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Static Structural Analysis of Different Materials for Connecting Rod

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Abstract: Connecting Rods are an important and irreplaceable part of IC Engines. It is responsible for converting the reciprocating motion of the piston into the rotary motion of the crankshaft. During this process, the connecting rod is subjected to various loads. Therefore, the materials used for connecting rod are also very important. In this paper, a static structural analysis of a connecting rod made of 5 different materials: Forged Steel, Carbon Steel, Stainless Steel, Grey Cast Iron and Titanium Alloy are compared. The connecting rod is analyzed only for the axial compressive load and not the axial tensile load because the tensile load is very much lesser than the compressive load. The connecting rod's model is developed in FUSION 360 software and then imported to and analyzed using Finite Element Method in the ANSYS 2021 WORKBENCH software. The equivalent stress, total deformation along with the factor of safety for all the materials is found and compared in the analysis and all the results are shown with the help of images and graphs.
Keywords: Connecting Rod, FEA, ANSYS WORKBENCH, Structural Analysis, Forged Steel, Carbon Steel, Stainless Steel, Grey Cast Iron, Titanium Alloy.

I. INTRODUCTION

A Connecting Rod is an irreplaceable part of an IC Engine. Each engine has one connecting rod per cylinder, therefore making it an important part in the automotive industry. It is connected to the piston at the smaller end using gudgeon pins and to the crankshaft at the bigger end using fasteners. Its main function is to connect the reciprocating piston to the rotating crankshaft, therefore transmitting motion. The stresses on connecting rod are due to two main reasons: Pressure generated due to combustion which are compressive in nature; and the inertia forces which are tensile in nature. Also, it undergoes high cyclic loads of order up to 10^9, being compressed and stretched at every rotation [5]. So, material selection for connecting rod becomes a very important factor considering that a failure in the connecting rod of an engine is irreparable. The same is described by Vegi [1], where they say "Failure of a connecting rod, usually called "throwing a rod" is one of the most common causes of catastrophic engine failure in cars". The CR are generally made of Forged Steels, Carbon steels, for lighter purposes Aluminum alloys are used and for heavy duty purposes, Titanium is used. The CR materials that we will be using in this research are Forged Steel, Carbon Steel, Stainless Steel, Grey Cast Iron and Titanium Alloy.

II. LITERATURE REVIEW

While the connecting rod was being designed, Vegi [1] suggested that measures have to be taken to reduce the stresses in the connecting rod. Methods, like grinding the edges to give smooth surface and radius to prevent crack initiation shot penning method, are used which induces compressive surface stress to balance the weight of the connecting rod and piston assembly to reduce the bending stress due to centrifugal action. Noor et al [2] conducted a study on failure analysis of connecting rod made up of different materials like carbon steel, brass, mild steel and aluminum. Abhinav et al [3] conducted a static structural analysis on a connecting rod made of SS 304 used in a Cummins NTA 885 BC engine using finite element analysis. He concluded that the root of the smaller end is very prone to failure due to higher crushing load due to gudgeon pin assembly.

Factor of safety with respect to fatigue strength was obtained by performing FEA with applied loads including bolt tightening load, piston pin interference load, compressive gas load and tensile inertia load [4].

Ramani et al [5] focused on the two subjects, first, load and stress analysis of the connecting rod, and second, optimization for weight reduction.

III. OBJECTIVE

The main objective of this research is to compare the CR made of 5 different materials using static structural analysis using finite element method. The model of the CR is made using the FUSION 360 software. The Equivalent (Von Mises) Stress, Total deformation and the Factor of Safety (FOS) are determined using the ANSYS software and the values of each are compared using graphs. For static structural analysis, the bigger end is fixed and an axial load (compressive) is applied at the smaller end.

IV. MATERIALS USED

The CR has been generally made of forged steel. Aluminum was also used for making CR but was replaced by forged steel again. Other materials which are used for making CR are cast iron and carbon steel. Titanium is also used for making CR which needs both strength as well as light weight. These are generally used for high performance engines but also are expensive comparatively.

The materials that we have used as connecting rod materials in this work are:

1) Forged Steel
2) Carbon Steel
3) Stainless Steel
4) Grey Cast Iron
5) Titanium Alloy

V. MODEL OF CR

The model of the connecting rod is made using Fusion 360 software and then imported to ANSYS 2021 software.

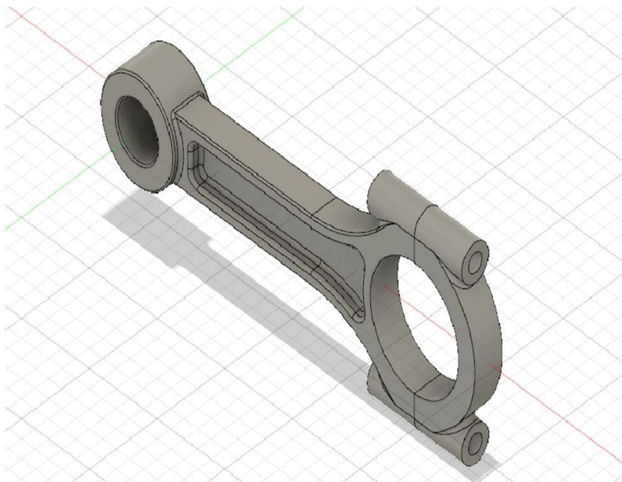


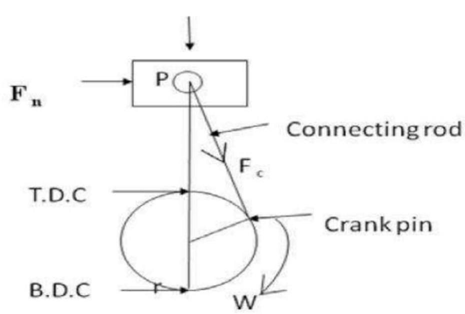
Fig1. Model of CR

VI. STATIC ANALYSIS OF CR

A. Forces Acting on CR

There are 3 types of forces that act on a connecting rod.

1) Force due to gas pressure on the piston
2) Inertia force of the connecting rod and reciprocating mass
3) Friction force on the piston and piston rings



For this research, we have only considered one axial compressive load acting on the connecting rod which is the largest in comparison to the other loads. The engine type is a 4 stroke, 6 cylinder engine and the minimum and maximum normal force acting on the CR is obtained from the relation: Power= Torque*Angular Velocity.

The engine is considered to be running at 300 HP @ 2100 rpm and the force acting on the CR is calculated to be 13.26 KN.

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B. Meshing of CR

To find stress and deformation of such complex structures without finite element method is very hard and tedious and always has the possibility of human errors which occur due to the presence of complex equations. The finite element analysis is done by dividing the whole body into very small elements which are called as mesh. These small elements are firstly solved individually and then solution of each of these elements is summed up to get the final solution. This method provides us with the closest solutions.

The mesh is generated with an element size of 2.5mm and minimum edge length of 0.81mm which gives 51593 nodes and 28959 elements for the full model geometry.

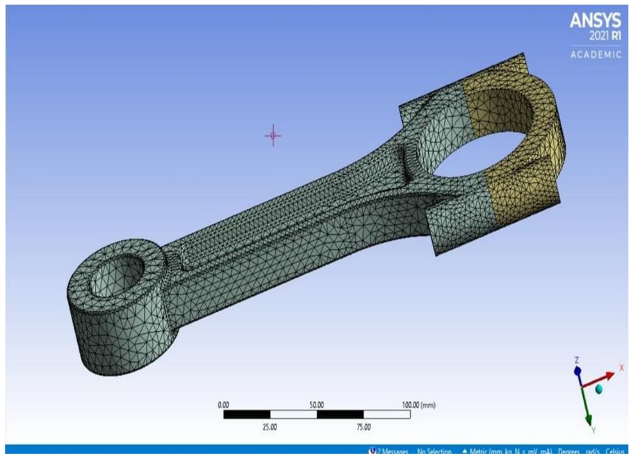

Fig2. Meshing of CR

C. Finite Element Analysis

After making the model of the connecting rod on FUSION 360 and importing it to ANSYS 2021 Workbench, the meshing of the model is done. Then the forces are applied. The bigger end of CR is fixed and an axial compressive load of magnitude 13.26 KN in applied at the smaller end. Then the Equivalent (Von Mises) stress, Total deformation and the Factor of Safety (FOS) are calculated for each material using ANSYS MECHANICAL.

1) Forged Steel

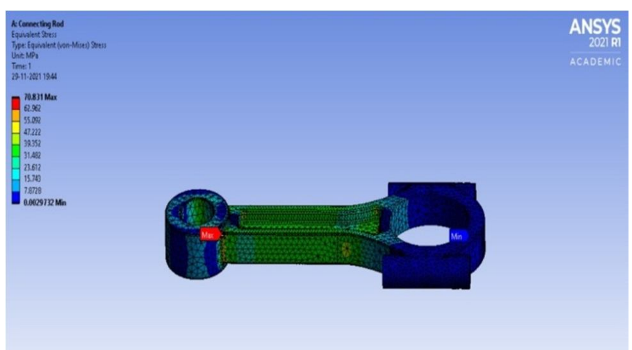

Fig3. Equivalent Stress

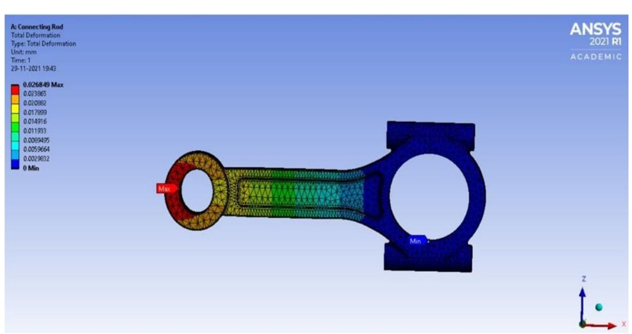

Fig4. Total Deformation

2) Carbon Steel

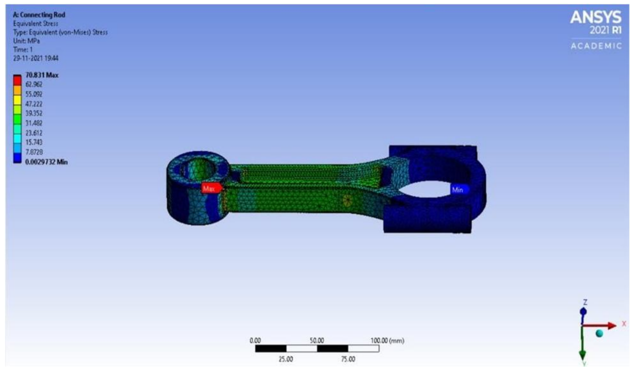

Fig5. Equivalent Stress

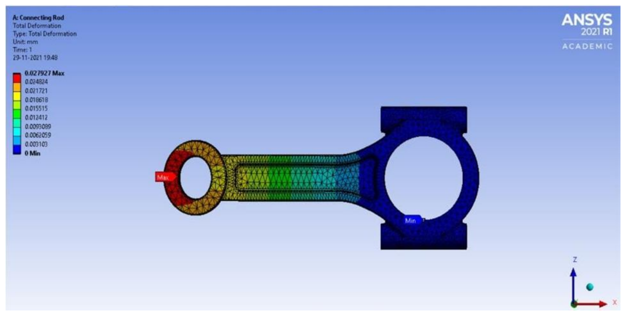

Fig6. Total Deformation

3) Grey Cast Iron

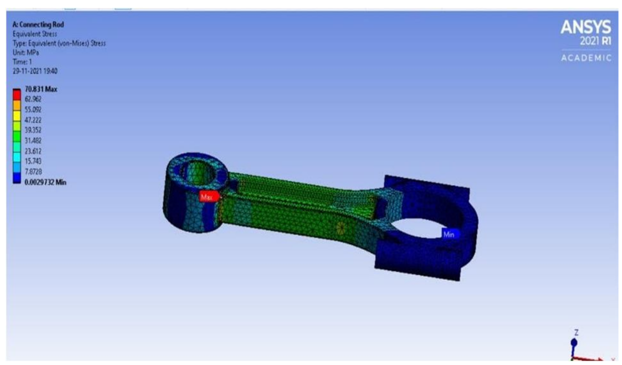

Fig7. Equivalent Stress

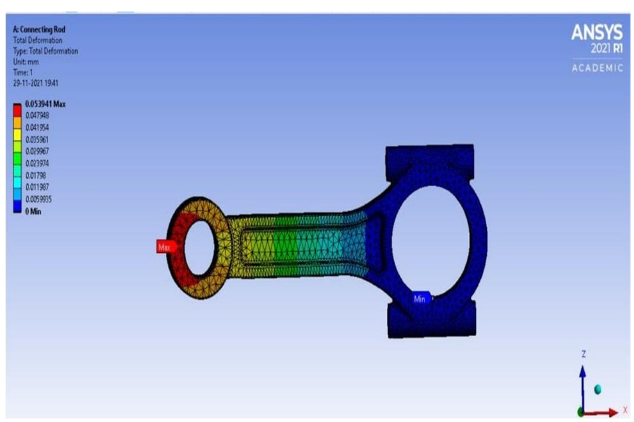

Fig8. Total Deformation

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4) Stainless Steel

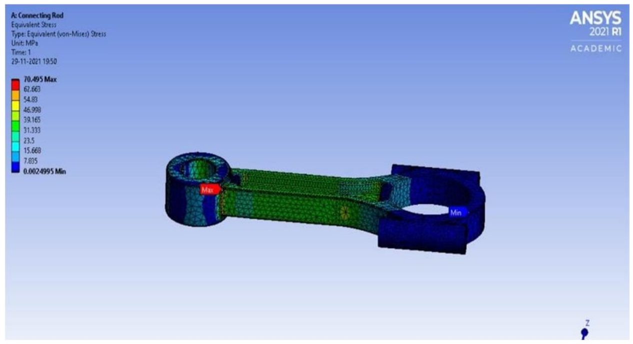


Fig9. Equivalent Stress

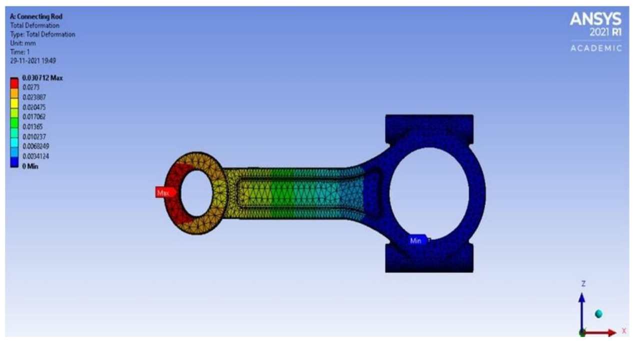


Fig10. Total deformation

5) Titanium Alloy

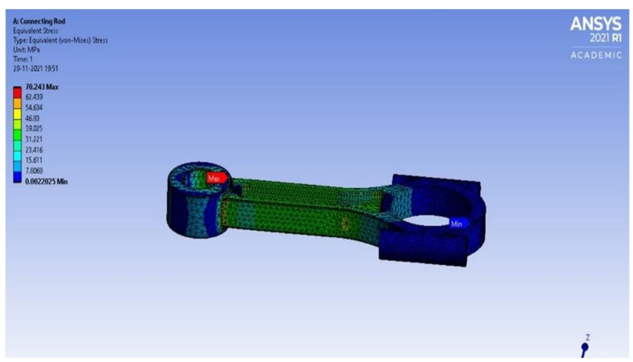


Fig11. Equivalent Stress

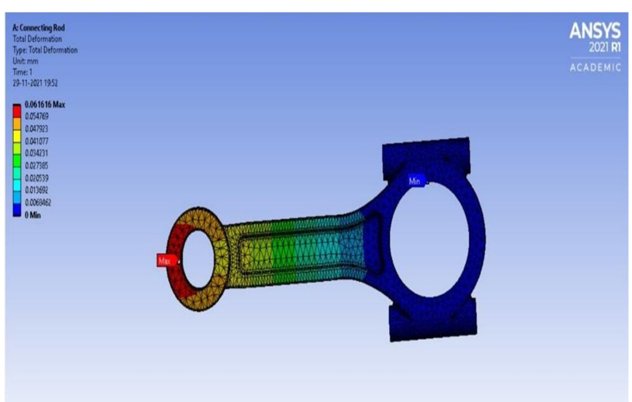


Fig12. Total Deformation

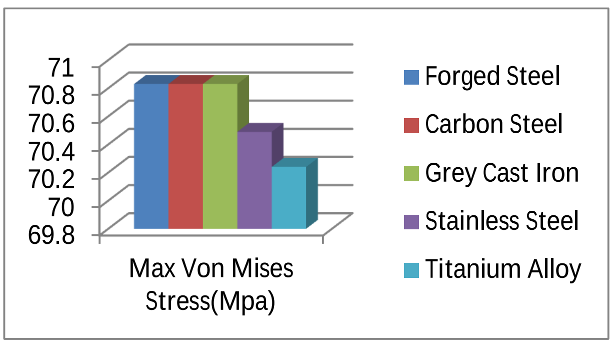
VII. RESULTS & COMPARISON

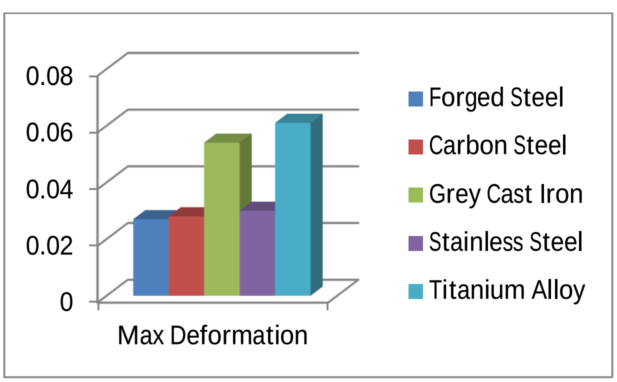
The obtained results are tabulated below in Table 7.1.

Material	Max Von Mises Stress (MPa)	Max Deformation (mm)	Min Factor of Safety
Forged Steel	70.831	0.027	8.82
Carbon Steel	70.831	0.028	4.15
Grey Cast Iron	70.83	0.054	2.54
Stainless Steel	70.49	0.030	2.93
Titanium Alloy	70.24	0.061	13.24

Table 1

It can be concluded from these observations that Forged Steel has the least deformation while Titanium Alloy has the most deformation followed by Grey Cast Iron and Stainless Steel.
The Von Mises stress is equal for Forged Steel, Carbon Steel and Grey Cast Iron followed by Titanium Alloy and Stainless Steel.
It is also observed that Titanium has the highest FOS among all the materials followed by Forged Steel, Carbon Steel, Stainless Steel and Grey Cast Iron.





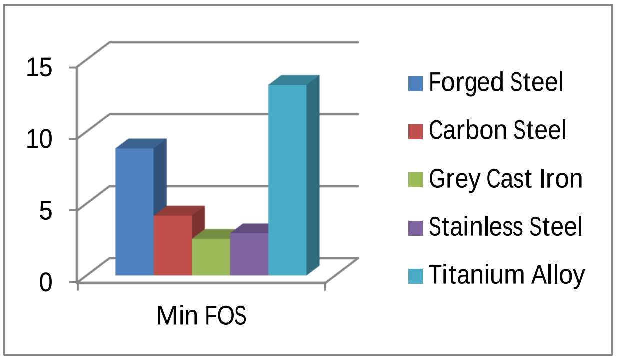


Fig 13, 14, 15: Comparison of values of different materials

VIII. CONCLUSION

From all these observations, we may conclude that in terms of factor of safety, Titanium has the highest FOS whereas Grey Cast Iron showed the least FOS. In terms of stress generated in all the CR, the maximum stress always was generated at the neck of the smaller end of the CR. The Von Mises stress generated is same in 3 materials while Titanium had the least max stress developed. The maximum deformation took place at the head of the smaller end with forged steel having the least deformation whereas Titanium, even though had the least stress has the maximum deformation.

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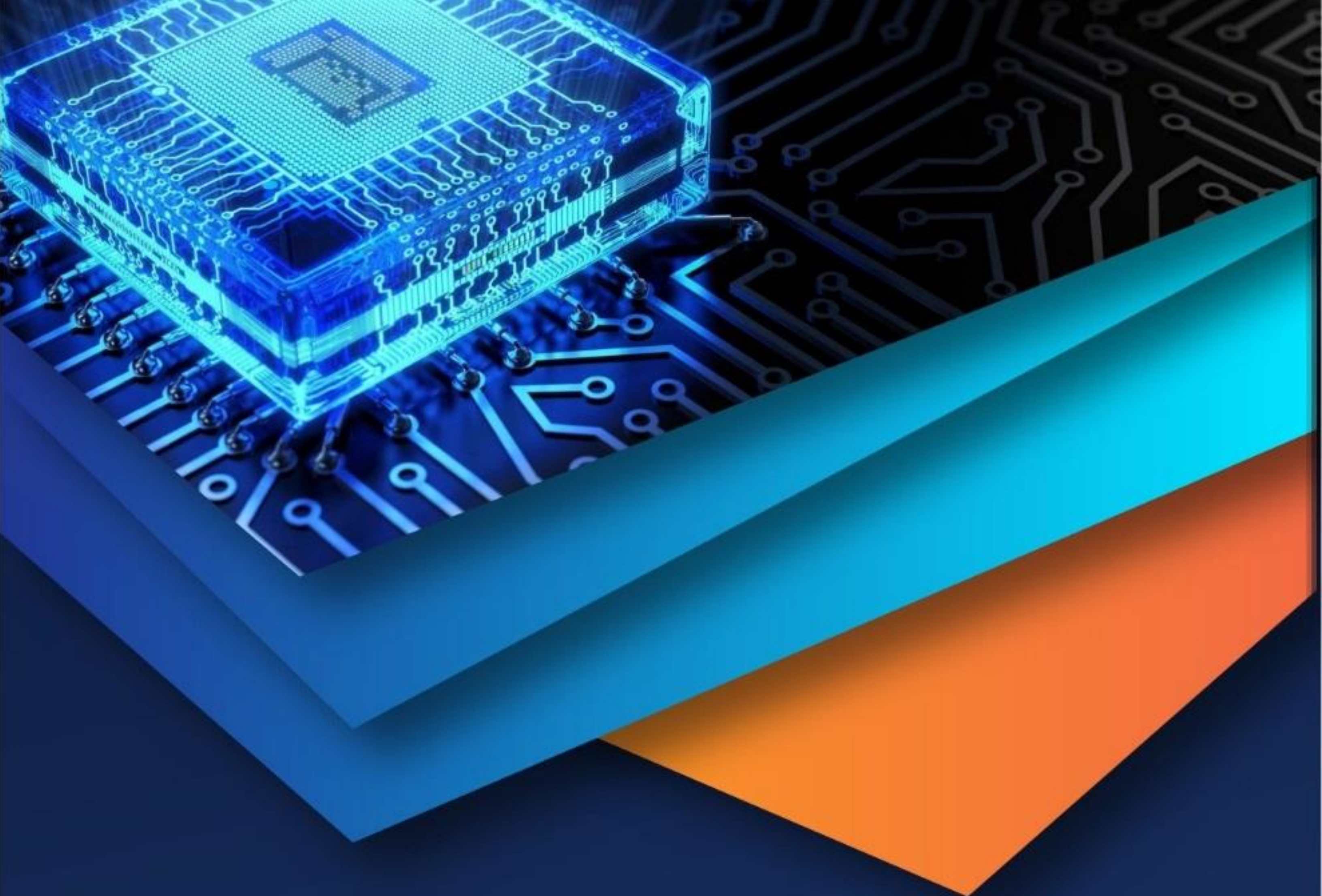

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