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Structural Analysis Of Turbine Blade Using Catia V5r18

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Abstract: Wind turbine blades are shaped to generate the maximum power from the wind at the minimum cost. Primarily the design is driven by the aerodynamic requirements but economics mean that the blade shape is a compromise to keep the cost of construction reasonable. In particular, the blade tends to be thicker than the aerodynamic optimum close to the root, where the stresses due to bending are greatest. The blade design process starts with a "best guess" compromise between aerodynamic and structural efficiency. The choice of materials and manufacturing process will also have an influence on how thin (hence aerodynamically ideal) the blade can be built. For instance, prepare carbon fiber is stiffer and stronger than infused glass fiber. The chosen aerodynamic shape gives rise to loads, which are fed into the structural design. Problems identified at this stage can then be used to modify the shape if necessary and recalculate the aerodynamic performance. In this, the Gas Turbine blade is modeled and structurally analysed in CATIA V5R18 for von misses stress of iron and steel compositions of materials and analytical results.
Keywords: Airfoil, blade section, blade Materials, Computations, Von Misses stress.

I. INTRODUCTION

The word "turbines" is associated with spinning. The idea that leads to the modern gas turbine can clearly be given to John Barber. In spite of the fact that John Barber's 1791 patent represented all of the important features of a successful gas turbine it wasn't until the early part of the 20th century that engineers were able to produce a machine that was useful.

A. G.T Equipment Data

Unit(s) number(s)	:	T 9E 128		
Type	:	PG 9171E		
G.T. Application	:	Generator Drive		
Cycle	:	Simple (Power) Cycle		
Type of operation	:			
Altitude	:	216 m		
Compressor	:	Stages: 17	Speed	: 3000 rpm
Turbine	:	Stages: 3	Speed	: 3000 rpm

The turbine rotor assembly consists of two wheel shafts, the 1st, 2nd & 3rd stage turbine wheels with buckets, & two turbine spacers. Concentricity control is achieved with matting rabbets on the turbine wheels, wheels shafts & spacers. The wheels are held together with through bolts. Selective positioning of rotor members is performed to minimize balance corrections.

II. BLADE MATERIALS

Turbine blades are designed for optimum aerodynamics and mass center location, and are made of advanced metal alloy castings to increase strength, resist extreme temperature, and avoid corrosion. Inaccuracies in blade geometry and positioning may cause energy conversion efficiency loss and untimely blade failure. Use of aluminum and composite materials in their blades has contributed to low rotational inertia, which means that newer wind turbines can accelerate quickly if the winds pick up, keeping the tip speed ratio more nearly constant. Operating closer to their optimal tip speed ratio during energetic gusts of wind allows wind turbines to improve energy capture from sudden gusts that are typical in urban settings. Most turbine blades are manufactured by investment casting (or lost-wax processing). This process involves making a precise negative die of the blade shape that is filled with wax to form the blade shape. If the blade is hollow (i.e., it has internal cooling passages), a ceramic core in the shape of the passage is inserted into the middle. The wax blade is coated with a heat resistant material to make a shell, and then that shell is filled with the blade ALLOY.

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III. BLADE MODELLING

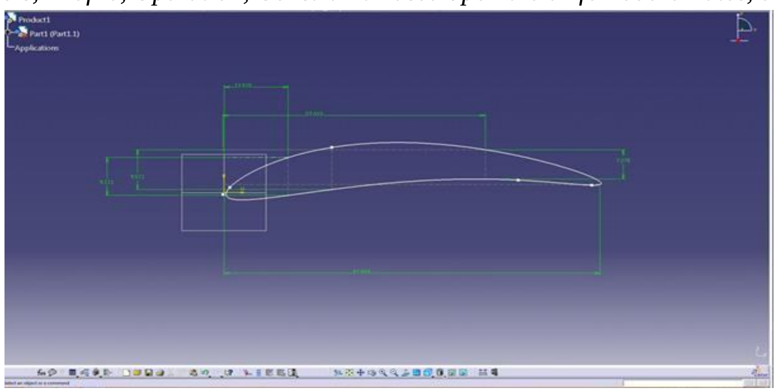
CATIA Computer Aided Three-dimensional Interactive Application is a multi-platform CAD/CAM/CAE commercial software suite developed by the French company Dassault Systems. CATIA competes in the high-end CAD/CAM/CAE market with Siemens NX.

Turbine Blade Pg9171e) Airfoil Coordinates

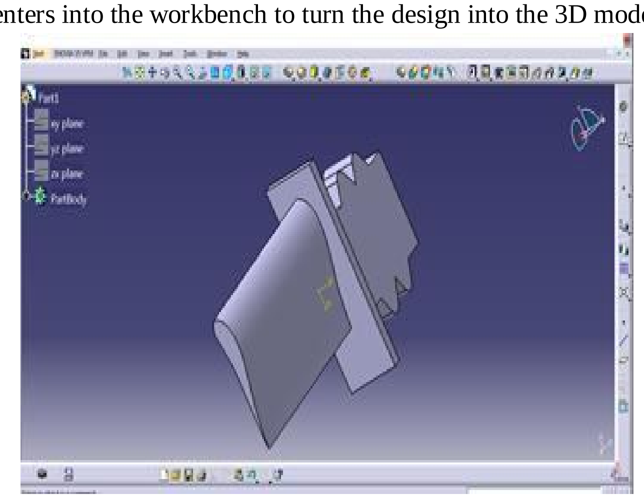
1	0.000	0.000
2	0.025	0.039777
3	0.1	0.073
4	0.3	0.098
5	0.6	0.08096
6	0.9	0.02664
7	1	0
8	0.05	-0.02232
9	0.15	-0.02856
10	0.4	-0.0265
11	0.7	-0.01348
12	0.95	-0.00208

A. Various designs used in catia

1) *Part design: Sketch tools, Profile, Operation, Constraint Based upon the airfoil coordinates, create a airfoil bladed section.*



2) Sketcher or Workbench: Sketch based features, Dress-up features, Transformation features:- After completion of geometry and constraints in part design is enters into the workbench to turn the design into the 3D model.



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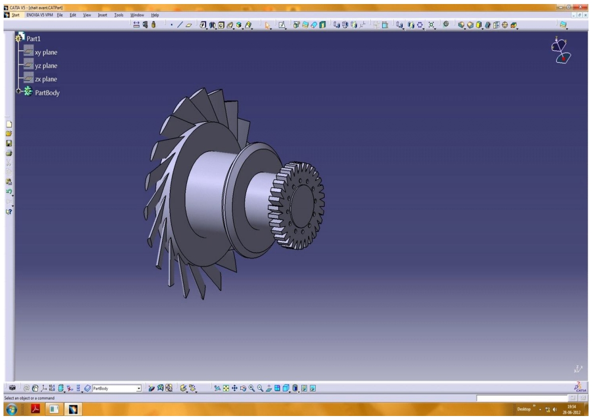
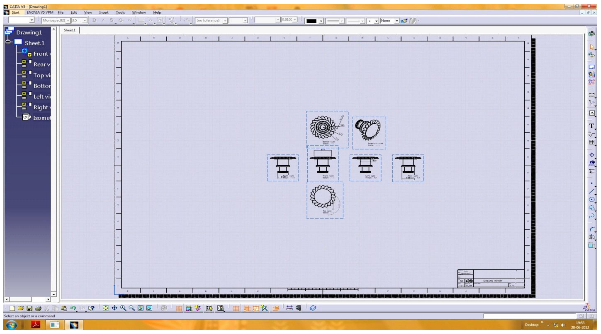
3) *Assemble: - Product structure toolbar, Move toolbar, Constraint toolbar.*

Often we use this option, like for example if we want to design aircraft, so we design each part of an aircraft in separate workbenches and we assemble all the parts in assembly design with all constraints.



Drafting of Turbine blade model: Analyzing the turbine blade model assembling by creating views of blade assembly (Top, Left side view, Right side view, Front view) as shown in below figure.



IV. ANALYSIS AND RESULTS

Import the blade model into analysis part of CATIA and analysis can be computed by the applying load, boundary conditions and stress calculations.

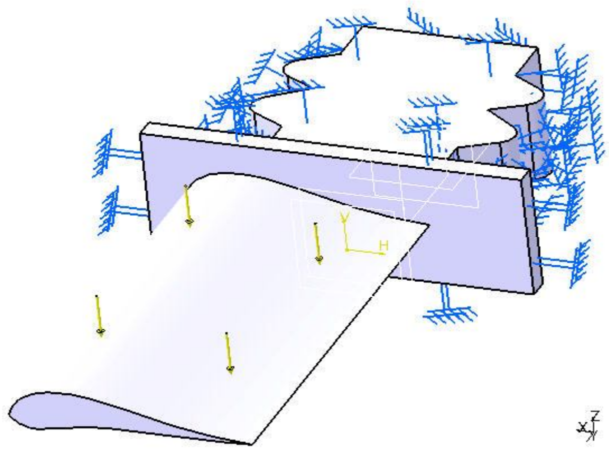
A. *Static Case 1*

Properties of iron as taken as follows;

Material	Iron
Young's Modulus	1.2e+011N_m2
Poisson's ratio	0.291
Density	7870 kg_m3
Coefficient of thermal expansion	1.21e-005_Kdeg
Yield strength	3.1e+008N_m2

B. *Boundary conditions*

After meshing of geometry, we will look for boundary conditions of model. From structural design and principle operation of turbine blade, it acts as cantilever beam .i.e., one end is fixed to the frame with help of diaphragms and other end is free and will be in action of process or work.



C. Structure Computation

Number of nodes	:	14117
Number of elements	:	57115
Number of D.O.F	:	42351
Number of Contact relations	:	0
Number of Kinematic relations	:	0
Linear tetrahedron	:	57115

D. load computation: (100 kn) By calculation, the amount of force released by working medium (air) on to the rotor blade.

Loads =100 Kn

Fx	-1.316e-10N
Fy	1.033e-010 N
Fz	-1.000e+002 N
Mx	-9.200e+000 Nxm
My	8.084e-001 Nxm
Mz	2.707e-011 Nxm

E. Direct method computation

The application of 100Kn applied on a rotor blade, the internal resistances like von misses and principal stress at the equilibrium conditions are estimated and the results noted as follows.

Strain Energy: 1.404e-003 J

Equilibrium:

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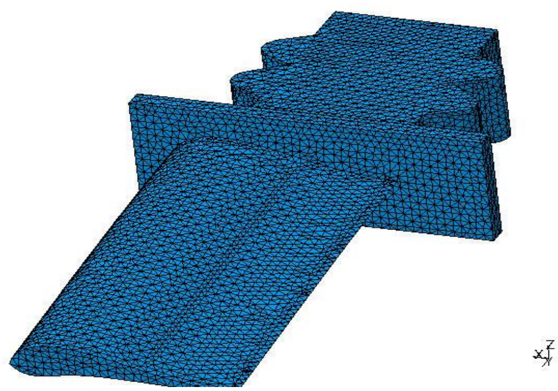
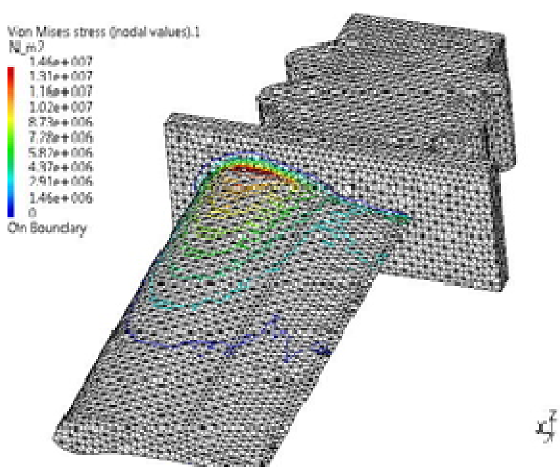
Components	Applied Forces	Reactions	Residual	Relative Magnitude Error
Fx	-1.3156e-010	1.0696e-010	-2.4609e-011	1.0105e-012
Fy	1.0326e-010	-9.4426e-011	8.8342e-012	3.6276e-013
Fz	-1.0000e+002	1.0000e+002	-2.3036e-010	9.4592e-012
Mx	-9.2000e+000	9.2000e+000	-7.3239e-012	2.1179e-012
My	8.0843e-001	-3.4073e-013	-3.4073e-013	9.8530e-014
Mz	2.7068e-011	6.4019e-012	6.4019e-012	1.8513e-012

1) *Static Case 1:* Solution - Deformed mesh--- On boundary ---- Over all the model



Von Misses stress (nodal values)



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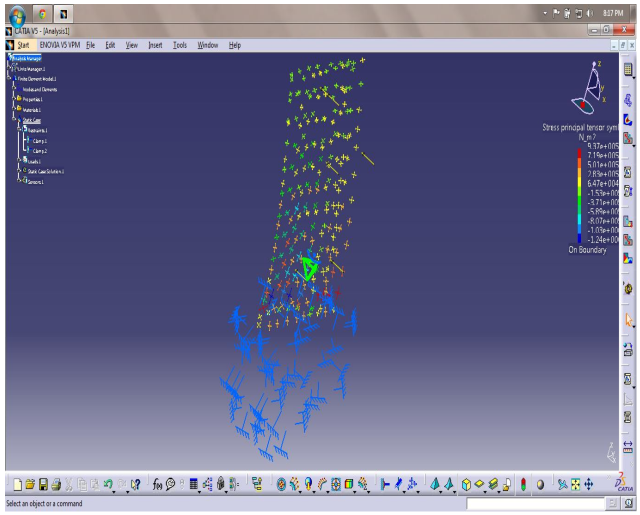
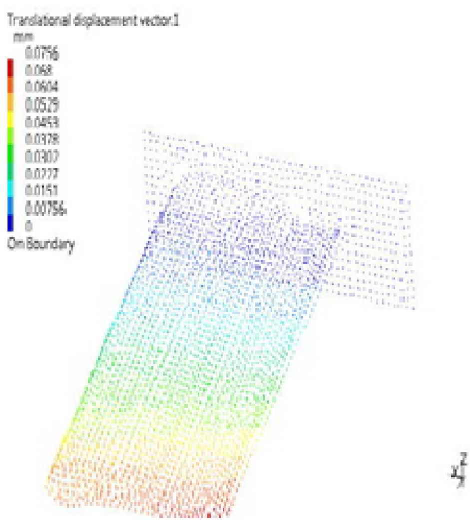
2) Principal Stress



3) Translational displacement vector



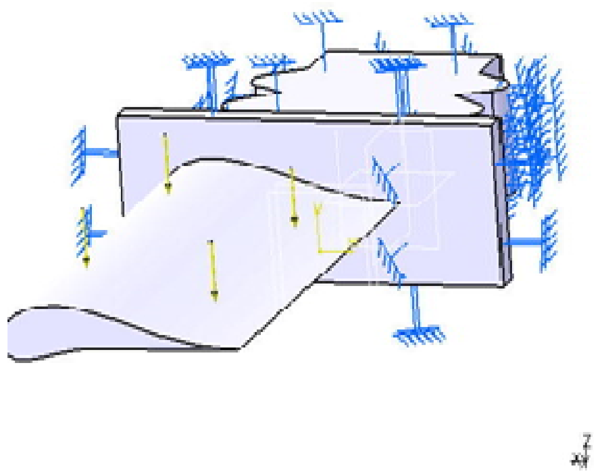
F. Static Case: 2

Properties of Steel as taken as follows:

Material	Steel
Young's Modulus	2e+011N_m2
Poisson's ratio	0.266
Density	7860 kg_m3
Coefficient of thermal expansion	1.17e-005_Kdeg
Yield strength	2.5e+008N_m2

G. Boundary Conditions

After meshing of geometry, we will look for boundary conditions of model. From structural design and principle operation of turbine blade, it acts as cantilever beam .i.e., one end is fixed to the frame with help of diaphragms and other end is free and will be in action of process or work.



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Linear tetrahedron	:	57115

I. Load Computation

By calculation amount of force released by working medium (air) on to the rotor blade

Name: Loads =100 Kn

Fx	-1.316e-10N
Fy	1.033e-010 N
Fz	-1.000e+002 N
Mx	-9.200e+000 Nxm
My	8.084e-001 Nxm
Mz	2.707e-011 Nxm

J. Direct Method Computation

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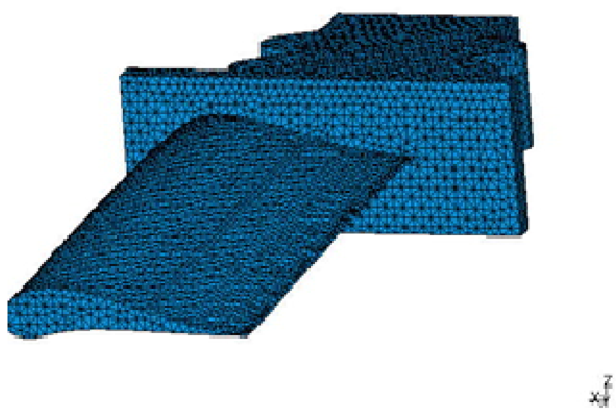
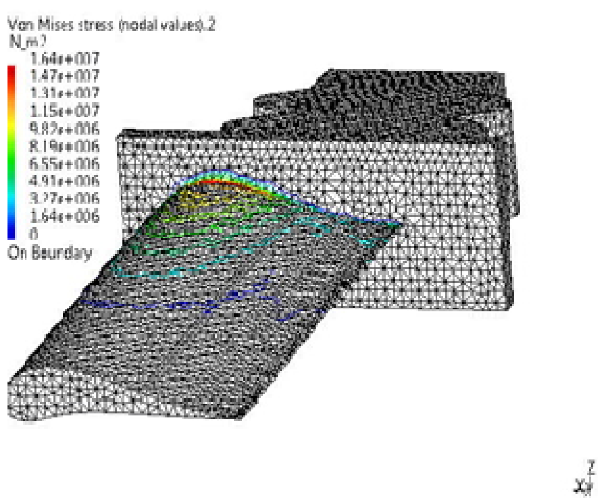
The application of 100Kn applied on a rotor blade, the internal resistances like von misses and principal stress at the equilibrium conditions are estimated and the results taken as follows.

Load: 100Kn Strain Energy: 7.914e-004 J

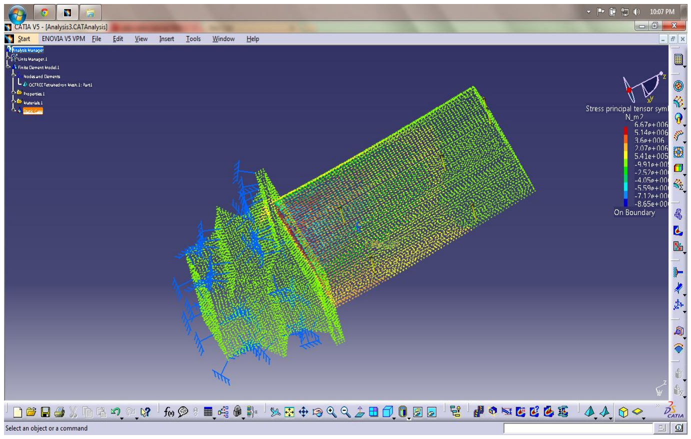
Components	Applied Forces	Reactions	Residual	Relative Magnitude Error
Fx	-1.3156e-010	1.3945e-010	7.8857e-012	1.5620e-013
Fy	1.0326e-010	-5.7966e-011	4.5294e-011	8.9722e-013
Fz	-1.0000e+002	1.0000e+002	-1.6641e-011	3.2963e-013
Mx	-9.2000e+000	9.2000e+000	3.2561e-012	4.5421e-013
My	8.0843e-001	-8.0843e-001	-5.7293e-012	7.9922e-013
Mz	2.7068e-011	6.4019e-012	-5.7626e-013	8.0387e-014

1) *Static Case 2* Solution - Deformed mesh. On deformed mesh ---- On boundary ---- Over all the model

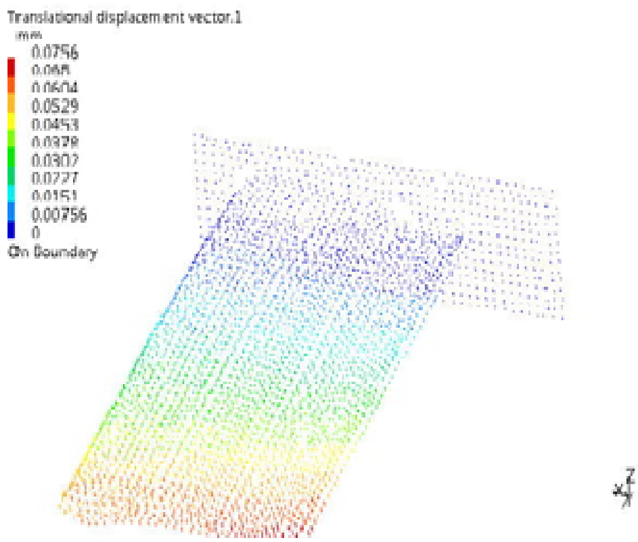




2) *Principal Stress*



3) Translational displacement vector



Material	Strain Energy (J)
Iron	1.404e-003 J
Steel	7.914e-004 J

V. CONCLUSION

From the analysis, we got the results of iron and steel materials of turbine blades with load of 100 Kn application, the developed strain energy determined the structural efficiency of blade. It is proved that steel has more capacity of storing internal energy when blade subjected to the loads and the performance of a turbine blade with steel is more efficient for high power generative industries. The Gas Turbine propulsion will be helpful to further development of aircraft propulsion system with high efficiency.

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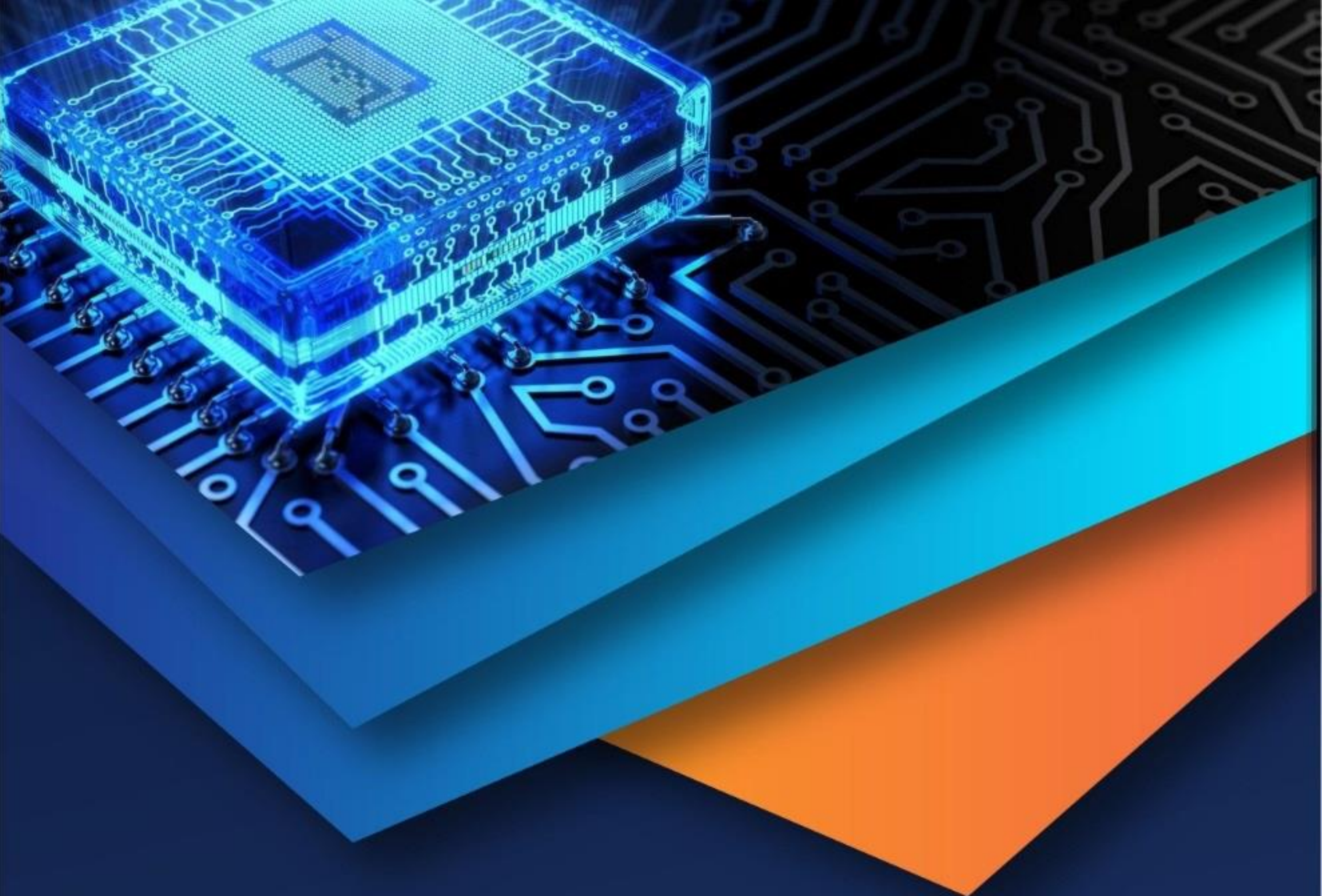

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