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Investigation of the Performance of Four-stroke Single Cylinder DI Diesel Engine of Toroidal Combustion Chamber Tested with Blends of Olive oil

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Abstract: Internal combustion engines are established as the main power source for automobile vehicles. At present emission norms become strict for any IC engine. The main emissions are CO, HC, NO_X, PM and sooth. These emissions are formed due to incomplete combustion of fuel and high temperature available in the combustion chamber. Many techniques are used to reduce this emissions such as changing the combustion chamber geometries, EGR, changing the pressure of intake air and using catalytic convertors. The present work discuss about the effect of toroidal shape combustion chamber geometry for four stroke single cylinder DI diesel engine fueled with blends of an olive oil. The idea behind this geometry is to provide a powerful squish along with air movement within the toroidal chamber. Due to powerful squish the mask needed on inlet valve is small and there is better utilization of oxygen. It is proposed to carry out an experiment on a four stroke single cylinder diesel engine by using olive oil as an alternate fuel at different proportions. Performance parameters such as Brake power, Brake specific fuel consumption and Brake thermal efficiency are calculated based on experimental study on the single cylinder four stroke CI engine and emissions such as CO, CO_2, UHC and NO_X are measured. Performance parameters and emissions characteristics of normal piston are compared with modified piston and other blends of olive oil. It has been observed that Performance parameters such as Brake Thermal efficiency is increased for modified piston with alternative fuel at B20 compared to Diesel fuel and Brake Specific Fuel Consumption is good for alternative fuel at B20 compared to Diesel fuel. Emissions such as CO is slightly decreased for alternative fuel at B30 compared to Diesel fuel and NO_X is slightly increased for modified piston with alternative fuel at B30 compared to Diesel fuel.
Keywords: CO- Carbon Monoxide, DI- Direct Injection, UHC- Unburnt Hydro Carbons, Transesterification, Olive oil, NO_x- Nitrogen oxide, MP-Modified Piston, NP-Normal Piston.

I. INTRODUCTION

The compression ignition engine is an internal combustion engine that uses the increase in temperature in the compression stroke to ignite a fuel charge (fuel air mixture). This is also called auto ignition. These engines are always fuel injected. Air is drawn into the cylinder through the intake manifold and compressed by the piston. The most important function of the C.I engine combustion chamber is to provide proper mixing of fuel and air (called carburetion) in a short time to lessen ignition lag phase. In order to achieve these, an organized air movement called air swirl is provided to produce high relative velocity between fuel droplets and air. When the liquid fuel is injected into the combustion chamber, the spray cone gets distributed due to the air motion and turbulence inside. The onset of combustion will cause an added turbulence that can be guided by the shape of the combustion chamber. Swirl is defined as organized rotation of charge about the cylinder axis. Swirl is created by bringing an intake flow into the cylinder with an angular momentum. Swirl is used in C.I engine concepts to promote more rapid mixing between the inducted air charge and the injected fuel. Squish is the name given to the radially inward or transverse gas motion that occurs towards the end of the compression stroke when apportion of piston face and cylinder head approach each other closely.

In the suction stroke inlet air which is entering in to the engine cylinder is compressed to higher pressure and temperature which is not sufficient to mix with the fuel injector and some of the fuel particular are not burnt in this process and leaves into atmosphere from exhaust stroke due to this there is a loss of fuel and also produces less power than the required power output. Engine performance improvement and exhaust emissions reduction are the two most important issues to develop a more efficient engine with less environmental impact. Better combustion characteristics would be achieved by introducing the swirl motion to inlet air with help of piston bowl geometry on piston crown.

Liquid biodiesels are more suitable for diesel engine applications as their properties are closer to diesel. The combustion chamber of an engine plays a major role during the combustion of wide variety of fuels. In this context, many researchers were performed both experimental and simulation studies on the use of various combustion chambers. Optimum combustion chamber geometry of engine must be considered to have a better engine operation, performance and emission levels. Suitable combustion geometry of bowl shape helps to increase squish area and proper mixing of gaseous fuel with air. Designing the combustion chamber with toroidal shape is to provide a powerful squish along with air movement, which helps to have desirable swirl and squish inside the combustion chamber, due to which the complete combustion will occur in the engine cylinder so that the emissions of an engine will reduce at some extent, experimental investigations were carried out on single cylinder four stroke direct injection diesel engine operated on blends of an Olive oil.

II. MATERIALS AND METHODS

A. Design of Piston Bowl Geometry

The shape of the combustion chamber and the fluid dynamics inside the chamber are important in diesel combustion. As the piston moves upward, the gas is pushed into the piston bowl. The geometry of the piston bowl can be designed to produce a squish and swirling action which can improve the fuel/air mixture formation before ignition takes place. The main goals desired from the design of chamber geometry are to optimize the mixing of the fuel and air, before and during ignition, and to improve the flow of the exhaust products once combustion is complete.

The idea behind this geometry is to provide a powerful squish along with air movement within the toroidal chamber. Due to powerful squish the mask needed on inlet valve is small and there is better utilization of oxygen. This geometry prevents the flame from spreading over to the squish region resulting in better mixture formation. As a result better air motion and lower exhaust soot thereby increase in swirl and tumble.

The piston crown of 80 mm diameter of base line engine is modified by producing a cavity bowl with 52mm diameter with a depth of 20mm and the radius of bowl curve 3mm is prepared with help of CNC lathe machine.

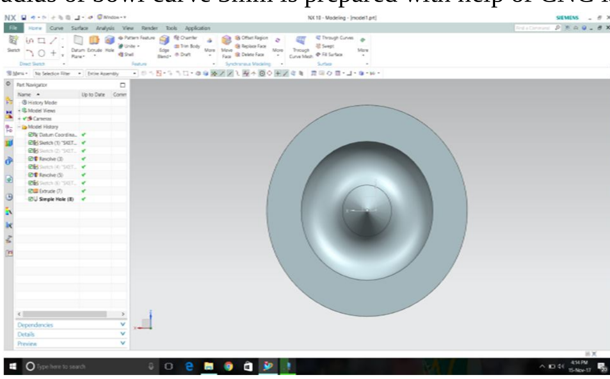

Fig 1 Modeling Piston

Fig 2 Manufactured Piston

III. EXPERIMENTAL SETUP

Experiment is carried out in diesel engine with the following engine specifications as shown in table:

A. Engine Specification

TABLE I: ENGINE SPECIFICATIONS

Model	AV1
Make	KIRLOSKAR
Type	Single cylinder, four stroke, water cooled
Bore	80mm
Stroke	110mm
Speed	1500rpm
Rated power	5hp

B. Procedure

Initially experiment is done on conventional engine fuelled with Diesel from no load to full load with the normal piston and the following readings are noted,

1) Engine speed
2) Time taken for 5cc of fuel consumption.
3) Voltmeter and ammeter readings.
4) Exhaust emissions such as CO2, CO, HC and NOx by using exhaust gas analyzer.

Then the experiment is carried out on conventional engine fuelled with pure diesel and blends of biodiesels (Olive oil) from no load to full load with the toroidal piston bowl geometry and the same procedure was repeated to evaluate the performance and emission characteristics. And the performance parameters and emission characteristics of Diesel and Biodiesel is compared.

Fig. 5 Engine Setup

C. Properties of Diesel and Olive oil

Table II: Properties Of Diesel And Olive Oil

PROPERTIES	DIESEL	OLIVE
Density (kg/M^3)	831	884.3
kinematic viscosity (CSt)	2.4	4.92
Calorific values (KJ/Kg)	42000	39952
Fire point(^{0}C)	68	120
Flash point(^{0}C)	51	111

Experimental Work carried out with Diesel and blends of olive oil with different Proportions

1) Normal Piston with 100% diesel
2) Modified Piston with 100% diesel
3) Modified Piston with B10 = (10% olive oil) + 90% Diesel
4) Modified Piston with B20 = (20% olive oil) + 80% Diesel
5) Modified Piston with B30 = (30% olive oil) + 70% Diesel
6) Modified Piston with B40= (40% olive oil) + 60% Diesel

IV. RESULTS AND DISCUSSIONS

A. Brake Specific Fuel Consumption

Brake specific fuel consumption (BSFC) is a measure of the fuel efficiency of any prime mover that burns fuel and produces rotational, or shaft, power. It is typically used for comparing the efficiency of internal combustion engines with a shaft output. It is widely used to measure engine performance.

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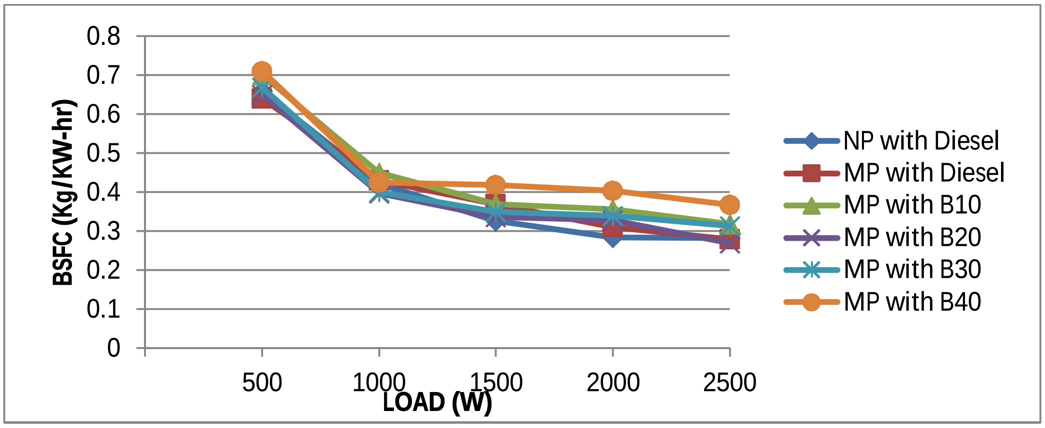

Fig. 7 Load vs Brake Specific Fuel Consumption

From the results, it is observed that the engine with modified piston results in good BSFC compared with naturally aspirated engine, among all the blends of olive oil B20 with modified piston gives good BSFC when engine is running at full load.

B. Brake Thermal Efficiency

Higher oxygen content and good spray characteristics resulting in high burning rate, which leads to high brake thermal efficiency.

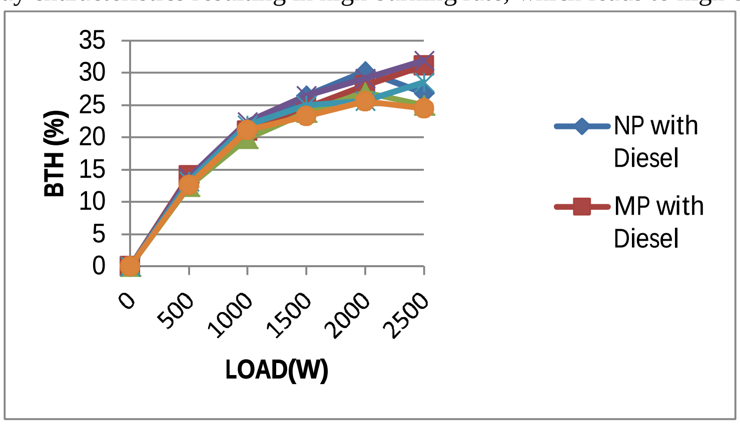

Fig. 8 Load vs Brake Thermal Efficiency

From the results, it is observed that the Brake thermal efficiency of the engine by different proportions normal piston with pure diesel, modified piston with pure diesel, modified piston with B10, modified piston with B20, modified piston with B30 and modified piston with B40 is observed as 29.68%, 31.1%, 25.2%, 31.9% 28.5% and 24.5% respectively. The B20 gives more brake thermal efficiency than the other fuels. As the engine produces higher power output, the frictional losses are changed and hence change in the brake thermal efficiency

C. Mechanical Efficiency

It is defined as the ratio of Brake power to the Indicated power.

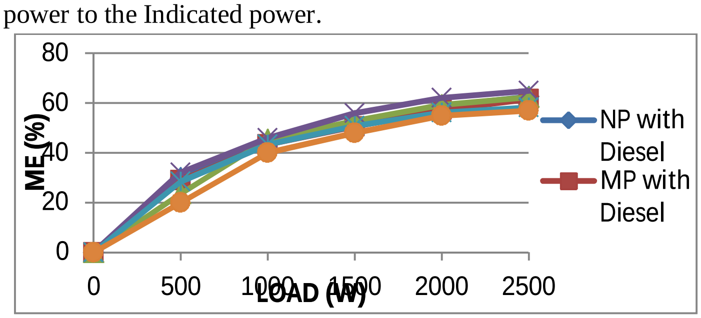

Fig 9 Load vs Mechanical Efficiency

From the results, it is clear that the value of Mechanical efficiency of blend B20 with modified piston is higher compared to diesel fuel (standard engine). The B20 fuel gives more mechanical efficiency than other fuels. As the engine produces higher power output, the frictional losses are changed and hence in the mechanical efficiency.

D. Exhaust Gas Emissions of Carbon monoxide (CO)

The CO which arises mainly due to incomplete combustion is a measure of combustion efficiency. Generally, oxygen availability in diesel fuel and biodiesel blends is high, so at high temperatures carbon easily combines with oxygen and reduces the CO emission.

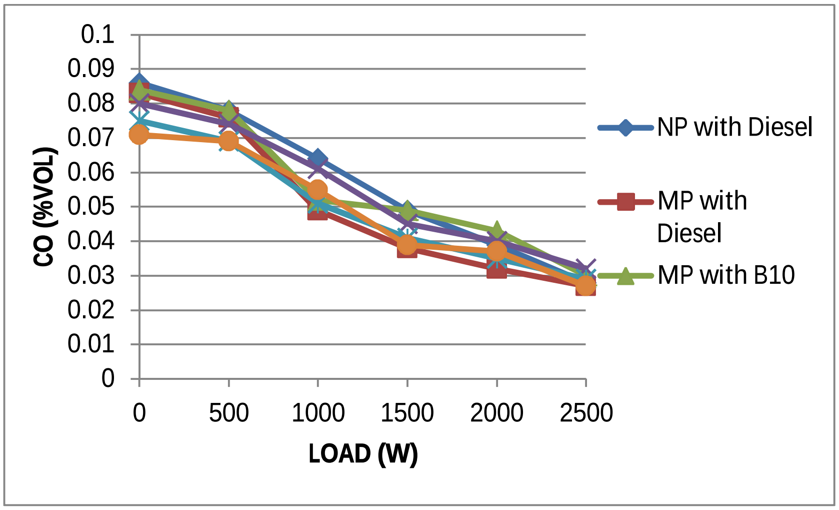

Fig. 10 Load vs CO Emissions

From the results, it is clear that CO is decreased due to the complete combustion. CO emission from diesel engine is related to the fuel properties as well as combustion characteristics. It is well known that better fuel combustion usually resulted in lower CO emission. It is clear that emission concentrations are lower than Bharath Stage III.

E. Exhaust Gas Emissions of Hydro Carbons (HC)

This may be due to an increase in residual gas temperature within the engine cylinder and decrease in flame quenching thickness at higher loads in the engine.

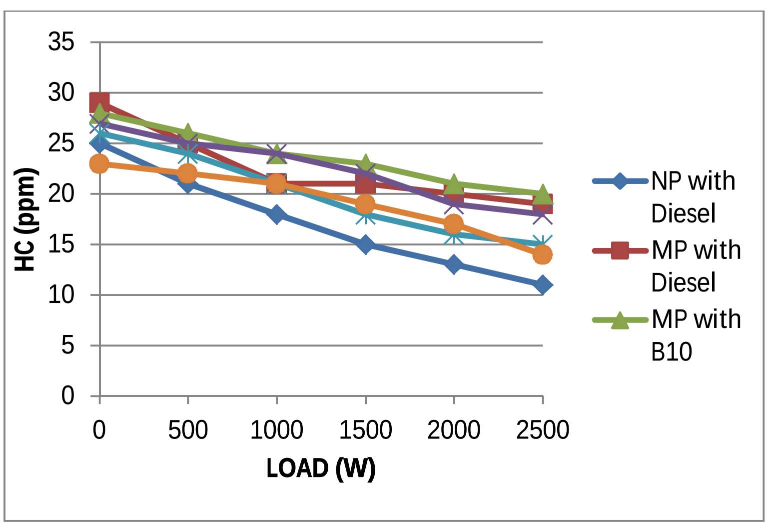

Fig. 11 Load vs HC Emissions

From the results, it is clear that the concentrations of HC emissions are decreased from no load to full load. But here the HC emissions for diesel fuel s comparatively low compared to other blends. It is clear that emission concentrations are lower than Bharath Stage III.

F. Exhaust Gas Emissions of Carbon dioxide (CO_2)

Complete oxidation of carbon particles present in the fuel.

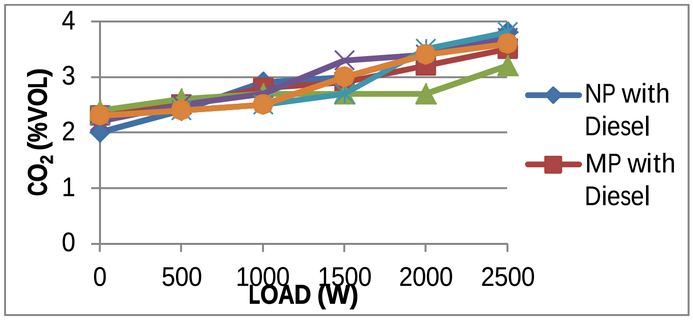

Fig. 12 Load vs CO_2 Emissions

From the results, it is observed that the amount of CO_2 produced while using blends of biodiesel are higher than diesel at full load condition that indicates the complete combustion of the fuel except at B10 blend. As a general rule, the higher the CO_2 reading, the more efficient the engine is operating.

G. Exhaust Gas Emissions of Nitrogen Oxides (NO_x)

The formation of nitrogen oxide emissions depends on the heat transfer rate and evaporation rate of the fuel. This increases further, with the availability of oxygen and the higher prevailing temperatures in the chamber.

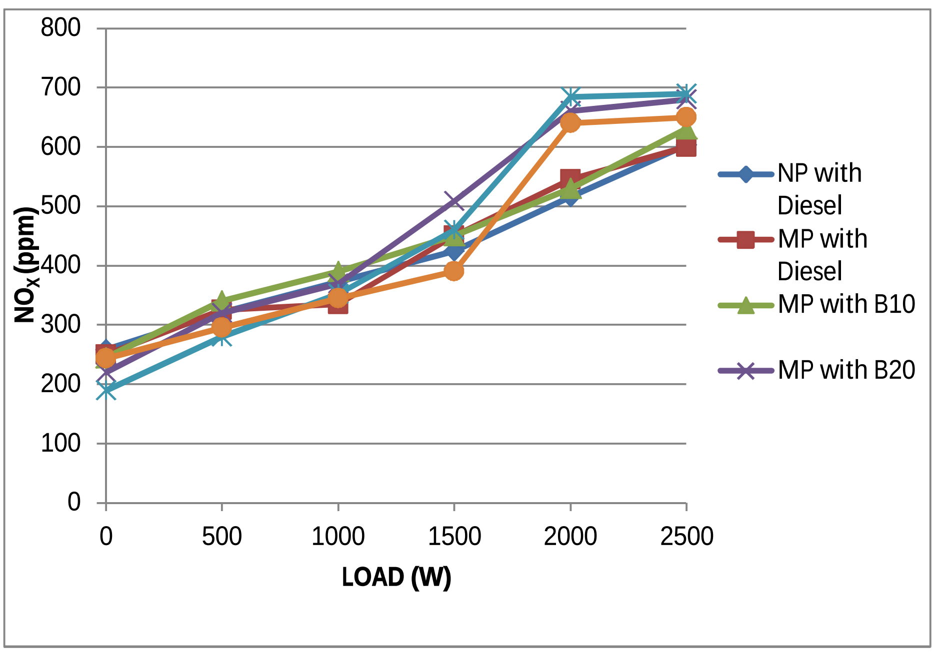

Fig. 13 Load vs NO_x Emissions

From the results, it is noticed that NO_x is slightly increased for biodiesel blends compared to diesel fuel (standard engine).

V. CONCLUSION

In this experiment, the performance and emission characteristics of a diesel engine operated on diesel fuel and blends of biodiesel (Olive oil) with modified piston such as B10, B20, B30 and B40 were experimentally investigated.

The performance of the engine was evaluated in terms of brake specific fuel consumption, brake thermal efficiency and Mechanical efficiency. The emission characteristics of the engine were studied in terms of concentration of CO, CO_2, HC and NO_x. The results obtained for Modified Piston with biodiesel fuel (Olive oil) blends are compared with the diesel fuel.

Following are the conclusions based on the experimental results obtained while operating single cylinder water cooled diesel engine with Modified Piston fuelled with (Olive) oil and its diesel blends.

A. The blend B20 of biodiesel shows lower brake specific fuel consumption (BSFC) than the diesel at full load (2500W). The BSFC of diesel fuel is 0.283 Kg/kW-hr and for blend B20 is 0.270 Kg/kW-hr. The BSFC is found to be reduced by 0.013 Kg/kW-hr.

B. Brake Thermal efficiency of the tested diesel engine is improved when it is fuelled biodiesel blend B20. The Brake Thermal efficiency of diesel fuel is 26.83% and for blend B20 is 31.9% at full load (2500). The Brake thermal efficiency to found to be increased by 5.07%.

C. Mechanical efficiency of the tested diesel engine is improved when it is fuelled with biodiesel blend B20. The Mechanical efficiency of diesel fuel is 60.46% and for blend B20 is 65.01%. Mechanical efficiency is increased by 4.55%.

D. CO emissions slightly decreased with increase in percentage of biodiesel blend in the diesel fuel. The CO emissions are found to be reduced by 0.04%vol at B30 with Modified Piston.

E. CO_2 emissions are slightly decreased with increase in percentage of biodiesel blend in the diesel fuel. The CO_2 emissions are found to be reduced by 0.3 %vol at B10 Modified Piston.

F. NO_x emissions of biodiesel blends are slightly higher than that of diesel. The NO_x emissions are found to be increased by 0.9%vol at B30 Modified Piston.

From the above all we found that modified piston with olive oil and its diesel blends are suitable substitute for diesel as an alternate fuel as they produce lesser emissions and have satisfactory performance and emission characteristics.

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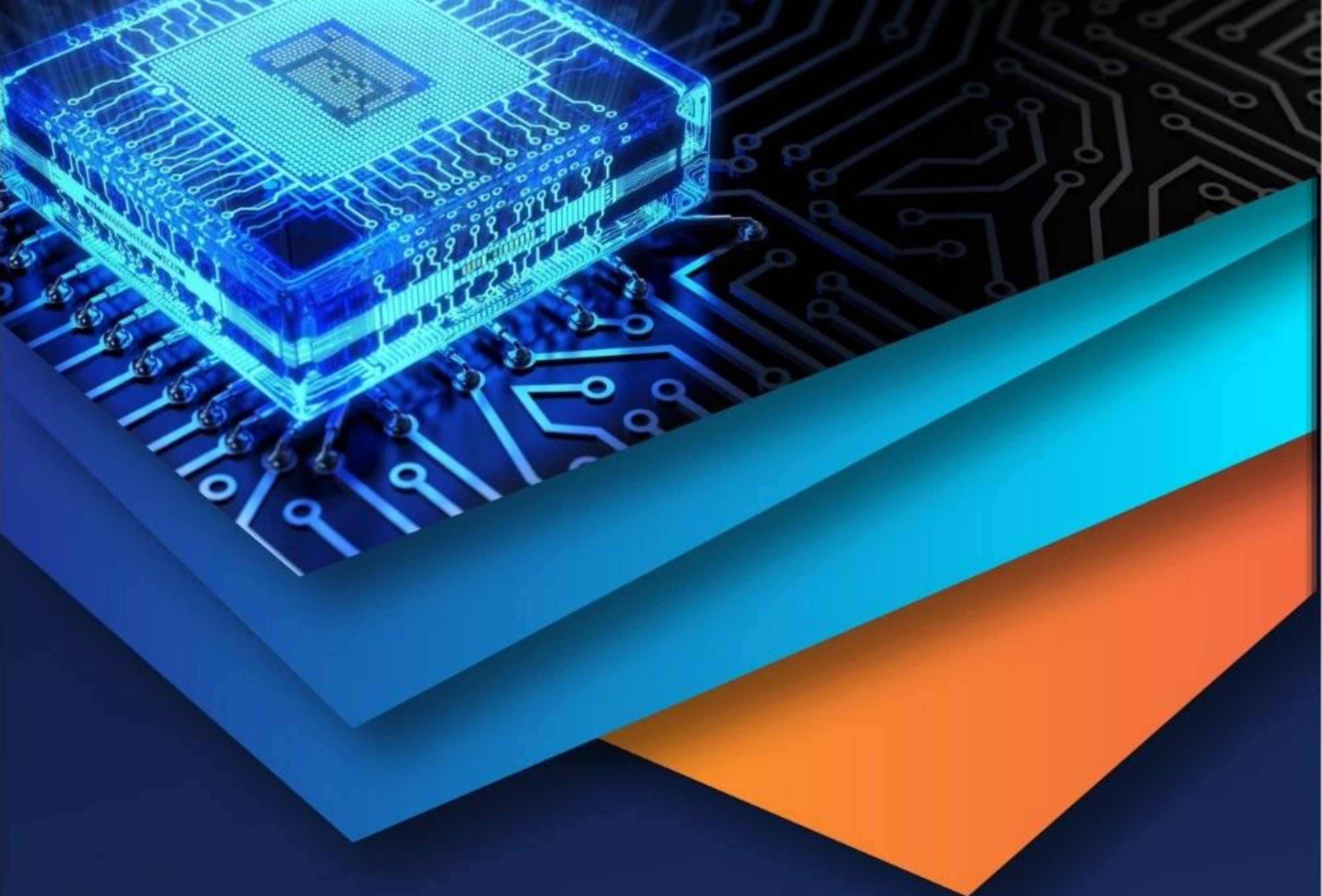

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