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Design Optimization of Induction Motor Stator Frame and its Finite Element Analysis

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Abstract: Induction motors are the most popular machines used in industrial motion control systems and main driven home appliances. The main advantages of induction motors are simple and durable design, low cost, low maintenance. Reduction in cost of components helps industries to maintain a continuous growth in this competitive world. Therefore, optimization places an important role in minimizing material use in the case of motor, to reduce motor expense. In this paper stator frame of 500 shaft centre height closed air circuit air cooled (CACA) induction motor is picked for optimization, which is one of the basic part of motor. This paper addresses the stress and deformation formed under normal loading condition in an engineered stator frame while the motor is in static condition and identifying the failure modes by the modal analysis. This involves 3D modelling in UG NX, meshing and analysis by ANSYS. Therefore, by taking into account all the design parameters, an initiation is made to optimize and study the optimized stator frame under static and Vibration stability.
Keywords: Stator frame, Optimization, Structural analysis, Modal analysis.

I. INTRODUCTION

Induction motor is a device in which electrical energy with electromagnetism as the intermediate concept is transformed into mechanical energy. Induction motors provide the motive power for many different pieces of equipment, including pumps, fans, compressors and refrigeration /cooling devices. Pumps are the most common industrial application of electric motors in India.

A. Constructional Features Of Induction Motors

Motor is made up of several parts, it includes:

1) Method of cooling / enclosure / ventilation.
2) Stator assembly
3) Rotor assembly
4) Endshields
5) Bearings
6) Slipring and brushes
7) Terminal boxes
8) Accessories

B. Stator

The major components of stator assembly are:

1) Stator frame
2) Stator core and winding (bar/coil)

The stator frame holds the complete stator and rotor assembly and protects these parts from the environment. The other function of the stator frame is to help in transfer of heat, generated inside the motor to the outside. That's why stator frame of motors often have cooling ribs to improve the heat dispersion by increasing surface area. [1].

The motor fixing feet and lifting lugs provided on the stator frame. There are end shields at both ends of the stator frame. Bearings provided at both end to hold the rotor shaft and these bearings mounted on end shields [1].

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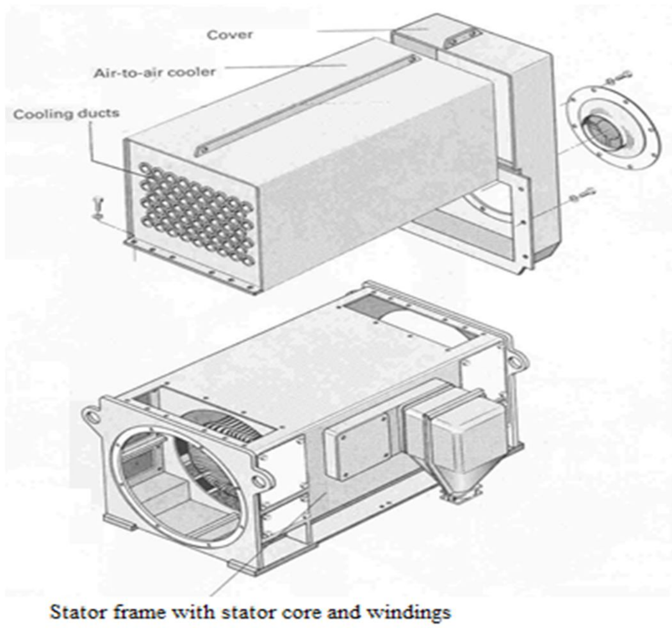

Fig.-1 Stator Assembly with CACA Cooler [4]

Stator is the biggest part in the entire induction motor. Thick structural steel plates are welded together to form a rigid and stable stator frame, thick steel plates helps in preventing distortion during operation. It is adequately design to prevent deformation during transportation and lifting. Such casings are durable and strong, designed to withstand the weight of a stator core, bending stresses and deflections. The stator frames are design to deal with mechanical as well as electrical forces. Numerous a factor in its plan is constrained by the producer's standard and innovation accessibility. To certain expand client necessity additionally assumes a significant job for the activity and support perspective. Likewise feasibility of stator frame manufacturing at work and transport to site is Important.

II. METHODOLOGY

The aim of this thesis is to optimize and analyse motor stator frame with the help of 3-D modelling and finite element analysis. A flow-chart has been plot as cited below which shows the steps involve in stator frame optimization and finite element analysis.

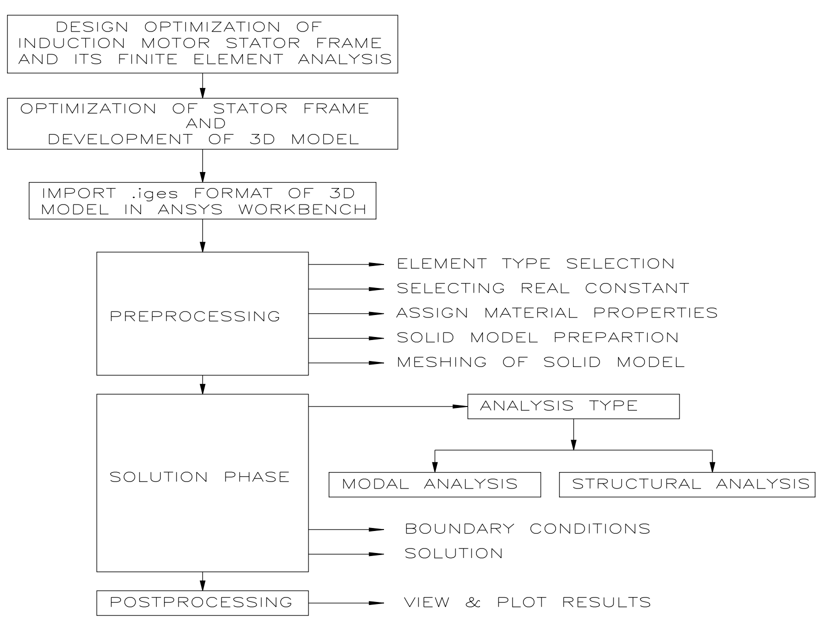

Fig.-2 Steps involve in optimization and finite element analysis of stator frame

A. Optimization and 3D Modelling of stator Frame

Optimization is a procedure of designing component which uses ideal amount of material and can sustain under specified loading and working condition.

In this paper we choose a stator frame of 500 shaft centre height closed air circuit air cooled (CACA) induction motor for optimization, existing stator frame shown as below.

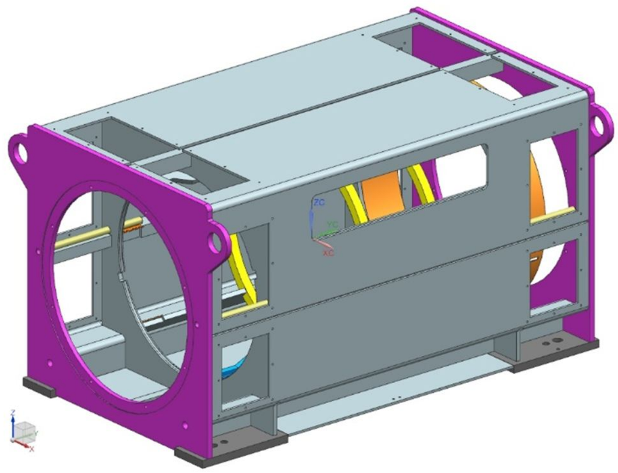

Fig.-3 Existing Stator Frame of 500 shaft height CACA motor

Following modifications were made to the existing stator frame design, to get the desired optimization i.e. shaft centre height of new frame is reduced to 450mm. from 500 mm.

1) Take the existing stator frame benchmark for the thickness of end-stand, ribs, foot plate, intermediate stand, cover plate and stator core mounting diameter along with thickness of rings used for guide and support to stator core.
2) Internal ribs height reduce to get desire shaft height of motor without losing strength of ribs in comparison with old stator frame ribs.
3) No. of rings welded in ribs increased to 3 nos. in place of 2 nos. in old stator frame.
4) Dimensions of end stands and intermediate stands modified as per stator capsule outer diameter.
5) Thickness of stator foot plate modified in new stator frame.
6) Terminal box mounting openings and opening provided for air ventilation changed as per new design requirement.

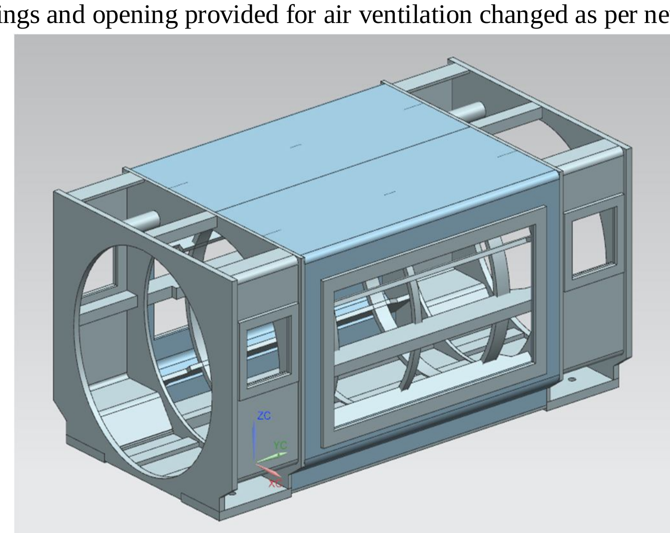

Fig.-4 New Stator Frame of 450 shaft height CACA motor

UG NX 10.0 software package is used for creating 3-D model of new stator frame. The mass of new stator frame reduced from 1250 kg. to 1050 kg. and size of motor decreased from 1920mm. x 1034mm. x 1023mm. to 1880mm. x 1034mm. x 900mm.

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B. Structural Analysis Of Stator Frame

The finite element analysis (FEA) process is used to analyse a part or assembly to accurately assess the integrity of the product's performance over its lifetime. FEA helps design engineers to simulate structural behaviour of object and make design changes and see the effects of the design changes quickly or even automatically.

Numerical analysis is done through the ANSYS Mechanical software. This software package is based on the finite element analysis and basic steps involved in this are as follows.

1) *Preprocessing:* In this step, finite element model is developed for various analysis. The various tasks in this step are as follows:
 a) Element type selection
 b) Providing real constant (if any)
 c) Assigning material properties
 d) Providing Section
 e) Solid Model Creation
 f) Meshing of Solid model

Structural steel as per IS:2062 ; GR: E250A is used for analysis. Mechanical properties of material is :

Table-1 Mechanical properties of material of components

Grade	Thickness(mm)	Min Yield	Tensile	Elongation
IS2062 E250A	<20mm	Min 250Mpa	410Mpa	23%
	20mm-40mm	Min 240Mpa	410Mpa	23%
	>40mm	Min 230Mpa	410Mpa	23%

2) *Solution Phase:* The finite element model created in preprocessing phase is solved in this phase. Steps involved are: •Analysis Type
 a) Boundary Condition
 b) Solution

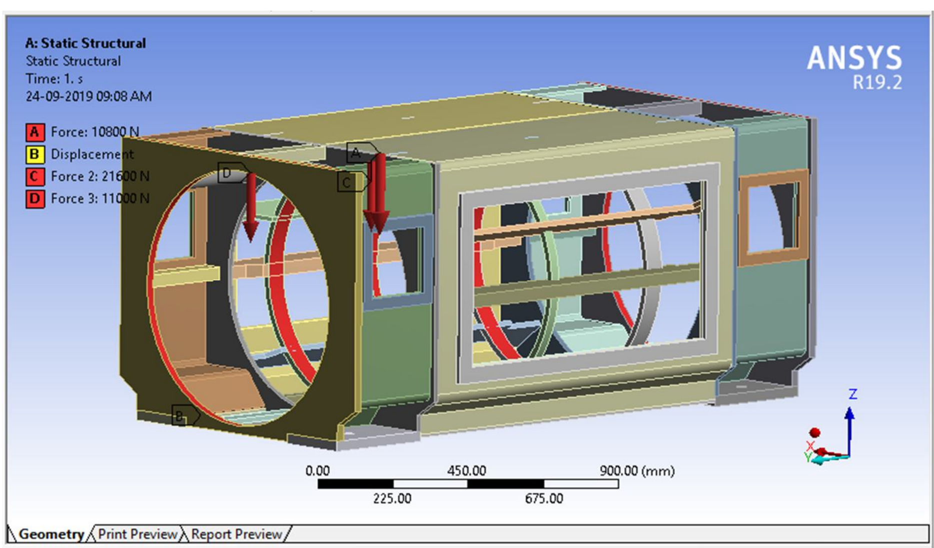

Fig.-5 loading point and boundary condition for static load

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3) Post Processing: In this phase of the analysis, results are viewed and plotted as shown in fig.-6

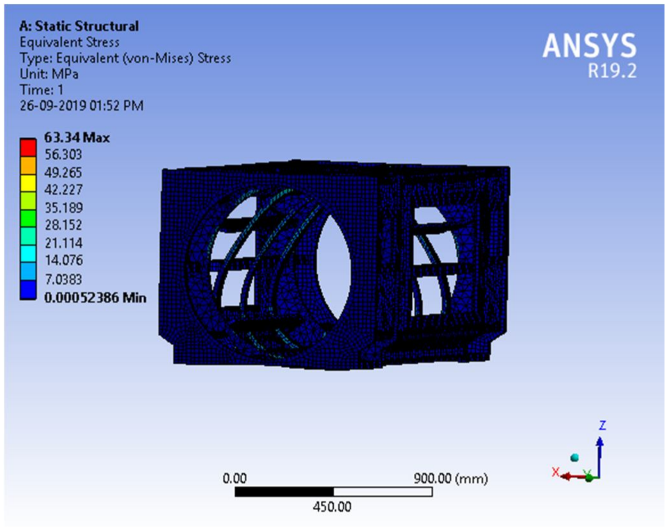

Fig.-6 Stress built up in frame due to static loads

C. Modal Analysis Of Stator Frame

It is important to find the system's natural frequency to predict the system's rate of vibration, so that The resonant frequency must not be the same as the operating frequency, in order to introduce smooth system operation by keeping the operating frequency well below the resonating frequency.

Therefore it is important to predict the system's natural frequency in order to avoid resonance. ANSYS software is used to predict the natural frequency of new stator frame. ANSYS solution of modal analysis shown in fig.-7.

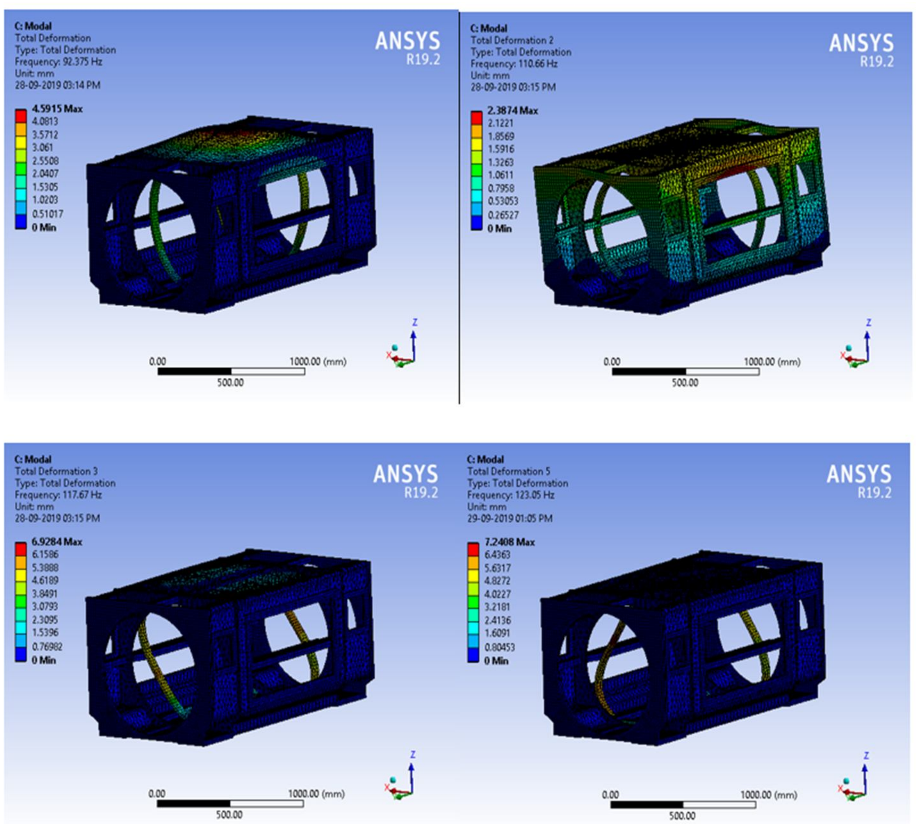

Fig.-7 Different modes of vibration

III. RESULTS AND DISCUSSION

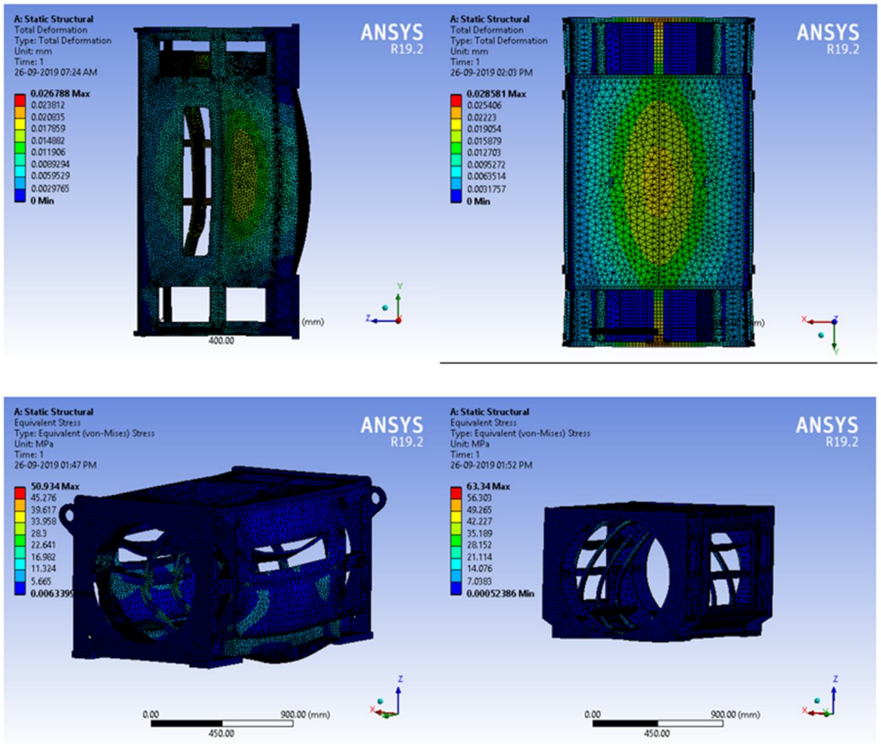

Fig.-8 Structural analysis results for optimized and old frame

From the above fig.-8, it is observed that static stress and total deformation developed in the new stator frame is slightly greater in comparison with old body. Deflection found in the new stator frame increases due to mass reduction. Therefore it will develop slightly high stress in the stator frame but In view of the motor stability, this small increase seems marginal in comparison to its factor of safety.

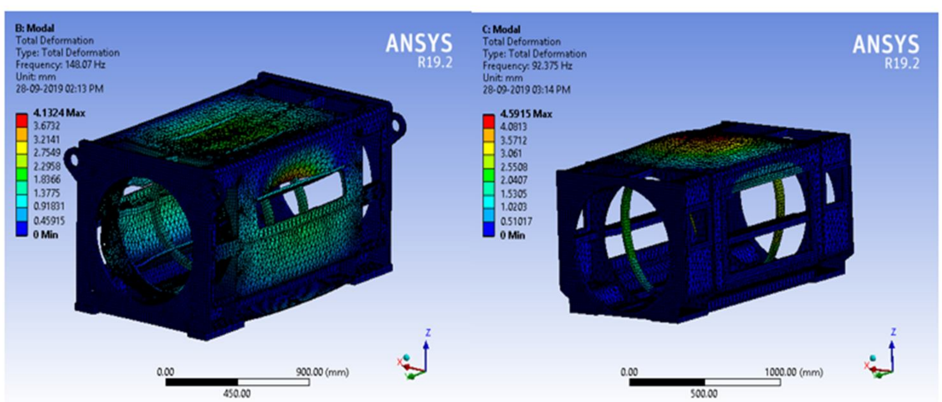

Fig.-9 Natural frequency of optimized and old frame

From the above result it is observed that in the old stator frame the amount of natural frequency is more compared to the new optimized stator frame, This is because the small amount of new frame mass was decreased during optimization when compared to the old body. As a result, the stiffness of the stator frame decreased with a small reduction in mass. But if we equate the frequency produced with the frequency of operation 50 Hz of the system, the difference between both of them is very large. Therefore, even small mass reduction will not impact system performance.

Table-2 Validation of results

Parameter	Existing stator frame	Optimized stator frame
Material	Structural steel E250 A	Structural steel E250 A
Total Deformation calculated	Max. 0.026788 mm.	Max. 0.028581 mm.
Equivalent stress calculated (in N/mm2)	Max. 50.93	Max. 63.34
Weight (in Kg.)	1250	1050

IV. CONCLUSION

Following are the conclusions drawn based on this work:

A. In concerned to stator frame optimization, mass of frame reduced to 1050 kg, in comparison with old frame mass i.e. 1250 kg. Size of stator frame also reduced from 1920mm. x 1034mm. x 1023mm. to 1880mm. x 1034mm. x 900mm.
B. In concerned to structural analysis of stator frame, amount of stress, 63.3 N/mm2 produced in the new optimized stator frame is more in comparison with the old stator frame but by observing the strength with respect to factor of safety the new frame seems to be highly stable for the specified loading condition.
C. In terms of modal analysis, the amount of natural frequency in the optimized new stator frame was smaller than in the previous old stator frame because of its stiffness and mass, Although after optimization the difference between operating frequency and resonating frequency is high.

V. SCOPE OF FUTURE WORK

The following areas as recommendations for further work study.

A. The study can further extended to thermal analysis of complete motor system.
B. Finite element analysis of stator frame can perform for different materials.
C. Static and dynamic analysis of complete motor system can perform.

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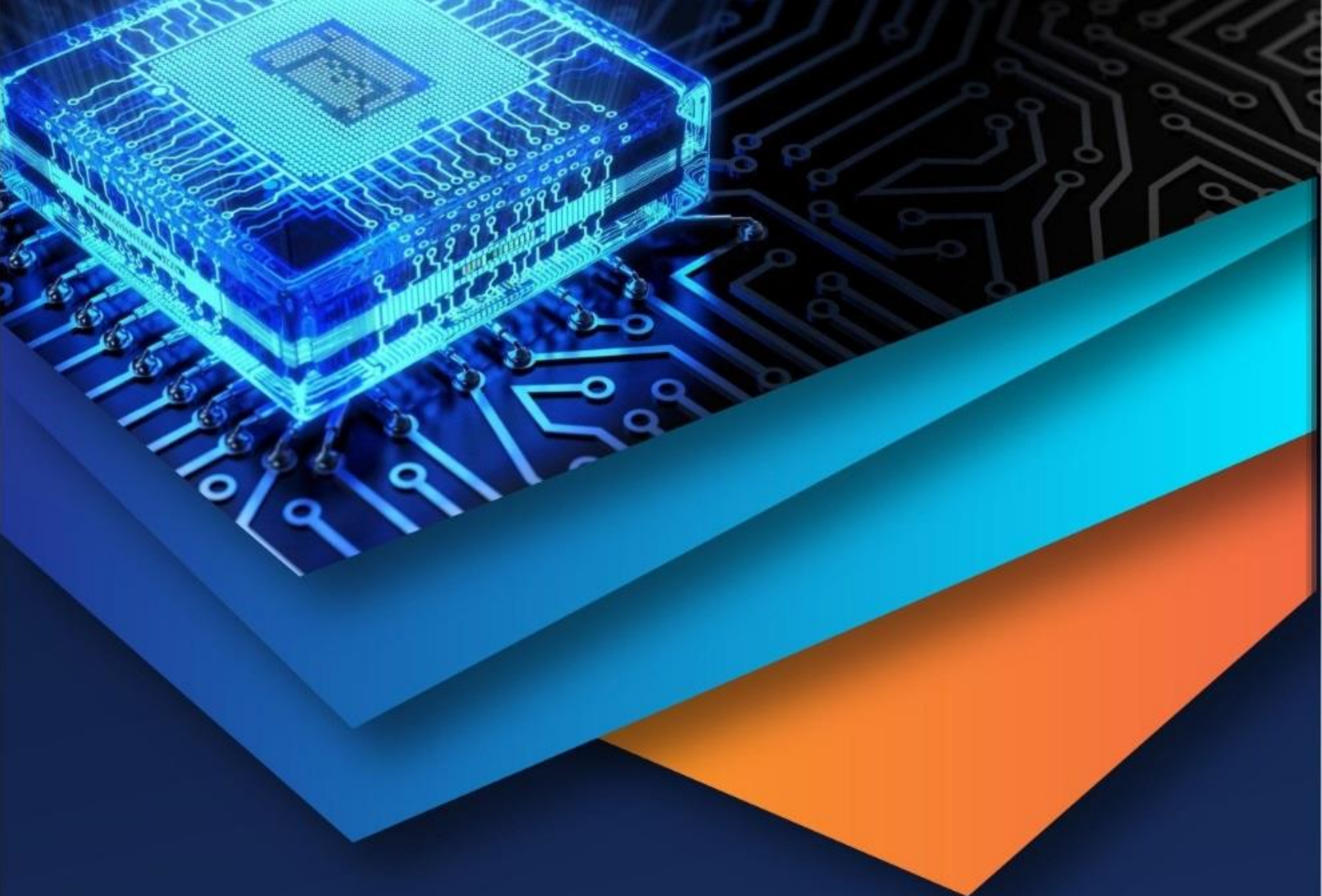

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