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Evaluating the Impact of Nanofluids on Outlet Temperature of Coolants in Heat Exchangers

Prof. Laxmikant Mangate[1], Mrunal Lenekar[2]
Department of Mechanical Engineering, Vishwakarma Institute of Technology, Pune, 411037, Maharashtra, India

Abstract: The engine in a vehicle burns fuel and creates energy, which generates heat. Venting this heat away from engine parts is important to prevent damage. Radiators work to eliminate heat from the engine. The process begins when the thermostat in the front of the engine detects excess heat. Then coolant and water get released from the radiator and sent through the engine to absorb this heat. Once the liquid picks up excess heat, it is sent back to the radiator, which works to blow air across it and cool it down, exchanging the heat with the air outside the vehicle. In this project, aim is to get lowest possible temperature at the outlet of the radiator, which can be achieved by mixing non-fluids with water.
Index Terms: Cooling, Efficient, Nano Materials, Perforations, Design
Keywords: Nanofluids, Al2O3 nanoparticles, heat exchanger, thermal conductivity, radiator, heat transfer, thermal management.

I. INTRODUCTION

The growth of technology found in high tech industries, such as automobiles, microelectronics, transportation, and manufacturing has created a specific way for scientific advances that would have wide ranging effects on many obstacles facing today's scientific world such as system efficiency, reliability and pollution. However, many factors are underlined in the development of the automotive industries among them as one point is the ability to rapid cooling of the products. Cooling is one of the important processes for maintaining and enhancing the operational performance of the system as a result caused by the increase in power and reduces in sizes and weight in future products. Continuous technological development in automotive industries has demand for high efficiency engines. A high efficiency engine is not only based on the performance of radiator but also depends on better fuel economy and less emission rate. Radiators are heat exchangers that transmit thermal energy from one medium to another for cooling and heating purposes. They are mostly used to cool internal combustion engines in automobiles, but they are also used in piston-engine aircraft, railway locomotives, motorbikes, stationary generating plants, and engines with comparable characteristics. In general, internal combustion engines are cooled by passing a liquid known as engine coolant through the engine block, where it is heated, then through the radiator, where it loses heat to the atmosphere, and finally back to the engine in a closed loop. So, addition of fins is one of the approaches to increase the heat transfer rate of radiator, provides greater heat transfer area and enhances the air convective heat transfer coefficient. Recently there has been considerable research outlining superior heat transfer performances of nano fluids in automotive radiator. As per need, there is a new and innovative heat transfer fluid, known as "Nanofluid". Al2O3 is one for the most common nanofluid use in the industry which results in improvement of the heat transfer rate in an automotive radiator. Nanofluids are superior as a heat transfer agent over conventional fluid. With the use of nano fluids, there be about 20-30The purpose of the paper is to predict the flow behaviour and temperature distribution of a perforated fins cooling units with nanofluids (Al2O3) and to calculate and compare the loss in temperature in conventional (Water) and nanofluids (Al2O3) as coolant in the radiator.

II. LITERATURE REVIEW

Sandesh S. Chougule S. K. Sahu "Thermal Performance of Automobile Radiator Using Carbon Nanotube-Water Nanofluid—Experimental Study"- Paper presented study of convective heat transfer enhancement inside an automobile radiator by using carbon nanotube (CNT) water nanofluid. Four different concentrations of nanofluid in range of 0.15-1 vol % prepared with adding of CNT nanoparticles in water. the effect of various parameter, synthesis method, variation in PH value and nano particle concentration on the Nusselt number are examined through the experimental investigation.

K.Y. Leong, R. Saidur, S.N. Kazi, A.H. Mamun" Performance investigation of an automotive car radiator operated with nanofluid-based coolants (nanofluid as a coolant in a radiator)"- Study focused on application of nanofluid in automotive cooling system using ethylene Glycol based copper nanofluid.

It was observed that by usage of nanofluid overall heat transfer coefficient and heat transfer rate in engine cooling system increased. Observe that 3.8% of heat transfer enhancement achieved with addition of 2% copper particles with Reynolds number 6000 and 5000 of air and coolant respectively. S.M. Peyghambarzadeh, S.H. Hashemabadi, M. Seifi Jamnani, S.M. Hoseini "Improving the cooling performance of automobile radiator with Al_2O_3/water nanofluid"- Study shows forced convective heat transfer in water based Nanofluid and experiment is compared with pure water. Five different concentrations of nanofluid in range 0.1 – 1 vol% prepared with addition of Al_2O_3 nanoparticles into the water. Result shows that increased fluid circulating rate can improve the heat transfer performance. application of nanofluid with low concentration can enhanced heat transfer efficiency up to 45% in compares with pure water.

Muhammad Mahmood Aslam Bhutta, Nasir Hayat, Muhammad Hassan Bashir, Ahmer Rais Khan, Kanwar Naveed Ahmad, Sarfaraz Khan" CFD applications in various heat exchangers design: A review"- Review show application of computational fluid dynamics in field of heat exchanger. paper found CFD can be employed in study of heat exchanger fluid flow maldistribution, flowing pressure drop, and thermal analysis in design and optimization phase. Sneha Shinde" CFD Analysis Of Car Radiator System Using Aluminium And Graphene Oxide Nano Fluids As Coolant" Nanoparticles with a volumetric concentration of 6%, 8%, and 10% and the inlet velocities of 0.025m/s, 0.05m/s, 0.075 m/s has been examined. Heat transfer performance is improved by using nanofluids with higher thermal conductivity. Results shows significant increase in effectiveness of coolant in car radiator with an increase in the nano particles concentration. Faheem Akthar , Abdul Razak Kaladgi, Asif Afzal, Abdulrajak Buradi, Abdul Aziz, Ahamed Saleel" Numerical analysis of rectangular fins with circular perforations"- Study show design of heat exchanger employing rectangular fins. Objective of study is to estimate temperature reduction across number of circular perforation on rectangular fin. Analysis was carried in ANSYS fluent code. Result shows that appreciable temperature drop and enhancement of heat transfer using circular perforation. C.Gopinath Dr.L.Poovazhagan" Design and Analysis of Fluid Flow and Heat Transfer in a Crossflow Radiator as Changing the Fin and Tube Material"- Study shows the suitable material for radiator in various working condition and its application. Analysis on existing radiator is done by changing tube and fin material for evaluating the fluid flow and heat transfer characteristics. the heat transfer rate, heat flux and the pressure and temperature distribution along the tube length and tube width are presented and analysed. Vishwa Deepak Dwivedi, Ranjeet Rai "Design and Performance Analysis of Louvered Fin Automotive Radiator using CAE Tools"- The research focuses on evaluating the performance of a louvred fin-based tube vehicle radiator that uses nanofluids as a coolant as these fluids have greater thermal conductivity. As a result, when compared to traditional coolant (water), the usage of a louvre fin heat exchanger with nanofluid (Si C + water) increases cooling capacity by 6%. K. Chinnarasu, M. Ranjithkumar, P. Lakshmanan, K. B. Hariharan, N. K. Vigneshwaran and S. Karan "Analysis of Varying Geometry Structures of Fins using Radiators"- investigated the automotive radiator using water and nano fluid as coolants with different geometrical fin structures such as e Box type, Sharp type, round type, Sharp type radiator fins. Through simulation it states that fins with a round shape exhibit significant temperature decreases & nanofluid can be used as a coolant to further boost this heat dissipation. Anzaman Hossen, Nazmus Sakib "Numerical Analysis on Heat Transfer with Nanofluid in an Automotive Radiator"- The computational investigation of the water-based Al_2O_3 nanofluid convective heat transfer in turbulent flow in conjunction with an automotive radiator has done. Which results in inclusion of nanofluid particles lowers the temperature at the outlet also density and viscosity of nanofluid increases with addition of Al_2O_3 nanoparticles

III. RADIATOR SYSTEM

A. Nanofluids

Traditionally the dissipation of heat in the automobile engine is done using the radiator cooled by coolants such as water or ethylene glycol. The nano fluids are suspensions of nano sized metallic or non-metallic oxides particles in a base fluid. These nano fluids exhibit good thermal properties when compared to the conventional fluids due to their possessing more surface area by virtue of existing in nano size. Further these nano fluids exhibit more inter particle/inter fluid-particles/fluid-particle-surface of flow passage, more turbulence and mixing. Hence the nano fluids are the promising material and technology for improving the efficiency of the automobile radiator and optimize its design. The nano particles by virtue of their smaller size possess more surface area than the bulk material, which shall enable them to absorb and dissipate heat at a faster rate. Generally, water and ethylene glycol are used as coolants in automobile radiators. Several investigators have used nano fluids consisting of nano size particles of TiO_2, Al_2O_3, SiO_2, CuO, Fe_2O_3, etc., suspended in the coolant used in the radiator of automobiles. These investigators have observed that the application of nano fluids increases the cooling rate and shall pave way for reducing the weight and size of the radiator, there by contributing to smaller and efficient radiators.

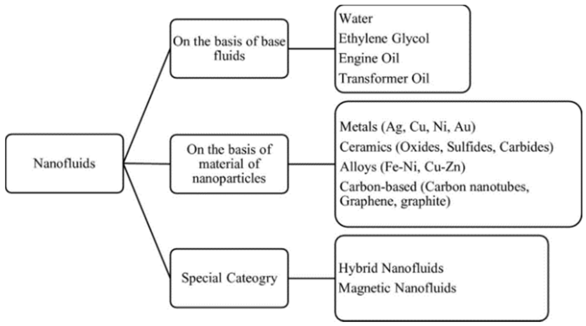

Fig. 1. Classification of Nanofluid

The use of Al2O3 nanofluids increases the pressure drop by up to about 13% due to the greater viscosity. In addition, the heat transfer coefficient of nanofluids increased with the volumetric concentration by up to approximately 19% induced by the enhanced thermal conductivity.

B. Material Of Fins

1) Fins are used to greatly increase the contact surface of the tubes to the air, thus increasing the exchange efficiency. Here perforated-fin structure is used for achieving the maximum enhancement on the heat transfer. As radiator fins are instrumental in the heat transfer process, a design change in them results in substantial changes in the output efficiency results. The central concept that is utilized is to increase the surface area of the fins, which would increase the rate of heat loss from the pipes.
2) Various materials such as aluminium alloys, magnesium alloys, and gray cast iron are use to increase heat transfer rate as this material preferably have high thermal conductivity.
3) Aluminium is one of the most frequently used materials for fin due to its higher thermal conductivity, comparatively low cost and have good corrosion resistance.

C. Radiator

A radiator is a heat exchanger that is used to transfer thermal energy from one medium to another for the essence of cooling and heating. Radiators are consisting of a large area of the cooling surface and use the stream of air to take away the surrounding heat. with easy access to the coolant heat, efficient cooling is achieved. Modern cars use aluminium radiators, but they usually made of copper and brass. This is because of their high heat conductivity.

Types of radiators: The various types of radiators are classified according to their core. • Tabular core type In these types of radiators, the upper and lower tanks are connected by a series of tubes that passes the water within the radiator. There are fins location around the tube for efficient heat transfer. It absorbs the heat from the coolant through the fans to the atmosphere. Due to the fact water passes through all tube in this radiator type, defect on one tube will affect the cooling process.

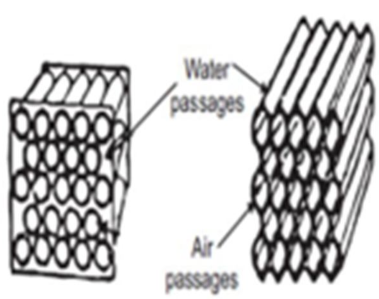

Fig. 2. Cellular Radiator

Cellular core type In the cellular types of radiators, the coolant flows through the spaces between the tubes. The core is made of a large number of individual air cells surrounded by the coolant. Air passes through the tubes while the coolant flows in the spaces between them. The cellular core radiator is also known as honeycomb radiator because of its appearance.

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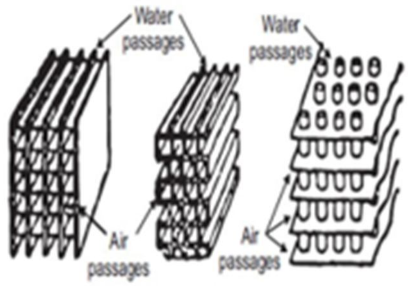

Fig. 3. Tubular Radiator

IV. DESIGN METHODOLOGY

1) Problem Statement To find the effect of Nano-fluids concentration in water flowing through radiator to obtain minimum possible temperature at the outlet of radiator.
2) Steps in Analysis In order to carry out the analysis, following steps need to be followed:

- Modelling of Radiator
- Importing the model in ANSYS 2022
- Meshing of Model
- Applying Boundary Conditions
- Solution using Iterations

To apply inlet and boundary conditions, it is required to know the properties of water - nano fluid mixture mixed in different proportion. From above table, 10% concentration nano-fluids properties are selected for the simulations. Results with 10% concentration discussed in next section.

V. CALCULATIONS

A. *Convective heat transfer coefficient*

To find out the convective coefficient of heat transfer first the mean film temperature is calculated. The surface temperature is assumed as the inlet temperature of the fluid 100°C and ambient temperature as 20°C.

$$T_f = \frac{T_s + T_\infty}{2} \quad (1)$$

Properties of air at mean film temperature (60°C) are calculated.

$$\rho = 1.0597 \frac{kg}{m^3}$$
$$\mu = 2.0061e-5 \frac{kg}{m.s}$$
$$C_p = 1008.1 \frac{KJ}{kgK}$$
$$k = 0.028517 \frac{W}{m.K}$$

From these values of properties of air Prandtl number, Reynolds number and Nusselt's number are calculated and convective heat transfer coefficient is found out.

$$Pr = \frac{C_p.\mu}{k} \quad (2)$$

$$L = \frac{V}{A_s} \quad (3)$$

$$Re = \frac{\rho.v.L}{\mu} \quad (4)$$

Solving above equations for the velocity of air is taken as 14 ms and mean film temperature as 60°C and L is 0.0264. Reynolds number (Re) & Prandtl number (Pr) are calculated as 20905.43 and 0.7092 respectively. As the Reynolds number is less than 300000 and the case is flow over flat plate i.e., external flow it can be concluded that the flow is laminar.

There are various empirical correlations for forced convection heat transfer over flat plate. However well-known correlations used to calculation the value of the Nusselt number for laminar flow over flat plate is:

$Nu = (0.664Re\ 0.5).\ Pr\ 1/3$ (5)

Using above equation, Nusselt number (Nu) equation is calculated as 85.616.

$$h = \frac{Nu.k}{L} \quad (6)$$

Using above equation, the heat transfer coefficient for the velocity of 15 m/s at 60℃ mean film temperature is calculatedas 92.5 W/ m 2 .

B. Nanofluid properties calculations

Before design a thermal system in which a nanofluid is used, it is important to know the thermo-physical properties of nanofluid such as thermal conductivity, heat capacity, viscosity and density. The thermo-physical Properties of nanofluids depends upon the various factors like preparation methods, working temperature, particle size and shape, and volume fractionconcentration. Generally, thermo-physical properties of nanofluids increase with an augmentation of volume fraction of nanoparticles and decreased with the temperature rise. The density of nanofluid can be numerically calculated by using the mass balance as:

$$\rho_{nf} = (1-\varphi)\rho_{bf} + \varphi.\rho_{np} \quad (7)$$

The specific heat of nanofluids can be calculated by using mass balance equation as:

$$C_{p_{nf}} = \frac{(1-\varphi)\rho_{bf}.C_{p_{bf}} + \varphi.\rho_{np}.C_{p_{np}}}{\rho_{nf}} \quad (8)$$

The static model of Maxwell has been used to determine the effective or thermal conductivity of liquid-solid suspensions of monodisperse, low-volume-fraction mixtures of spherical particles.

$$\frac{k_{nf}}{k_{bf}} = 1 + \frac{3(\frac{k_{np}}{k_{bf}}-1)\varphi}{(\frac{k_{np}}{k_{bf}}+2)-(\frac{k_{np}}{k_{bf}}-1)\varphi} \quad (9)$$

Table 1 represents all the calculated properties of water and nano particle mixture using equations 7, 8, 9.

Nanoparticle and its Volume Concentration	Density	Specific Heat	Thermal Conductivity
Al2O3 (0.3)	1007.1154	4143.18755	1.30938
Al2O3 (0.3)	1013.059	4117.6921	2.2036
GO (0.3)	1006.0054	4145.3167	1.37077
GO (0.3)	1011.209	4121.1758	2.39784
Cu2O (0.3)	1014.7054	4112.01023	1.15336
Cu2O (0.3)	1025.709	4066.602	1.6103

TABLE I
PROPERTIES OF NANO-FLUID

For analyzing the effect of fluid flowing through the radiator, three fluid mixtures are analyzed while they are flowing through the radiator tubes. Using standard dimensions of the radiator, geometry of the radiator is created in SolidWorks.

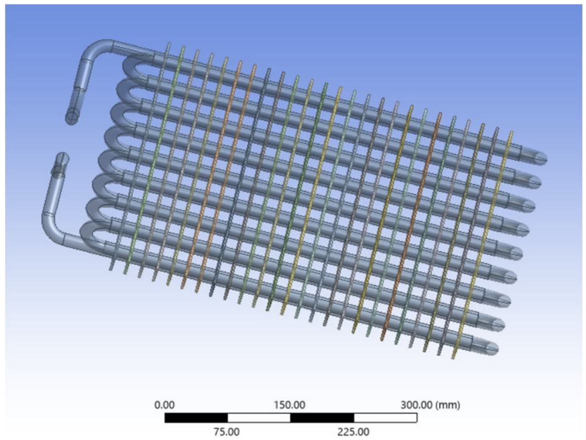

Fig. 4. Model of Radiator

In order to obtain accurate results of the simulation, very fine mesh of the geometry is created in ANSYS Software. While doing meshing in the software, it is required to maintain optimum aspect ratio, skewness, etc.

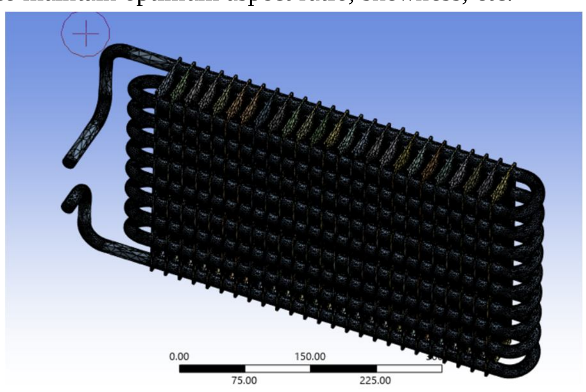

Fig. 5. Meshing of Radiator

After meshing, it is required to give boundary conditions to the meshed model. For the given model the boundary conditions are given as follows:

- Inlet Temperature: 373K
- Ambient Temperature: 393K
- Material for Fins and Body: Aluminum
- Heat transfer coefficient: 92.5 W/m2
- Fluid: Water and Nano-fluid Mixture

After applying the same boundary conditions for the same geometry, Outlet temperature is calculated using different nano-fluid mixture. Nano-fluids which are used in the mixture are:

1) Water (H20)
2) Aluminium oxide (0.3) and water mixture
3) Aluminium oxide (0.5) and water mixture
4) Graphene oxide (0.3) and water mixture
5) Graphene oxide (0.5) and water mixture
6) Copper oxide (0.3) and water mixture
7) Copper oxide (0.5) and water mixture

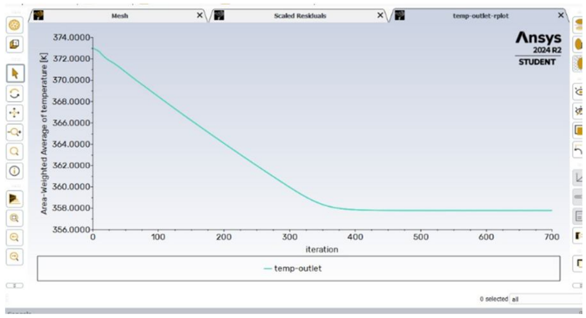

Fig. 6. Iterations result using H20

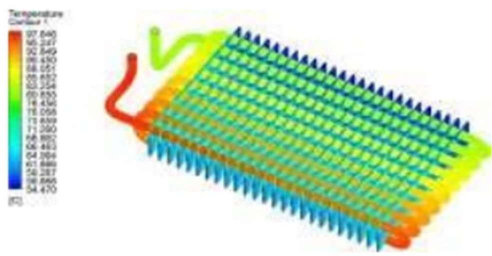

Fig. 7. Simulation Result using H20

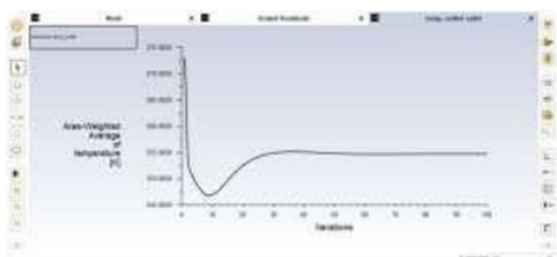

Fig. 8. Iterations result using Al203

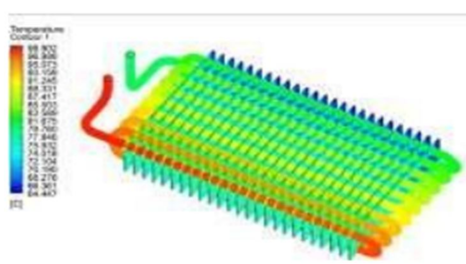

Fig. 9. Simulation Result using Al203

Following results are obtained using different nano-fluid mixture (Al2O3)

TABLE II Simulation Results

VI. CONCLUSION

It is observed that nano particle concentration plays an important role towards heat transfer enhancement. It is found that Effectiveness increases significantly with the increase of particle loading. But this is only true when velocity of the fluid is properly adjusted. If no changes done in velocity then there will not be significant drop in outlet temperature. By comparing both nano fluids with water, it is observed that effectiveness of Graphene Oxide nanofluids is higher than other nano-fluid mixture.

VII. FUTURE SCOPE

It is observed that nano particle concentration plays an important role towards heat transfer enhancement. It is found that Effectiveness increases significantly with the increase of particle loading. But this is only true when velocity of the fluid is properly adjusted. If no changes done in velocity then there will not be significant drop in outlet temperature. By comparing both nano fluids with water, it is observed that effectiveness of Graphene Oxide nanofluids is higher than other nano-fluid mixture.

VIII. FUTURE SCOPE

Nano fluids are mixed with the water in order to improve thermal conductivity of mixture to get maximum heat transfer. It's been found that, there is insignificant effect of nano-fluids to control the outlet temperature if only concentration is taken into account. Along with the concentration of the nano fluids, if velocities are also adjusted then there fill be significant effect in outlet temperature as concluded from the literature review.

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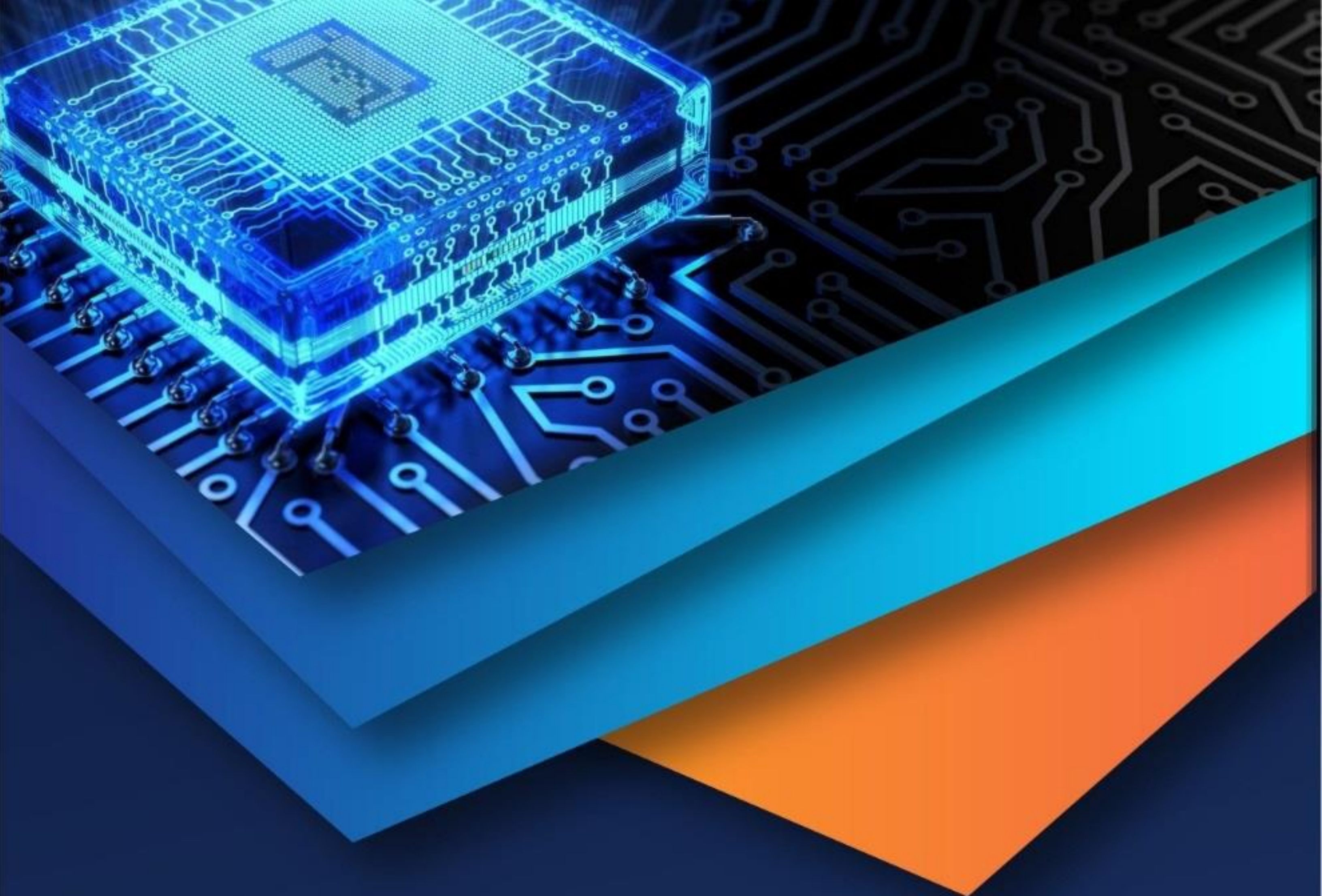

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