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Parametric Analysis of Parabolic Leaf Spring for En45 /GFRP/Epoxy

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Abstract: Comparative analysis of parabolic leaf spring for different materials has been conducted in the present work using FEA software. Three materials considered for spring areEN45, epoxy and GFRP (Glass fibre reinforced polymer). Springs absorb vibrations, shocks and loads in the form of potential energy andthis quality of springs makes the suspension systemeasy.A comparative study has been conducted in this paper to investigate the design and analysis of parabolic spring by analysing stress and deformation. Weight analysis has also been conducted for different cases considered in the work. Parabolic leaf spring made of epoxy-material shows less deformation for same loading condition which indicates large load bearing capability of epoxy material compared to the GFRP and EN45. Same amount of stress has been observed in the GFRP, epoxy and EN45 under loading condition.One fourth weight reduction in parabolic leaf spring has been found when it is made of epoxy and GFRP compared to the EN45. It can be concluded that epoxy serves better in respect of weight and deformation. This study helps in better understanding of the leaf spring.

I. INTRODUCTION

Every vehicle needs a suspension system and every suspension system works with spring. Earlier steel leaf springs were the widely used types of springs but with the time they are getting replaced. Parabolic leaf springs are replacing the leaf spring as they can carry wide variety of load as compared to conventional leaf spring. They have different advantages like they can be guided to absorb the more amount of energy, they offer good breaking torque and they can absorb more driving torque and shocks delivered by vehicle compared to conventional leaf springs. Parabolic leaf spring comes in various shapes like multi parabolic, z-parabolic and simple parabolic.Commonly used material for leaf spring is plain carbon steel with 0.9-1% carbon. Spring materials first heat treated which provides strength and load carrying capacity.

II. LITERATURE REVIEW

Kong et al [1] in 2013 conducted the nonlinear finite element analysis of parabolic leaf spring under the variable load condition. They designed the parabolic leaf spring under the condition of vertical deflection and stresses.Shi et al [2] in 2016 conducted the study on calculating the composite stiffness of parabolic leaf spring for vehicle rear suspension. They varied the load values to conduct comparative study. They targeted their study towards reducing the calculation time and complexity of calculating composite stiffness.Karthik et al [3] in 2012 predicted the fatigue life of parabolic leaf spring under varying amplitude loading using finite element method. They estimated the fatigue life using Palmgren-Miner rule. They concluded that when loading is tensile in nature leaf spring life is more conservative according to Goodman approach and its values is around 2.9201×10^{5}. Dewangan et al [4] in 2012 conducted the study on parabolic leaf spring to reduce the stress generation using simulated annealing approach. They used computer aided design to model the geometry of the parabolic leaf spring and 55Si2Mn90 as a material of the spring.Kumar and Agrawal [5] in 2013 conducted computer aided finite element analysis of parabolic leaf spring made of EN45A material. They conducted the modeling of the geometry in the computer aided software while for finite element analysis they utilized ANSYS software.Chauhan and John [6] in 2016 conducted the static analysis of parabolic leaf spring. They also studied the conventional leaf spring to compare the results of parabolic leaf spring with conventional leaf spring. The used ANSYS to conduct the finite element analysis, parabolic leaf spring modelled by them only has one leaf while conventional leaf spring has three number of leafs.Kumar and Agrawal [7] in 2015 conducted study to predict the fatigue life of parabolic leaf spring. Parabolic leaf spring considered by them has three numbers of layers and is made of EN45A material. They calculated the alternating stress and life of the model generated.

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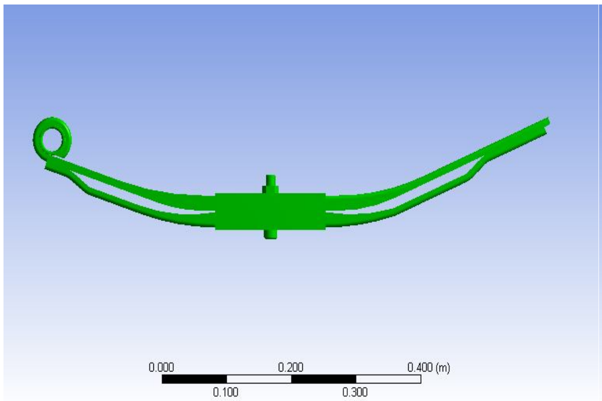
Kumar and Agrawal [8] in 2015 conducted the finite element analysis of mono parabolic leaf spring utilizing CAE software. They considered two different materials EN45 and glass fibre reinforced polymer as a composite materials. The mono leaf spring generated by them has one master leaf having eye at both ends.Shokrieh and Rezaei [9] in 2003 studied design, analysis and optimization of leaf spring. In their study they replaced a steel leaf spring by a composite one.Refngah et al [10] in 2009 conducted the study on fatigue life evaluation of two types of leaf spring. They compared results of parabolic leaf spring with that of multi leaf spring. They study the stress distribution in the parabolic leaf spring and multi leaf spring.

III. METHODOLOGY

A. arabolic leaf spring modelled

A parabolic leaf spring has been designed in the present work. Eye has been provided at the one end of the parabolic leaf spring. A screw has been provided at the centre of the parabolic leaf spring for keeping two leafs together. Their varying thickness along its length helps in improving the load bearing capacity of the automobile.



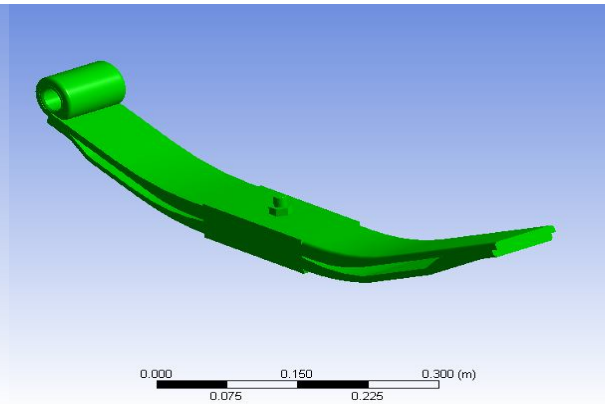


Figure 1: Front view of parabolic springFigure 2: Isometric view of parabolic spring

B. Materials

Table 1 and 2 represents the material properties of EN45 and epoxy. EN45 is conventional steel and epoxy is a composite material.

Physical property of EN45, epoxy and GFRP

S.N.	Material property	EN45	Epoxy	GFRP
1	Young Modulus (E) N/mm^2	2.1×10^5	8.5×10^7	8.9×10^4
2	Poisson's ratio (μ)	0.3	0.23	0.1
3	Density kg/m^3	7850	2160	1850
4	Bulk modulus N/mm^2	1.667×10^5	5.247×10^7	3.7083×10^4
5	Shear modulus N/mm^2	7.692×10^5	3.455×10^7	4.055×10^4

C. Boundary conditions

Two types of boundary conditions have been considered in the present work one is vertical load and other one is fixed support. Fixed support keeps the boundary at that position while load applied the force on the boundary. Eye and extreme right portion of the spring are kept fixed while load has been applied at the centre surface of the top leaf as shown in figure 3.

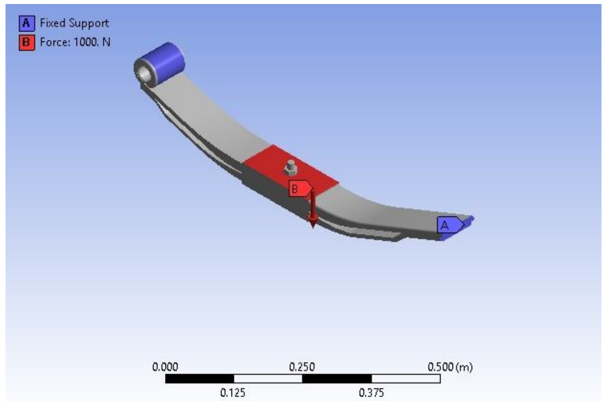


Figure 3 Boundary condition applied on the parabolic leaf spring

D. Meshing

Meshing also plays a vital role in the finite element results. A fine meshing can give good results while a coarse meshing can give inaccurate results. A fine meshing has been considered in the present work to get a better solution and results.

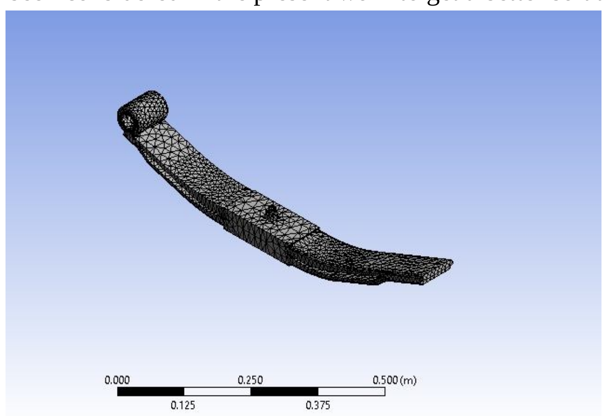
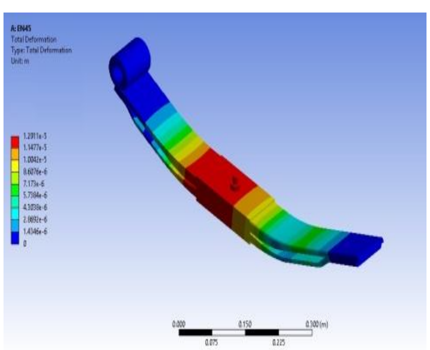


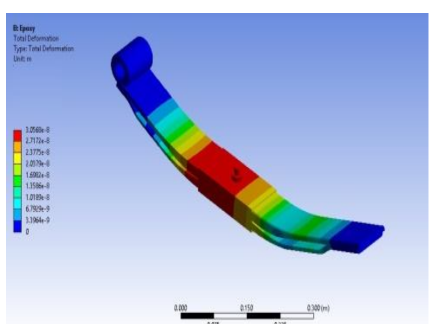
Figure 4 Meshing of the parabolic leaf spring

IV. RESULTS AND DISCUSSION

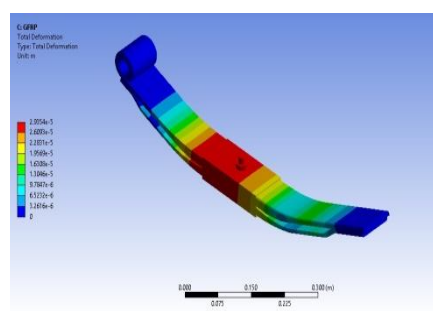
Figure 5, 6 and 7 represents the variation of the deformation, strain and stress generated in the parabolic leaf spring. A vertical load of 1000N has been applied to study this. Three different materials considered to study the above parameters are EN45 (conventional steel), epoxy and GFRPwhich is a composite material.



(a) EN45

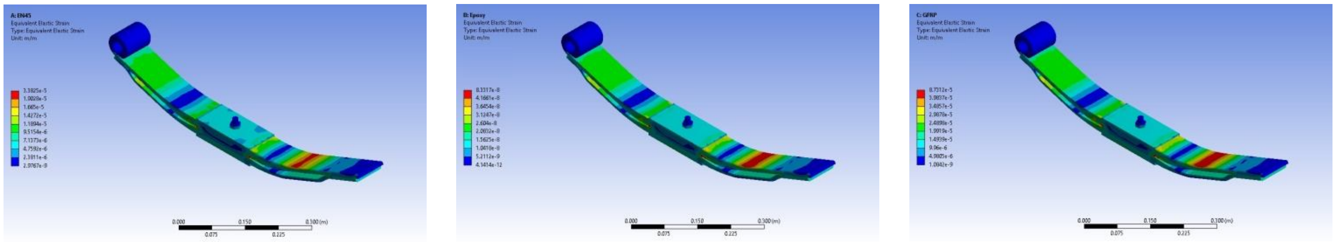


(b) Epoxy



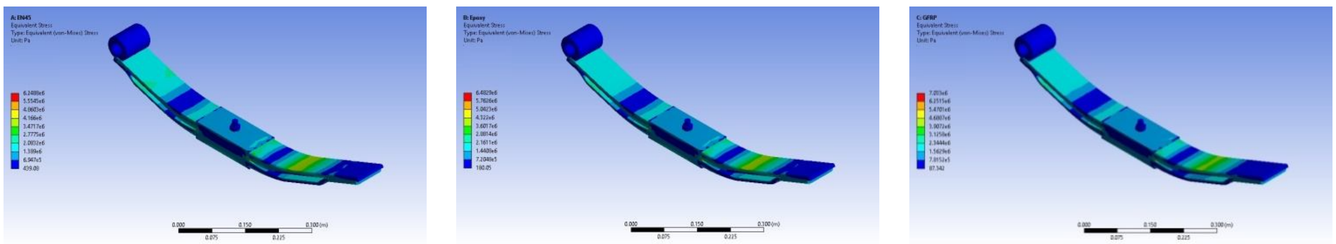
(c) GFRP

Figure 5Deformation generated in the parabolic leaf spring



(a) EN45 (b) Epoxy (c) GFRP

Figure 6Strain generated in the parabolic leaf spring



(a) EN45 (b) Epoxy (c) GFRP

Figure 7Stress generated in the parabolic leaf spring

From the results it can be observed that for applied load parabolic leaf spring made of epoxy material shows less amount of deformation generated which indicates that the parabolic leaf spring made of epoxy material have high amount of load bearing capacity compared to the conventional steel and GFRP parabolic leaf spring. From the figures it can also be observed that stresses generated in the parabolic leaf spring areof same order for the applied load values.

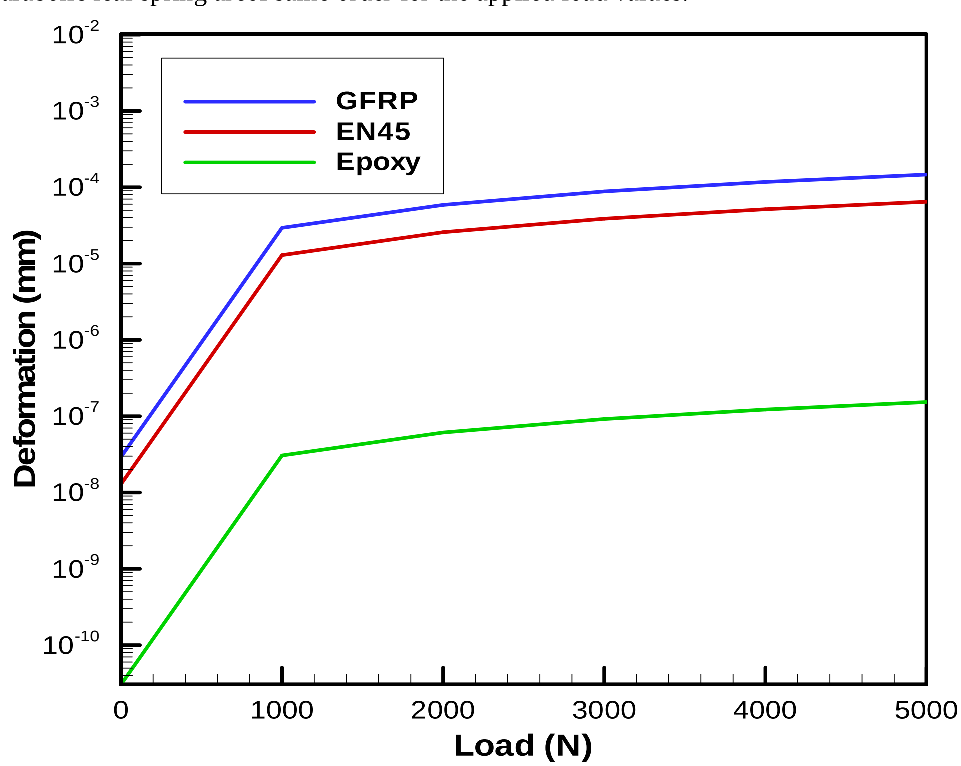


Figure 8 Deformation vs. load

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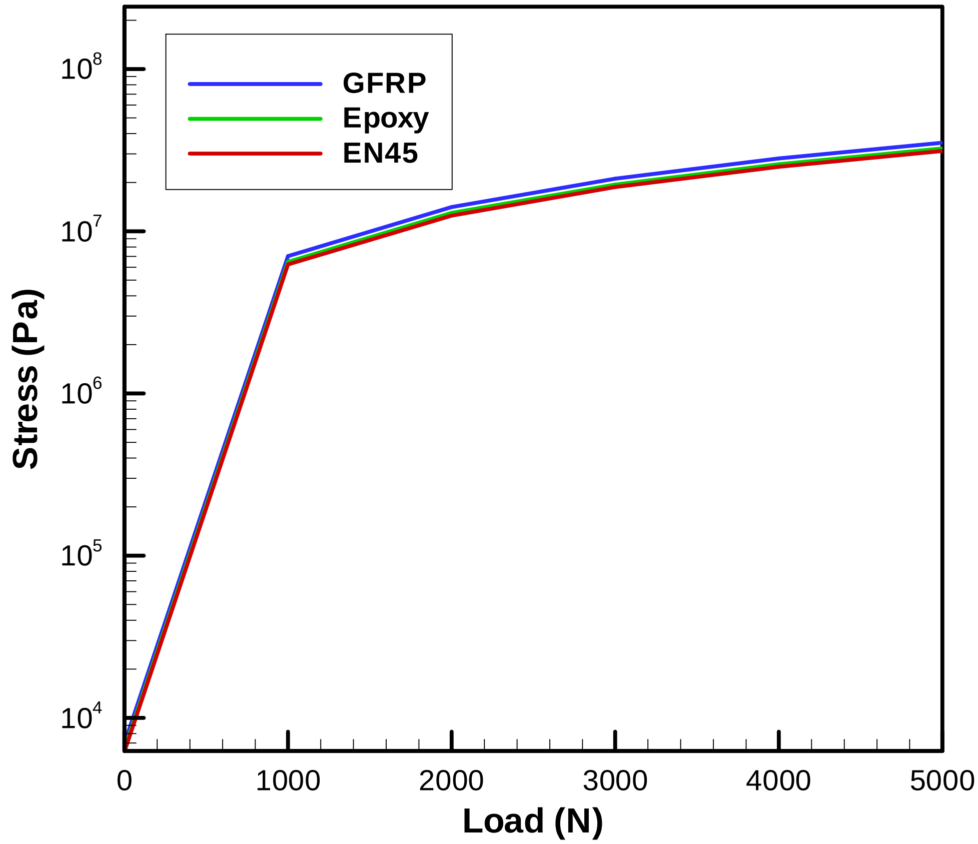

Figure 9 Stress vs. load

From the above figures it can be observed that the deformation in the parabolic leaf spring made of epoxy is less compared to the EN45 and GFRP made leaf spring. Present parabolic leaf spring made of conventional steel EN45 weigh around 16.011kg,in case of epoxy it weigh around 4.4055kg and in case of GFRPit weigh around 3.7732kg. Figure 10 shows the comparison of the weight in the form of a bar chart. It can be easily observed that the parabolic leaf spring made of EN45 weight maximum. It can be observed that parabolic leaf spring weigh minimum when made of GFRPmaterial compared to when made of epoxy and EN45.The reason behind the maximum weight of EN45 and minimum weight of GFRP is the density of these materials.

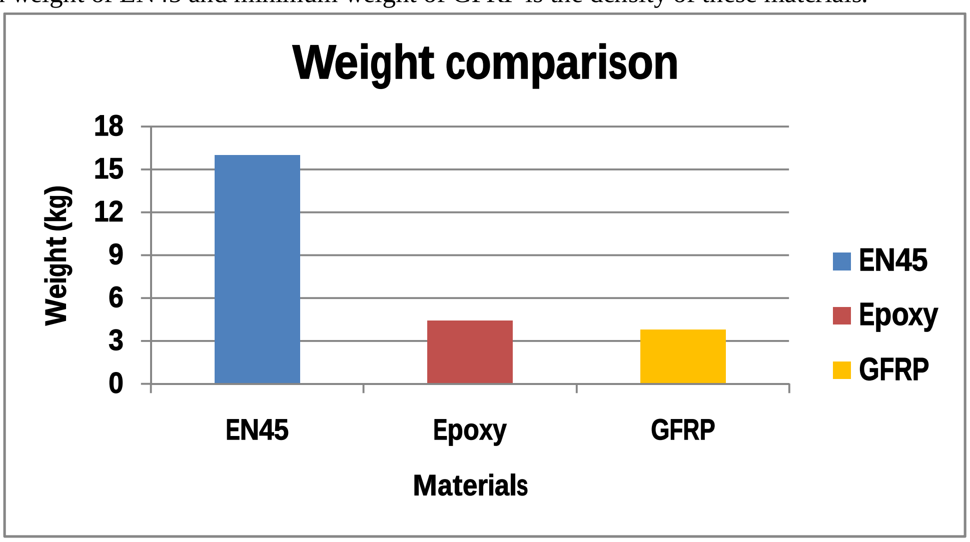

Figure 10 Weight comparison of parabolic leaf spring

V. CONCLUSIONS

A. Parabolic leaf spring made of epoxy materials shows less deformation which indicates large load bearing capability.
B. Parabolic leaf spring shows same order of stress generated in all the materials considered epoxy,EN45 and GFRP.
C. One fourth weight reduction in parabolic leaf spring has been found when it is made of epoxy and GFRPmaterial compared to the EN45.
D. This study helps in better understanding of the leaf spring and in saving the material and cost.

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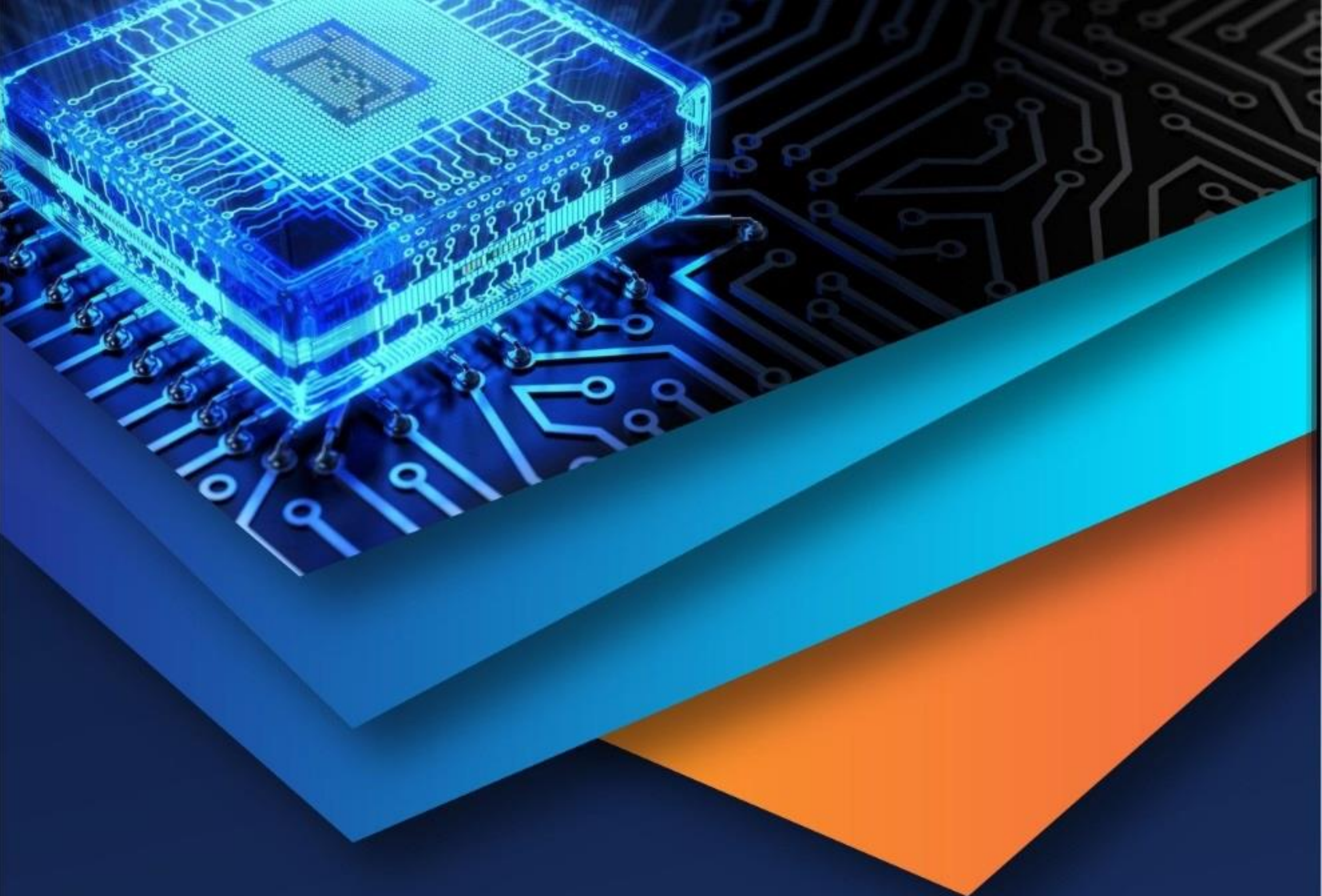

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