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CFD Analysis of Two Pass Double Pipe Heat Exchanger with TiO_2/Ethylene Glycol Nano Fluid

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Abstract: ***This paper deals with the numerical simulation of cold fluid forced convection heat transfer under turbulent flow condition with different flow rates of 8, 10, 12, 14, 16 lpm and at various Nano fluid volume-fractions of 0.03%, 0.1%, 0.2%, 0.3% and 0.4% with constant hot fluid flow rate of 8 lpm. In this study, TiO2/Ethylene Glycol Nano fluid is used as cold fluid and pure water is used as hot fluid around initial temperatures of 27 °C and 60 °C, respectively. The objective is to augment the heat transfer coefficient and friction-factor of 2 pass Double pipe heat exchanger at various Reynolds numbers range of 9,000 to 25,000 using Computational Fluid Dynamics (CFD). The present study explored that the effect of volume concentration in 2 pass Double pipe counter flow heat exchanger on convective heat transfer and friction characteristics in a tube. The simulations were done for these flow rates at different volume concentrations. The results showed that an enhancement in heat transfer coefficient is increased by 34.93% at 0.4% volume concentration at Reynolds number range of 9000 to 24,000 when compared to water. The maximum friction factor obtained is 1.34 times at 0.3% volume-fraction of TiO2/Ethylene Glycol Nano fluid at Reynolds number of 10,833, when compared to water.***
Keywords: Heat Pipe, Nano fluid, CFD Analysis, Double pipe heat pipe.

I. INTRODUCTION

Heat exchangers are essential engineering devices in several process industries as the efficiency and economy of the process largely depends on the performance of the heat exchangers and other important engineering applications in heat exchangers such as power plants, air-conditioning, petrochemical industry, natural gas processing, refrigeration, solar water heater, chemical reactors, sewage treatment, shell and tube heat exchangers in nuclear reactors. The design method for heat exchangers is very critical, as it needs perfect analysis on rate of heat transfer and pressure drop estimations. The rate of heat transfer can be enriched by producing a disturbance in the flow of fluid by breaking the viscous boundary and thermal boundary layers, This problem can be rectified in the other type as there exists a fairly constant difference in temperature. Double pie heat exchanger is a simple exchanger which consists of two pairs of pipes are arranged in the hairpin alignment, for noticeable causes. Butteries of this type of heat exchangers are connected in series-parallel or series in arrangements in order to obtain grater area of surface for heat transfer. The working fluids that are transmitting heat energy from one fluid to another fluid depending up on our requirement in the inner and outer pipes. The increase of heating and cooling systems in a factories or industrial aspects will create a saving the energy, reducing the process-time, raising the temperature and increasing the life of apparatus. The improvement of high operation of thermal processes for augmentation of heat transfer will become trendy now-a-days. There are various methods to develop the efficiency heat transfer by use of extended surfaces that are Passive methods and aspect of vibration to the heat transfer parts that are Active methods etc. Efficiency of heat transfer can be developed by raising the thermal conductivity of the base fluids. Generally water, ethylene glycol, and engine oil etc., are having low thermal conductivity and used as base fluids, when compared to solid particles. To raise the thermal conductivity of these fluids, solid particles, generally having higher thermal conductivity, are used to mix with these fluids with a certain concentrations.

These are having following drawbacks represented below:

A. The particles are settled down rapidly and form a small layer on the surface and dropping the heat transfer rate.
B. Whenever rate of circulation increases, sedimentation is diminished, but increasing the erosion rapidly of the heat exchanger parts such as pipe walls, etc.
C. Particles are of large size tends to block the flow loops.
D. The pressure drop increases hastily in the fluid.
E. Finally, development of conductivity based on particle-concentration is reached. That is the higher the particle volume-fraction is, higher the improvement and having major problems.

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II. OBJECTIVE AND METHODOLOGY

Several research works have been done in the tube flow recently on heat transfer aspects. Convective heat transfer improvement with different types of Nano fluid in a plain tube is clarified by several researchers.

A closer observation at experi0mental and numerical results reveals that most of the convective heat transfer studies in the tube flow have been done with Al_2O_3, CuO, SiC, CNT and Fe_3O_4 etc., Nano fluids itself. So in the present work, TiO2/Ethylene Glycol is considered as a Nano fluid because of the advantage with this, there is a possibility of separation of magnetic Nanoparticles (Fe_3O_4) from the base fluid, isis not achievable with non-magnetic (Al_2O_3, CuO and TiO_2) type nanoparticles.

In order to complete a project successfully, the objectives for the project must be determined and the objectives of this project includes:

A. To investigate numerically the behavior of Nano fluid (TiO2/Ethylene Glycol) at different Reynolds numbers and volume concentrations (0.03%, 0.1%, 0.2%, 0.3%, 0.4%) during the forced convection heat transfer using ANSYS FLUENT.

B. To compare the results obtained from the numerical simulation software with the Analytical results by using the several correlations given by different authors, who have researched on this work and study the enhancement of the heat transfer in comparison with that of water.

III. CFD ANALYSIS OF DOUBLE PIPE HEAT EXCHANGER AND SIMULATION

This chapter deals with the computational fluid dynamics (CFD) analysis of the behavior of the turbulent flow through a 2 pass double pipe heat exchanger using ANSYS FLUENT 16 software.

A. Geometry and Modeling Specifications of Geometry and Boundary conditions

The analysis is performed on a 2-pass double pipe heat exchanger with the inner diameter of inner pipe is 0.019 m & outer diameter of inner pipe is 0.025 m, similarly for annulus pipe, the inner diameter of outer pipe is 0.05 m & outer diameter of outer pipe is 0.056 m and the total length of heat exchanger is 2.36 m (2-pass)

B. Meshing of Geometry

Structured meshing method in ANSYS WORKBENCH was used for the geometry. The element for meshing considered is hexahedral shape with number of elements of 876874 to 1240000 as shown in Fig.1. Naming selections were also done at required places.

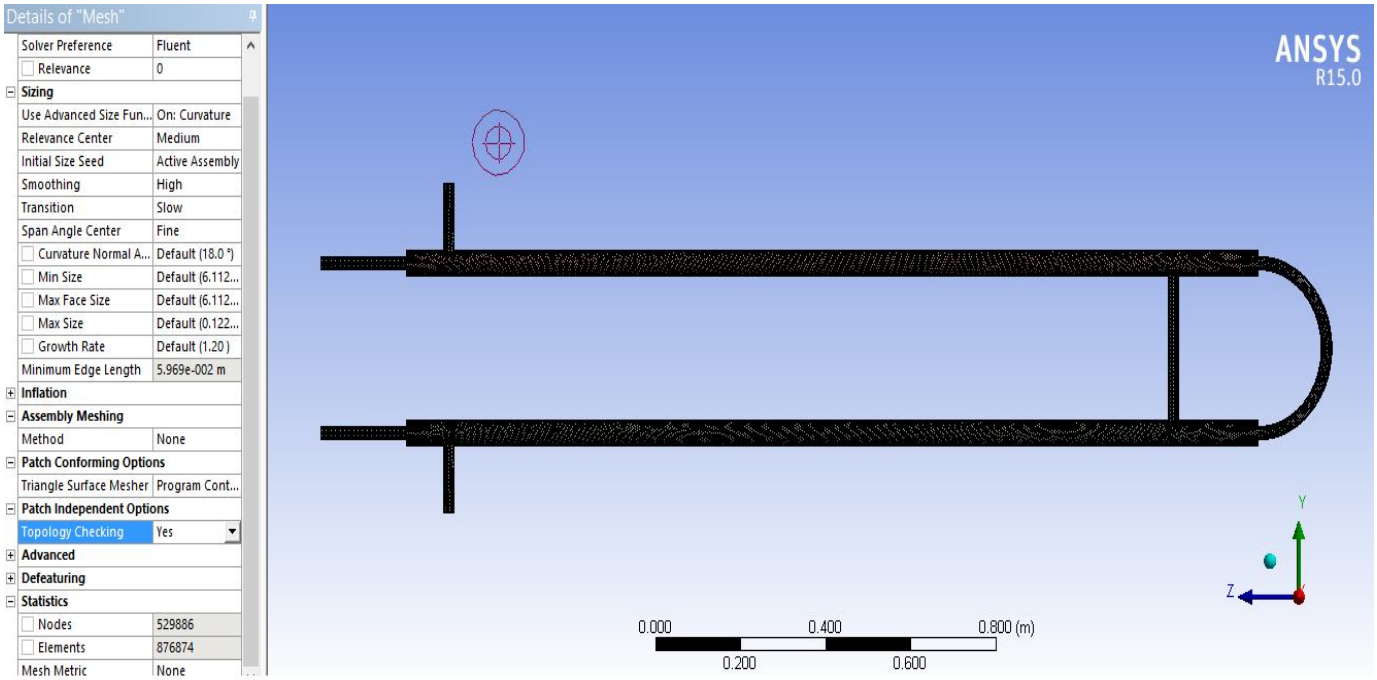


Fig. 1. Meshing of 2 pass double pipe heat exchanger in ANSYS Workbench

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C. Grid Independence Test

Grid independence test was conducted at 8 lpm hot water and 10 lpm cold water flow rates in ANSYS-FLUENT, by decreasing and increasing the size of the elements. The gained results are tabulated in Table 5.1, for outlet temperatures of cold water and hot water of 2-pass double pipe heat exchanger.

TABLE 5.1 Grid Test Results

No. of elements	Coldwater outlet temperature (°C)	Hotwater outlet temperature (°C)
876874	31.458	53.970
895812	31.652	53.625
856253	30.256	54.325

Finally, I selected as final mesh elements of 876874 for further simulation purpose.

D. Physical Models

The standard k-ϵ (k-epsilon) model is used for single phase turbulent flow in circular pipe channel. Based on the Reynolds number, ρVd/μ either viscous laminar or standard k-ϵ model is used for laminar and turbulent flow respectively. The choice of the model is shown in Table 5.2. Where, d is the diameter of the pipe, ρ is are the density and μ is viscosity of the fluid.

E. Material Properties

Pure water is used as base fluid, steel is used for pipes and TiO2/Ethylene Glycol used as cold fluid, the properties are shown in Table 5.3.

Table 1: Properties of Water and Fe_3O_4 Nanoparticles

S.no	Substance	Mean Diameter	Density (kg/m^3)	Thermalconductivity (W/m-K)	Specificheat(J/kg-k)	Kinematic Viscosity (m^2/s)
1	Ethylene Glycol	--	1220	0.258	2360	8.32E-07
2	TiO2	50-100	3970	11.8	683	-----

F. Boundary Conditions

A Velocity inlet, uniform mass flow inlets and a constant inlet temperature were assigned at the channel inlet. At the exit, pressure was specified. The boundary conditions assigned as shown in Figure 5.4.

Table 2: Boundary Conditions

S. No	Boundary type	Annulus Pipe	Inside Pipe
1	Mass flow rate at Inlets	0.134 kg/s	0.134 to 0.267 kg/s
2	Temperatures	333 K	300 K
3	Constant heat flux at pipe wall (Insulation)	0 W/m^2	---

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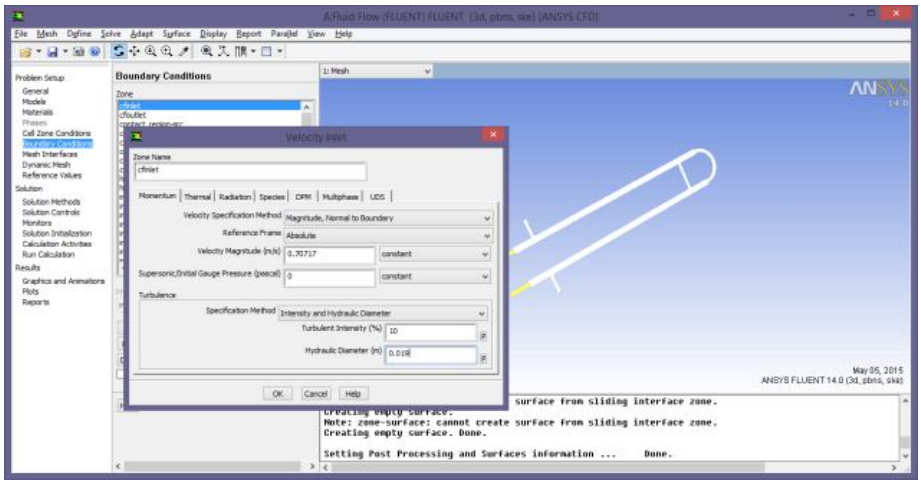


Fig. 2: Boundary conditions given in Problem setup in ANSYS-FLUENT

G. Method of Solution

The CFD method follows the use of commercial software ANSYS FLUENT 15.0 to solving the problem. The solver in ANSYS-FLUENT used a pressure correction based SIMPLEalgorithm with 2nd order upwind scheme for discretizing the convective transport terms. The criteria for convergence dependent variables are specified as 0.001.

In the present analysis, the analytical values of heat transfer coefficients are calculated. The heat transfer coefficients are also obtained using CFD methods and compared with analytical values.

The Flow diagram of 2 Pass Double Pipe Heat Exchanger as shown in Figure below

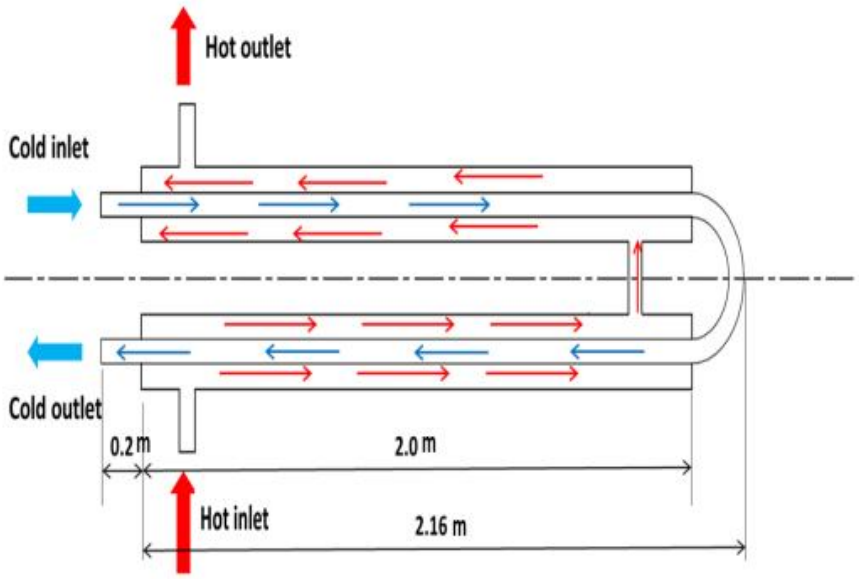


Fig.3: Flow diagram of double pipe heat exchanger

The CFD method follows the use of commercial software ANSYS FLUENT 15.0 to solving the problem. The solver in ANSYS-FLUENT used a pressure correction based SIMPLE algorithm with 2nd order upwind scheme for discretizing the convective transport terms. The criteria for convergence dependent variables are specified as 0.001.

In the present analysis, the analytical values of heat transfer coefficients are calculated. The heat transfer coefficients are also obtained using CFD methods and compared with analytical values.

H. Model Calculations

Model calculations were taken at 0.03% Nano fluid at 8 lpm hot fluid and 12 lpm cold fluid:

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IV. RESULTS AND DISCUSSION

A. Validation of Numerical Results

Effect of Nusselt number on Reynolds number. Here Analytical relation taken by **Sunder and Sharma[22]** equation.

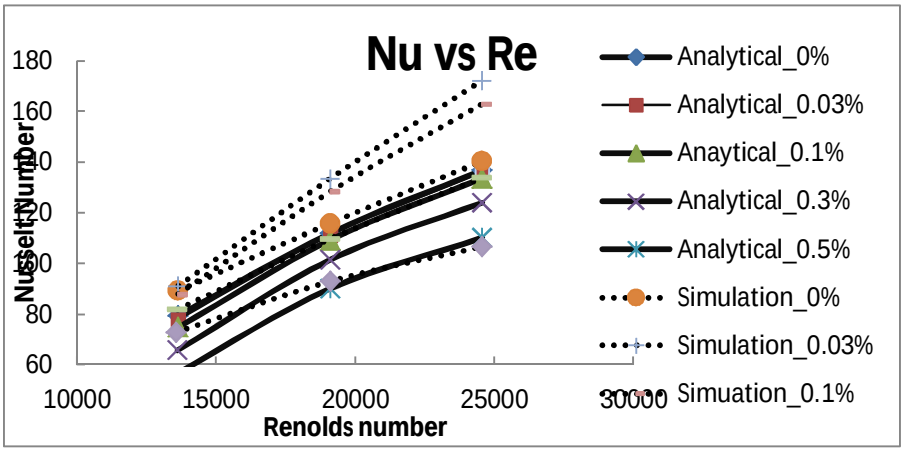


Fig 4:Effect of friction factor on Reynolds number.

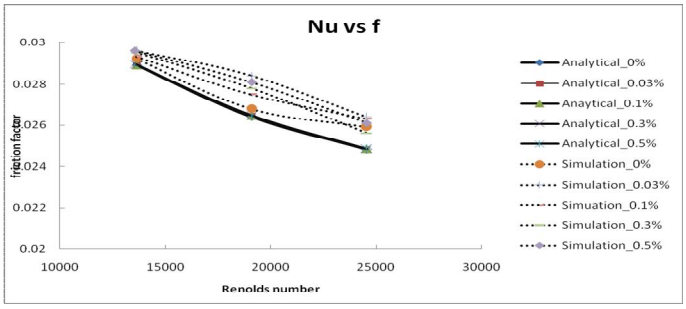


Fig.5: shows that comparison of Numerical friction factor with Blasius correlation for pure water.

From this illustration, it was observed that there is a closer agreement for simulation results with Analytical data is achieved. The figure shows comparison of friction factor values of Analytical and Simulation results at corresponding Reynolds numbers. It was observed that the friction factor values are closer to the values obtained by correlation by Sunder and Sharma.

V. CONCLUSION

In this work the hydrodynamics and thermal behavior of Double pipe 2 pass heat exchanger were studied. Pure water and its Nano fluids (TiO2/Ethylene Glycol) were considered in pipe channel. A steady state computational fluid dynamics (CFD) models was simulated by ANSYS FLUENT 15.0. The effect of Reynolds number and Nusselt number on the flow behavior of the pipe was studied

Conclusion of the present work can be summarized as follows.

A. The heattransfer enhancement is observed that better in the turbulent region compared to that in the laminar region for all volume fractions considered in the analysis.

B. There is a good agreement between the results gained from the simulation and analytical data. The maximum error was found that 10.56%.

C. It is observed that according to simulation results there is a 34.93% enhancement in heattransfer coefficient at 0.4% volume-concentration of Nanofluid when compared to water at Reynolds number range of 9000 to 22,000.

D. It is observed that there is a maximum friction-factor found that 1.34 times at 0.3% volume-concentration of TiO2/Ethylene Glycol Nanofluid at Reynolds number of 10,833 when compared to water.

E. The friction-factor is increased with the increase of volume concentration but it is observed that the friction-factor enhancement is less compared to the enhancement to the heat transfer for volume fraction considered in the analysis.

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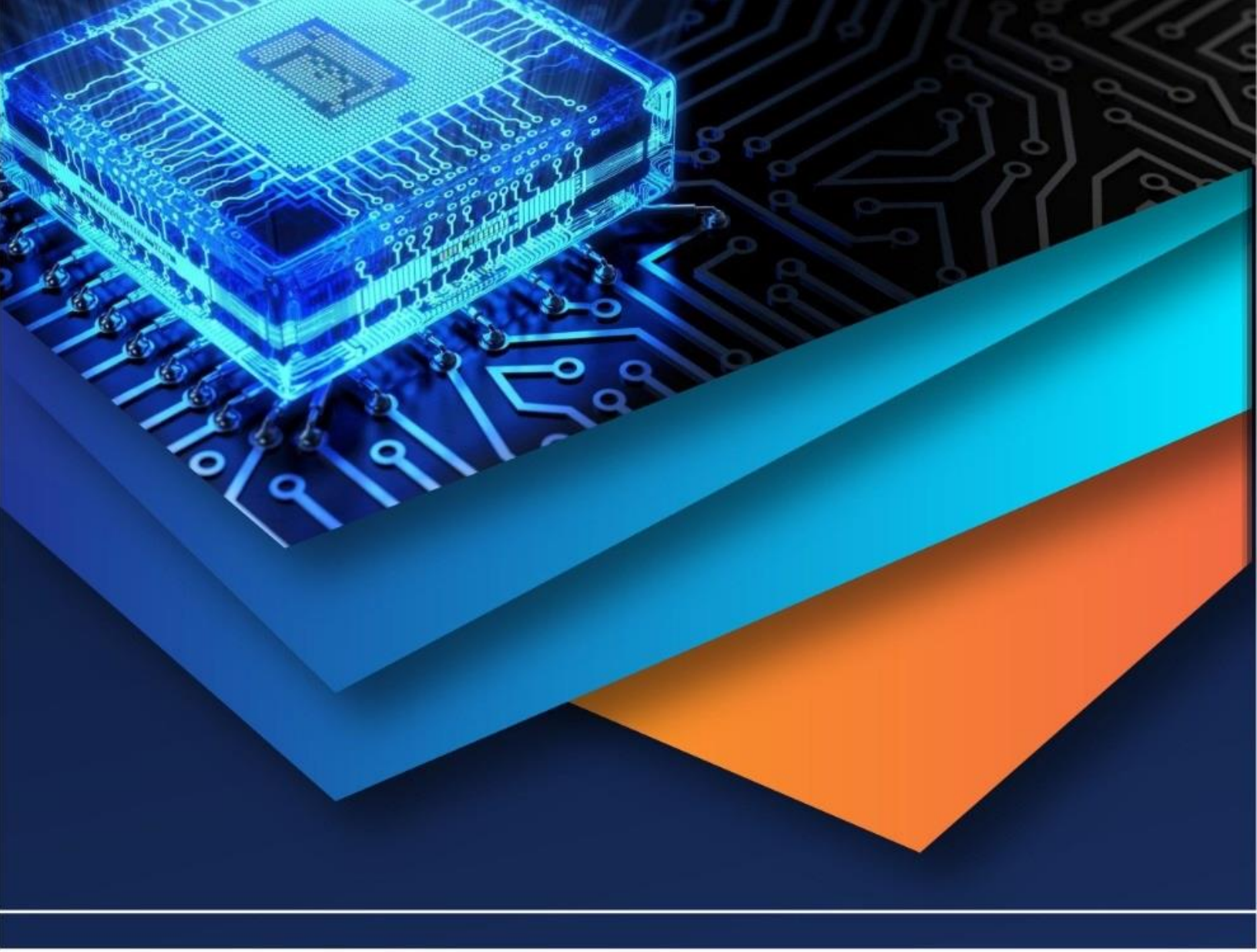
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