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Optimisation of Engine Efficiency by Reducing the weight of Connecting Rod by using Composite Material Carbon Fiber Epoxy

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Abstract: Current automotive IC engines connecting rods are made of steel. In this article, a composite material called carbon-fiber epoxy is suggested for connecting rod. It is light in weight and has ability to absorb high impact. A comparison study of stresses induced in connecting rod made of steel and carbon fiber epoxy is done and it is found that stresses in connecting rod made of carbon fiber epoxy is less. Analysis is performed on the connecting rod made of structural steel and composite material, carbon fiber epoxy to find stresses using the Analysis Software ANSYS 15. The aspect of this article is to optimize the weight of the connecting rod. Due to its large volume production, it is logical that optimization of the connecting rod for its weight or volume will result in large-scale savings. It can also achieve the objective of reducing the weight of the engine component, thus reducing inertia loads, reducing engine weight and improving engine performance and fuel economy.

Key Words: IC engine, Connecting Rod, Composite Material, Optimization

I. INTRODUCTION

Connecting rod is best known through its use in internal combustion engines. Connecting rod is one of the largest volume production component in automotive cylinder engine. It works as the connection of the piston and the crankshaft and takes charge of transferring power from the piston to the crankshaft and sending it in to transmission. The major stresses induced in the connecting rod are a combination of axial and bending stresses in operation. Cylinder gas pressure and inertia force will produce axial stress. Connecting rod is made of small end, long shank and a big end. Cross section of long shank is usually of rectangular, circular, tubular, I-section or H-section. In this paper, the connecting rod which we have selected consists of long shank made of I-section cross section. Connecting rod must withstand a complex state of loading. It need to undergo high cyclic loads due to combustion, to high tensile loads due to inertia. Therefore, durability of this component is vital. Due to these factors, automotive connecting rods have been the topic of research for different aspects such as production technology, materials, performance, simulation, fatigue etc.

II. MATERIALS USED FOR CONNECTING ROD

A. Steel

Steel is an alloy of iron and other elements, primarily carbon, widely used in construction and other applications because of its high tensile strength and low cost. Carbon, other elements, and inclusions within iron act as hardening agents that prevent the movement of dislocations that otherwise occur in the crystal lattices of iron atoms. The carbon in typical steel alloys may contribute up to 2.1% of its weight. Varying the amount of alloying elements, their formation in the steel either as solute elements, or as precipitated phases, retards the movement of those dislocations that make iron comparatively ductile and weak, or thus controls qualities such as the hardness, ductility, and tensile strength of the resulting steel. Steel's strength compared to pure iron is only possible at the expense of ductility, of which iron has an excess Iron is commonly found in the Earth's crust in the form of an ore, usually an iron oxide, such as magnetite, hematite etc. Iron is extracted from iron ore by removing the oxygen through combination with a preferred chemical partner such as carbon that is lost to the atmosphere as carbon dioxide. This process, known as smelting, was first applied to metals with lower melting points, such as tin, which melts at approximately 250 °C (482 °F) and copper, which melts at approximately 1,100 °C (2,010 °F). In comparison, cast iron melts at approximately 1,375 °C (2,507 °F). Small quantities of iron were smelted in ancient times, in the solid state, by heating the ore buried in a charcoal fire and welding the metal together with a hammer, squeezing out the impurities. With care, the carbon content could be controlled by moving it around in the fire.

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FIG 1: Connecting Rod Made of Steel

B. Carbon Fibre

Tolerance and low thermal expansion, make them very popular in aerospace, civil engineering, military, and motorsports, along with other competition sports. However, they are relatively expensive when compared with similar fibre, such as glass fibre or plastic fibre. Carbon fibre is usually combined with other materials to form a composite. When combined with a plastic resin and wound or moulded it forms carbon-fibre-reinforced polymer (often referred to as carbon fibre) which has a very high strength-to-weight ratio, and is extremely rigid although somewhat brittle. However, carbon fibre are also composited with other materials, such as with graphite to form carbon-carbon composites, which have a very high heat tolerance.

C. Structure and Properties

Carbon fibre is frequently supplied in the form of a continuous tow wound onto a reel. The tow is a bundle of thousands of continuous individual carbon filaments held together and protected by an organic coating, or size, such as polyethylene oxide (PEO) or polyvinyl alcohol (PVA). The tow can be conveniently unwound from the reel for use. Each carbon filament in the tow is a continuous cylinder with a diameter of 5–10 micrometers and consists almost exclusively of carbon. The earliest generation (e.g. T300, HTA and AS4) had diameters of 16–22micrometers. Later fibre (e.g. IM6 or IM600) have diameters that are approximately 5 micrometers. The atomic structure of carbon fibre is similar to that of graphite, consisting of sheets of carbon atoms arranged in a regular hexagonal pattern (graphene sheets), the difference being in the way these sheets interlock. Graphite is a crystalline material in which the sheets are stacked parallel to one another in regular fashion. The intermolecular forces between the sheets are relatively weak Vander Waals forces, giving graphite its soft and brittle characteristics.

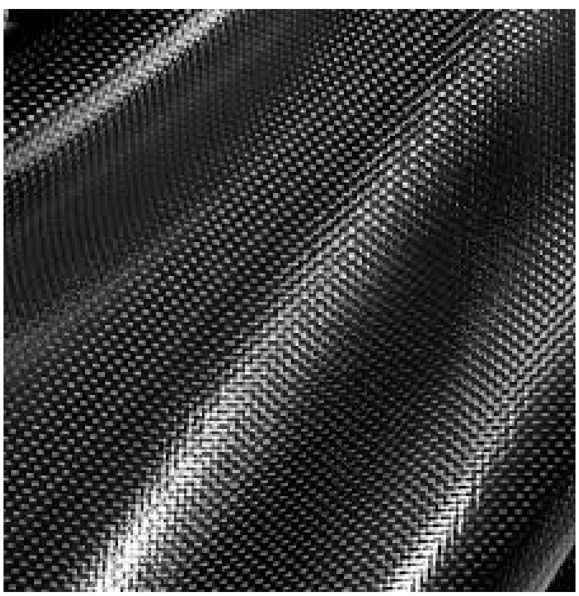

FIG 2: Sheet made of Carbon Fiber

D. Epoxy Resin

Epoxy resins are low molecular weight pre-polymers or higher molecular weight polymers which normally contain at least two epoxide groups. The epoxide group is also sometimes referred to as a glycidyl or oxirane group. A wide range of epoxy resins are produced industrially. The raw materials for epoxy resin production are today largely petroleum derived, although some plant derived sources are now becoming commercially available (e.g. plant derived glycerol used to make epichloro hydrin).Epoxy resins are polymeric or semi-polymeric materials, and as such rarely exist as pure substances, since variable chain length results from the polymerisation reaction used to produce them. High purity grades can be produced for certain applications, e.g. using a distillation purification process. One downside of high purity liquid grades is their tendency to form crystalline solids due to their highly regular structure, which require melting to enable processing. An important criterion for epoxy resins is the epoxide content. This is commonly expressed as the epoxide number, which is the number of epoxide equivalents in 1 kg of resin (Eq./kg), or as the equivalent weight, which is the weight in grams of resin containing 1 mole equivalent of epoxide (g/mol). One measure may be simply converted to another: Equivalent weight (g/mol) = 1000 / epoxide number (Eq./kg)

E. Applications of Epoxy Resin

1) The applications for epoxy-based materials are extensive and include coatings, adhesives and composite materials such as those using carbon fibre and fibre glass reinforcements.
2) The chemistry of epoxies and the range of commercially available variations allow cure polymers to be produced with a very broad range of properties.
3) In general, epoxies are known for their excellent adhesion, chemical and heat resistance, good-to-excellent mechanical properties and very good electrical insulating properties.

F. Why only Epoxy with Carbon Fiber?

1) CARBON FIBER-REINFORCED EPOXY composites exhibit high specific strength, high specific stiffness and good fatigue tolerance Furthermore, the fabrication of components and structures from composites allows for the integration of design principles and manufacturing processes, resulting in optimally tailored mechanical and physical characteristics.
2) Epoxy resins are typically about three times stronger than the next strongest resin type. Epoxy adheres to Carbon Fibre, Fibre glass, and Aramid (Kevlar), very well and forms a virtually leak- proof barrier.
3) The epoxy can undergo plasticization and hydrolysis, which cause reversible and irreversible changes in the polymer structure. Due to these processes both the modulus and glass transition temperature are lowered

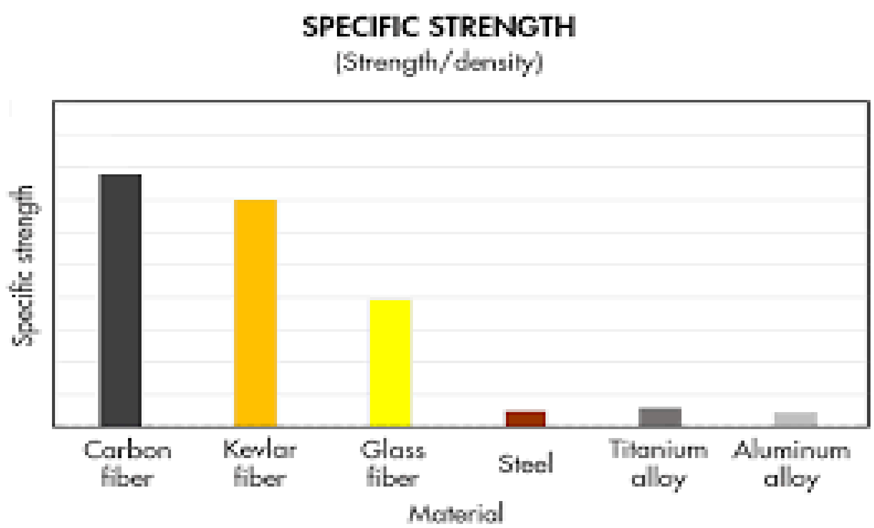

FIG 3: Graph showing strength of Carbon Fiber Material

A connecting rod is one of the most mechanically stressed components in internal combustion engines. The object of the activity is to select the appropriate material for a connecting rod where the constraints are to make the product as light and cheap as possible and yet strong enough to carry peak load without failure in cyclic fatigue. Fig.4 shows the connecting rod which is used in the present paper for analysis.

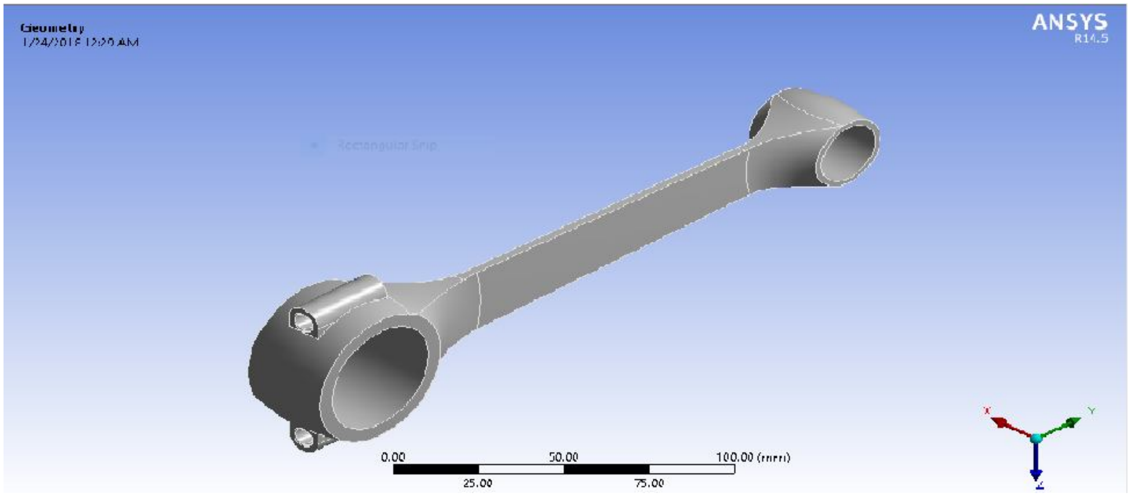

Fig 4. Connecting Rod

G. Structural Analysis

Analysis is carried out on connecting rod made of both the materials, whose properties are tabulated as given below

H. Properties of Steel

STEEL	
YOUNGS MODULUS (Pa)	**2e11**
POISON RATIO	**0.29**
DENSITY (kg/m^3)	**7850**
YEID STRNGTH (Pa)	**2.5e8**

I. Properties of Composite Material Carbon Fiber Epoxy

CARBON FIBRE EPOXY	
YOUNGS MODULUS(Mpa) Exx	91820
YOUNGS MODULUS(Mpa) Eyy	91820
YOUNGS MODULUS(Mpa) Ezz	9000
POISSON RATIO xy	0.05
POISSON RATIO yz	0.3
POISSON RATIO zx	0.3
DENSITY (kg/m^3)	1480
YIELD STRENGTH (Pa)	3.35e8

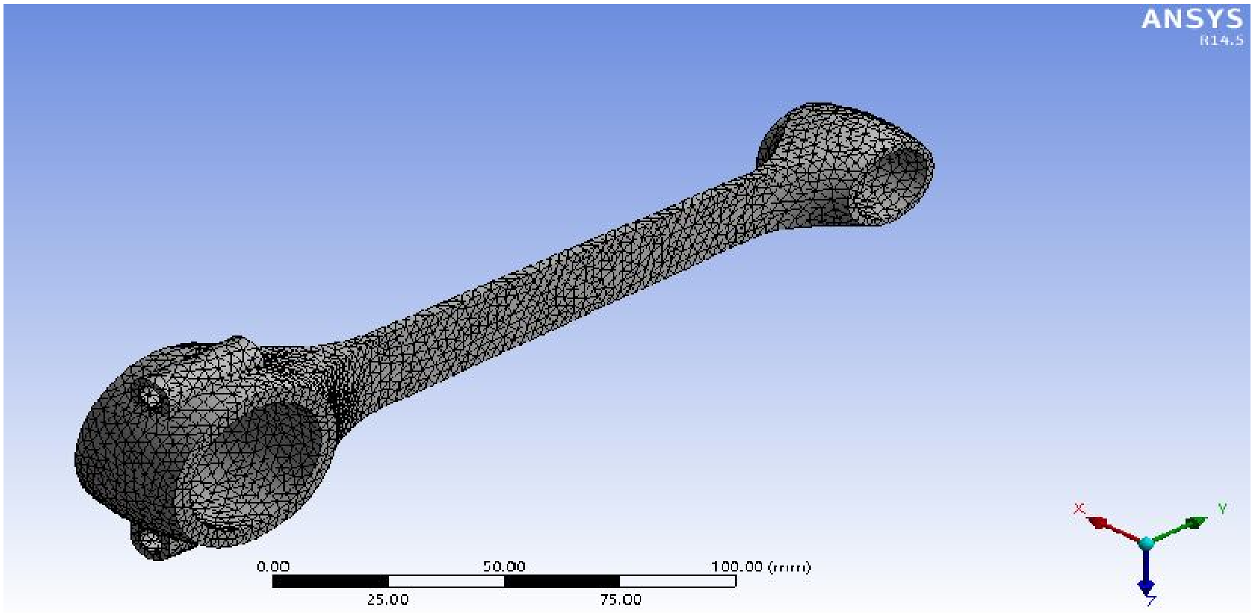

FIG 5: Connecting Rod in Meshing

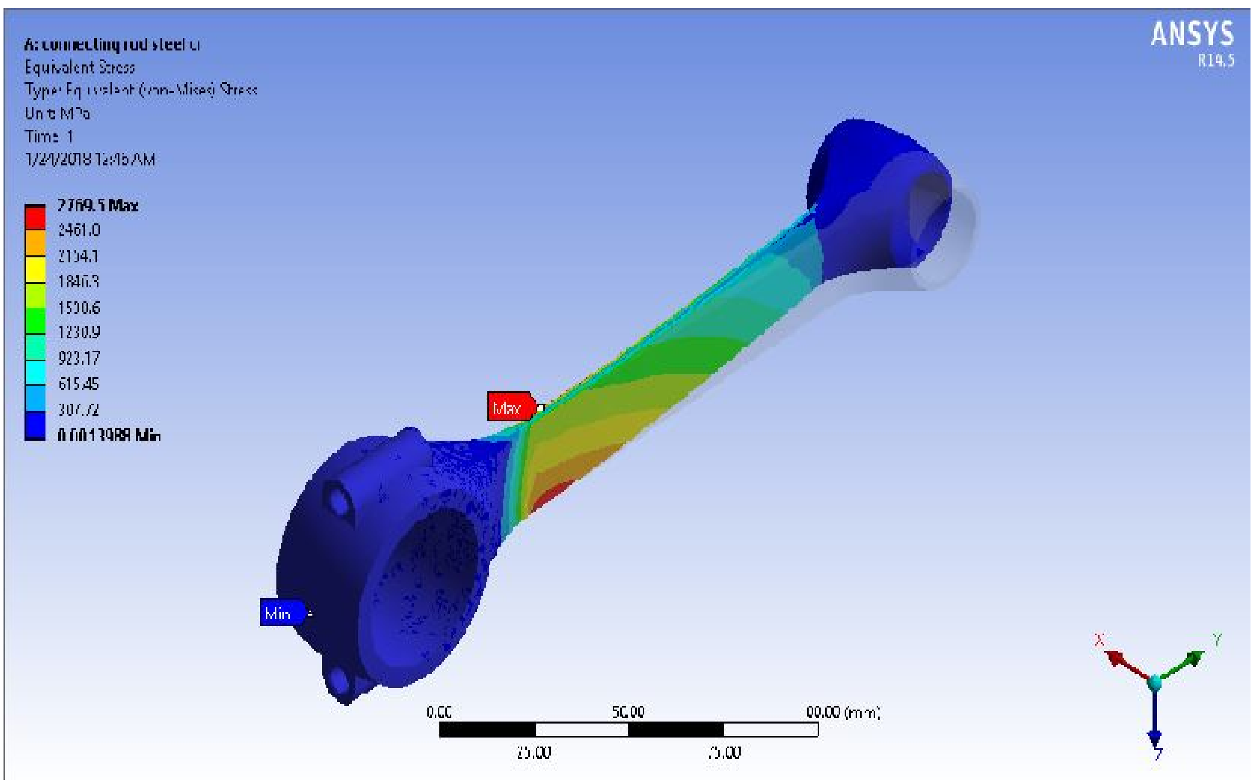

FIG 5: Analysis on Connecting Rod made of Steel in ANSYS 14.5

Results for Connecting Rod made of Carbon Fiber Epoxy

	Structural steel	Carbon epoxy fiber
Stress (Mpa)	2769.5	2675.2

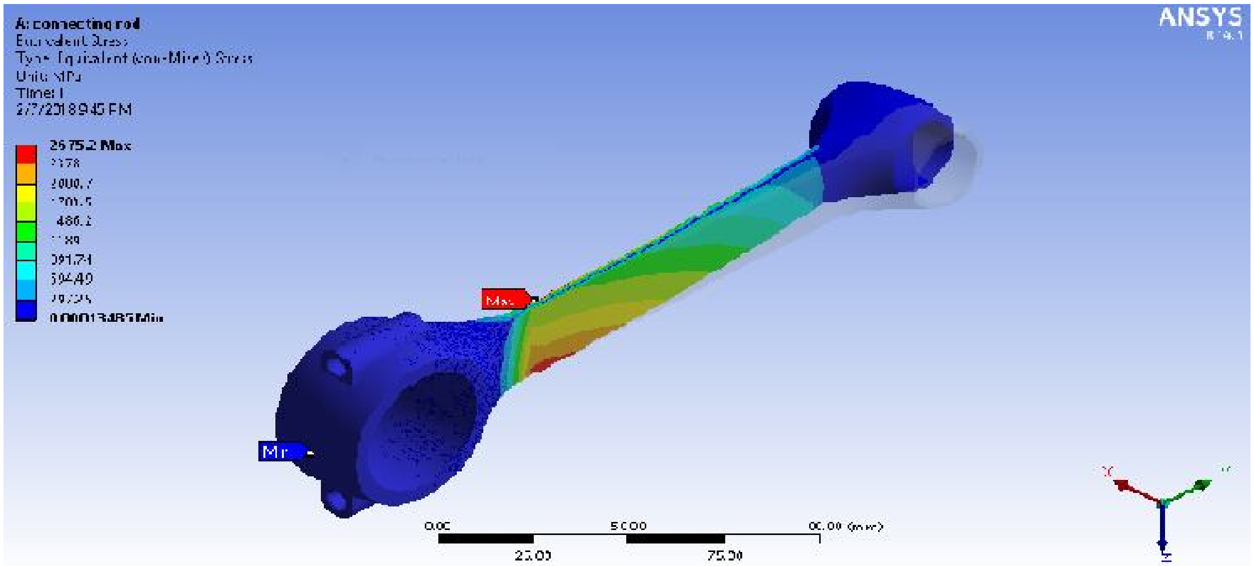

FIG 6: Analysis on Connecting Rod made of Carbon Fiber Epoxy in ANSYS 14.5

III. CONCLUSION

A. From the results of structural analysis, we can say that due to the less stress induced , connecting rod made with carbon fiber epoxy material shows good mechanical properties as compared with the connecting rod made of steel.

B. As carbon fiber is light in weight and has good elasticity property thus reduce inertia loads, reducing engine weight and improving engine performance.

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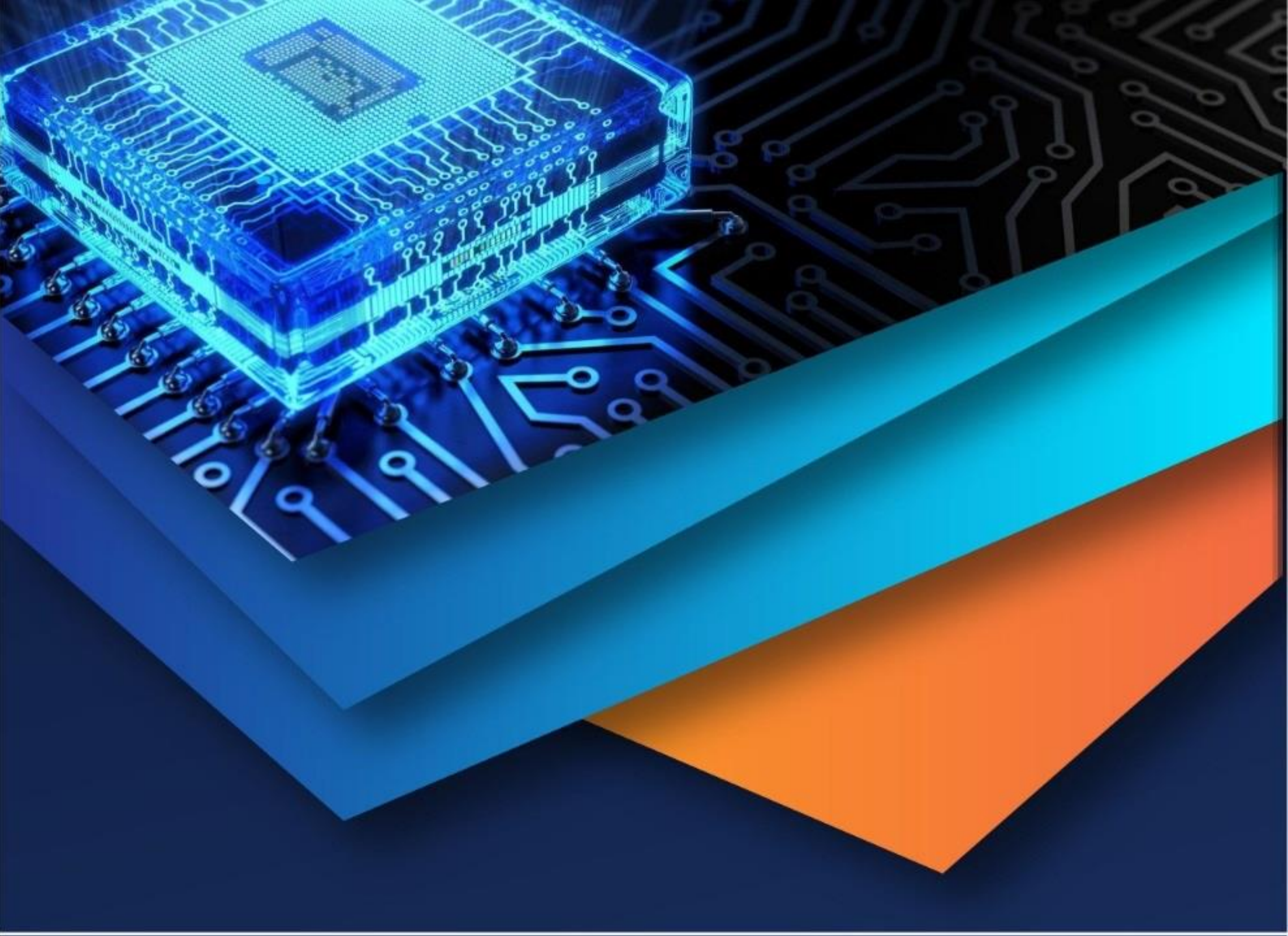

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