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Convergent Divergent Nozzle Design and Analysis to Increase Working Effectiveness

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Abstract: Our project's major goal is to develop and examine a Convergent- Divergent rocket nozzle in order to lower nozzle costs. Here, convergent divergent nozzle uses an alternative material. The design is based on earlier designs that served as a guide for our own. A nozzle is a crucial component that merits consideration in this era of expanding rocket propulsion for a variety of uses, including the launch of satellites into space or human missions. With this in mind, a fundamental design is created utilising the understanding of compressible flow, and the resulting thrust is estimated. use the layout established by hand computations. Utilising the ANSYS Fluent programme, the work is done in, the calculations and results are validated.
Keywords: convergen divergen nozzle, aggreacte deformation, equavilent elastic strain ,3d modle of nozzle, material nickle chromium material,

I. INTRODUCTION

A nozzle is a tool used to change the properties of a fluid flow as it leaves (or enters) a closed chamber, particularly to increase velocity. A nozzle can be used to guide or change the flow of a fluid (liquid or gas), and it is frequently a pipe or tube with a variable cross sectional area. Nozzles are widely used to regulate the stream that emerges from them in terms of flow rate, speed, direction, mass, form, and/or pressure. The energy released during the combustion of fuel, which is added to the inducted air, causes a jet exhaust to provide a net thrust. This heated air is sent into a propelling nozzle at high speed, greatly increasing its kinetic energy. To what end

A convergent-divergent nozzle (also known as a "con-di nozzle") is characterised by a convergent segment followed by a divergent part. Subsonic fluids are accelerated by convergent nozzles. The flow will attain sonic velocity at the nozzle throat, which is also the narrowest point, if the nozzle pressure ratio is high enough.

The nozzle is considered to be clogged in this instance. No more nozzle pressure ratio increases will result in a throat Mach number greater than unity. The flow is allowed to grow to supersonic speeds downwind, or exterior to the nozzle. Because the speed of sound changes with the square root of absolute temperature, it should be noted that Mach 1 can be a very high speed for a hot gas. The speed at a nozzle throat can therefore be much higher . This fact is heavily utilised in the rocketry industry, where hypersonic flows are necessary and certain propellant combinations are chosen to further accelerate the sonic speed. Divergent nozzles speed up sonic or supersonic fluids while slowing subsonic fluids.

Therefore, fluids that have clogged in the convergent segment can be accelerated to supersonic speeds using convergent-divergent nozzles. In comparison to enabling a convergent nozzle to grow supersonically externally, the CD method is more effective. Because any lateral component would not contribute to thrust, the form of the diverging section also assures that the path of the departing gases is directly rearward. Three basic components make up a rocket nozzle: a throat, a converging segment, and a diverging section.. The converging portion is where combustion exhaust gas is introduced first. Through this region, the gas travels at subsonic rates, accelerating as the cross sectional area shrinks. The gas must first travel through the throat, a region with a minimal cross sectional area, in order to attain supersonic speeds. The supersonic gas then continues to expand into the convergent portion before emerging through the nozzle. As it grows, supersonic flow accelerates. A nozzle is a tool used to change the properties of a fluid flow as it leaves (or enters) a closed chamber or conduit, particularly to enhance velocity.A nozzle can be used to guide or change the flow of a fluid (liquid or gas), and it is frequently a pipe or tube with a variable cross sectional area. Nozzles are widely used to regulate the stream that emerges from them in terms of flow rate, speed, direction, mass, form, and/or pressure. The fluid's pressure energy is lost as its velocity rises in a nozzle.

II. LITERATURE REVIEW

A. Review Of The Literature

When nozzles were first developed, they were primarily used to alter a flow's characteristic, such as its pressure or velocity. Karl Gustaf Patrik de Laval, a Swedish engineer and inventor, created a convergent-divergent nozzle in 1890 that could accelerate a steam jet to supersonic speed. Later, this nozzle—known as the de Laval nozzle—was utilised for rocket propulsion. Robert Goddard, an American engineer, would be the first to combine a de Laval nozzle with a combustion chamber, enhancing efficiency and attaining supersonic speeds about Mach 7.

However, there has been a growth in the application of the supersonic nozzle in other sectors. A de Laval nozzle is typically used for rocket propulsion. The American military has been coating missile systems with high-velocity particles made of metals, ceramics, and polymeric materials utilising rocket nozzles. The characteristics of the nozzle have evolved along with the prominence of de Laval nozzles in rocket design. Numerous studies and activities have been done 29 to more effectively optimise the nozzle so that it can satisfy particular requirements. This survey focuses on de Laval nozzle simulation and optimisation because of the project's multi-objective optimisation. In order to determine the best configuration for improving the uniformity of the gas flow leaving the condi-nozzle, Karla Quintano presented her research in a master's thesis that was published in 2012. The job was done using a variety of software programmes. For the 40 various nozzle shapes, a FORTRAN code was employed. The forms' required parameters were optimised using ANSYS and mode Frontier, which was also used to do simulations of flow and heat transport. The findings of the thesis demonstrated that the nozzle's shape significantly affected the creation of exit flows. A dissertation by Jean-Baptiste Mbuyamba on nozzle design for a cold gas dynamic spray was published. The dissertation examines de Laval nozzles for design even though they are not specifically connected to rocket nozzles. Additionally, it discusses a number of theoretical aspects of Compressible gas flow in a convergent-divergent nozzle and methods for calculating certain parameters.

A thorough literature search was conducted before optimisation commenced in order to gather all pertinent data about supersonic nozzles. In this experiment, the behaviour of flow composed mostly of compressible fluids was heavily stressed. ANSYS Fluent and a LOCI FORTRAN programme were only two of the software tools used to model the movement of air as an ideal cold gas. Furthermore, using software to analyse several fluid gradients including pressure, temperature, density, and velocity, a hot-gas application was modelled using the same testing settings as the cold gas. To enhance the supersonic flight, the Computer Aided Engineering (CAE) programme, Frontier, was used.

The design of a CD nozzle starts with the nozzle form since the walls of the nozzle have a number of parabolas that are subject to partial differential equations. By using methods of characteristics, these partial differential equations are converted to ordinary differential equations. Due to its capacity to expand effectively, contour nozzle was chosen as the expansion zone since it required just 80% as much length as a conical nozzle to offer the same area ratio. According to G.V.R. Rao, a parabola might be tangent to the exit, making it possible to identify the parabola using straightforward geometric analysis. The de Laval nozzle 30 was plotted using the throat approach radius of 1.5 rt and the throat expansion radius of.4 rt. At the Chemical Engineering laboratories, Prototype Development Section (PDS), Chemical Engineering and Technology group, BARC, a water channel has been designed and set up to study the behavior of bodies immersed in a supersonic gas stream with respect to shock wave patterns, wake patterns, etc. Two exhaust nozzles that may be used on a vehicle operating through a flight profile starting with a subsonic launch and accelerating to a flight Mach number greater than 4 are studied for their aerodynamic design and performance. Regarding the time-sensitive strike mission, these criteria were outlined by the Air Vehicle Base Line (AVBL) research that the Office of Naval Research (ONR) had funded. This flight profile is extremely comparable to what NASA's Revolutionary Turbine Accelerator (RTA) research program is taking into account.

III. MODELING

A. Designing Of Convergent - Divergent Nozzle

A nozzle in a rocket engine accelerates hot exhaust to create thrust in accordance with Newton's third law of motion. The mass flow rate through the engine, the flow's exit velocity, and the pressure at the engine's exit all affect how much thrust is generated. The design of the rocket nozzle affects each of these three flow variables' values. Simple in design, a nozzle is nothing more than a tube with a unique form through which hot gases flow. The nozzle of a rocket is normally designed with a set convergent part and a fixed divergent section.. A convergent-divergent, or CD, nozzle is the name given to this arrangement of nozzles. The hot exhaust from the combustion chamber converges towards the nozzle's minimum area, or throat, in a CD rocket nozzle. The throat size is selected to restrict the flow and regulate the system's mass flow rate. Because the flow in the throat is sonic, the throat's Mach number is one. The flow is is entropically extended to a supersonic Mach number downstream of the throat, where the geometry diverges and relies on the area ratio of the exit to the throat.

B. Dimensions And Boundary Conditions Assumed

Inlet diameter	69
Exit diameter	82
Inlet pressure	210000
Temperature	300k

Table no 3.2 CD JET Porportion &Premise Condition

The quantity of expansion also affects the pressure and temperature at the exit of a supersonic flow because it causes the static pressure and temperature to drop from the throat to the exit. The exit temperature controls the sound's exit velocity, which is controlled by the exit velocity. The amount of thrust generated by the nozzle depends on the exit velocity, pressure, and mass flow through it.

C. 3-D MODEL of CD nozzle

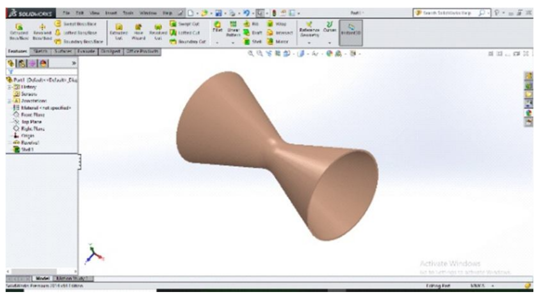
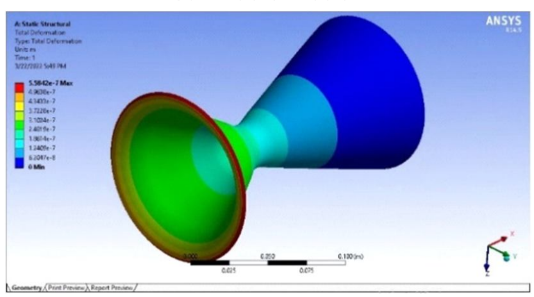


Fig no. 4.3 3D View of CD nozzle

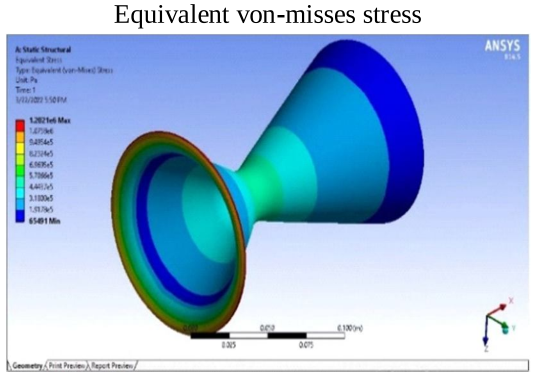
IV. RESULT AND DISCUSSION

A. Material: Nickel Chromium

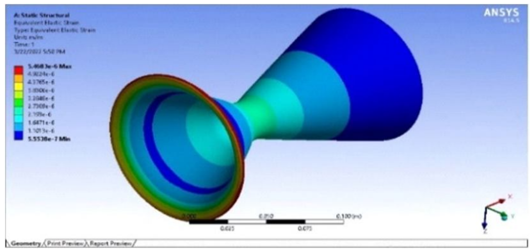
Sum deformation



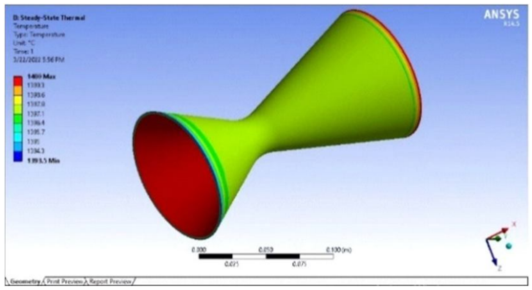
Equivalent von-misses stress



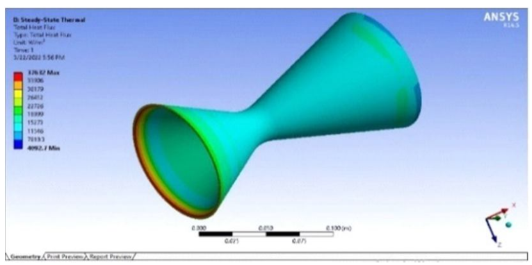
Identical resultasnt strain



Temperature distribution

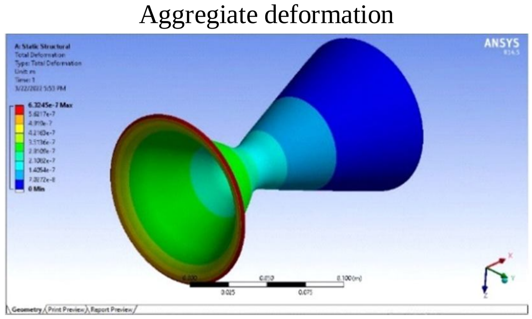


Total heat flux

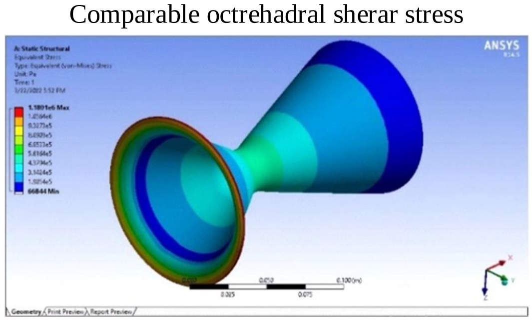


B. Material: Stainless Steel Alloy

Aggregiate deformation



Comparable octrehadral sherar stress



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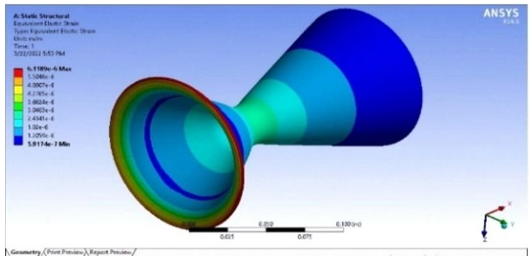
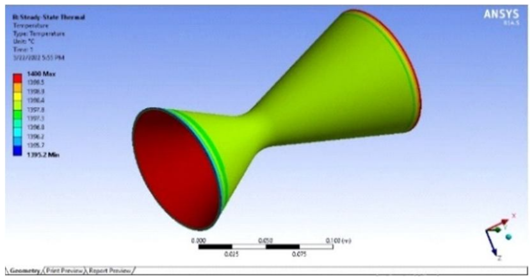
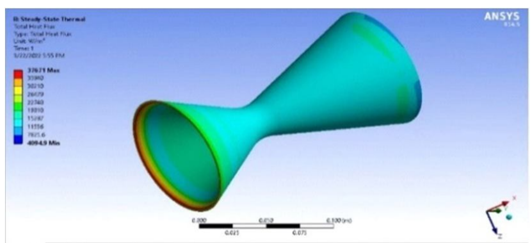
Equivalent elastic strain



Temperature distribution

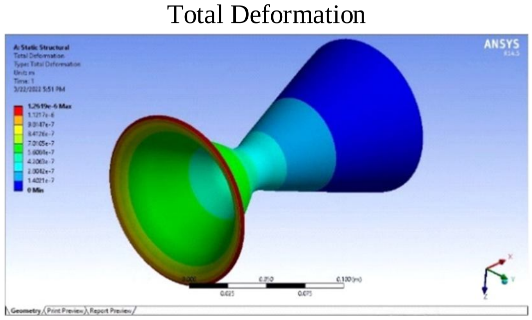


Total heat flux

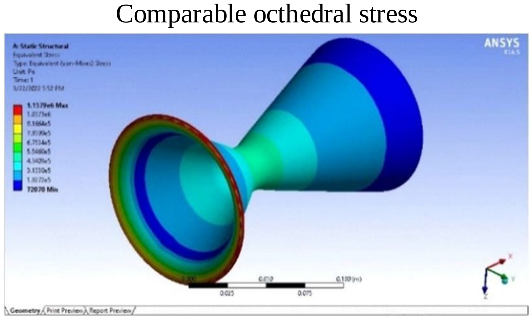


C. Material: Titanium

Total Deformation



Comparable octhedral stress



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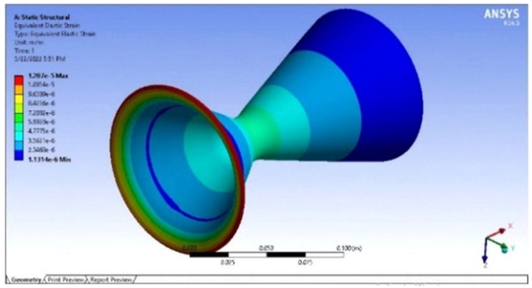
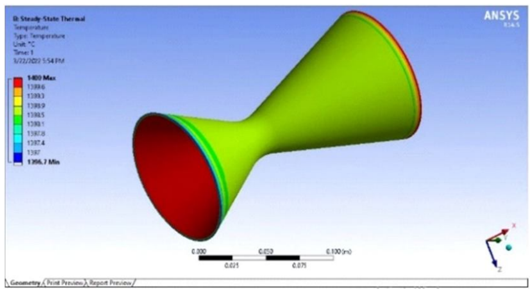
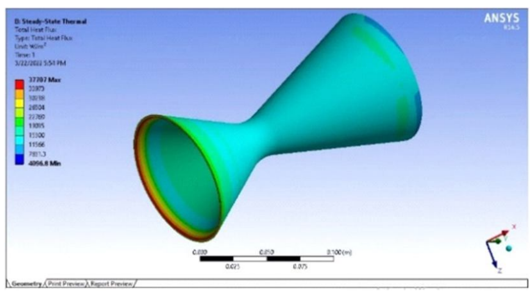
Idential resultant strain



Temperature distribution



Total heat flux



D. Comparison of Results

Properties / Materials	Stress(pa)	Strain	Deformation(m)	Heat flux(w/m2)	Temperature
NiCr	1.2021x10^6	5.468x10^-6	5.584x10^-7	37632	1400
Stainless steel alloy	1.1801x10^6	6.118x10^6	6.324x10^-7	37671	1400
Titanium	1.1579x10^6	1.207x10^-5	1.2619x10^-6	37707	1400

Table no. 5.4 comparison of results

V. CONCLUSION

Engineers created nozzles as tools to regulate the properties of the fluid. It is primarily utilised to enhance the fluid's velocity, which typically comprises of convergent, throat, and divergent sections. In this project, solid works and ANSYS are used to build and analyse a convergent-divergent nozzle in search of a high heat absorbent material. In this section, we analyse the CD nozzle's numerous parameters, including stress, strain, deformation, and heat flux. The tables lead to the conclusion that titanium is producing effective outcomes. Thus, compared to other materials, the heat flow of the material is high. Therefore, among the three applied materials, titanium is preferred.

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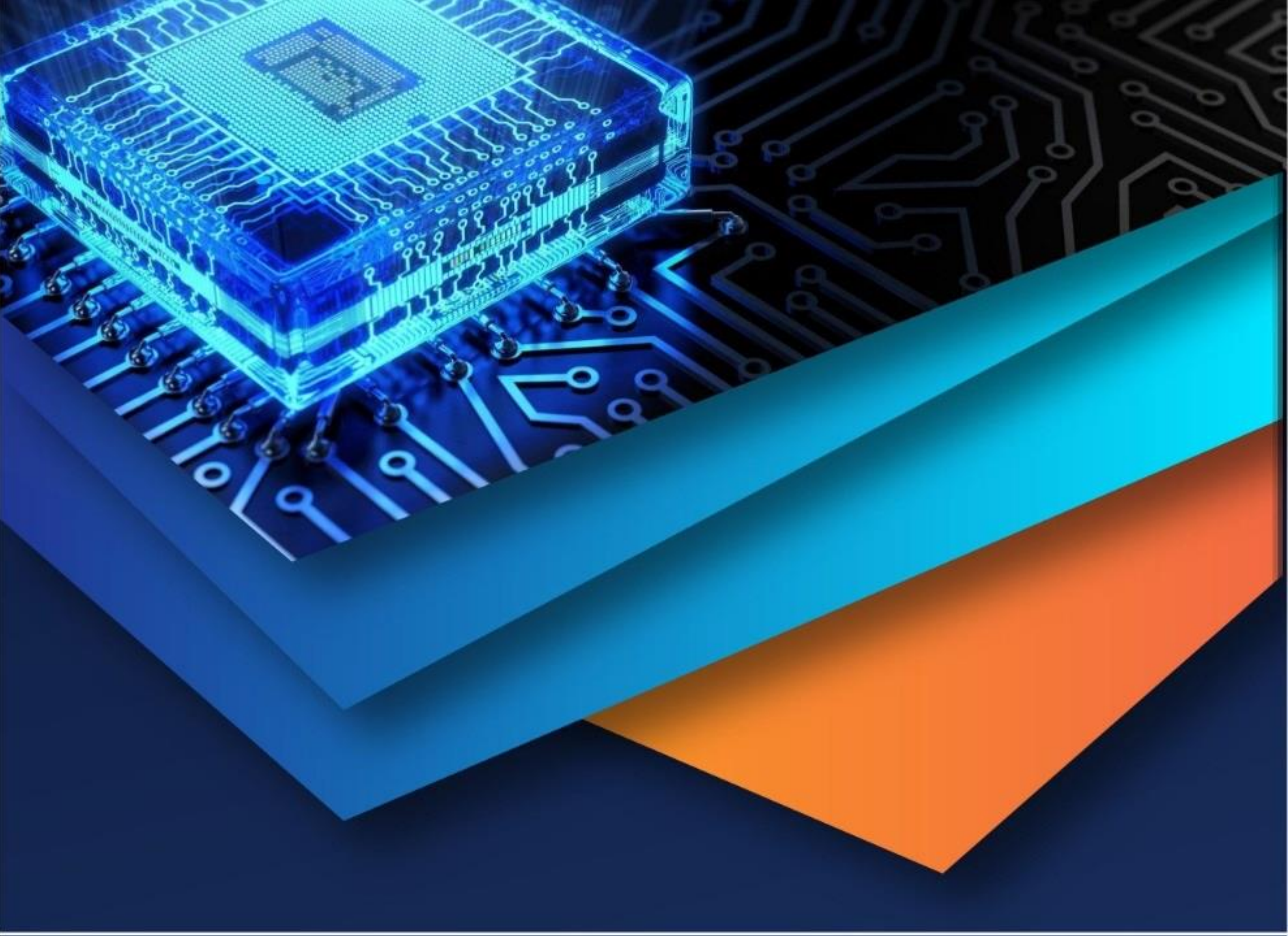

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