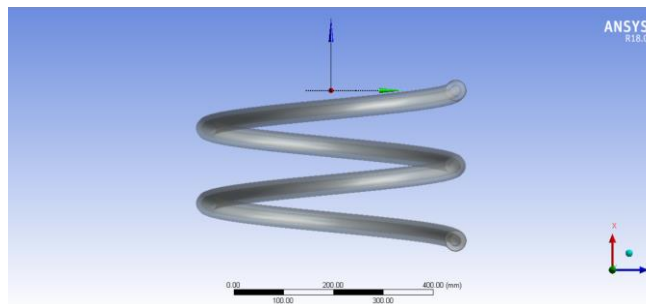
(c)

(d)

(e)

(f)

(g)

Figure 3.1: Geometry of Heat Exchanger (a) Straight Tube, (b) Number of Turns=1 (c) Number of Turns=2 (d) Number of Turns=3 (e) Number of Turns=4 (f) Number of Turns=5 (g) Number of Turns=6
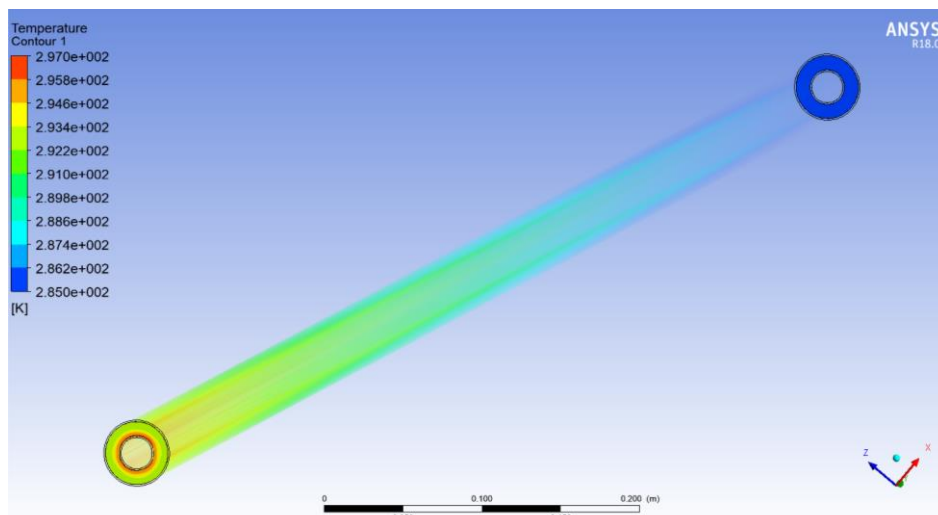
IV.   RESULTS ANALYSIS

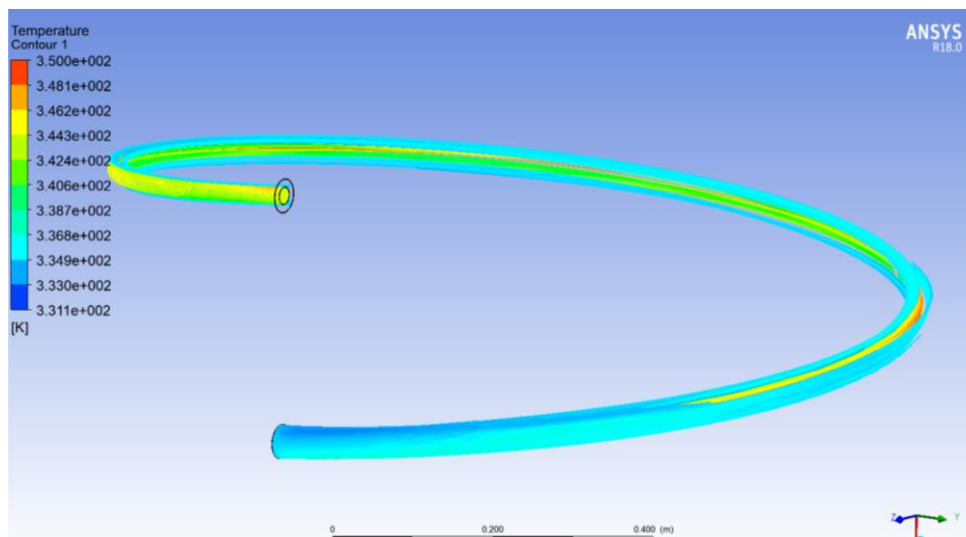CFD Results for Heat Exchanger containing Io-nano Fluid with Boron Nitride Nanoparticles at 0% Weight Fraction

Figure 4.1 to 4.14 shows the Hot and Cold fluid temperature variation for straight and curved Helical tube double pipe heat exchanger having different number of turns containing Io-nano Fluid with Boron Nitride Nanoparticles at 0% Weight Fraction
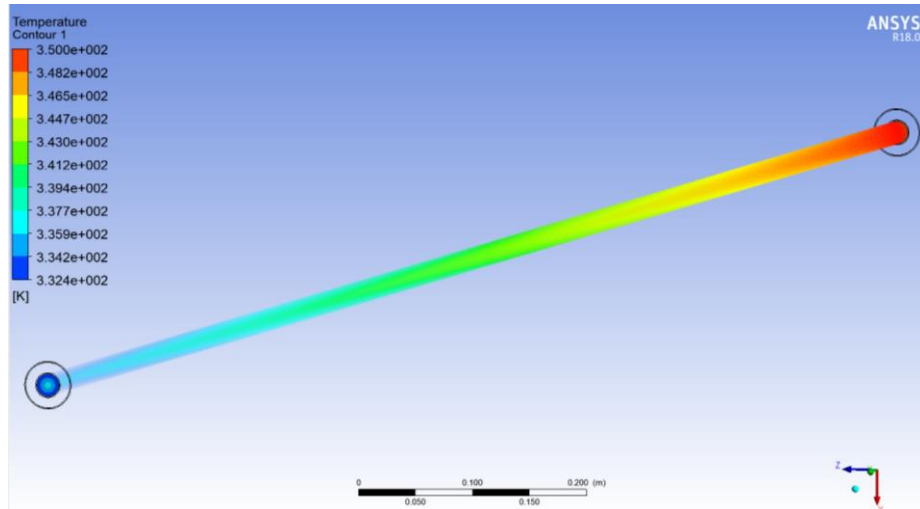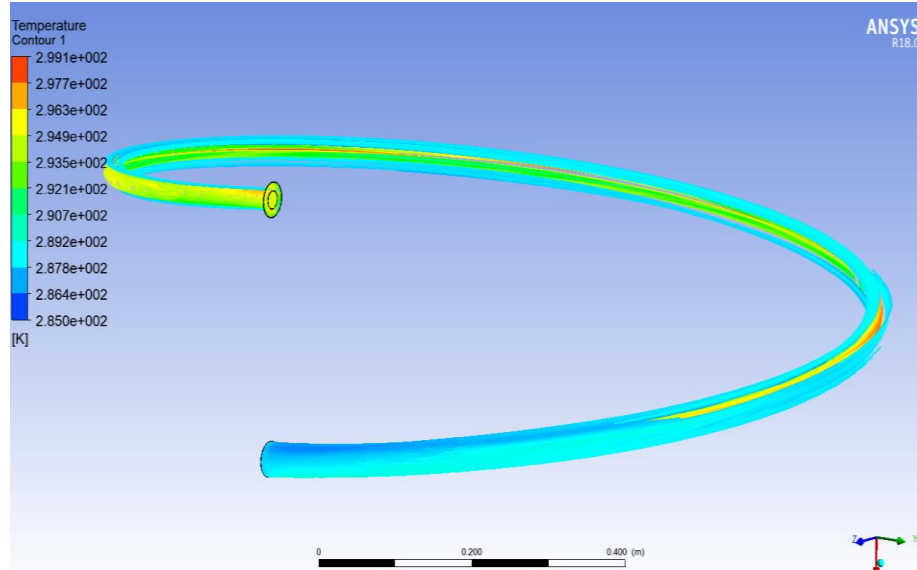
Figure 4.1: Hot fluid temperature variation for Straight tube double pipe heat exchanger containing Io-nano Fluid with Boron Nitride Nanoparticles at 0% Weight Fraction
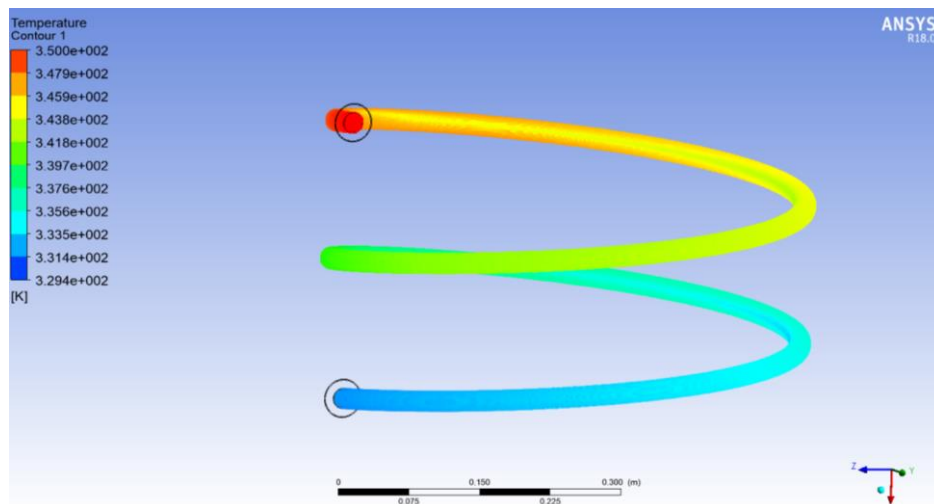

Figure 4.2: Cold fluid temperature variation for Straight tube double pipe heat exchanger containing Io-nano Fluid with Boron Nitride Nanoparticles at 0% Weight Fraction
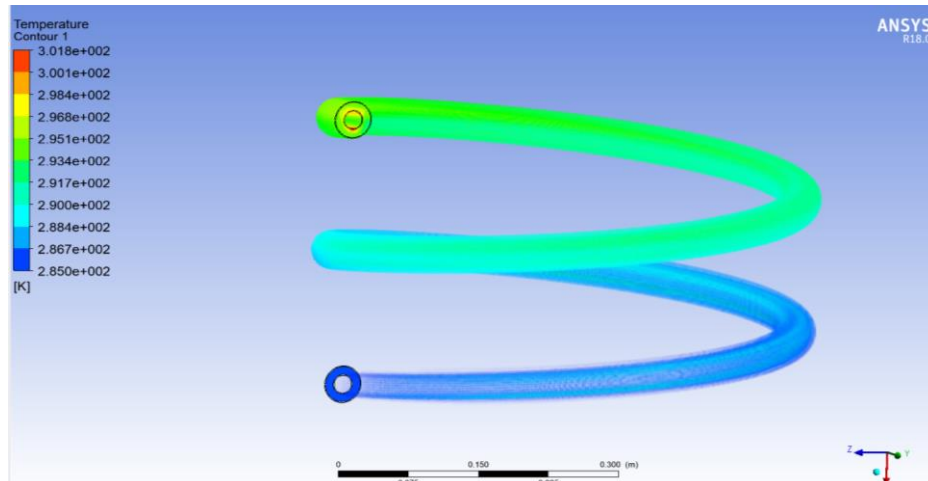

Figure 4.3: Hot fluid temperature variation for Helical tube double pipe heat exchanger having 1 turn containing Io-nano Fluid with Boron Nitride Nanoparticles at 0% Weight Fraction

Figure 4.4: Cold fluid temperature variation for Helical tube double pipe heat exchanger having 1 turn containing Io-nano Fluid with Boron Nitride Nanoparticles at 0% Weight Fraction
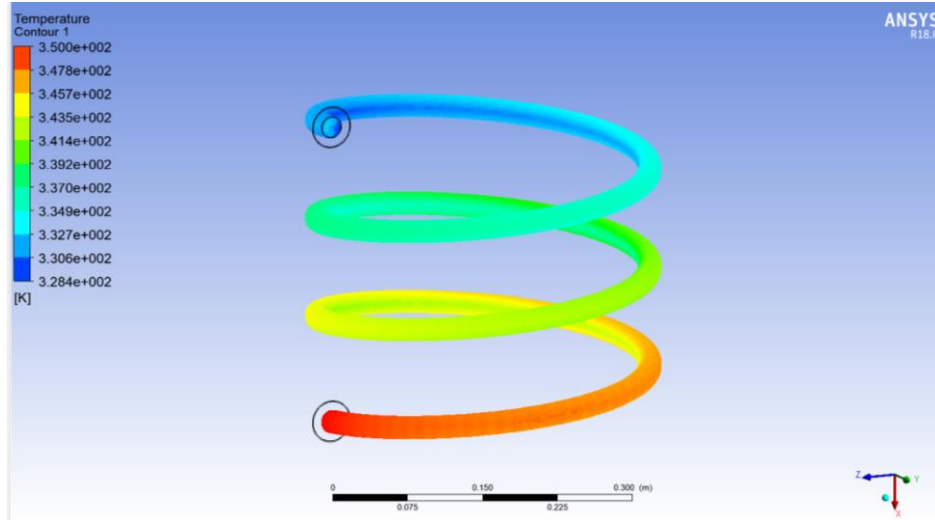

Figure 4.5: Hot fluid temperature variation for Helical tube double pipe heat exchanger having 2 turn containing Io-nano Fluid with Boron Nitride Nanoparticles at 0% Weight Fraction
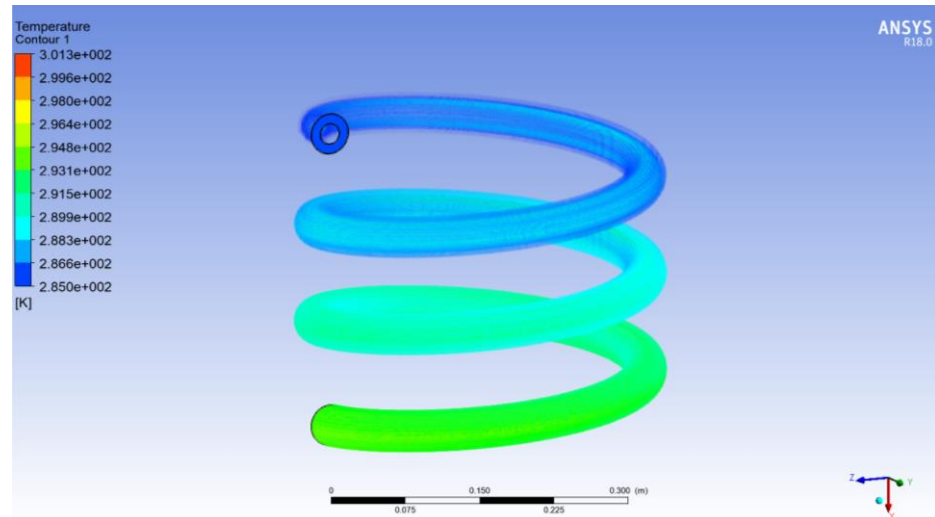

Figure 4.6: Cold fluid temperature variation for Helical tube double pipe heat exchanger having 2 turn containing Io-nano Fluid with Boron Nitride Nanoparticles at 0% Weight Fraction
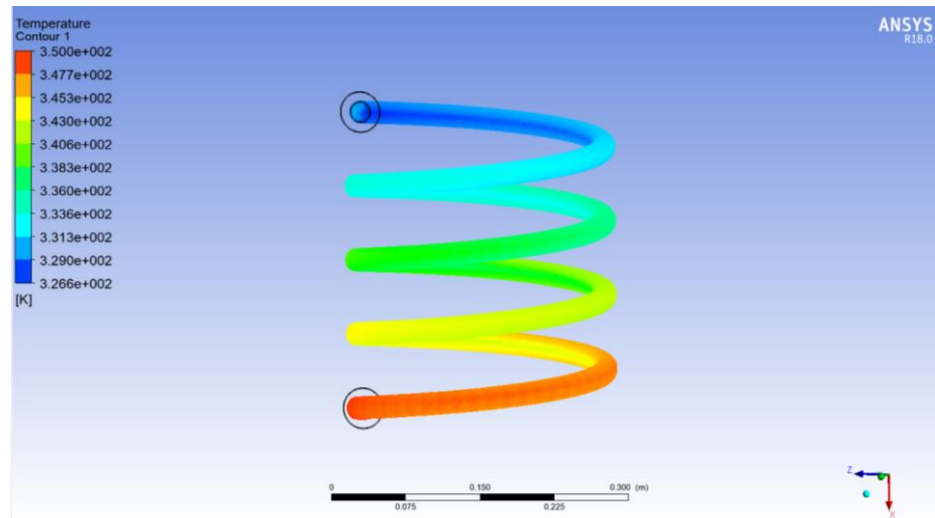
Figure 4.7: Hot fluid temperature variation for Helical tube double pipe heat exchanger having 3 turn containing Io-nano Fluid with Boron Nitride Nanoparticles at 0% Weight Fraction

Figure 4.8: Cold fluid temperature variation for Helical tube double pipe heat exchanger having 3 turn containing Io-nano Fluid with Boron Nitride Nanoparticles at 0% Weight Fraction

Figure 4.9: Hot fluid temperature variation for Helical tube double pipe heat exchanger having 4 turn containing Io-nano Fluid with Boron Nitride Nanoparticles at 0% Weight Fraction
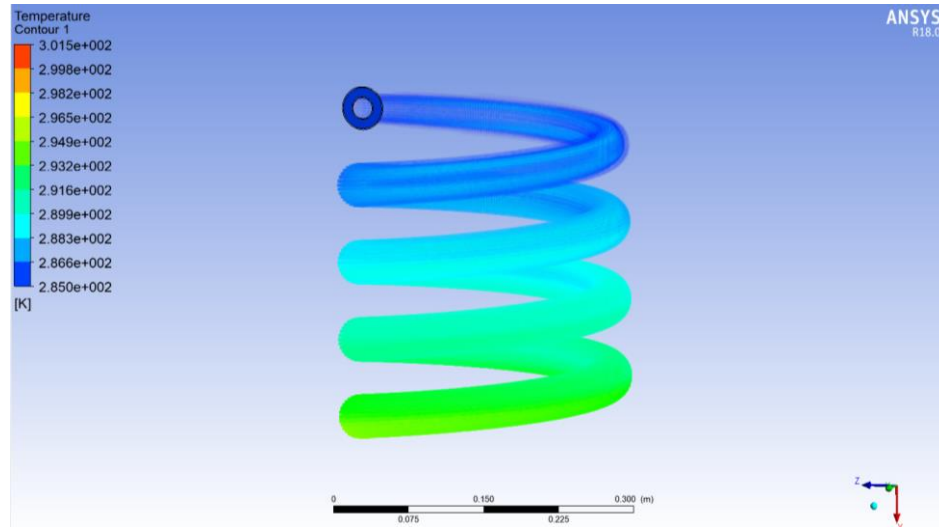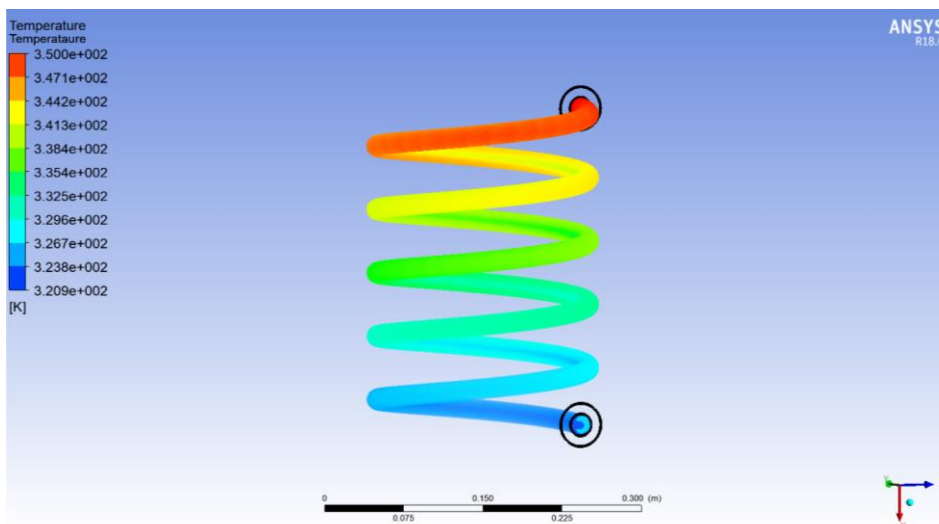
Figure 4.10: Cold fluid temperature variation for Helical tube double pipe heat exchanger having 4 turn containing Io-nano Fluid with Boron Nitride Nanoparticles at 0% Weight Fraction

Figure 4.11: Hot fluid temperature variation for Helical tube double pipe heat exchanger having 5 turn containing Io-nano Fluid with Boron Nitride Nanoparticles at 0% Weight Fraction

Figure 4.12: Cold fluid temperature variation for Helical tube double pipe heat exchanger having 5 turn containing Io-nano Fluid with Boron Nitride Nanoparticles at 0% Weight Fraction
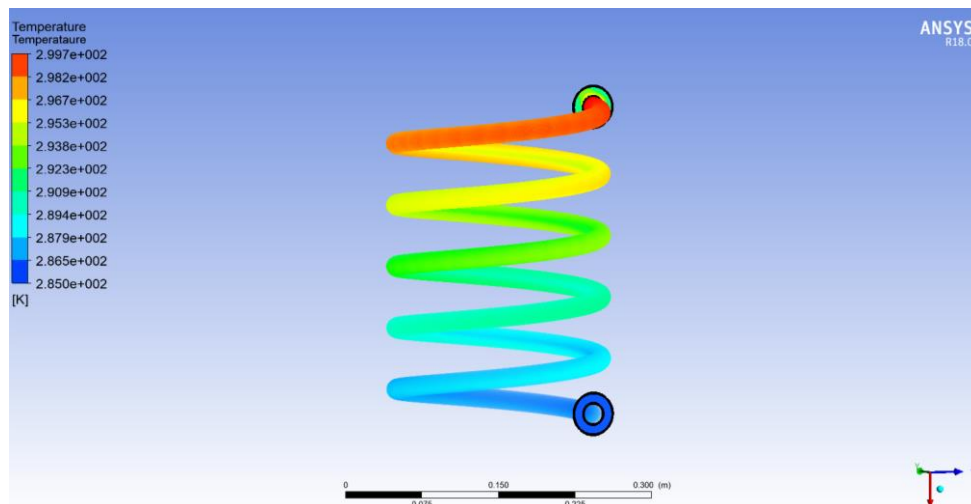
Figure 4.13: Hot fluid temperature variation for Helical tube double pipe heat exchanger having 6 turn containing Io-nano Fluid with Boron Nitride Nanoparticles at 0% Weight Fraction
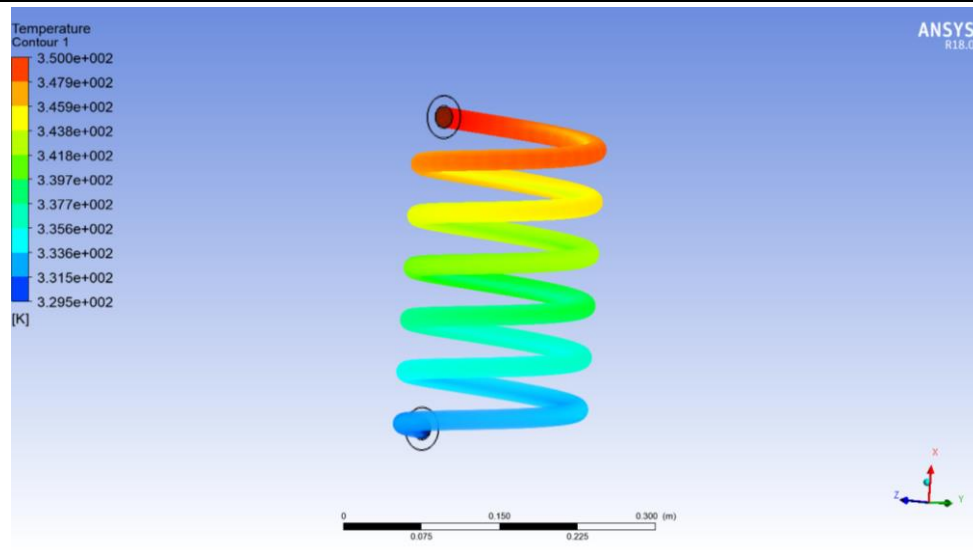

Figure 4.14: Cold fluid temperature variation for Helical tube double pipe heat exchanger having 6 turn containing Io-nano Fluid with Boron Nitride Nanoparticles at 0% Weight Fraction
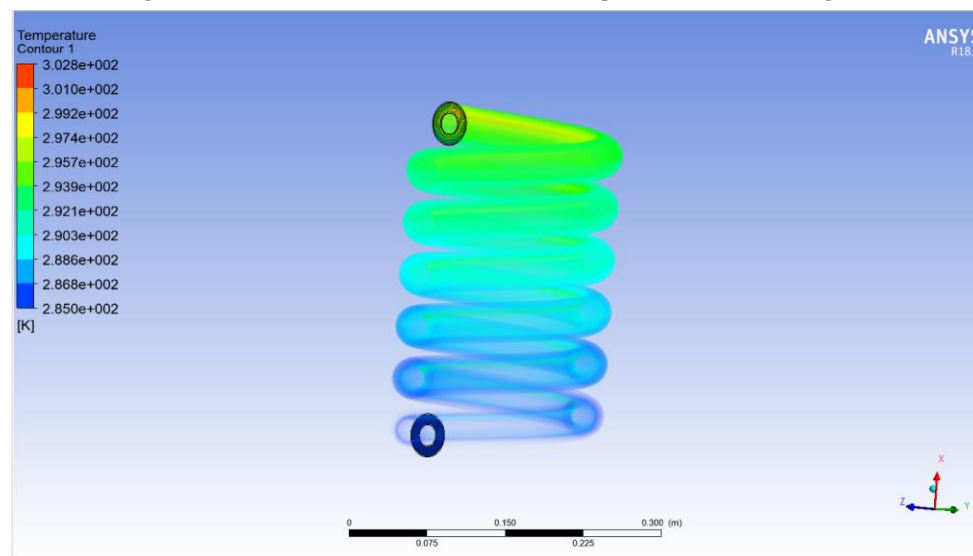
V.   CONCLUSION

Nanofluids, as heat transfer medium, have been applied into various fields because of their excellent thermal performance. A numerical study of a double-pipe helical heat exchanger was performed using six differently sized heat exchangers (i.e., different number of turns). The following conclusions can be made:

- The mass flow rate of each fluid remains constant, and the fluid properties such as temperature and velocity at any inlet or outlet remain the same.

- The heat transfer rate is maximum for the 0.5% weight fraction boron nitride particle Io-nano fluid and 5 number turns heat exchanger.

VI.   REFERENCES

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