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Emission Analysis of Compression Ignition Engine Fuelled with Biodiesel Derived from Waste Cooking Oil

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Abstract: Production of Biodiesel has witnessed rapid technological changes in academics as well as industries. Increasing Prices and Recent problems like smog in Delhi have increased awareness in common public about harmful effects of continuous use of petro-fuels. To address such issues, Government of India also wants to promote use of green fuels like Biodiesel. In the present research, waste cooking oil was used for production of biodiesel through the process of alkali based chemical process of transesterification. Biodiesel so produced was tested experimentally on 5BHP rated power, 4- Stroke, single cylinder compression ignition engine. Emissions of the engine were analyzed for variations of NOx, Hydrocarbon and Carbon monoxide emissions were measured with Engine load. It was observed that emission characteristics of Biodiesel are comparable to that of Diesel Fuel but it cannot replace conventional fuel completely.
Keywords: Biodiesel, Emission, Diesel Engine, Waste Cooking oil

I. INTRODUCTION

Now a day's Biodiesel is regarded as an alternative fuel for internal combustion engines which has potential to curb air pollution. Generally, it is produced from edible and non edible vegetable oils and animal fats. Previous research (D. Rachel Evangelene Tulip and K.V. Radha, 2013) have illustrated the fact that biodiesel is an eco-friendly alternative fuel, which can reduce the disadvantages associated with vehicular emissions. Since, Biodiesel is free from Sulphur and aromatic compounds so, it produces smaller amount of soot. Because of its environment friendly nature and economically viable production process, it has gained quick popularity across the different nations [McCarthy P. et al, 2011]. Direct use of vegetable oils in engines is not acceptable due to high viscous nature and edible oils cannot be used due to food crisis in the countries like India. Therefore, waste cooking oil was used in this research work and its viscosity was lowered by converting it into methyl esters through the process of transesterification process. These methyl esters are termed as biodiesel because it can be blended with petro-diesel [Sarala R. et al, 2012]. Air-Pollution has become a serious issue; its negative effects were seen in Bejing and Delhi, which directs our focus to Biodiesel. Biodiesel is comparatively more safe, non-toxic and biodegradable fuel [Sarala R. et al, 20123]. We can directly use biodiesel as fuel in internal combustion engines without any major modifications in their design and structures. [Zhang J. et al, 2011]. On use of Biodiesel as alternative fuel in internal combustion engines, emission of various pollutatants likes Carbon monoxide, Nitrogen Oxides, Unburnt Hydrocarbons decreases [Barabas I. et al, 2010]. Emission of NOx was observed to increase with increased concentration in blends of biodiesel, which may be attributed to the change in combustion and oxygen content properties of the fuel [M. Christopher and R. Sabarish , 2014].

In the poor and developing countries, there is a common habit of using cooking oil repeatedly for the purpose of frying. It is never discarded, although it becomes toxic due to chnge in chemical structure and formation of aldehydes and alylbenzenes (Maria D. Guillen et al, 2012) in it. Scientifically, it was found that repeated use of cooking oil may impose several health problems like cardiac problem and cancer. India, being second populated country in the world produces several metric ton of waste cooking oil. If, a proper collection system is developed by municipal corporations of different cities then best used of waste cooking oil will be its conversion into biodiesel by the process of transesterification. Before conversion, Free Fatty acid test is conducted, if it is less than 2.5 %, then we proceed to the process of alcoholysis, otherwise 3 step processes will be followed for conversion.

II. TRANSESTERIFICATION

Triglycerides are present in the waste cooking oils. Conversion of these triglycerides into a mixture of mono-alkyl esters takes place in the process of transesterification. In this process methanol along with alkali catalyst was used (Sivakumar P. et al, 2011). Mixture

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of Methyl or ethyl esters obtained as product of this process is known as biodiesel [Mohan B. et al, 2015] whose properties are very much similar and comparable to the conventional diesel fuels. Main byproduct of this process is glycerol, which itself is a very useful liquid in chemical and cosmetic industry. The most commonly used alcohol to manufacture biodiesel is methanol (CH_3OH) due to the reason of cheaper price and comparatively it is found to give better conversion rates. Some Other alcohols like plant based alcohols ethanol, propanol, butanol etc., are also used. Trans-esterification is a reversible chemical reaction. In the presence of alcohol in excess, the rate of forward reaction becomes greater than that of backward reaction. Different types of catalysts like acid, alkali and solids are used in the process of transesterification [Gautam Kumar and Anoop Kumar, 2013]; still, process of trans-esterification can be accomplished at a higher rate with the use of an alkali catalyst like NaOH and KOH.

TRANS-ESTERIFICATION

$$\begin{array}{l} CH_2-OCOCR_1 \\ CH-OCOR_2 \\ CH_2-OCOR_3 \end{array} + 3HOCH_3 \underset{}{\overset{Catalyst}{\rightleftharpoons}} \begin{array}{l} CH_2-OH \\ CH-OH \\ CH_2-OH \end{array} + \begin{array}{l} R_1-COOCH_3 \\ R_2-COOCH_3 \\ R3-COOCH_3 \end{array}$$

Waste Cooking Oil (Triglyceride)	Methanol (Alcohol)	Glycerol	Bio-diesel (Methyl Esters)

III. METHODOLOGY

Primary Waste cooking oil was collected from as the residue oil of a marriage function in Morena and local restaurant in Achrol Jaipur. In view of the fact that Oil was dirty and blackish in colour, Hence paper filter (pore size 11 micrometer) was taken in use for removing debris and suspended food particles present in oil for a period of 7-8 hours. To obtain best results, Process of filtration was done twice by using paper filter. Thereafter, free fatty acid (FFA) test was done in a lab of Jaipur. FFA of oil was 0.2543 %. If FFA < = 2.5 % then it is a better feedstock to convert into biodiesel. Following material was used in experiments:

A. 5 litre of waste Cooking oil, 1 litre of Methanol, 50 gm Potassium Hydroxide
B. Flask, Balance, Timer, Beaker Tongs, Heater Plate of Stir Type
C. Thermometer, pH Paper, Separating Funnel, Beakers, Spatulas

Initially, it is ensured that all the glass wares were clean and dry. 100 ml Methanol was measured using graduated cylinder. 5 gm KOH was measured using electronic balance. These quantities of methanol and KOH were added to the 250 ml flask. Then magnetic stir bar was also put in it. Flask covered with parafilm was placed on the stir plate and a it was rotated at a medium speed. It is stirred until KOH dissolves completely, it takes few minutes. Once the KOH was dissolved, we had a substance known as potassium methoxide. Then 500 mL of waste cooking oil was added poured into a beaker of 1000 mL capacity. This mixture was heated till the temperature becomes between 50-60 °C and stirring was carried out for 50-60 minutes. When this mixture has reacted for 50-60 minutes then pours it in a separate funnel and then it was allowed to settle down for 7-8 hours. The bottom layer was of glycerol which is main byproduct, and biodiesel was in the top layer. By turning stopcock, glycerol was slowly drained out in a small beaker. Stopper at the top of funnel was removed for proper draining of glycerol. When, biodiesel layer was coming closer to the bottom of the funnel, and then stopcock was turned so that drop wise exit may take place.

Figure 1: Water Washing

When first drop of biodiesel exits, turn stopcock completely. Now, what we have that is crude biodiesel, it was washed twice with hot water so that it becomes free from traces of impurities. Then it was tested in the lab for pH value If the colour of the litmus doesn't change, it means that Bio-diesel was prepared and it is now ready for further processing. Various properties of Biodiesel were tested in a private lab are shown in the table-1

Table – 1: Properties of Biodiesel (Sharma S.K. et al, 2017)			
Property	Bio-diesel	Petro-Diesel	Testing Method
Density (at 15 °C) Kg/m^3	967	820-845	IS 1448 Part - 1
Kinematic Viscosity Centi Stoke	4.25	2.228	IS 1448 Part - 1
Flash Point (Abel) in °C	147	52-96	IS 1448 Part - 1
Pour Point in °C	5.2	3	IS 1448 Part - 1
Calorific Value kJ/Kg	36504	44800	Bomb Calorimeter
Cetane Index	48.2	46	D 4737 / ISO 4264
Content of Sulphur in PPM	5.7	350	ISO 8754/ P:83

IV. EXPERIMENTAL SETUP

Biodiesel was tested experimentally on a 4 - stroke single cylinder water cooled direct injection Kirloskar AV1 diesel engine of rated power of 5 BHP and running at 1500 rpm. This Test rig (Figure 1) mainly has an engine test bed along with a system for fuel supply.

Figure:2- Engine Test Rig

This test rig has various metering and measuring devices. This engine was coupled with a water brake dynamometer. Load was varied through flow control of the dynamometer. Fuel Tank is clearly visible in the figure. Before, final use, blended Fuel was also preheated manually using a gas burner. A Digital tachometer was taken in use for measurement of peed of engine in rpm. Platinum-type thermocouple was used to measure lubricating oil temperature and temperature of exhaust manifold was measured by using laser gun thermometer. Test Rig Specifications of the engine is given in Table 2.

Table -2: Test Rig Specifications (Sharma S.K. et al, 2017)	
Detail	Specification
Type	Vertical CI Engine
Number of Cylinder	Single Cylinder
No. of Stroke	4
Bore (mm)	87.5
Stroke length (mm)	110
Speed	1500 RPM
Cooling	Water cooled
Compression Ration	19:1
Starting Method	Hand Starting
Lubricating Oil Used	SAE40
Rated Power	5 BHP
CC of engine	600

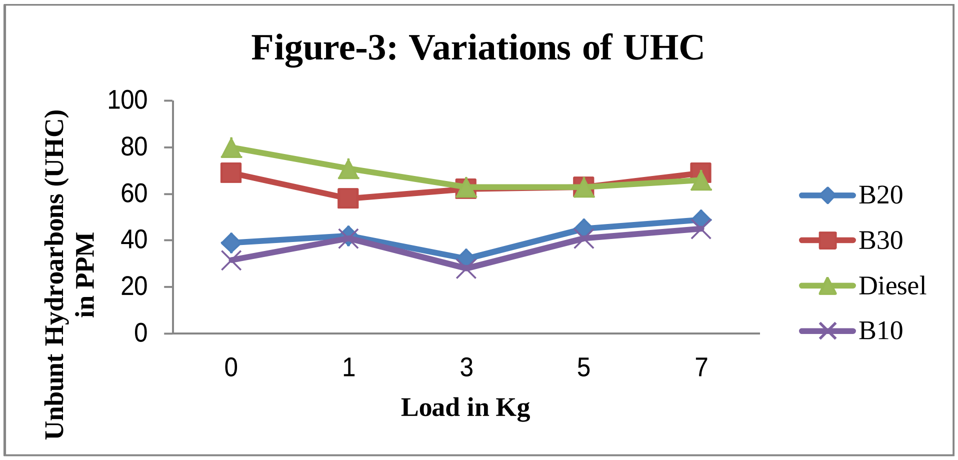
Engine was run at different 4 (No load, Part load and full load) loads for each of the fuel blend; the engine load was controlled by dynamometer. AVL 437 C Smoke meter was used to measure opacity of smoke and AVL 444 5 Gas analyzer was used to measure volumes of different gases (CO, CO2, HC, O2, NOx).

V. RESULT AND DISCUSSION

Emission Analysis of Diesel engine fuelled with biodiesel was carried out for CO, CO2, HC, O2, NOx. These results are discussed here in following texts.

A. *Variation of Unburnt Hydrocarbons*

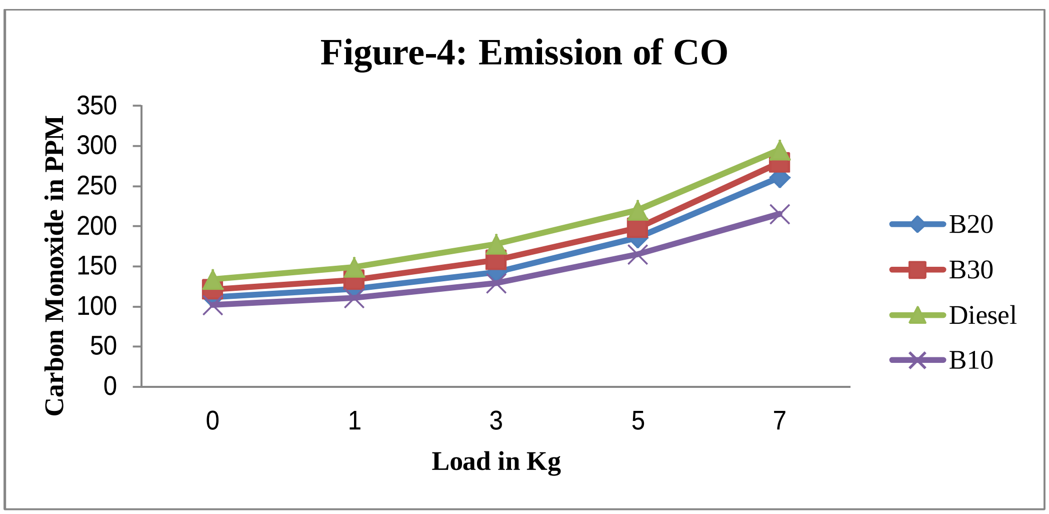
Figure 3 portrays variation of Unburnt Hydrocarbons with change in concentration of Biodiesel in different blends.



It can be seen that UHC increases with concentration but variations with load at any blend ratio are almost linear. It is crystal clear that the UHC emissions for all the biodiesel blends are lower than that of conventional diesel for all the variations of load. It means biodiesel is better in this aspect.

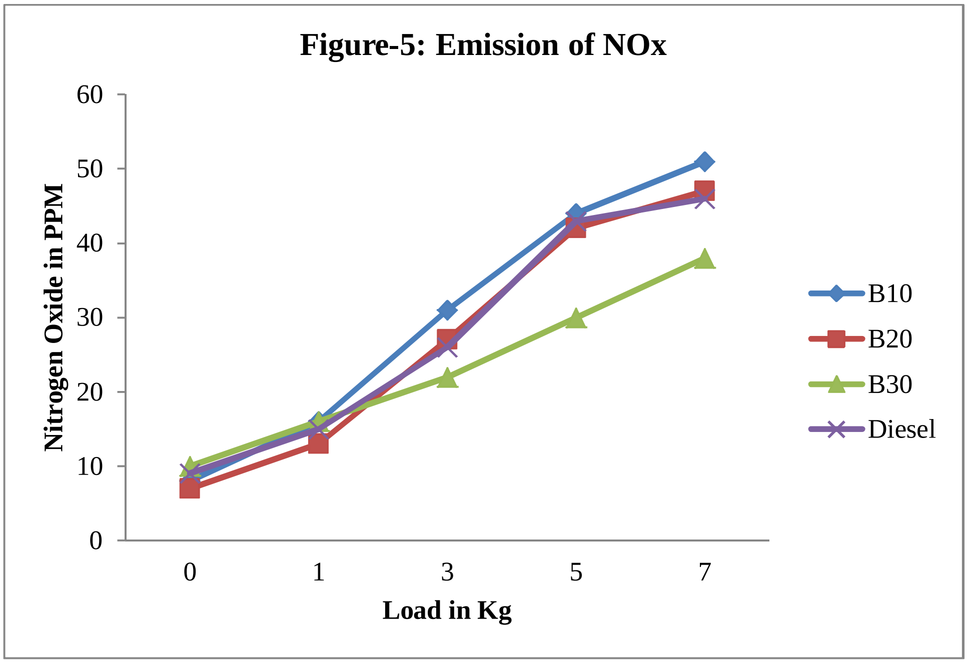
B. *Emission Variations of Carbon Monoxide*

Fig.4. reflects the Emission Variations of Carbon Monoxide of CI Engine at different loads for different Blends of biodiesel. It can be seen from figure-4 that the CO emission is increasing with increasing load for the all the blends of fuel under test. As one can see the biodiesel blends have lower rate of CO emissions.



C. *Emission Variations of Nitrogen Oxides (NOx)*

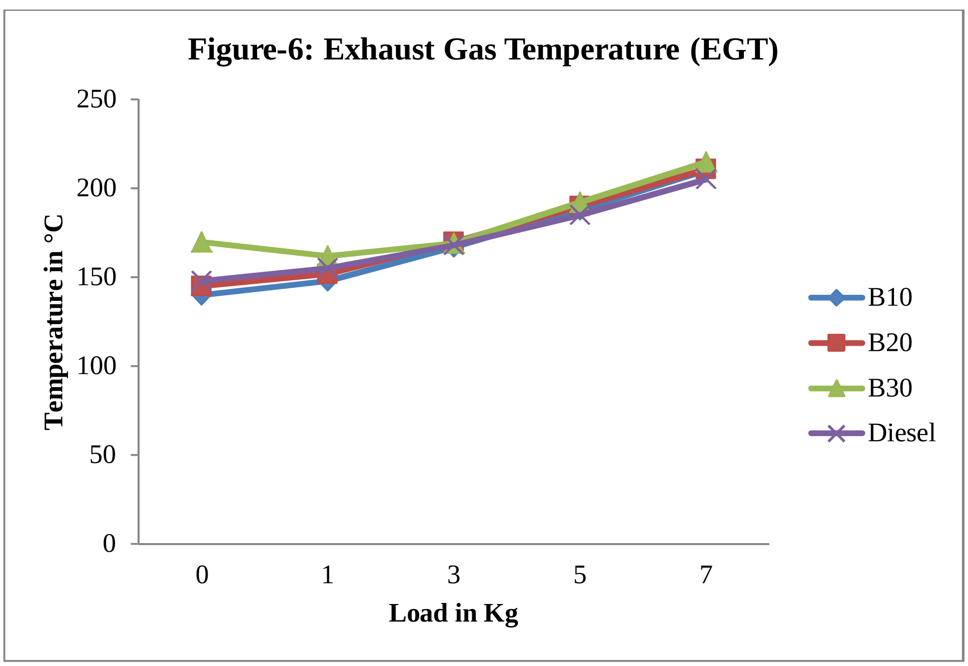
Figure - 5 illustrates the Emission Variations of Nitrogen Oxide of Diesel Engine at different loads for 3 Blends of biodiesel.



At condition of no load NOx emission was approximately same for all the blends and Diesel. Amount of NOx emitted increased with increasing load. It happened because temperature of combustion chamber was also increasing with increments in loads. [S.K. Hoekman and C. Robbins, 2012]. At the condition of full load, Amount of NOx was also approximately in the same range foe Diesel, B10 and B20 Blends, while it was smaller for B30 Blend.

D. Variations of Exhaust Gas Temperature

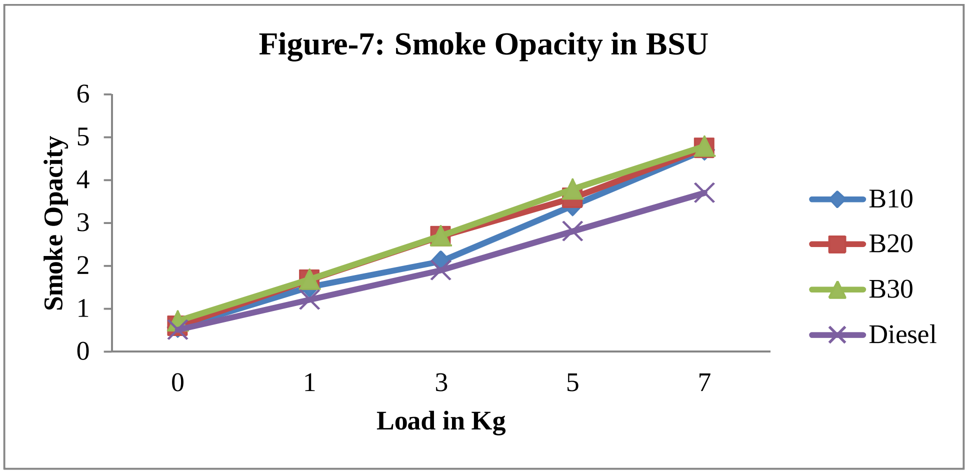
Figure - 6 illustrates Variations of Exhaust Gas Temperature of Diesel Engine at different loads for 3 Blends of biodiesel.



It was observed that with rise in engine load, exhaust gas temperature was found to rise. B10 registered smallest EGT among all the test blends and Diesel. As load on engine increases, burning of more fuel takes place, which is responsible for rise in exhaust gas temperature.

E. Variations of Smoke Opacity

The variations of smoke opacity with load on engine for all the test blends of biodiesel and diesel are shown Figure-7.



Smoke opacity is indication of type of combustion (Complete or Incomplete). It is clearly seen from the figure that at higher load, the smoke intensity for blended fuels was found higher than that of diesel fuel.

VI. CONCLUSIONS

In this experimental work, waste cooking oil was used to prepare biodiesel through the process of transesterification. Fuel Properties of biodiesel were found to be very much similar to that of conventional diesel fuel. Some noteworthy points from investigations carried so far are as follows:

A. Biodiesel cannot replace petroleum diesel completely but it can help to maintain a balance energy policy in any country like India [P. McCarthy, 2011].
B. Ultimate aim of biodiesel production is to build a better, self sustained community based model to produce biodiesel on large scale.
C. Because of lower exhaust emissions, biodiesel can help to curb air pollution and improve human habitat. Lower CO2 emissions will definitely help to reduce the adverse effects of global warming.
D. One of the great advantages of biodiesel is that it can be used in existing engines, vehicles and infrastructure with practically no changes.
E. With the use of Bio-diesel, problem of disposal of waste oil can be solved and further it can act as booster for rural economy

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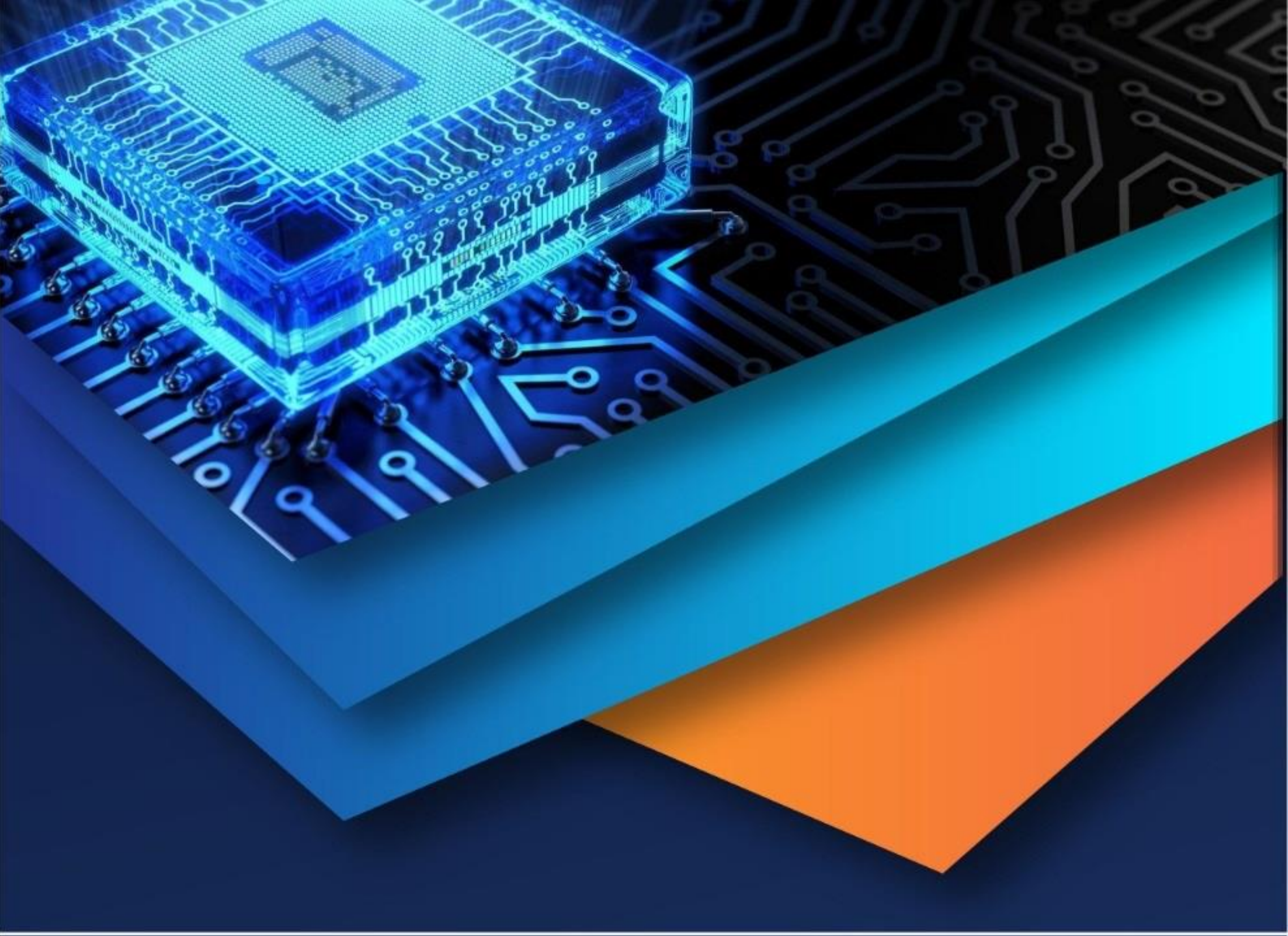

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