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CFD Study on Heat Transfer in Hybrid Nanofluid with Coil Controller in Double Tube Heat Exchanger

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***Abstract:** Heat exchanger that heats up to two or more processing fluids. Heat exchangers have a range of domestic and commercial applications. Use in steam plants, manufacturing plants, heat and air conditioning facilities, transportation, and cooling systems. Through analysis, Ordinarily, the presence of Cu+Al_2O_3 nanoparticles in the base fluid increases the properties of convective heat transfer and is thus more efficient than Al_2O_3 nanoparticles (at a steady concentration of volume). The findings revealed that the average heat transfer coefficient increases in line with the Reynolds number. Analysis has shown that the average thermal transfer coefficient value for hybrid nanofluid is 12 percent greater than the average for a single nanofluid. In the case of hybrid nanofluid compared to Mono nanofluid, the value of Nusselt is 18 per cent higher.*
***Keywords:** Heat Exchanger, CFD, double pipe, nanofluid, temperature contour, Nusselt number, Reynolds number.*

I. INTRODUCTION

Heat exchangers were used in a wide-ranging of applications including power generation plants, nuclear reactors for generation of electricity, Refrigeration & Air Conditioning (RAC) systems, self-propelled industries, food industries, heat retrieval systems, and chemical handling. The upgrading methods can be distributed into two groups: active and passive methods. The active method requires peripheral forces. The passive methods need discrete surface geometries. Both methods have been commonly used to improve performance of heat exchangers. Due to their compact structure and high heat transfer coefficient helical tubes have been declared as one of the passive heat transfer improvement method and they are broadly used in many industrial applications. Several studies have specified that helical tubes are greater to straight tubes when working in heat transfer applications. The centrifugal force will be occurring because of twisting in tube and it improves the heat transfer rate in secondary flowThis sight can be useful, especially in the laminar flow system. Heat transfer rate of helical tube is more than straight tube heat exchanger. It required small volume of base area related to other heat exchangers. The major problem of helical tube heat exchanger is the difficulty in calculating the heat transfer coefficients and the surface area available for heat transfer. This problem comes because of deficiency of data in helical tube heat exchangers, and the poor probability of the flow characteristics around the outside of the coil.

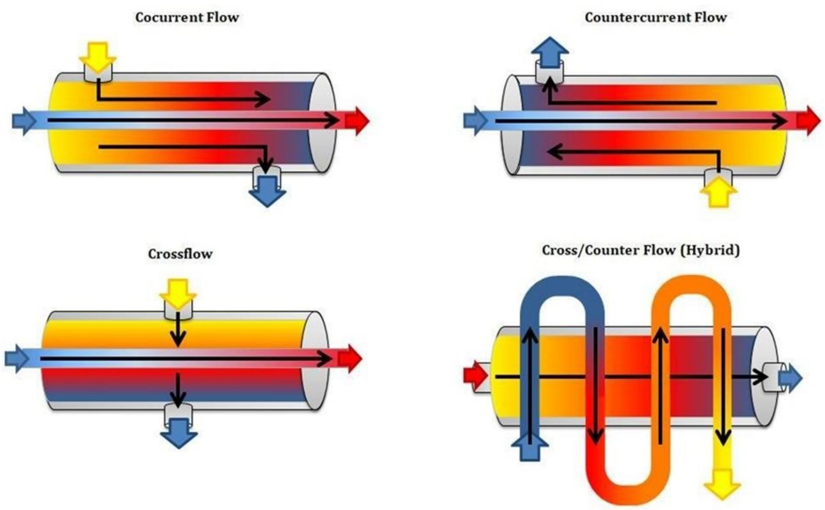

Figure 1 Categorization on the basis of flow diagram

Heat transfer fluid is one of the serious factors as it disturbs the size and cost of heat exchanger systems. Conventional fluids like oil and water have partial heat transfer potentialities. There is top priority for developing different group of fluids so as to reduce cost and meet the increasing demand of industry and commerce. By chance, the developments in nanotechnology make it possible to get higher efficiency and cost saving in heat transfer methods. Nanoparticles are taken as the fresh group of materials which having potential applications in the heat transfer area.
Nano Fluid Nano fluid is nothing but fluid particles which are less than even a micron (9-10 times) smaller in diameter and highly reactive and proficient material which can be used to increase factor like rate of reaction, thermal conductivity of any metal or material, they are that much reactive and strong.

There are different types of Nano fluids basically:
1) Al_2O_3 + Water
2) CuO + Water
3) ZnO + Water
4) TiO_2 + Water
5) TiN + Water

The following benefits are expected when the nano particles of nano fluids are properly circulated:
a) *Heat Conduction is Higher:* The thermal interaction is directly available if the particles are finer than 20 nm & if they carry 20% of their atoms on their surface. The nanoparticle is of μ size so there will be the advantage in the movement of particles and it increased the heat transfer because of micro convection of fluid. When the nano particles having large heat surface area then the large heat transfer is allowable. Dispersion of heat is increasing in the fluid at a faster rate because of large heat transfer. When there will be a rise in temperature then the thermal conductivity of nanofluid increases significantly.
b) *Stability:* The nanoparticle of nano-fluids is smaller in size (9-10 times smaller) or in μ size, so they are weightless, that's why the chances of sedimentation are reduced. When sedimentation is reducing it will provide the stability in nanofluid by settling the nanoparticles.
c) *Choking does not Occur in Micro Passage Cooling:* For transferring heat in heat exchanger the nanofluid is a best option in overall and they can be perfect for micro passage uses where high heat loads are faced. A large area of heat transfer and highly conducting fluids will occur by the mixture of micro passage and nanofluid and it cannot be managed with meso or micro-particles because they clog micro passages. Nano particles are smaller in size it is μ which is very small to micro passage.
d) *Probabilities of Erosion Reduced:* The momentum which is conveyed by a solid wall is minor because nanoparticles are very small. The probability of erosion of components is reducing when the momentum reduces and it occursin pipelines, pumps and heat exchangers.
e) *Pumping Power is Reducing:* Pumping power is increasing by a factor of ten when the heat transfer of conventional fluid is increased by a factor of two. If there is a severe increase in fluid viscosity then the pumping power will be increased satisfactory. Thus, a large savings in pumping power can be attained. Thermal conductivity can be increased by small volume fraction of particles.

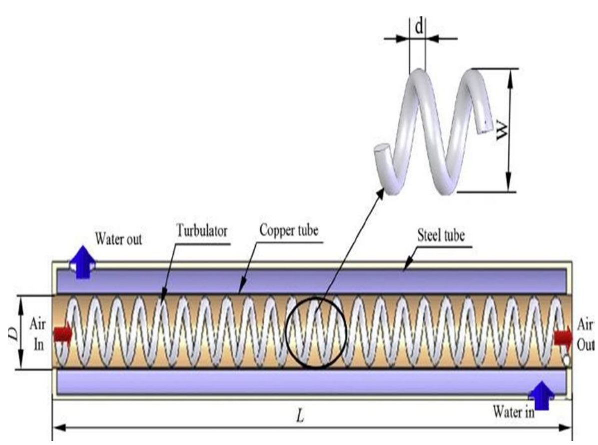

Figure 2 Schematic diagram which shows a dual pipe heat exchanger using the turbulator.

II. LITERATURE REVIEW

Alok Kumar et.al. [1] Heat transfer performance can be improved by increasing the secondary flow in the spiral. This can be facilitated by proper mixing of fluids within the spiral coil. In addition, I plan to work on CFD to study helical coils using ANSYS. Observing the CFD analysis results, the high-temperature fluid pressure drop of Al2O3 and SiO2 nanofluids with water as the base fluid is larger in the shell and spiral heat exchangers.

Pranita Bichkar et.al. [2] has completed his research in Shell and Tube Warmness Exchangers with the effects of various baffles. This implies that baffles have an effect on stress decrease in shell and tube heat exchangers. Single segmental baffles exhibit the establishment of dead zones wherein the warmth switch cannot take place effectively. When compared to single segmental baffles, double segmental baffles reduce vibrational damage. The use of helical baffles results in a lower strain drop due to the elimination of unnecessary zones. The fewer dead zones result in more heat transmission. The smaller stress drop leads in lower pumping electricity, which boosts overall system performance.

Vidula Vishnu Suryawanshi et.al. [3] He completed his examination in format and assessment of heat exchanger. In this article, CFD evaluation has been performed by way of severa exceptional diameter one-of-a-kind material. Future efforts wanted for better development of helical warmth exchanger.

Vishal Momale et.al. [4] Examine the usual overall performance of a conical helical tube heat exchanger with right away and conical shell using cfd. Computational fluid dynamics is used to evaluate the conical helical tube warmth exchanger. Heat transfer can progress significantly because the larger shell fluid comes into contact with the tube fluid even when we employ a conical shell rather than a helical shell. With a conical shell configuration, the stress drop will increase. However, if we utilise baffles, we will increase the warmth switch.

The Mohamed Ali et.al. [5] The experimental study of natural convection was carried out to investigate, regular type natural convection was received from turbulence herbal convection to water. The experiment was carried out with a four coil diameter to tube diameter ratio for five and ten coil tubes, as well as a five pitch outer diameter ratio. He linked Rayleigh range for two exceptional coil units, and the heat transfer coefficient falls with coil period for tube diameter do =.012m but increases with coil period for do=.008m. Important D/d0 is obtained for a maximum warmness transfer coefficient for a tube diameter of 0.012 m with either five or ten coil turns.

R. Patil et.al. [6] recommended design approach for helical coil heat exchanger. The internal coil diameter hi is used to determine the heat transfer coefficient, which is based entirely on one of the Sieder-Tate equations or a plot of the Colburn aspect, JH versus Re. The outer heat transfer coefficient is derived using correlation for a wide range of Reynolds numbers. Helical coil heat exchangers are preferred when space is limited and low flow charges or laminar flow conditions exist.

N. Ghorbani et.al. [7] The goal of this text is to gain access to the influence of tube diameter, coil pitch, shell aspect, and tube facet mass drift fee on the modified effectiveness and performance coefficient of vertical helical coiled tube warmth exchanger. The computation was completed for the constant condition, and the experiment was carried out for each laminar and turbulent float internal coil. It was discovered that the mass flow rate of the tube aspect to shell ratio was effective at the axial temperature profiles of the warmth exchanger. He reasoned that when the mass glide rate ratio increased, the logarithmic mean temperature difference dropped and the modified effective's

Sunil Kumar et.al. [8] has carried out his research on optimising the design of a helical coil heat exchanger using fins and evaluating pressure and temperature using traditional design. The final outcomes of the study increased the overall heat switch price within the domain.

And increase the stress decrease inside the domain. The water outlet temperature can drop to 315 degrees Celsius, but the bloodless outlet temperature can rise to 320 degrees Celsius, and the overall pressure drop increases as the temperature rises. Following that, the CFD data was compared to previous records, and the whole strain drop increase was reduced to zero. Sixty-five bar for case-2. The overall efficiency of the system inspires 5% to 6%.

III. CFD

Computer primarily based simulation is mentioned during this chapter. procedure simulation is technique for examining fluid flow, heat transfer and connected phenomena like chemical reactions. This project uses CFD for analysis of flow and warmth transfer. CFD analysis accepted go in the various industries is employed in R&D and producing of craft, combustion engines and in powerhouse combustion similarly as in several industrial applications.

A. Why Computational Simulation

Three-dimensional (3D) numerical analysis of whorled coil tubes is dispensed by victimization business CFD tool ANSYS 18.2. this can become troublesome and time overwhelming, if this analysis is dispensed by experimentation. Experimental setup is extremely expensive that's why in my work I take facilitate of CFD to create it easier and fewer time overwhelming.

B. Computational Fluid Dynamics

Computational fluid dynamics, because the name implies, could be a subject that deals with procedure approach to fluid dynamics by means that of a numerical resolution of the equations that cause the fluid flow and though it's known as procedure fluid dynamics; it doesn't simply wear down the equations of the fluid flow, it's conjointly generic enough to be ready to solve at the same time along the equations that direct the energy transfer and similarly the equations that verify the chemical process rates and the way the chemical process takings and mass transfer takes place; of these things may be tackled along in a regular format. So, this define permits America to wear down a really complicated flow circumstances in fairly quick time, specified for a specific set of conditions, associate degree engineer would be ready to simulate and see however the flow is happening and what quite temperature distribution there's and what quite product area unit created and wherever they're fashioned, in order that {we can|we will|we area unit able to} build changes to the parameters that area unit below his management to switch the approach that these items are happening. So, therein sense procedure fluid dynamics or CFD becomes a good tool for a designer for associate degree engineer. it's conjointly a good tool for associate degree associate degreealysis for associate degree examination of a reactor or an instrumentality that isn't functioning well as a result of in typical industrial applications, several things is also happening associate degreed what a designer has had in mind at the time of fabricating or coming up with the instrumentality won't be really what an operator of the instrumentality introduces into the instrumentality at the time of operation, perhaps once 5 years or 10 years changes might need taken place in between; and in such a case, the presentation of the instrumentality won't be up to the quality and you'd wish to modify it in such some way that you just will restore performance. So, the question is then, what this can managed to the autumn within the performance associate degreed what quite measures we are able to build while not creating an overall adjustment within the finish of apparatus.

Is it potential to urge improved performance from the equipment? Is it potential to extend the productivity? If you wish to appear on of these analysis, then procedure fluid dynamics is employed.

IV. METHODOLOGY AND MATHEMATICAL MODEL USED

A. Steps Taken During the Analysis

- Firstly we design the turbulator double pipe heat exchanger on Workbench of ANSYS 16.0Software.
- After designing the model it is transferred to ANSYS for CFD analysis.
- Meshing of model is done on CFD pre-processor.
- In solving the problem, the finite volume approach is used.
- Solution is calculated by giving iterations to the mathematical and energy equations applied onmodel.
- The results can be visualized in the form contours and graphs by CFD post processor.
- Result analysis.

The study uses the CFD model in this section to examine the heat transfer physiognomies of the dual- pipe turbulator heat exchanger using hybrid nanofluids.

CFD review involves three major steps: (a) pre- processing and (b) solver execution. The first step includes the creation of the geometry and mesh generation of the desired model, while the results are seen as expected in the last step. In the execution ofthe solver (medium) stage, the boundary conditions are fed into the model.

The inner tubing was made of aluminum from which the nano-fluid flows. The aluminum tube devises an internal diameter of12 mm, and wall thickness of 2 mm. The external tube is made of polyethylene with an inner diameter of 33 mm. The test segment is of an average length of 1300 mm. Turbulators with a pitch of 39 mm and a length of 1300 mm were used in the concentric heat exchanger to examine the influence on the heat transfer physiognomies. The part of the model built for ANSYS (fluent) workbench 16.0 applications.

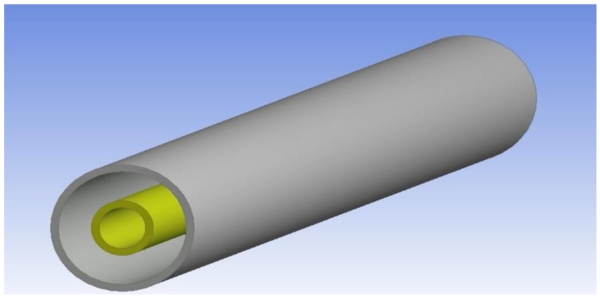

Figure 3 Dual pipe heat exchanger model on ANSYS workbench.

- CFD analysis of the heat exchanger shall be done in the ANSYS Fluent module.
- The solid heat exchanger model is constructed with a modular style.

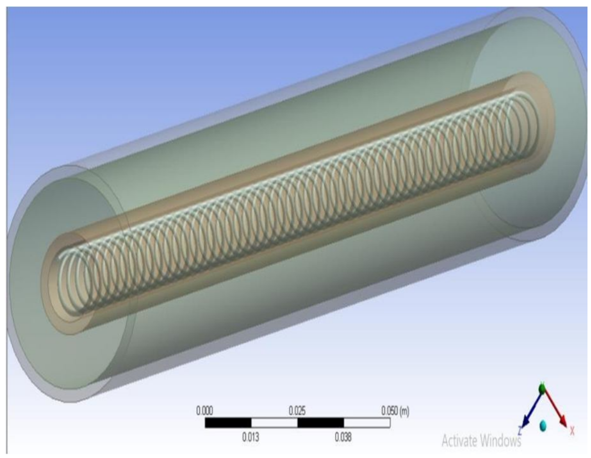

Figure 4 Model of turbulator double pipe heat exchanger.

B. Meshing

In the ANSYS FLUENT R16.0 pre-processor stage, a three-dimensional discreet turbulator dual pipe heat exchanger model was developed. While grid types are related to simulation output, the entire system is divided into the finite volume of Quad-core tetrahedral grids in command to reliably calculate the thermal properties of turbulator double pipe heat exchanger using the correct grids.

Table 1 Meshing Details

No. of Nodes	648975
No.of Elements	2012875

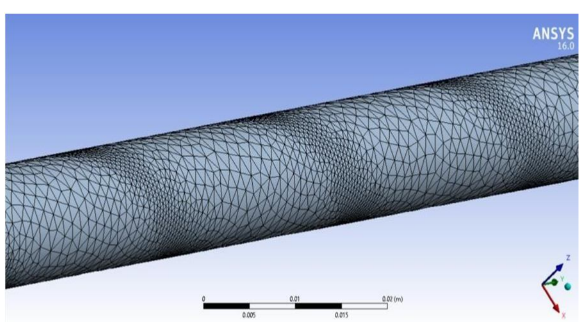

Figure 5 Refinement of mesh at critical zone where turbulator and cold fluid is in contact

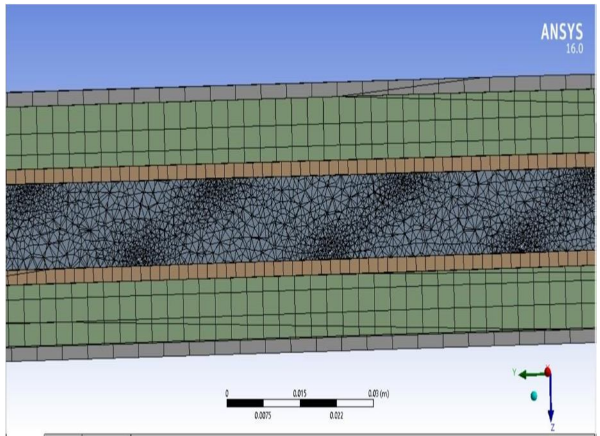

Figure 6 Heat exchanger cross-sectional view of mesh.

V. RESULT

Here we consider aluminium oxide (Al_2O_3) to be a nanoparticle; it is mixed with 0.4% fraction volume water and is used in a heat exchanger as a nano-fluid. The temperature contours of the aluminium nanofluid on 4000 Re-numbers are seen in the following section:

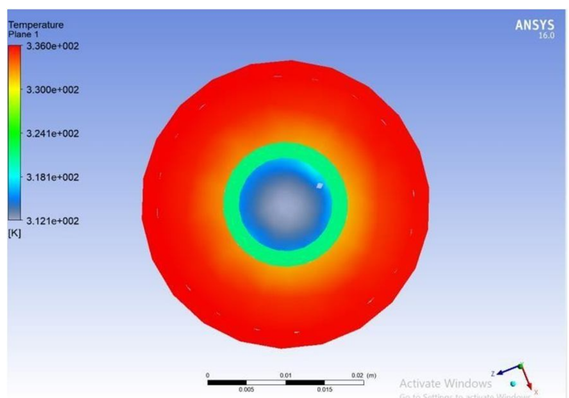

Fig 7 Cold fluid inlet temperature contour for Re = 4000 at 0.4 percent volume fraction for Al_2O_3.

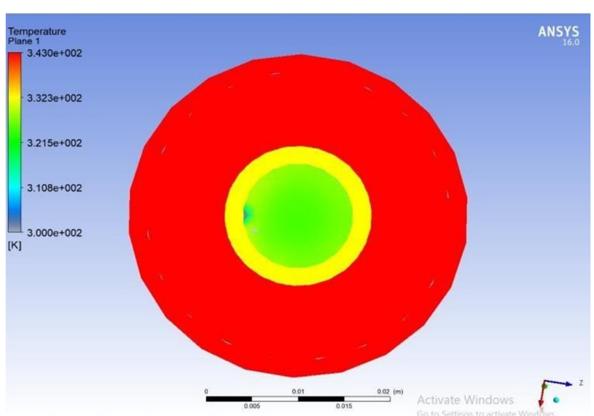

Fig 8 Cold fluid outlet temperature contour for Re = 4000 at 0.4 percent volume fraction for Al_2O_3.

Likewise, aluminium oxide (Al_2O_3) can be a nanoparticle, being used as a nanofluid in heat transfer combined with water on vol. fraction of 0.8 percent. Aluminium nano-fluid thermal contours at Re=4000 are seen in the following section:

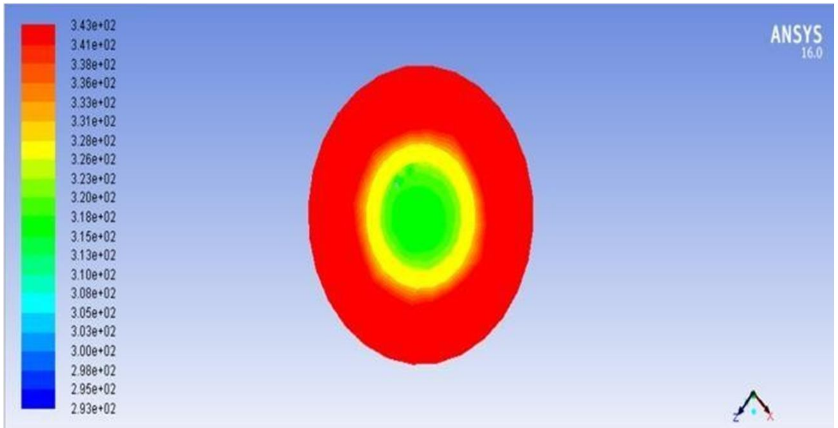

Fig 9 Cold fluid inlet temperature contour for Re = 4000 at 0.8 percent volume fraction for Al_2O_3.

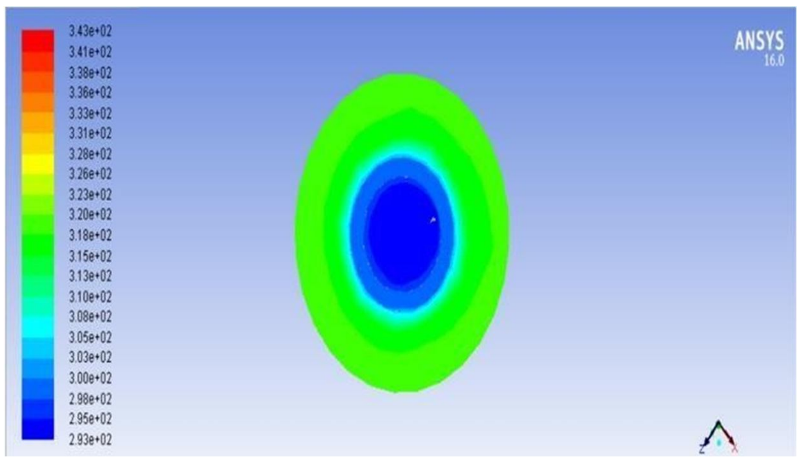

Fig 10 Cold fluid outlet temperature contour for Re = 4000 at 0.8 percent volume fraction for Al_2O_3.

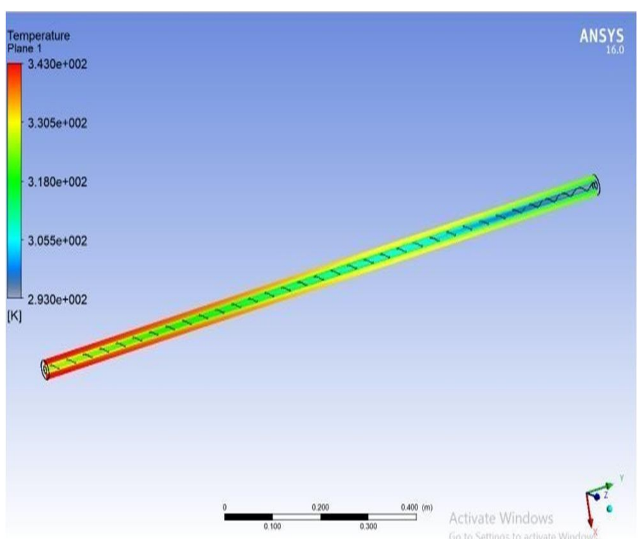

Figure 11 Center plane Temperature contour of heat exchangerat 0.8% volume fraction for Al_2O_3.

Aluminum oxide (Al_2O_3) also acts as a nanoparticle; it is used as a nanofluid in the heat exchanger, mixed with water at a volume of 1.2 %. The aluminium nano-fluid temperature contours at Re=4000 are seen in the following section:

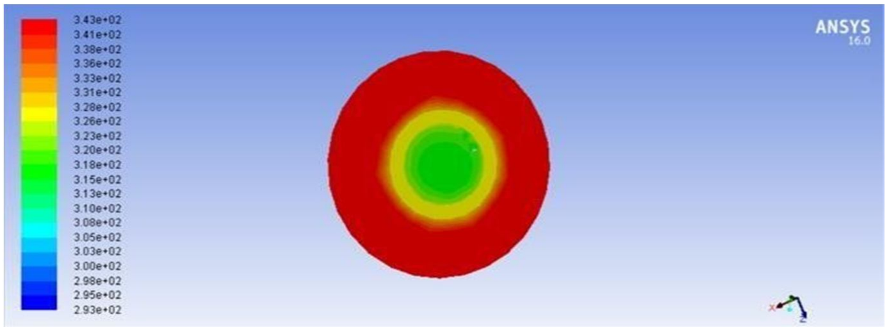

Fig 12 Cold fluid inlet temperature contour for Re = 4000 at 1.2 percent volume fraction for Al_2O_3.

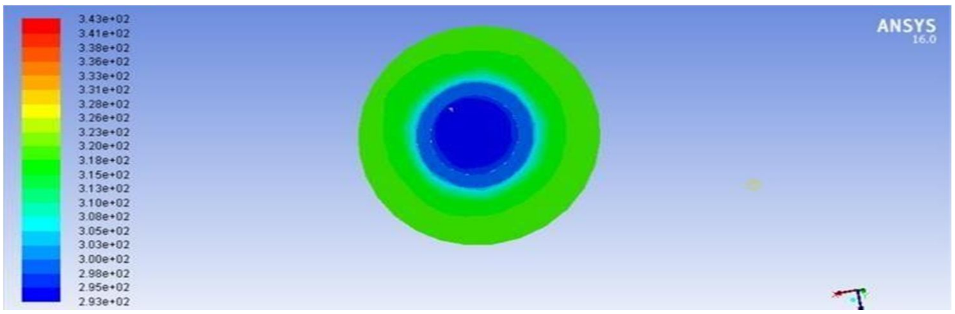

Fig 13 Cold fluid outlet temperature contour for Re = 4000 at 1.2 percent volume fraction for Al_2O_3.

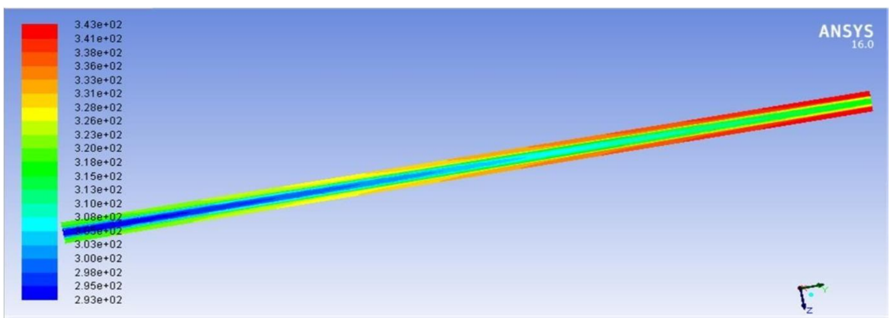

Figure 14 Center plane Temperature contour of heat exchangerat 1.2 % volume fraction for Al_2O_3.

By CFD analysis, the value of the hot and cold fluid in the Re = 4000 inlet / outlet was determined in a number of volume fractions depending on which the value of the Nusselt volume and the overall heat transfer coefficient is estimated.

S.No.	Reynold's number	Overall heat transfer coefficient (W/m^2-K)(Base Paper)	Overall heat transfer coefficient (W/m^2-K) (Present Study)
1.	4000	1250	1253.45
2.	8000	1310	1315.83
3.	12000	1380	1384.95
4.	16000	1435	1440.71
5.	20000	1480	1487.98

Table 2 Overall heat transfer coefficient values at 0.4 percent volume fraction for Al_2O_3

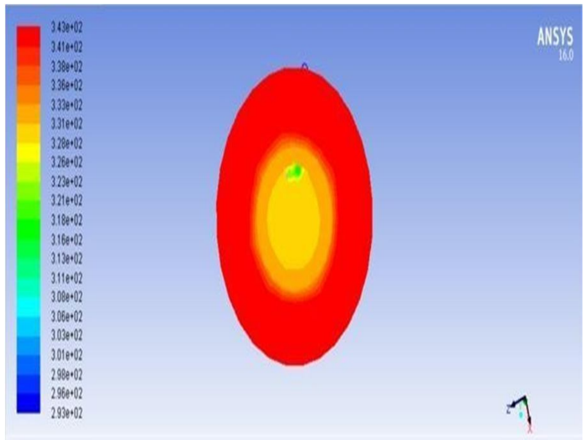

Figure 15 Temperature contour at the exit of cold fluid i.e. Cu+Al_2O_3/water based hybrid nanofluid atRe = 4000 at 0.4% volume fraction

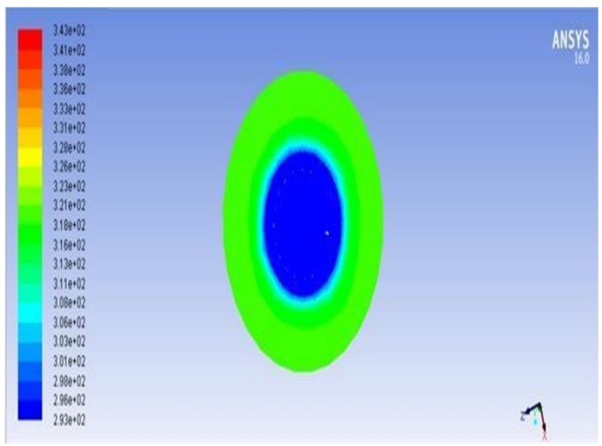

Figure 16 Temperature contour at the inlet of cold fluid i.e. Cu+Al_2O_3/water basedhybrid nanofluidatRe = 4000 at 0.4% volume fraction.

Now at 0.8% volume concentration of nano particles hybrid nano fluid having at Re =4000.

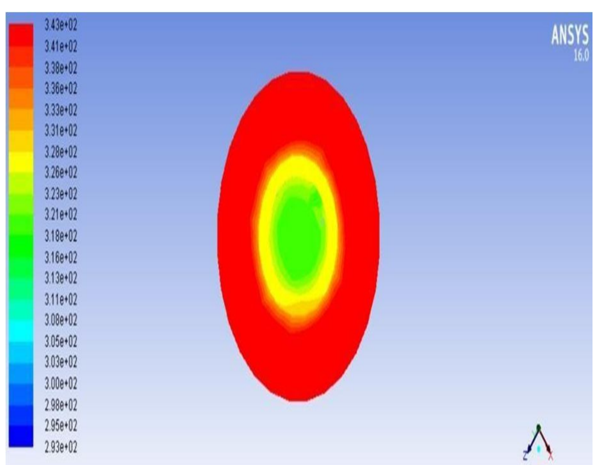

Figure 17 Temperature contour at the exit of cold fluid i.e. Cu+Al_2O_3/water basedhybrid nanofluid atRe = 4000 at 0.8% volume fraction.

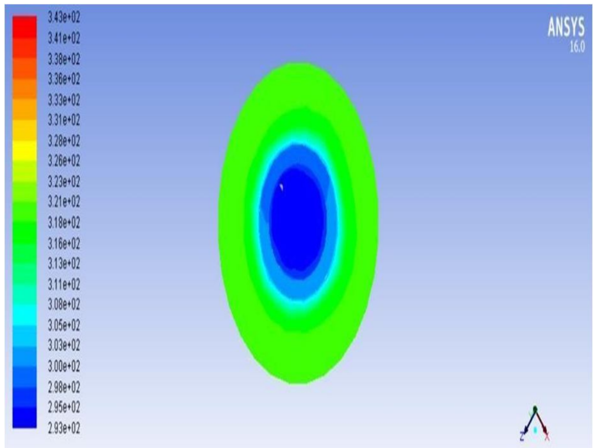

Figure 18 Temperature contour at the inlet of cold fluid i.e. Cu+Al2O3/water basedhybrid nanofluidatRe = 4000 at 0.8% volume fraction.

Similarly at 1.2 % volume concentration of nano particles hybrid nano fluid having at Re =4000.

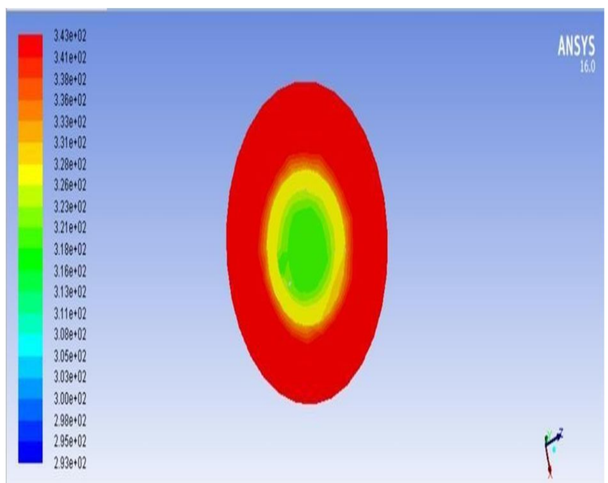

Figure 19 Temperature contour at the exit of cold fluid i.e. Cu+Al2O3/water based hybrid nanofluid at Re = 4000 at 1.2% volume fraction.

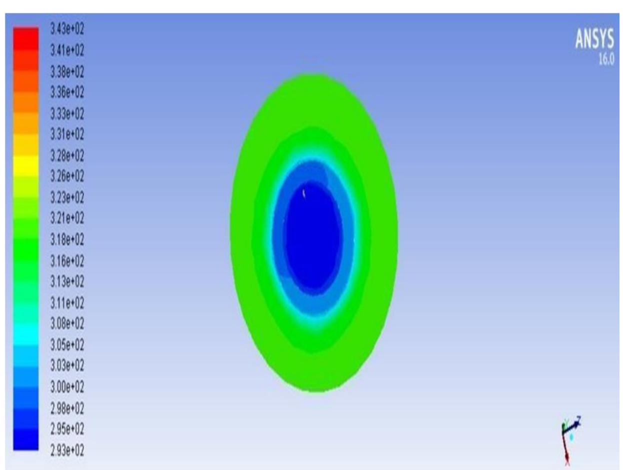

Figure 20 Temperature contour at the inlet of cold fluid i.e. Cu+Al2O3/water based hybrid nanofluid at Re= 4000 at 1.2% volume fraction.

VI. CONCLUSION

CFD turbulent heat flow simulations in a dual pipe heat interchangeable with a turbulator using the nanofluid hybrid, i.e. Cu+Al_2O_3 / water was carried out at varying volume concentrations at different numbers of Reynolds. The calculations were performed for variable Reynolds numbers ($4000 \leq Re \leq 20000$), volume fractions (0.4-1.2 percent). Based on the effects of the CFD measurements, it is observedthat:

1) Ordinarily, the presence of Cu+Al_2O_3 nanoparticles in the base fluid increases the properties of convective heat transfer and is thus more efficient than Al_2O_3 nanoparticles (at a steady concentration of volume)
2) The findings revealed that the average heat transfer coefficient increases in line with the Reynolds number
3) Analysis has shown that the average thermal transfer coefficient value for hybrid nanofluid is 12 percent greater than the average for a single nanofluid.
4) In the case of hybrid nanofluid compared to Mono nanofluid, the value of Nusselt is 18 per cent higher.
5) Investigations revealed the superior thermal efficiency of the hybrid nanofluid in a flow- suitable two-pipe heat interchangeable turbulator.

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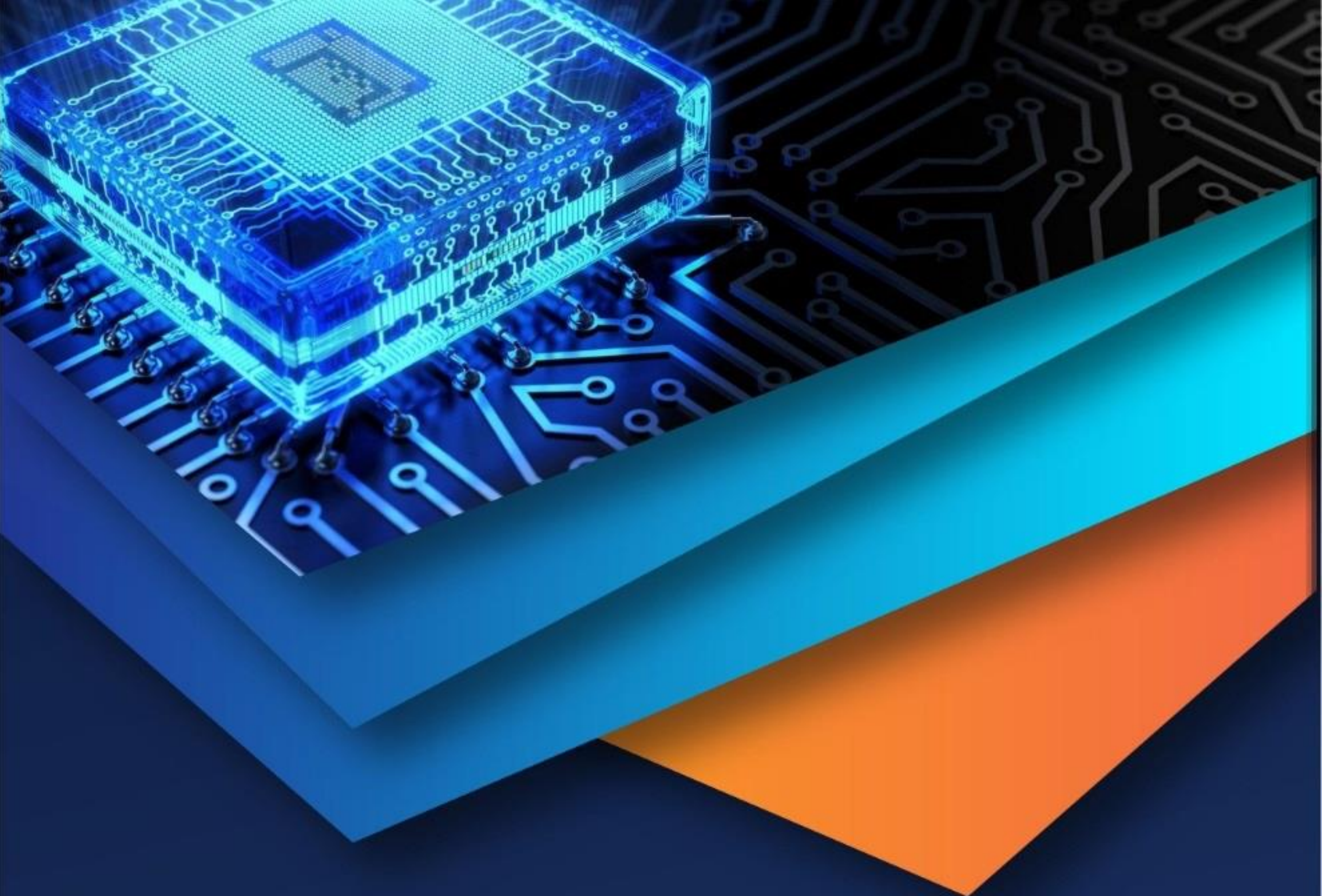

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