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Failure Analysis and Design Modification of Propeller Shaft of Bus

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Abstract*: Propeller shaft is a mechanical instrument which is used in automobile while coming to the construction it was long cylindrical structure consists of three universal joints. Propeller shaft is used to transfer rotary motion to the differential by using constant mesh synchromesh gear box. This rotary motion is used to run the rear wheel of Bus. The aim of this work is to replace the propeller shaft of S.T bus with an appropriate change of material. The existing Propeller Shaft of S.T bus is made up of SAE 1045 steel for reducing natural frequency, torsional buckling and critical stresses developed on propeller shaft the nickel chromium steel SAE 3145 shafts can be made thus reducing the stresses developed. Nickel chromium steel SAE3145 were designed and analyzed for their appropriateness in terms of torsional strength, bending natural frequency and torsional buckling. This paper contains the study design modification and analysis. of propeller shaft of bus...Because of the external factors like road condition, different driving situations, different road adhesion, traffic condition vibration and Sudden Jerks are set up in Propeller Shaft. Propeller Shaft generally buckle under the action of tensile force due to the large ratio of propeller shaft length to its radius of gyration when it becomes worn out the vehicle will get stop. Thus the aim of the project is to analyze propeller shaft to improve the mass and buckling load of propeller shaft and to find out max. deformation and stress Propeller shaft failure is one of the major problems facing for MSRTC workshop Supervisor.
***Keywords*: Buckling Load, Compressive load, CAD, FEM, MSRTC Bus, Propeller Shaft etc.**

I. INTRODUCTION

A nickel chromium steel SAE3145 is a structural material consisting nickel and chromium. Generally this material has very high specific strength and specific modulus. The strength of nickel chromium steel SAE3145may be the same, but its specific strength is thrice as that of SAE1045 steel. The transmission is linked to the Propeller shaft by a yoke and universal joint, or u-joint, assembly. The Propeller shaft transmits the power to the rear end through another yoke and u-joint assembly. The power is then transferred by the rig and pinion or rear differential to the rear wheels. The aim of this project is to find out what are various stresses occurs in propeller shaft which are obtained by analyzing it by using ANSYS software 14.0

The basic function of a Propeller shaft is to transmit power from one point to another in a smooth and continuous action. In automobiles trucks and construction equipment the drive train is designed to send torque through an angle from the transmission to the axle. The Propeller shaft must operate through constantly changing relative angles between the transmission and axle. It must also be capable of changing length while transmitting torque.

Fig:-Existing Propeller Shaft

II. LITERATURE REVIEW

TITTLE OF PAPER: - A REVIEW ON MODELING AND ANALYSIS OF COMPOSITE DRIVE SHAFT.

Author: - T Sivaprasad,T Krishnaiah,S Timothy
Publisher: - *(International Journal of Innovative Science and Modern Engg).*
ISSN: 2319-6386, Vol-2, Issue-5 April 2014.

Investigation by T Sivaprasad [1], T Krishnaiah [2], S Timothy [3]
In this paper more attention is given on material properties.
In present investigation, the author focused on composite material .FEA approaches by the researchers for drive shaft were also studied here. Reduction in weight is a need of automobiles Industry. Thus they focused on to design shaft which is have less weight. This leads to critical material and manufacturing processes.
Finite element analysis has used for shape optimization of drive shaft as well as for validation of final geometry. This process was performed in order to have minimum weight under design constraints. These optimizations were carried out under static load conditions. The geometry and manufacturing constraints were considered during optimization process. The optimized geometry was analyzed under natural frequency using FEA tool.
The ultimate object of this study was to provide a tool which can be used to decrease the bending stress. In this long continuous drive shaft is made by replacing the discontinuous two piece conventional driveshaft. The materials which used in this were E-glass epoxy, high strength carbon Epoxy and high modulus carbon epoxy.

TITTLE OF PAPER :- BUCKLING ANALYSIS OF COMPOSITE DRIVESHAFT FOR AUTOMOTIVE APPLICATIONS.

Author :- Madhu K.S, Darshan B.H, Manjunath K .
Publisher :- (Journal of Innovative Research and Solutions.) ISSN: 2320 1932 Volume No.1A, Issue No.2, Page No: 63 -70, Jan – Jun 2013.
Investigation by Madhu K.S [1], Darshan B.H[2], Manjunath K [3]
In this the author carried out work on the stress analysis of drive shaft which is employed in rear wheel driving vehicles. In the design the author has been made attempt to check the suitability of one piece composite drive shaft with various composite material combinations to fulfil the functional requirements.
In addition to this analytical relation to calculate the critical load of composite shaft have been carried out. the structural reliability of the drive shaft must therefore be ensured so for this purpose the static stress analysis using finite element method ANSYS 10 has been done in order to find out the detailed stress distribution of the drive shaft.

TITTLE OF PAPER :-STRUCTURAL DESIGN OF COMPOSITE DRIVESHAFT FOR REAR-WHEEL DRIVE ENGINE

Author: - K.V.N. Parvathi, CH. Prabhakara Rao.
Publisher: - *(International Journal of Advanced Engineering Research and Studies) E-ISSN2249–8974 IJAERS/Vol. II/ Issue I/Oct.-Dec.,2012/85-89.*
Investigation by K.V.N. Parvathi. [1] , CH. Prabhakara Rao. [2]
Drive shafts are important part of vehicles which is used to transmit power from one point to another in smooth and continuous actions. In this work an attempt is made to evaluate the suitability of composite material for the purpose of automotive driveshaft.
A static and dynamic analysis composite shaft is analyzed using finite element analysis software which helps to minimize the weight of the shaft which is subjected to the constraints such as torque transmission, critical buckling torque capacity and also they are modifying the geometric shape to improve efficiency.

TITTLE OF PAPER :-OPTIMAL DESIGN AND ANALYSIS OF COMPOSITE DRIVESHAFT FOR A LIGHT COMMERCIAL VEHICLE

Author: - Deepti kushwaha, Gaurav Saxena.
Publisher: - *(International Journal of Advance Engineering and Research Development (IJAERD) Volume 1, Issue 8, August -2014).*
Investigation by Deepti kushwaha [1], Gaurav Saxena. [2]
In this paper more attention is given on modeling and analysis of both the steel and composite drive shaft. In this the author used same drive shaft by changing in diameter to carried out the work.
In this the modeling have been done by using Pro-E and done analysis the same using ANSYS 12.1 software. in this the driveshaft is of light commercial vehicle such as cars. By using such material drive shaft would induce less amount of stress which additionally reduces the weight of the vehicle.

Volume 4 Issue X, October 2016
ISSN: 2321-9653

International Journal for Research in Applied Science & Engineering Technology (IJRASET)

TITTLE OF PAPER :-DESIGN OF AUTOMOBILE DRIVESHAFT USING CARBON/EPOXY AND KEVLAR/EPOXY COMPOSITES

Author: - R.Srinivasa Moorthy, Yonas Mitiku, K.Sridhar

Publisher:- (*American Journal of Engineering Research (AJER)e-ISSN:2320-0847 p-ISSN:2320-0936 Volume-02,Issue-10,pp-173-179)*

Investigation by R.SrinivasaMoorthy [1] YonasMitiku [2], K.Sridhar [3],

The aim of this work is to replace the conventional steel driveshaft of automobiles with an appropriate composite driveshaft .The conventional driveshaft's are made in two pieces for reducing the bending natural frequency, whereas the composites shafts can be made as single-piece shafts, thus reducing the overall weight.

Use of advanced composites has resulted in remarkable achievements in many fields including aviation, marine and automobile engineering, medicine, prosthetics and sports, in terms of improved fatigue and corrosion resistances, high specific strength and specific modulus and reduction in energy requirements owing to reduction in weight. Carbon/ Epoxy and Kevlar/Epoxy composites were designed and analyzed for their appropriateness in terms of torsional strength, bending natural frequency and torsional buckling by comparing them with the conventional steel driveshaft under the same grounds of design constraints and the best suited composites was recommended.

Since one piece composites driveshaft will suffice in the place of a two-piece steel driveshaft. It substantially reduces the inertial mass. Moreover, a composites driveshaft can be perfectly designed to effectively meet the strength and stiffness requirements.

III.DESIGN AND SPECIFICATION -DATA COLLECTION

A. Input data used for Propeller Shaft

The major dimensions of propeller shaft considered for present analysis are as follows :-

Length of 1st piece of Propeller Shaft =475mm

Length of 2nd piece of Propeller Shaft =1245mm

Length of 3rd piece of Propeller Shaft=1200mm

Outer Diameter of Propeller Shaft=111mm

Inner Diameter of Propeller Shaft=75mm

Gears	Speed(r.p.m)
1st Gear	0-15
2nd Gear	20-30
3rd Gear	35-40
Top or 4th Gear	40-70

Table 3.1:-Speed on different gear

Speed for 1st gear N_1=15

Power P=120 H.p.

1 H.p=0.736 Kw.

P=120×0.736

=88.32 KW.

K_L=1.75 load factor

$$P = \frac{2\pi NT}{60}$$

$$T_1 = \frac{60 \times P \times Kl}{2\pi N}$$

$$T_1 = \frac{60 \times 88.32 \times 1.75}{2 \times \pi \times 15}$$

T_1 =98.39 KN-M.

Speed for 2nd gear N_2=25

$T_2 = \frac{60 \times 88.32 \times 1.75}{2 \times \pi \times 25}$

T_2= 59.037 KN-M.

Speed for 3rd gear N_3=35

$T_3 = \frac{60 \times 88.32 \times 1.75}{2 \times \pi \times 35}$

T_3 =42.16 KN-M.

Speed for 4th gear N_4=45

$T_4 = \frac{60 \times 88.32 \times 1.75}{2 \times \pi \times 45}$

T_4= 32.79 KN-M.

From above calculations it is observed that as the speed increases torque decreases.

B. Design Specification

1) The Following Specifications were assumed suitably based on the literature and available standards of automobile propeller shafts.
2) The Torque transmission capacity of the Propeller Shaft (T) =98390 N-m.
3) The Shafts needs to withstand torsional buckling (Tb) such that Tb>T.
4) The minimum bending natural frequency of the Shaft (Fnb min) =80Hz.
5) Length of the Propeller Shaft=1.24m.

When Shaft subjected to twisting moment only:-

TORSION EQUATION

$$\frac{T}{J} = \frac{\tau}{ro}$$

$$J = \frac{\Pi}{32}(do^4 - di^4)$$

By substituting the values in above

$$\frac{98.39}{\frac{\pi}{32}(do^4 - di^4)} = \frac{\tau}{ro}$$

$$\frac{98.39}{\frac{\pi}{32}(0.111^4 - 0.075^4)} = \frac{\tau}{0.0555}$$

τ = 462872.03 KN/m².

$$\tau = \frac{462872.03 \times 10^3}{10^6}$$

τ_{max} =462.87 N/mm²

For material Nickel Chromium Steel SAE 3145 properties of material are:-

Sr. no	Symbols	Parameter	Values
1	E	Modulus of elasticity	204 G.P.a
2	ρ	Density	7800kg/m³
3	µ	Poisson’s ratio	0.3

Table 3.1.2:-Material properties of Nickel Chromium Steel SAE 3145.

Volume 4 Issue X, October 2016
ISSN: 2321-9653
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Allowable stress for existing material of shaft i.e. SAE1045

S_{ut}= 780 Mpa

F.O.S=2

$$\tau = \frac{780}{2}$$

τ= 390 N/mm².

τ_{max} (Permissible) > τ_{max} (Allowable)

Hence failure of propeller shaft occurs.

- Selecting suitable material i.e.(Nickel Chromium Steel SAE 3145)
  Properties of material are-

Density (ρ) = 7800 Kg/m³.

Poisson's ratio (µ)=0.29

Young's modulus (E) = 204 Gpa.

S_{ut} = 1350 Mpa

F.O.S = 2

$$\tau = \frac{1350}{2}$$

= 675 N/mm².

Hence Selecting Nickel Chromium Steel SAE 3145 since its valuable stress is greater than induced stresses hence design is safe.

Materials	SAE 1045(Existing)	SAE 3145(Modified)
Torque (N-m)	98390 N-m	98390 N-m
Permissible stress(N/mm^2)	462.87 N/mm^2	462.87 N/mm^2
Allowable stress(N/mm^2)	390 N/mm^2	675 N/mm^2

Table 3.1.3:- Comparisons of results calculated manually.

Bending Natural Frequency

If a system, after an initial disturbance, is left to vibrate on its own the frequency with which it oscillates without external forces is known as its bending natural frequency.

According to Bernoulli -Euler beam theory by neglecting shear deformation and rotational inertia effects the bending natural frequency of a rotating shaft is given by:-

$$F_{nb} = \frac{\Pi}{2l^2}\sqrt{\frac{E \times I}{m'}}$$

For material SAE 3145

Density (ρ)=7800 Kg/m³.

Poisson's ratio (µ)=0.3

Young's modulus (E)=203 Gpa.

$I = \frac{\pi}{64}(do^4 - di^4)$ I= area moment of inertia in mm^4.

= 5.89×10^{-6} m^4.

$m' = \rho \times \frac{\pi}{4}(d_o^2 - d_i^2)$

$m' = 7800 \times \frac{\pi}{4}(0.111^2 - 0.075^2)$

m'=41.02Kg/m. m'=mass per unit length in kg/m

Substituting this value in equation-

$$F_{nb} = \frac{\pi}{2 \times 1.24^2}\sqrt{\frac{203\times10^9\times5.89\times10^{-6}}{41.02}}$$

F_{nb} = 174.41Hz.

The value of obtained frequency is minimum hence safe.

The Total mass of the Shaft is -

$M = m'_L$

$= 41.02 \times 1.24$

$= 50.86$kg

Torsional Buckling

A Shaft is considered as a long Shaft

$$\frac{1}{\sqrt{(1-\mu^2)}} \times \frac{L^2 \times t}{(2r)^3}$$

$$\frac{1}{\sqrt{(1-0.3^2)}} \times \frac{1.24^2 \times 0.018}{(2 \times 0.0465)^3}$$

=36.070

For a long shaft the torsional buckling capacity is

$T_b = \tau_{cr}(2 \times \pi \times r^2 \times t)$

$r = (r_i + r_o)/2$

$= (0.0375+0.0555)/2$

$= 0.0465$m

Thickness $t = r_o - r_i$

$= 0.0555-0.0375$

$= 0.018$ m.

Then the critical stress is given by

$$\tau_{cr} = \frac{E}{\sqrt[3]{2(1-\mu^2)3/4}} \times \left(\frac{t}{r}\right)^{3/2}$$

$$\tau_{cr} = \frac{203\times10^9}{\sqrt[3]{2(1-0.3^2)3/4}} \times \left(\frac{0.018}{0.0465}\right)^{3/2}$$

$\tau_{cr} = 12.36 \times 10^9$ N/m²

$T_b = \tau_{cr}(2 \times \pi \times r^2 \times t)$

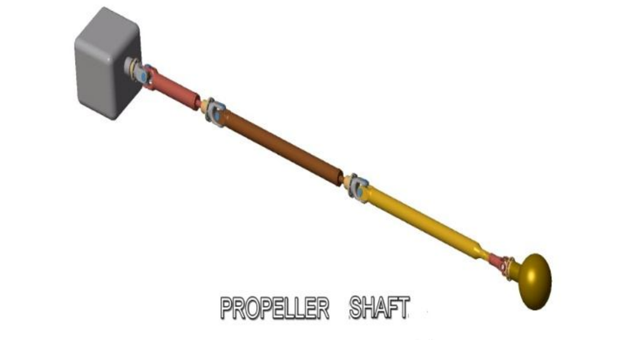
$= 12.36 \times 10^9 \times 2 \times \pi \times 0.0465^2 \times 0.018$

$T_b = 3.02 \times 10^6$ N-m.>T = 98390 N-m.

The torque developed is less than the buckling torque hence safe. Hence the designed Nickel Chromium steel SAE 3145 meets all requirements.

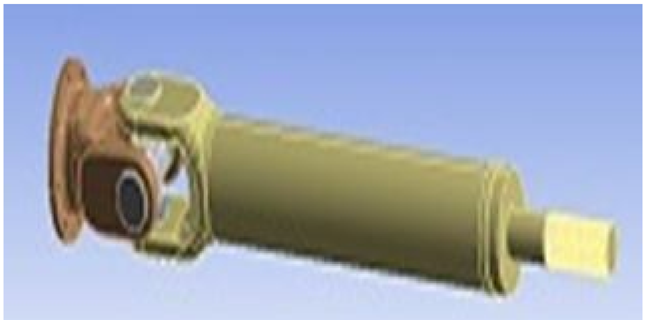
Volume 4 Issue X, October 2016
ISSN: 2321-9653

IV. MODELING OF PROPELLER SHAFT OF S.T BUS

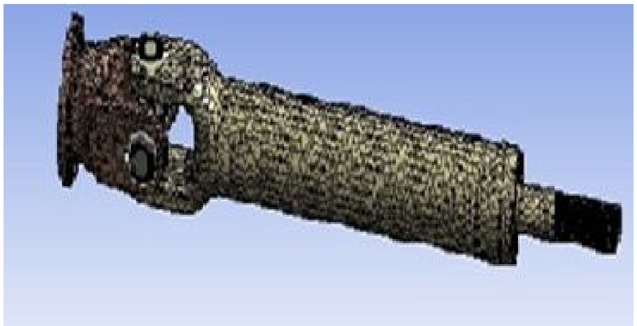


V. ANALYSIS OF PROPELLER SHAFT OF BUS BY USING ANSYS SOFTWARE

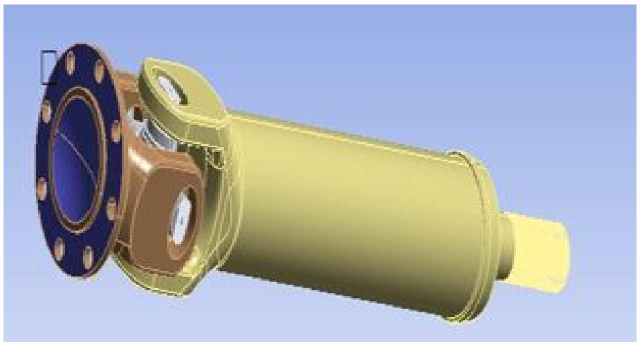
A. Geometry



B. Meshing

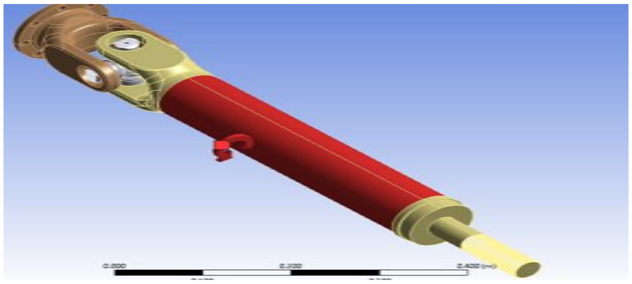


C. Fixed Support

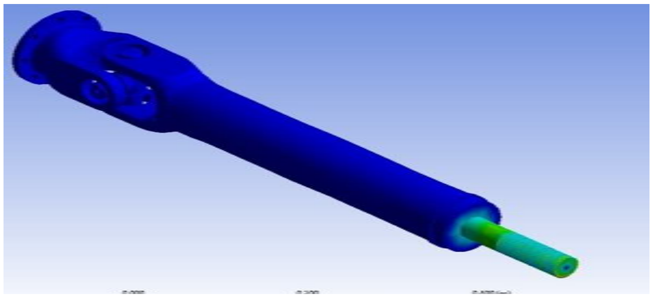


Volume 4 Issue X, October 2016
ISSN: 2321-9653

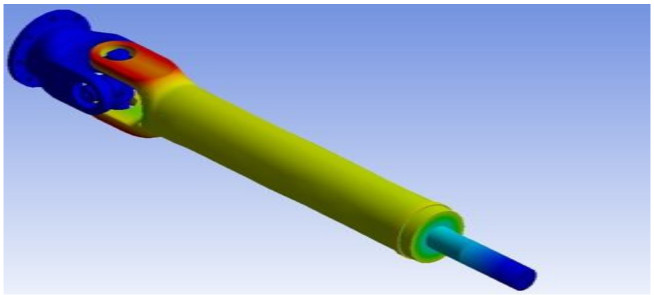
D. Force Applied



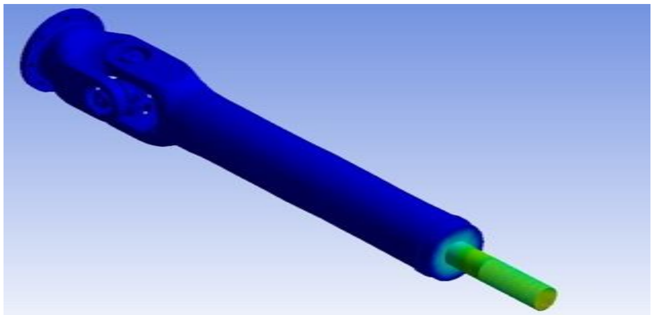
E. Equivalent Voin Mises Stress



F. Total Deformation



G. Equivalent Elastic Strain



VI. CONCLUSION

Data are collected for the propeller shaft of bus from S.T Workshop and various dimensions are taken by measurement.

Length of 1st piece of propeller shaft= 475mm

Length of 2^{nd} piece of propeller shaft = 1245mm

Length of 3^{rd} piece of propeller shaft = 1200mm

Outer diameter of propeller shaft = 111mm

Inner diameter of propeller shaft = 75mm

Various speeds are taken by using tachometer manually at different gears those are as follow.

Gears	Speed(r.p.m)
1st Gear	0-15
2nd Gear	20-30
3rd Gear	35-40
Top or 4th Gear	40-70

Propeller shaft design is based on stresses induced due to different road condition.
Various dimensions are taken by measurement manually.
Various torques are calculated on different speed using conventional design method.

GEAR	SPEED(r.p.m)	TORQUE(N-m)
1st	15	98390
2nd	25	59030
3rd	35	42160
4th	45	32790

The gear which produces highest torque is selected for propeller shaft design.
Propeller shaft is designed by conventional method and various stresses induced and natural frequency is calculated.

TORQUE(N-M)	STRESS (N/mm^2)	FREQUENCY(Hz)
98390	462.87	174.41

The existing propeller shaft is modelled using CRE-O 3.0 software and the same propeller shaft is analyzed by FEM using ANSYS 14.0(WORKBENCH) software.
The results obtained by FEM analysis are as follows:-

Material	Equivalent Von mises stress (Mpa)	Equivalent elastic strain	Total deformation(m)
SAE 1045(existing)	400	0.00196	1.102
Nickel Chromium steel SAE3145(modified)	492	0.00242	1.362

It is observed that Nickel Chromium SAE 3145 material is based fitted for present application. since it gives less deformation for the same loading condition and it gives higher factor of safety for the same loading conditions.

VII. FUTURE SCOPE

A. For further evaluation of results obtained, it is recommended to use different software packages for the same models of design solutions and the same configuration of loads.

B. Comparative study is required to be carried out on propeller shaft assembly to measure forces during the process. For the further study following consideration are suggested.
C. Similar analysis approach can be followed for any type of propeller shaft, in general for heavy and light vehicle.
D. Dynamic analysis can be carried out for the Impact loading and random changes of the load on propeller shaft due to uneven road.
E. Fatigue life estimation of each component can be performed for propeller shaft.
F. Nonlinear analysis can be carried out for propeller shaft component.

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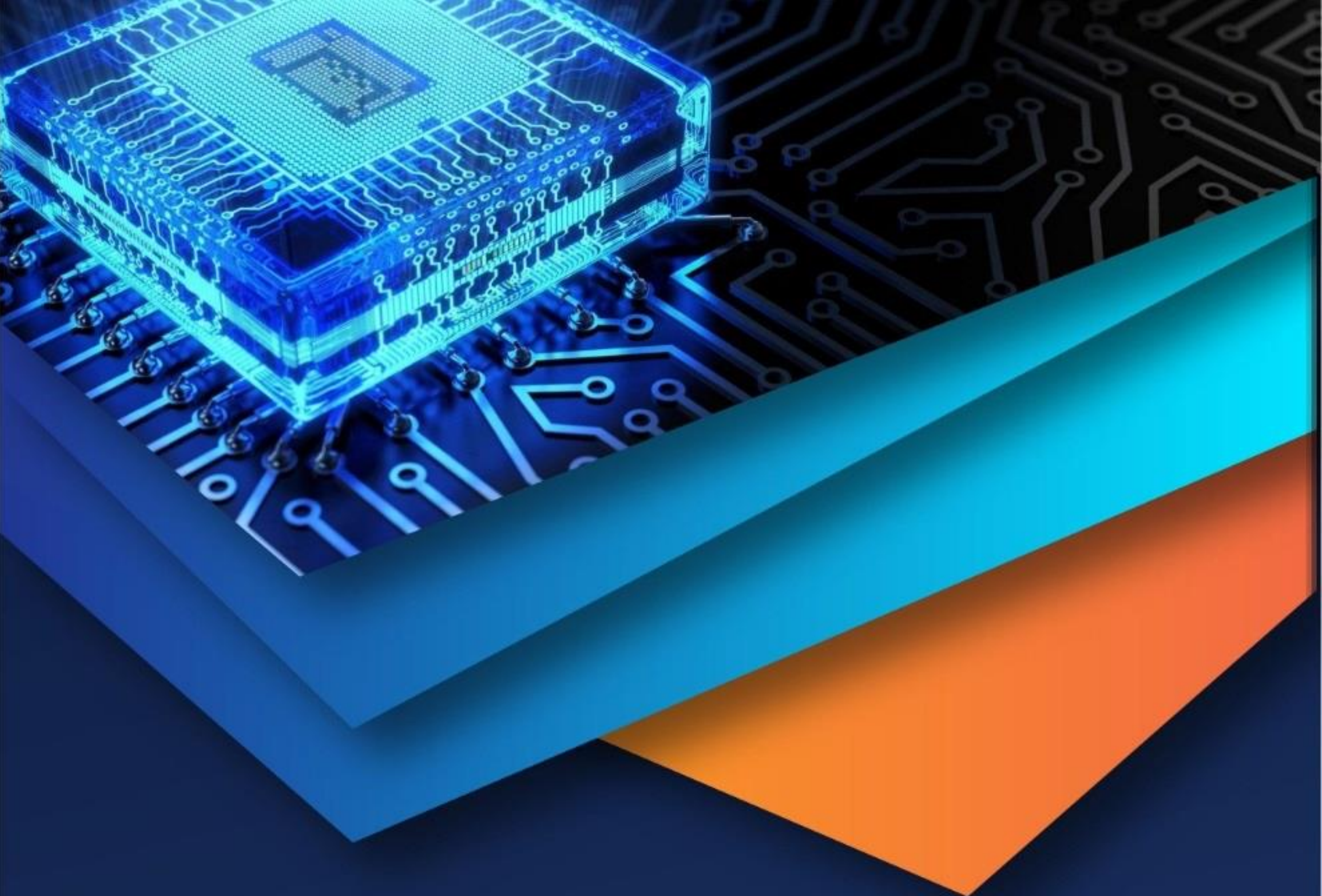

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