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Solenoid and Electromagnet Engine

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Abstract: ***While researching in the field of ic engine development, I found research using a solenoid system in the IC engine to reduce the use of endless and essential fuel and reduce carbon emissions by cars because electric cars are promising technologies for the future. The research I encountered was prioritized by Ad. Bulman in his book 'Model Making For Young Physicists' with Alfred p. Morgan in his book 'The Electric Boy'. The main difference in their studies was that 'Burman' had one solenoid while 'Morgan' had two and the only commonality among the models was that they had moving parts.***
Our project is based on the policy of developing an alternative EV prime mover design to replace an electric vehicle. The design works as the IC engine works. Our design uses a TDC solenoid and an electromagnet in the BDC area of the cylinder. Our piston is hollow cylindrical shaped and have permanents magnet at the top and the bottom. Instead of compression rings we are using ball bearings to make the movement smoother. Solenoid and electromagnet are powered by a battery of suitable voltages. The solenoid has variable polarity so that the solenoid produce attraction and repulsion and electromagnet fixed with repulsive polarity. The electrical system generally operates on the principles of electromagnetic induction by converting electrical energy into kinetic energy. The whole system is working on the application of magnetic field magnetic field and electromagnetic repulsion so in this way this force moves the piston TDC TO BDC to this symmetric step of the piston when the movement is transferred to the crankshaft with the connecting rod. Our goal is to remove the flywheel to make the system more stable which makes the system produce less vibration, ease and reduce various engine losses, the benefit of our system is that we use a hollow rifle making the engine lighter and using the ball bearings instead of piston rings this will make movement easier, we can use luggage because there is no outbreak so we do not need to prevent overflow. The solenoid is controlled by a small controller and transmits through the crank sensor.
Keywords: Solenoid, TDC (upper dead center), BDC (lower dead center), Micro controller.

I. INTRODUCTION

The internal combustion engine is a type of thermal engine in which the combustion of the fuel takes place in the presence of air inside a combustion chamber. This combustion leads to the expansion of fuel producing high temperature and high pressure, this high pressure high temperature gas is then used to apply force to some parts of engine. Power is usually applied to a piston, turbine blade, nozzle or rotor. This force moves that part at a distance, turning chemical energy into useful work.
The term internal combustion engine usually refers to an engine in which the combustion is carried out at irregular intervals, the best known being the four-stroke and two-stroke piston engines.
In a spark-ignition engine, fuel is mixed with air and then injected into the cylinder during the intake process. The piston then compresses the fuel-air mixture, this mixture is then ignited by a spark plug which leads to the combustion of gases. The expansion of combustion gases pushes the piston during a power stroke. Piston's Top Dead Center (TDC) in the 4-stroke engine is the closest point to the valves; The Bottom Dead Center (BDC) below is the opposite point away from them. A stroke is a movement of a piston from TDC to BDC or vice versa, together with the associated process. While an engine is in operation, the crankshaft rotates continuously at a nearly constant speed.
In a 4-stroke ICE, each piston experiences 2 strokes per crankshaft revolution in the following order

A. Intake, induction or suction
B. Compression
C. Power or working stroke
D. Exhaust

A two-stroke (or two-cycle) engine is a type of internal combustion engine which completes the power cycle with two strokes (movement up and down) of the piston during a single rotation. This is in contrast to a "four-stroke engine", which requires four strokes of the piston to complete a power cycle during two crankshaft revolutions. In a two-stroke engine, combustion stroke end and compression stroke onset occur simultaneously, while intake and exhaust (or scavenging) functions occur simultaneously.

1) Power
2) Scavenging
3) Compression

The solenoid is a generic term for a coil of wire used as an electromagnet. In other words solenoid is a long piece of wire which is wound in the shape of a coil. It also refers to any device that converts electrical energy to mechanical energy using a solenoid. The device creates a magnetic field from electric current and uses the magnetic field to create linear motion. A solenoid is a type of electromagnet, the purpose of which is to generate a controlled magnetic field through a coil wound into a tightly packed helix. The coil can be fitted to produce a uniform magnetic field through which the electric current passes. The main advantage of an electromagnetic engine is that it does not use petroleum-based fuel, so there is no pollution.

II. WORKING PRINCIPLE

The system consists of a solenoid at the TDC (top dead centre) of the cylinder and an electromagnet at the BDC (bottom dead centre which is hollow disc type electromagnet) of the cylinder, and piston which itself is hollow and has hollow disk type permanent magnet at the lower end, disk type permanent magnet at the upper end (which reduce the size and weight of the piston as compared to a conventional piston) as shown in figure 1. The solenoid has variable polarity and the electromagnet is set with a fixed polarity which is repulsive polarity. This electromagnet (hollow disc type electromagnet is used at BDC) helps the system to work efficiently and effectively at high speed which is the main demerit of one solenoid type system and also helps to remove the flywheel. The compression and oil ring are also removed instead of that ball bearing are used to smoothen the process of linear motion of the piston and it also reduces friction loss. The solenoid inside cylinder (as shown in figure 2) produces a circular magnetic field which attracts and repel the piston according to the input sinusoidal form of current and BDC electromagnet is used to repel the piston upward direction so whole system work as when the piston is at BDC it gets repelled by an electromagnet which pushes the piston in an upward direction towards TDC, at TDC solenoid(circular shape) is present inside the cylinder, it attracts the piston and after that, it repels the piston towards BDC this is because sinusoidal input at first coil attracts then repel piston and electromagnet is used to power up the piston in upward motion just like a flywheel. The coil magnetic field prevents the piston from touching the cylinder wall and ball bearing also used to smoothen the motion (as shown in figure 4) so in this way the whole system works. In this system, whole system is controlled by a microcontroller, the ON/OFF timing of electromagnet i.e., at what time it should be off and at what time attraction of solenoid should start when the piston is moving downward, microcontroller switches of the solenoid and turns ON electromagnet. Hollow disk type Electromagnet is used in consideration of the movement of connecting rod as shown in the diagram. This attraction of solenoid (TDC) and electromagnetic (BDC) repulsion prevents any starting problem and therefore no additional starter is required. The piston is hollow lightweight and has a permanent magnet at both ends but at the lower end of the piston hollow disk type permanent magnet is used the same as electromagnet due to movement of connecting rod. The electromagnet at BDC (hollow disc type electromagnet) and solenoid at TDC are powered by the battery of suitable voltage as shown in figure 3. The advantage of this system is that our design consist of hollow piston making the engine lighter also we are using ball bearings instead of piston rings this will make movement smoother, we can use bearing because there is no combustion so we don't need to prevent the escape of any gasses. We are also not using flywheel which makes the engine lighter, the usage of a solenoid and the electromagnet at the TDC and BDC (hollow disc type electromagnet) respectively is that it helps us in the removal of the fuel supply system, ignition system, cooling system and also removes the flywheel which stores the energy during the expansion stroke and provide this energy during the exhaust stroke, but here the solenoid at BDC provides the repulsive force and thus the energy to move the piston from BDC TO TDC, thus eliminating the various engine losses. By repeating this series of electromagnetic forces and magnetic resonance energy it forces the recursive movement of the piston. The maximum constant pull happens when one end of the piston is at the middle of the solenoid.

$$F=CAnI/L$$

Where,

C = proportionality constant.
A = cross-sectional area of the piston.
n = number of turns wire in the solenoid.
I = current through the solenoid wire.
L = length of the solenoid.

The solenoid pulls when the piston is far away, but it greatly increases the pull force when it is near.

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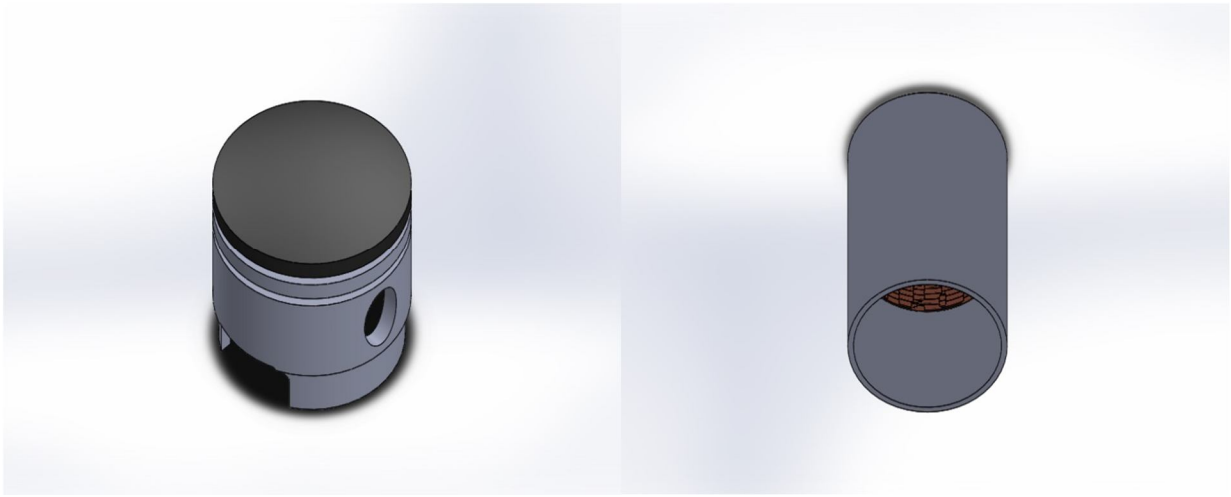


Figure.1. Disk type permanent magnet at the upper end and hollow disk type magnet at lower end

Figure.2. Solenoid (circular shape) is present inside the cylinder

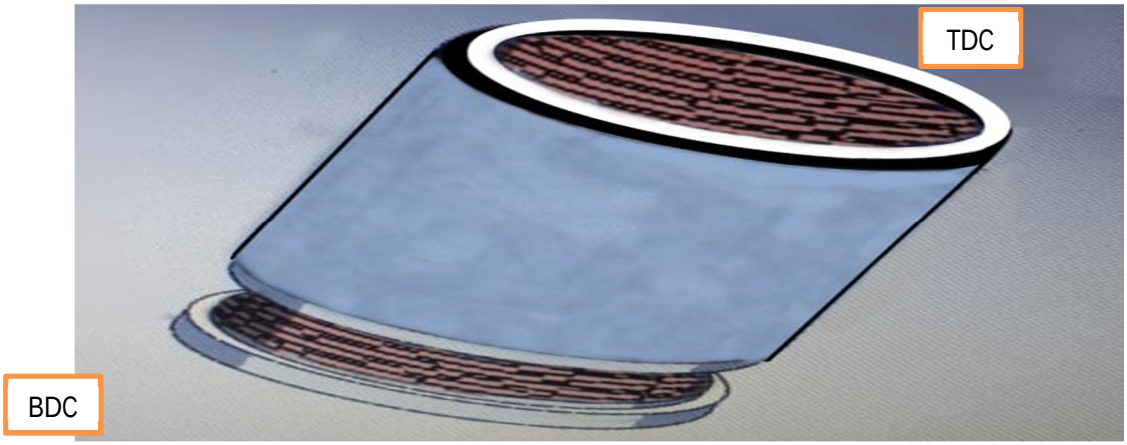


Figure.3. Solenoid fitted inside the cylinder at TDC and electromagnet is fitted lower end of cylinder at BDC

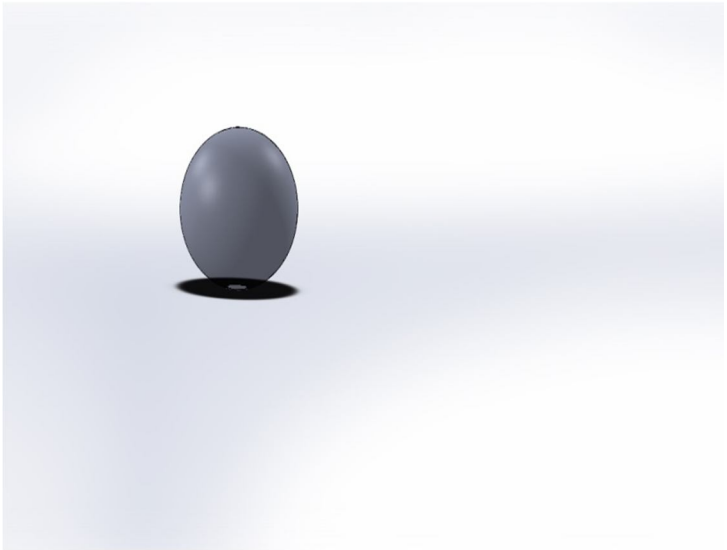


Figure.4. Steel ball used in bearing ring

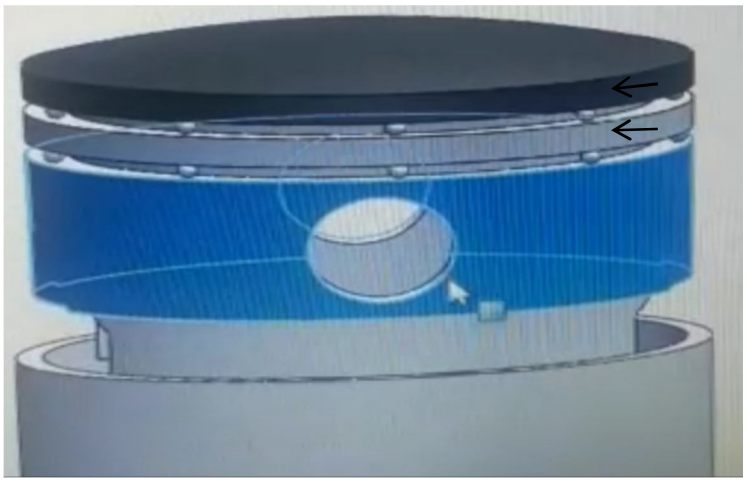


Figure.5. Bearing rings for smoothening the reciprocating Motion

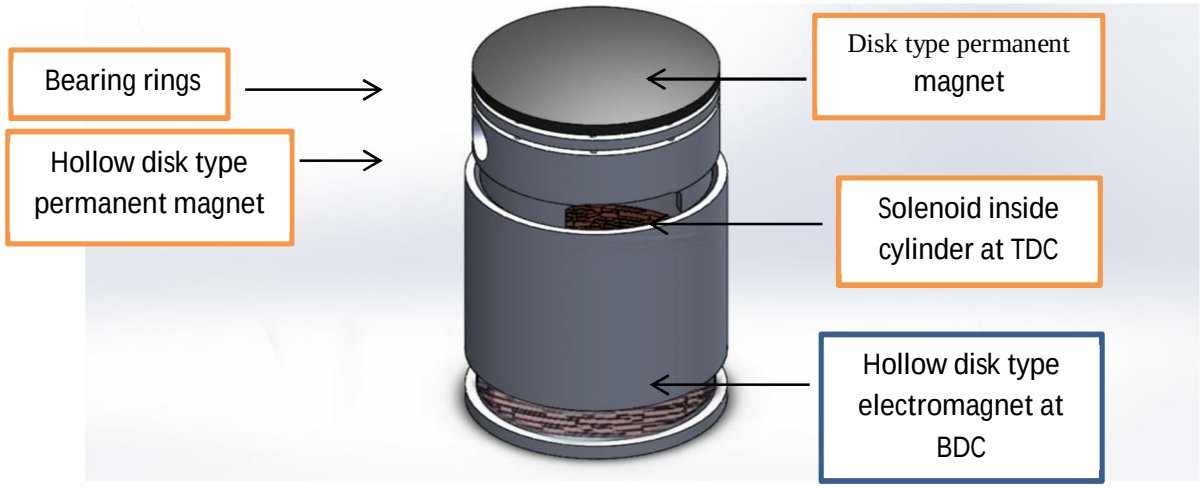


Figure.6. complete system assembly

III. MATHEMATICAL CALCULATION

As per the system requirement maximum force exerted by the solenoid on the piston

$F1 = N^2*I^2*K*A / 2G^2$

So now let us consider the bore radius of the cylinder is 0.0186m and the stroke length of the cylinder is 0.184m

So the volume of the cylinder is $.0002m^3$ or in other words, it is a 200cc engine

So now for the maximum force exerted by a solenoid on the piston

$F_1=N^2*I^2*K*A/2G^2$ …….. (I)

Where N is no of wounds in the solenoid

I is the current in the wire of the solenoid

K is the permeability constant

A is base area of the solenoid

G is the gap between the piston and the cylinder

So according to system predicted requirement

N = 1050

I = 1.5A

$K = 4pi*10^{-7}$

$A = pi*r^2$

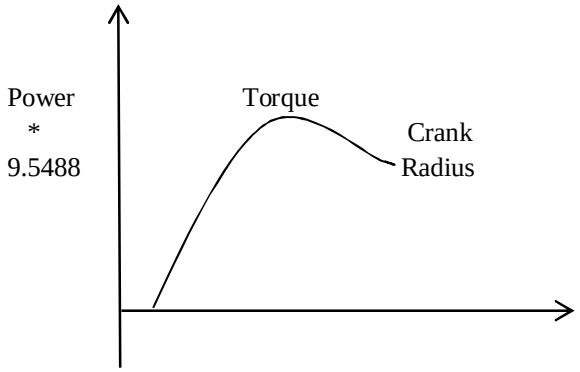
$A = pi*(.0186)^2 =0.001086m^2$

G = 0.004m
By putting the values in equation (I)
$F_1 = (1050)^2*(1.5)^2*4pi*10^{-7}*.001086 / 2*(.004)^2$
$F_1 = 105.73$ N
Now the force exerted by the permanent magnet (on top of the piston) to the solenoid
$F_2 = B^2*A / 2\mu_O$
Where B is flux density (T)
A is the cross-sectional area of permanent magnet = $pi*r^2$
μ_O permeability of free space = $4pi*10^{-7}$
For flux density
$B = Br/2 \times [(D + z)/ \sqrt{(R^2 + (D + z)^{2)}} - z/ \sqrt{(R^2 + z^2)}]$ …….. (II)
B_r: Remanence field, independent of the magnet's geometry = 1.37 T
z: Distance from a pole face on the symmetrical axis = 0.004m
D: Thickness of the cylinder = 0.0125m
R: Semi-diameter (radius) of the cylinder = 0.0136m
Put the values in equation (II)
So B = 0.337568
Now the force exerted by the permanent magnet on the solenoid
$F_2 = B^2*A / 2\mu_O$ …… (III)
Put the values in equation (III)
So $F_2 = 26.3$ N
Now the force exerted by the permanent magnet (mounted on bottom of the piston) on the electromagnet
$B=Br / 2[D +z / \sqrt{R_O^2 +((D + z)^2)} - z/ \sqrt{(R_O^2 + z^2)} -\{ D +z / \sqrt{R_i^2 + ((D + z)^2)} - z/ \sqrt{(R_i^2 + z^2)}\}]$
…….... (IV)
B_r: Remanence field, independent of the magnet's geometry = 1.37 T
z: Distance from a pole face on the symmetry axis = 0.004m
D: Thickness of the cylinder = 0.013m
R_o: Outside radius of the ring = 0.0136m
R_i: Inside radius of the ring = 0.0036m
So putting the value in equation (IV)
B = –.1920545942
So $F_3 = B^2*A / 2\mu_O$ …….... (V)
A (area of permanent magnet used in bottom end of piston = $pi * (R^2 - r^2)$
$A = 3.14 * ((0.0136)^2 - (0.0036)^2)$ (R = 0.0136 and r = 0.0036)
$A = 0.00054008$ m^2
B = 0.337568
$\mu_O = 4pi*10^{-7}$
Putting value in equation (V)
We get $F_3 = 7.6$ N
Force exerted by the electromagnet on the piston
So according to system predicted requirement
N= 1300
I= 1.5A
K= $4pi*10^{-7}$
A= $pi * (R^2 - r^2)$
$A = 3.14 * ((0.0136)^2 - (0.0036)^2)$ (R = 0.0136 and r = 0.0036)
G = 0.004m
$F_4 = (1100)^2*(2)^2*4pi*10^{-7}*0.00054008 / 2*(.004)^2$ …….. (VI)
By putting the values in equation (VI)
So $F_4 = 102.6$ N

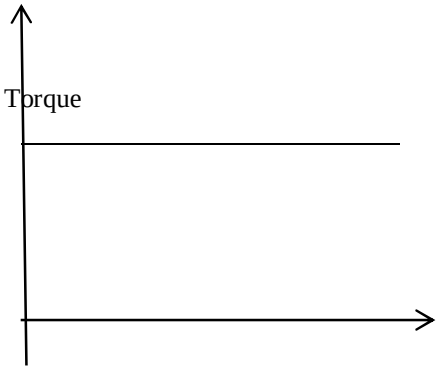
Now calculation of torque total downward force acting on the piston
Torque (Nm) = Force (N) x Crank Radius (m) (Where R = .092)
So torque is
$F = F_1 - F_2 + F_3 - F_4$, F = 6 N
T = 0.552 Nm
Now power generated by Conventional 200 cc engine can be calculated by relation 14cc = 1hp
So HP = 200 / 14, HP = 14.28571KW
Torque (Nm) = 9.5488 x Power (kW) / Speed (RPM)
So assume that system is working at 200 RPM
So torque is 0.662Nm

IV. RESULTS

The prototype works just like an internal combustion engine but produces less amount of torque as compared to a conventional IC engine that is 0.552Nm.so further development is necessary to develop the system to produce more torque.



Speed (Fig.1)



Force (Fig.2)

As shown in figure.1torque will increase at certain point and after that it will decrease as speed increases torque will decreases as according to formula (Torque (Nm) = 9.5488 x Power (kW) / Speed (RPM)). But in figure.2 shows that force is variable and crank radius is constant so force will increases as current increase in that way torque is constant throughout power band which makes system efficient as according to formula (Torque (Nm) = Force x Crank Radius).

V. CONCLUSION

A. The system works efficiently and effectively on high speed which is the main demerit of one solenoid engine
B. There is no need for flywheel instead of flywheel, system equipped with an electromagnet to give power as a flywheel to complete the cycle.
C. The system consists of solenoid and electromagnet (which is specially designed according to connecting rod moment
D. The system also consists of two permanent magnets one is at the top of piston which is solid disk type of certain thickness and another is at the bottom of the piston which is hollow disk type of certain thickness
E. The main advantage of the system that is doesn't produce any kind of pollution as compared traditional petroleum fuel-based engine and this engine helps to reduce the dependency on fossil fuel.

This system required more development for its use in the near future. Further improvement in design is needed to work effectively in the future.

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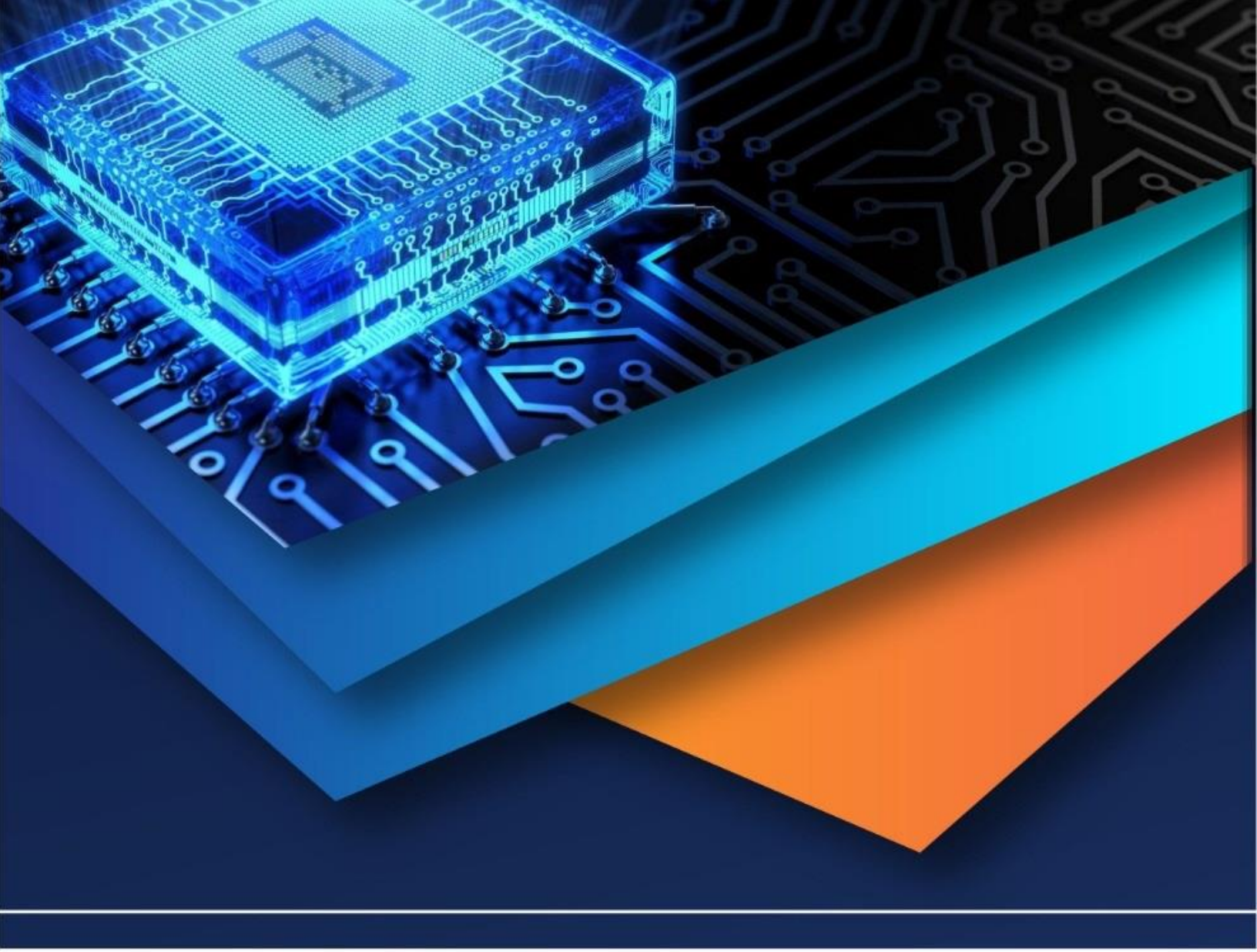

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