iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 11 Issue: VII Month of publication: July 2023

DOI: https://doi.org/10.22214/ijraset.2023.54929

Lift and Drag Analysis of NACA 1412 Airfoil Using Unstructured Mesh

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Abstract: This research paper gives insight to the analysis of NACA 1412 airfoil. The airfoil is the two-dimensional cross section of the aircraft's wing. The aircraft flies due to generation of the lift, this lift is caused by the pressure difference on the upper and lower surface of the airfoil. The pressure on the lower surface is greater than the pressure on upper surface which provides a lift to the airfoil. We are going to see the airfoil's behaviour in incompressible flow at different angles of attack with constant velocity. In this research, we are going to use the Ansys software to do the analysis. This research is based on the computational fluid dynamics concepts. At the end, we will see how the lift and drag changes at different angles of attack and some graphical results from the research.
Keywords: Airfoil, Ansys, mesh, angle of attack, stall.

I. INTRODUCTION

When the aircraft is flying, there are four main forces which acts on it, they are, lift, drag, thrust and gravity. Wherever there's a lift, drag is there. To reduce this drag force and to increase the aircraft's efficiency the designers use different types of airfoils like symmetrical and unsymmetrical or camber. Before all the software, we had to do all the analysis in the wind tunnels, but now Ansys has taken its position and it's playing an important role in the aviation industry. Here, we are going to use the Design Modeler to design the airfoil and the respective domain and grid our geometry in the Mesh. Fluent solver makes the important part of the analysis. NACA 1412 is a four-digit airfoil. It is an unsymmetrical or cambered airfoil. National Advisory Committee for Aeronautics first developed these NACA airfoils. In the four digits, the first number denotes the maximum camber in percentage with respect to the chord. Second number indicates the location of the maximum camber which is given in tenth of chord and the percentage of maximum thickness of the airfoil is given by the last two numbers with respect to chord. In NACA 1412, we have camber of 1% which is located at the 40% behind the leading edge of the airfoil and it has maximum thickness of 12%. This paper describes the behaviour of the airfoil at 0, 3, 6, 9 and 12 degrees of angle of attack at the constant velocity and then the values of coefficient of lift and coefficient of drag will be plotted with the help of graphs.

II. BASIC TERMINOLOGIES OF THE AIRFOIL

Lift : The aerodynamic force which is perpendicular to the direction of the wind due the pressure difference between upper and lower surface of the object is called lift.
Drag : It is an opposing force acting on a body.
Angle of attack : The angle between the chord line and free stream velocity is called angle of attack.
Chord line : The straight line joining the leading edge and trailing edge is called chord line.
Mean camber line : The line dividing the airfoil into two equal parts is known as mean camber line.
Reynold's number : It is the ratio of inertial force to the viscous force.

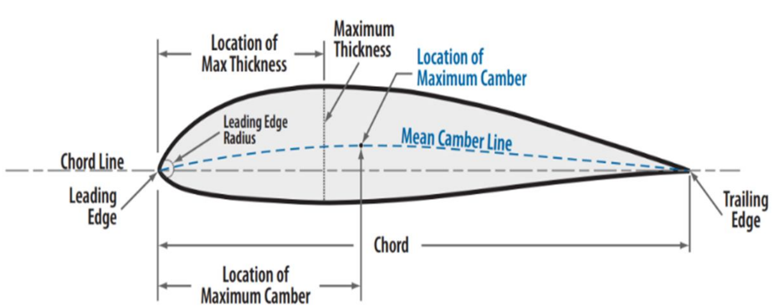


Fig. 1 Airfoil nomenclature

Coefficient of lift : $C_l = \frac{L}{\frac{1}{2}\rho v^2 S}$

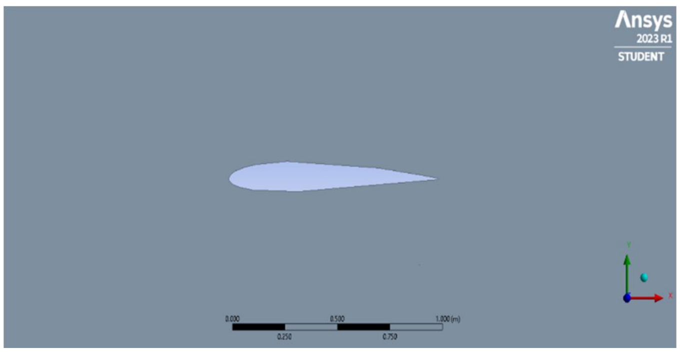
where L = Lift, ρ = Air density, v = Velocity, S = Area of the airfoil

Coefficient of drag : $C_d = \frac{D}{\frac{1}{2}\rho v^2 S}$

where D = Drag, ρ = Air density, v = Velocity, S = Area of the airfoil

III. DESIGNING AND MESHING OF THE AIRFOIL

NACA 1412 is an unsymmetrical airfoil with the maximum thickness of 12%. The design of the given airfoil is done in the Ansys Design Modeler. The co-ordinates of the airfoil are imported from the airfoiltools into the Design Modeler. The figures below show the design and the complete Unstructured mesh of the airfoil.



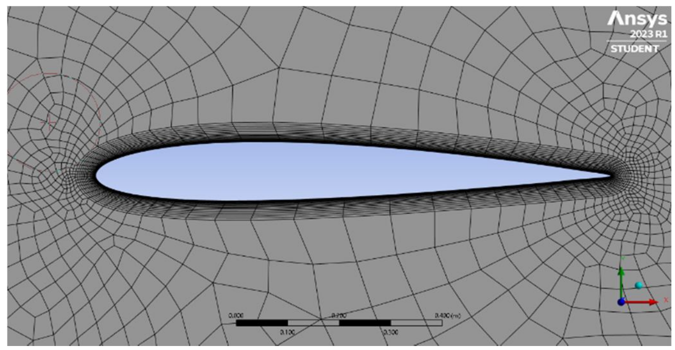


Fig. 2 Desing of airfoil Fig. 3 Inflation layers

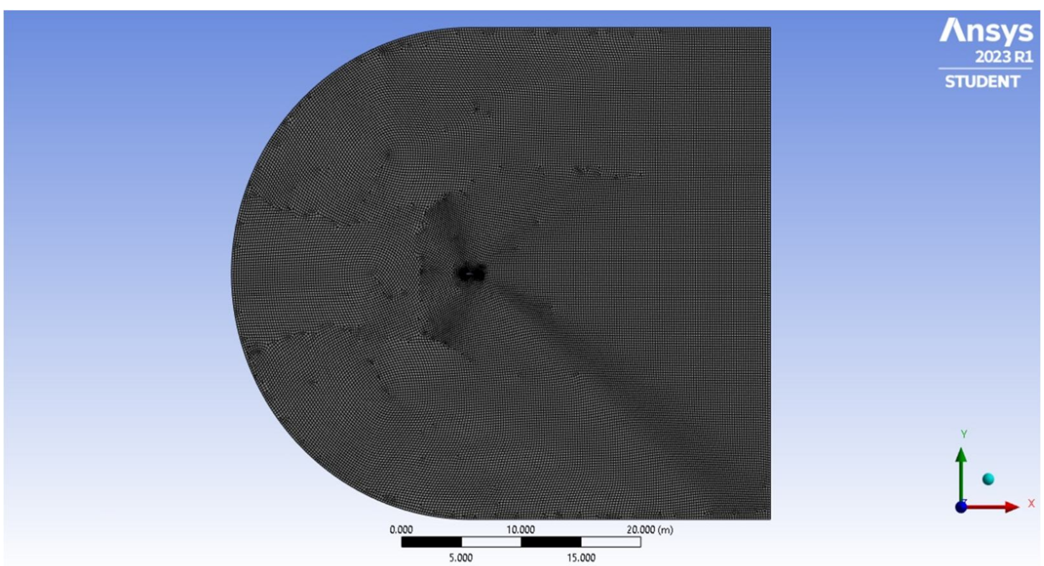


Fig. 2 Unstructured mesh

IV. BOUNDARY CONDITIONS

This NACA 1412 airfoil will be tested at different angles of attack i.e., 0, 3, 6, 9 and 12 degrees. In boundary conditions, the inlet velocity is given as 88.653 m/s at constant air temperature of 288.16 K. Here, two equation model k-ε is used where k is the kinetic energy and ε is the rate of dissipation of the turbulent kinetic energy. The production of kinetic energy is larger due to large rate of dissipation. The effect of turbulent kinetic energy can be observed by the k-ε model.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 11 Issue VII Jul 2023- Available at www.ijraset.com

TABLE 1 Operating Conditions

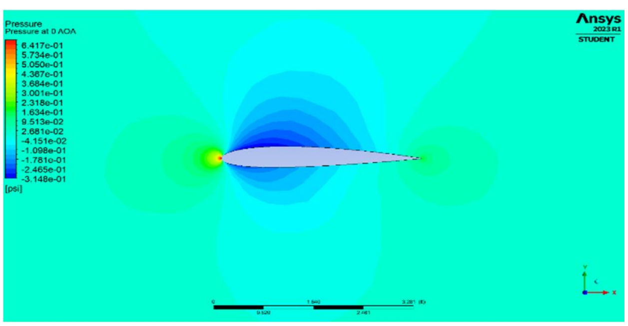
Inputs	**Values**
Velocity at the inlet	88.653 m/s
Fluid	Air
Density of the fluid	1.225 kg/m^3
Operating pressure	101325 Pa
Chord length	1 m
Model	Standard k-ε
Angles of attack	0, 3, 6, 9 and 12
Reynold's number	6000000

V. RESULTS

In the velocity contours, the blue coloured region at the leading edge is the stagnation point at which the velocity of the fluid is almost equal to zero. The upper surface of the airfoil faces the higher velocity than the lower surface. This causes the pressure difference on the both upper and lower surfaces, the pressure on the lower surface is higher than the pressure on the upper surface which creates the lift.

A. *Velocity and Pressure Contours*

1) *At 0^0 Angle of Attack*



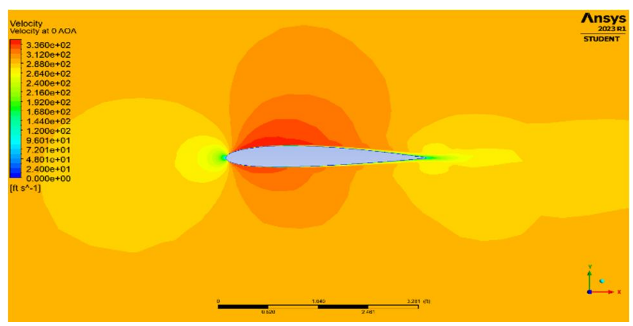
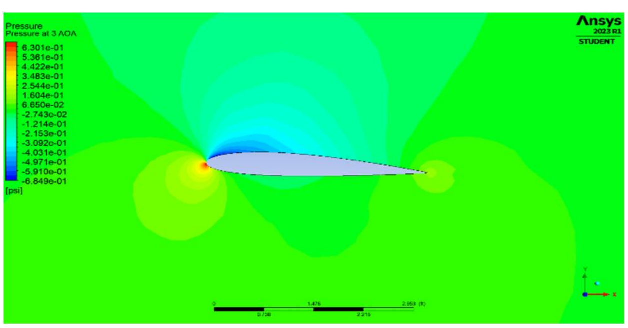


Fig. 5(a) Pressure contour Fig. 5(b) Velocity contour

2) *At 30 Angle of Attack*



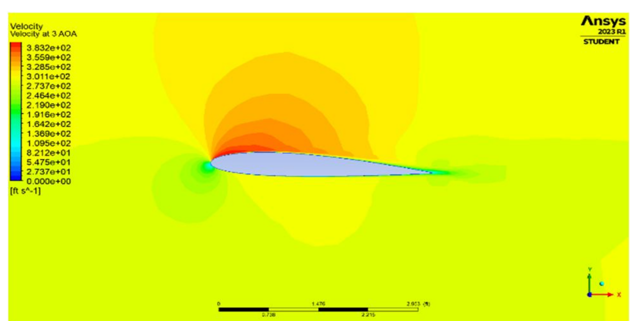
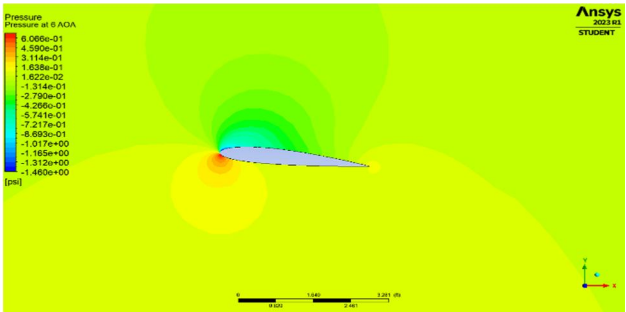


Fig. 6(a) Pressure contour Fig. 6(b) Velocity contour

3) At 60 Angles of Attack



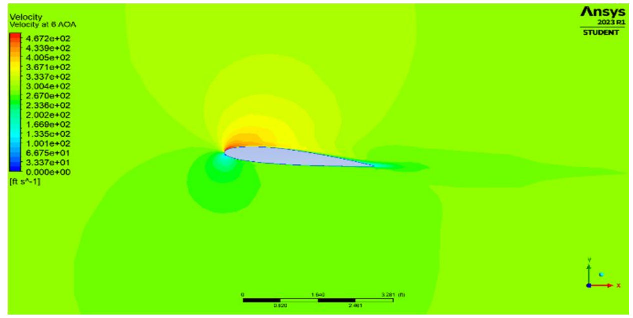
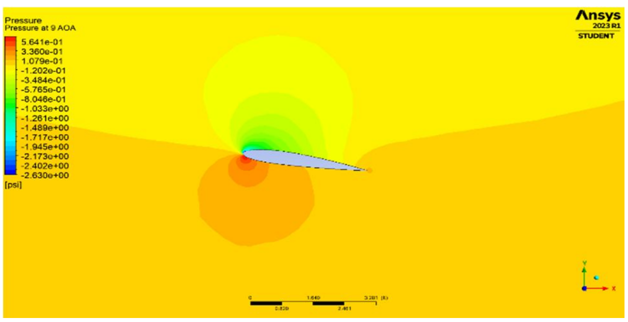


Fig. 7(a) Pressure contour   Fig. 7(b) Velocity contour

4) At 90 Angles of Attack



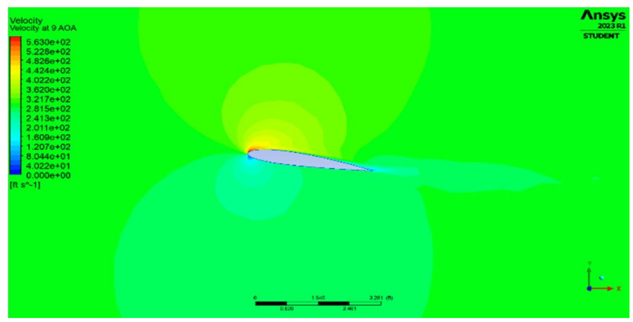
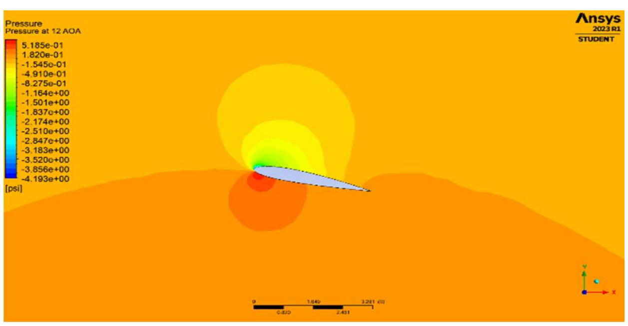
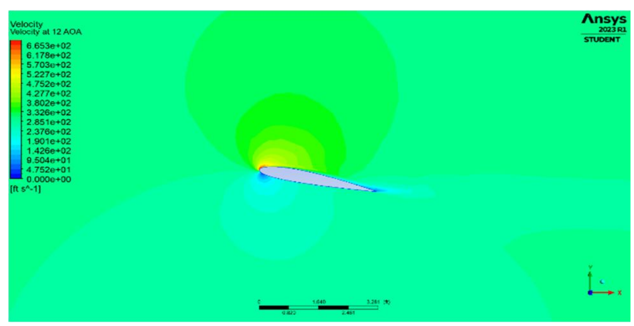


Fig. 8(a) Pressure contour   Fig. 8(b) Velocity contour

5) At 120 Angle of Attack





Fig, 9(a) Pressure contour   Fig. 9(b) Velocity contour

TABLE 2 COMPUTED DATA

Angle of attack	Cl	Cd	Cl/Cd
0	0.104	0.010	10.40
3	0.427	0.011	38.81
6	0.737	0.016	46.06
9	1.033	0.022	46.95
12	1.286	0.033	38.96

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
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Volume 11 Issue VII Jul 2023- Available at www.ijraset.com

B. Graphs

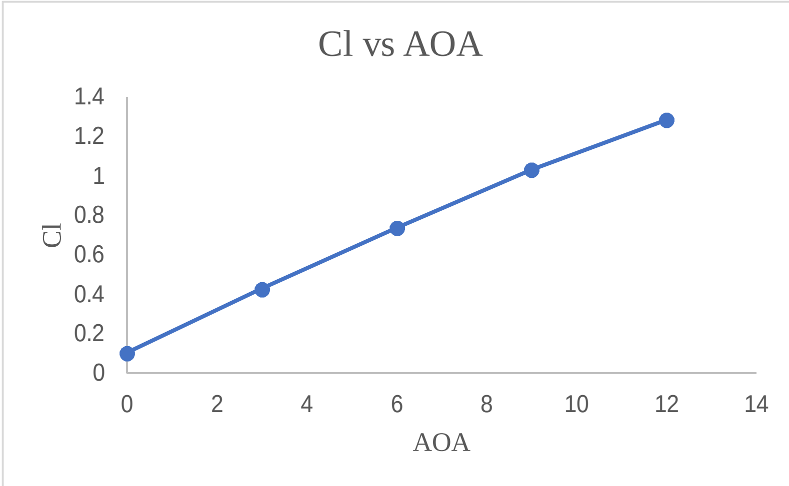

Fig. 10 Cl vs Angle of attack

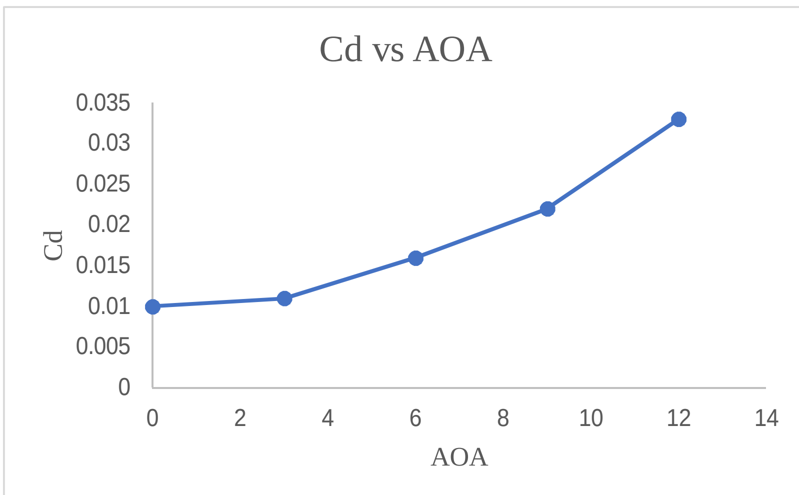

Fig. 11 Cd vs Angle of attack

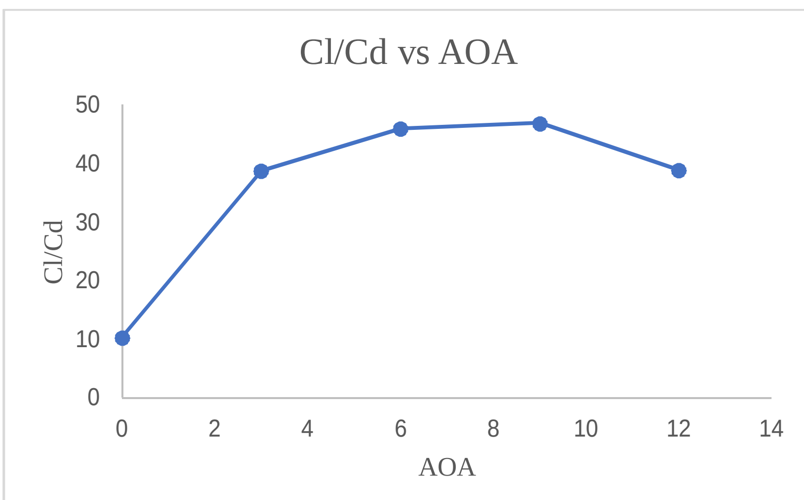

Fig. 12 Cl/Cd vs Angle of attack

VI. CONCLUSION

As the angle of attack increases, the Cl and Cd values increases. From the figures 5, 6, 7, 8 and 9, it can be seen that the upper surface of the airfoil experiences low pressure and the lower surface experiences high pressure. In case of velocity, the velocity is higher over the airfoil as compared to the bottom of the airfoil. At certain angle the lift suddenly goes down due to the gradually increasing drag and the flow separation. This condition is called stalling and the angle is known as critical angle. This type of airfoil is used in the aircraft's wing.

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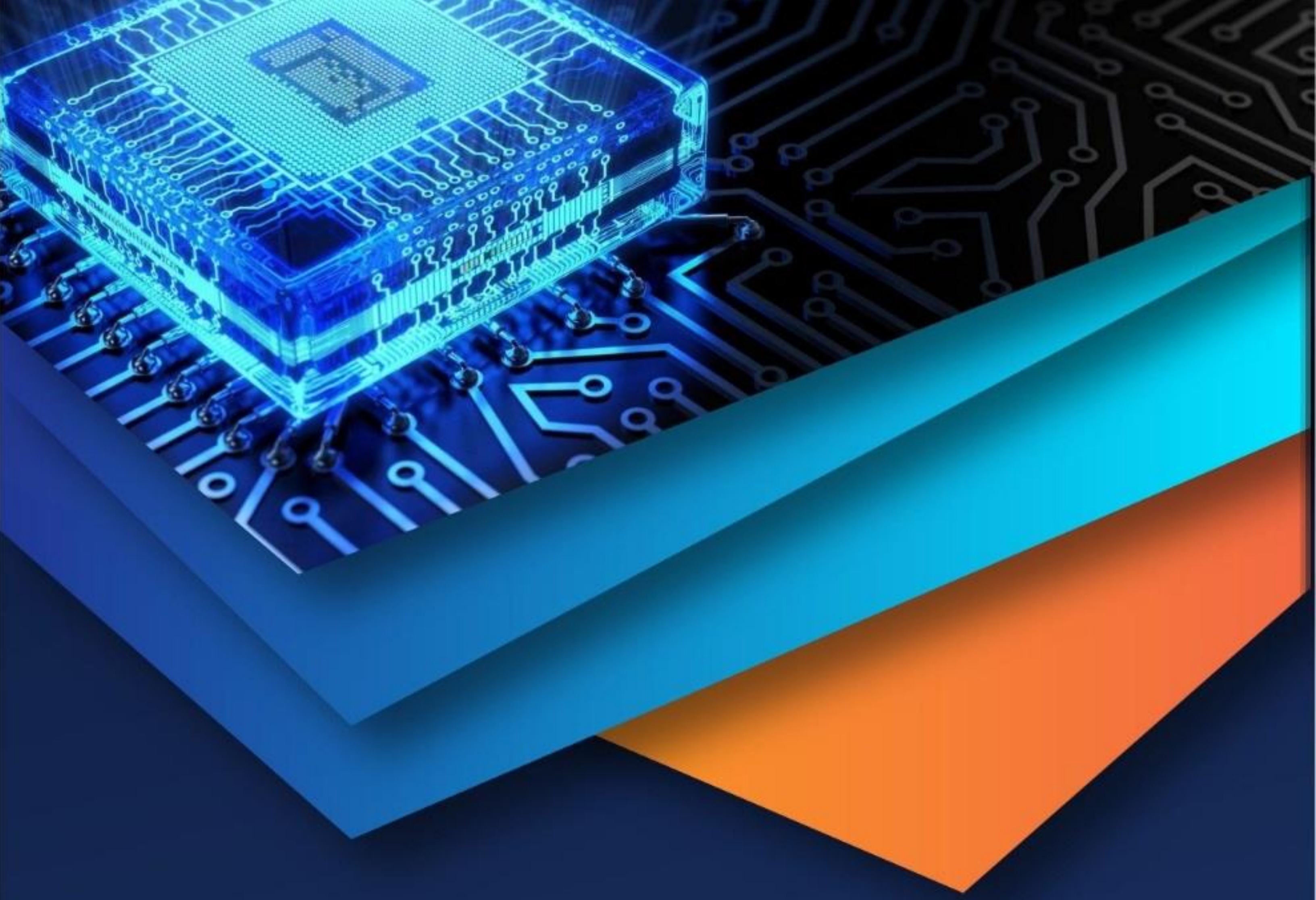

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