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Experimental Analysis on Exhaust Emissions of Diesel Engine using Madhuca Indica Biodiesel and its Diesel Blends

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Abstract*: The usage of fossil fuels are rising rapidly and diminishing its reserves at the same phase. Moreover petroleum based fuels are emitting enormous toxic exhaust emissions which are perilous to the environment. This environmental pollution is causing triple impact on health of humans, plants and other living habitats. In the recent time, the plant based biodiesel are becoming a hopeful alternative renewable fuel especially with non-edible oils as feed stock, to replace the conventional diesel fuel. The present research paper aims to perform experimental evaluation of the exhaust emissions from direct injection diesel engine when madhuca indica oil methyl ester and its diesel blends used as fuel. Madhuca indica oil methyl ester (MIOME) was prepared through transesterification process using methyl alcohol and an experimental study was carried-out using a 4-stroke, single cylinder, compression ignition direct injection engine fuelled with MIOME, different blends (B20M, B40M, B60M and B100M) of MIOME and diesel fuel. The experimental tests revealed that the emission of B100M biodiesel has lower carbon monoxide (CO), particle pollution, and smoke opacity emissions when compared to diesel fuel. Biodiesels are naturally oxidized fuels and so emitting lower exhaust emissions due to its higher cetane number than diesel fuel with less or no sulphur content.
***Keywords*: Non-edible oils, Biodiesel, Methyl Ester, Mahuca Indica Oil, Emission Characteristics, and Transesterification.**

I. INTRODUCTION

The declining fossil fuel reserves, increased production cost with growing demand and harmful exhaust emissions raised a concern to focus for alternative renewable energy resources. Even though, the growth is rising every year, but the renewable energy systems such as wind, solar, geothermal energy sources are currently contributing very minimal amount of global primary energy supply. Furthermore, massive usage of conventional fossil fuel in automotives, agriculture and power generation is the leading causes of air pollution and the main source of global warming emissions. The past literature reveals that the most viable way to meet this increasing demand is by using biodiesel as alternative fuels [1-4]. In general, biodiesel is the most alluring category of fuel that can be utilized directly in any unmodified diesel engine. Moreover biodiesel is the most desirable form of fuel that can be used directly in any existing, unmodified diesel engine. Besides the biodiesels are more environmental friendly than gasoline and other petroleum based fossil fuels. Despite the fact that biodiesel has many advantage over diesel fuel, but the production cost of the feedstock and its quality for continuous production is the primary obstacle to its commercial application [5].

In the recent decades, numerous researchers and analysts were focused to reduce the consumption of diesel fuel with multifaceted advanced technology to use vegetable oils as feedstock to prepare biodiesel. Since vegetable oils as biodiesel have many preferences such as raw material could be produced short period of time, many plants related non-edible vegetable oil can grow in waste lands with less/no water source and thus have the potential of making marginal lands productive, and safer to store and handle [6-8]. Vegetable oils can be utilized specifically in diesel engine, yet not ideal because of their higher viscosities and lower volatilities which make it inefficient for combustion engines. Be that as it may, the possibility of using vegetable oils as fuel has been perceived, just when therefore modified by using transesterification process to get fatty alkyl esters of the vegetable oil which is considered as biodiesel [9]. The nations which do not have sufficient fossil fuel resources are facing a severe foreign exchange crisis, mainly due to the imported cost of petroleum oil. The previous research studies revealed that many vegetable oils such as palm, peanut, soybean, coconut, corn, sunflower, rice bran oils were suitable for preparation of biodiesel. Recently, many countries are already using vegetable oils in commercial production such as Palm oil in Malaysia [10], Soybean oil in USA [11], Castor oil in Brazil [12], Olive, Rapeseed oils in Europe [13]. In developing nations like India with a massive population, there is an increasing demand for vegetable oils for cooking purpose. Therefore, production of biodiesel from non-edible oil is preferred than edible oils, because edible usage is impacting on the price of the oil due to food crisis. Agriculture based economies like India has vast unused, unfertile and uncultivated land in all states/provinces. Moreover Mahua oil was not used in food processing industries and available

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abundantly with low price in forest areas. The physico-chemical properties of Madhuca indica oil are almost comparable with diesel and Madhuca indica oil biodiesel and its diesel blendes could be potentially reduce or partially replace the diesel fuel requirement of the country.

Dhinagar et al., were experimental investigated using non-edible vegetable oil with a LHR diesel engine and noticed reduced performance with lower exhaust emissions [14]. Sirivella et al., were conducted experiments using non-edible oil based Jatropha oil as an alternate fuel in direct injection diesel engine and noticed the exhaust emissions of the engine such as carbon monoxide, smoke opacity and particulate matter has emitted lower emissions when compared with petro-diesel [15] . Reyes et al. have conducted tests on power and particulate matter emissions of diesel engine fuelled with biodiesel made of salmon oil with elevated content free fatty acids. The chemical composition of the salmon oil was also examined. The results indicated a maximum power loss of about 3.5 % and also near 50 % PM-10 reduction with 100 % refined biodiesel when used in diesel engine as a fuel [16].

II. MATERIALS AND METHODS

The Madhuca indica (Mahua) oil was bought from local vendor in Chennai, Tamilnadu, India and transesterified using methyl alcohol. The crude Madhuca indica oil has higher viscosity and density which causes problems to the engine and transesterification process was used to improve the properties and make it compatible for combustion. In this process, the carbonyl carbon of the starting ester carry out nucleophilic attack by the arriving alkoxide (R2O−) to give a tetrahedral intermediate, which either reverts to the starting material or proceeds to the transesterified product (RCOOR2). The chemical reaction of transesterification process was given in figure 1.

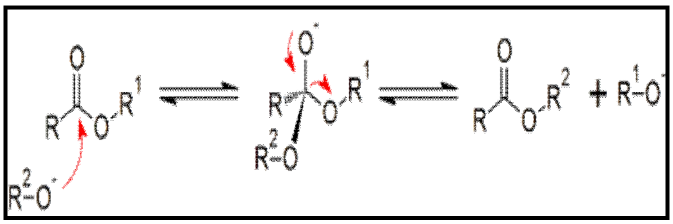

Fig. 1 Transesterification Process.

A. Fuel Properties of Diesel and Madhuca Indica Biodiesel

For the present research study, methyl ester of madhuca indica (mahua) oil and its diesel fuel blends were prepared by mixing 20% (B20M), 40% (B40M), 60% (B60M) and 100% (B100M) respective methyl ester with diesel fuel on volume basis. The chemical properties of diesel fuel and madhuca indica oil methyl ester (MIOME) were evaluated . The properties of diesel and biodiesel blends are presented in Table I.

TABLE I
PROPERTIES OF DIESEL AND MIOME BIODIESEL

Property	Diesel	MIOME
Kinematic Viscosity at 40^0 C (Cst)	3.58	4.8
Density at 15^0 C (Kg/m^3)	830	862
Flash Point (^{0}C)	51	127
Cetane Number	50	65
Calorific Value (KJ/kg)	42000	38200
Total Sulphur (% by mass)	0.01	Nil

B. Experimental Setup

For the present experimental research study of emission characteristics, a single cylinder, 4-stroke water cooled compression ignition direct injection (CIDI) engine was used when it is fueled with MIOME. The experiment setup is illustrated as schematic diagram below at figure 2. The setup consists of 3.7 KW diesel engine, eddy current dynamometer, smoke meter, and exhaust gas analyser.

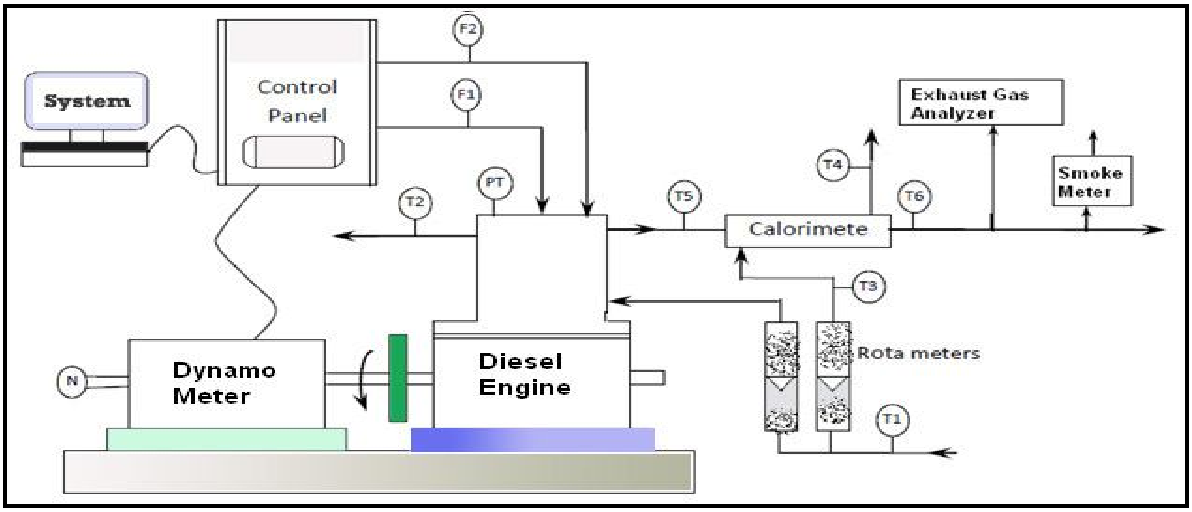

Fig. 2. Schematic Diagram of Experimental Setup

T1	Inlet water temparature	PT	Pressure transducer
T2	Outlet engine jacket water temp	F1	Air intake differential pressure unit
T3	Inlet water temparatue	F2	FuelFlow differential pressure unit
T4	Outletcal.water temparature	T6	Exhaust gas temparatue after Cal
T5	Exhaust gas temparatue before Cal		

The eddy current dynamometer was coupled with a test engine to operate the engine at various loads such as 25, 50, 75 and 100% load conditions. The engine was initially started with diesel and then repeated with MIOME biodiesel and its diesel blends. After the engine has reached the stabilized working condition at constant rated speed of 1500 rpm, time for 10ml of fuel consumption was recorded for each applied load for diesel and each biodiesel blend in order to calculate the performance characteristics of DI diesel engine. The engine rated fuel injection pressure of 200 bar was maintained for all experimental tests.
The specification of the test engine was presented in Table II.

TABLE III
SPECIFICATION OF TEST DIESEL ENGINE

Engine Make	Kirloskar AV1, India
No. of Cylinders	One
Engine Details	Four stroke, Water cooled
Injection Type	Direct Injection
Bore & Stroke	80 × 110 mm
Rated Power	3.7 KW (5 HP) at 1500 rpm
Speed	1500 rpm
Injection Pressure	200 bar
Compression Ratio	16.5:1
Dynamometer	Eddy Current

III.RESULTS AND ANALYSIS

The experimental evaluation of exhaust emissions of a DI diesel engine using Madhuca indica (Mahua) oil methyl ester was evaluated based on the CO, smoke opacity and particle pollution. The test results and discussion was presented in below paragraphs.

A. CO Emission

The variation of CO emission with engine load for diesel fuel and Madhuca indica oil methyl ester (MIOME) blends at constant engine speed of 1500 rpm was depicted in Figure 3. The graph in figure indicates that 100% MIOME has lower CO emission values among all blends of MIOME biodiesel and diesel fuel and the highest CO emission by diesel fuel. The carbon monoxide emissions were decreased with the increase of MIOME percentage in biodiesel and for every increased in percentage MIOME blend in biodiesel, CO emission was reduced. It was observed that CO emission from neat MIOME is less than the emission of neat diesel and for every 20% addition of MIOME in the blend, the CO emission is reduced by an average of 18%.

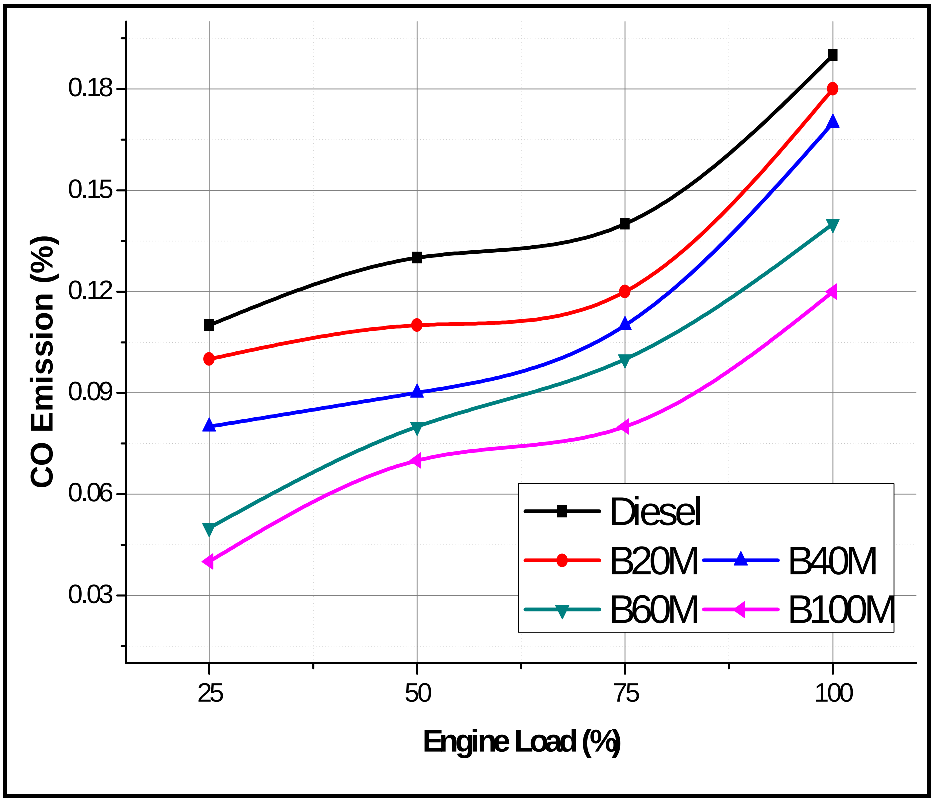

Fig. 3 Variations of CO emission with engine load for diesel and different biodiesel blends

B. Particle Pollution (PP)

The particulate pollution is called as particulate matter (PM). The variation of particulate matter (PM) with reference to engine load for diesel and MIOME biodiesel blends at constant rated speed of the engine is presented in Figure 4. With the increase of engine load, the particle pollution (PM) is also increasing for all blends and diesel, but decreased with the increase of MIOME blend percentage in biodiesel. The particle pollution has decreased by about 17% of neat biodiesel than neat diesel and for every 20% addition of MIOME blend in biodiesel, PM emissions are decreased by around 6-7%. It was also observed that the lower particulate matter at low and medium loads and considerably higher particulate matter at high load conditions with all fuel modes.

C. Smoke Opacity

The variation of smoke opacity with brake power for diesel and MIOME blends at constant rated speed of 1500 rpm was presented in figure 5. It was noticed that with the increase of load, the smoke opacity is also increased for all tested fuels and decreased with the increase of MIOME blend percentage in biodiesel. For every 20% addition of MIOME blend in biodiesel, the smoke opacity is reduced by 6%. The graph also corroborating that the B100M has very low smoke density and diesel fuel has highest among diesel and all the blends of MIOME biodiesel.

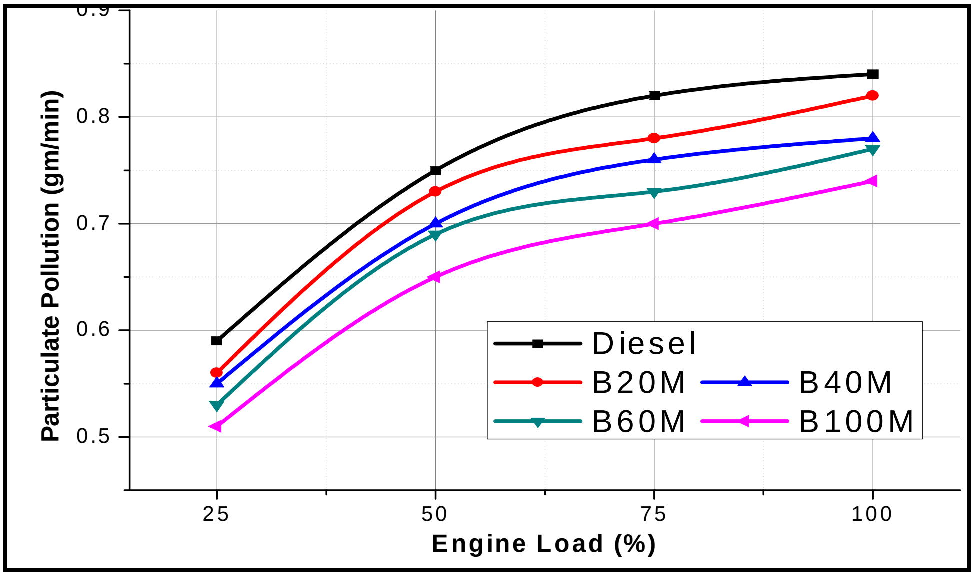

Fig. 4 Variations of Particle Pollution with engine load for diesel and different biodiesel blends

D. Smoke Opacity

The variation of smoke opacity with brake power for diesel and MIOME blends at constant rated speed of 1500 rpm was presented in figure 5. It was noticed that with the increase of load, the smoke opacity is also increased for all fuels and decreased with the increase of MIOME blend percentage in biodiesel. For every 20% addition of MIOME blend in biodiesel, the smoke opacity is reduced by 6%. The graph also corroborating that the BM100 has very low smoke density and diesel fuel has highest among all the blends of MIOME biodiesel.

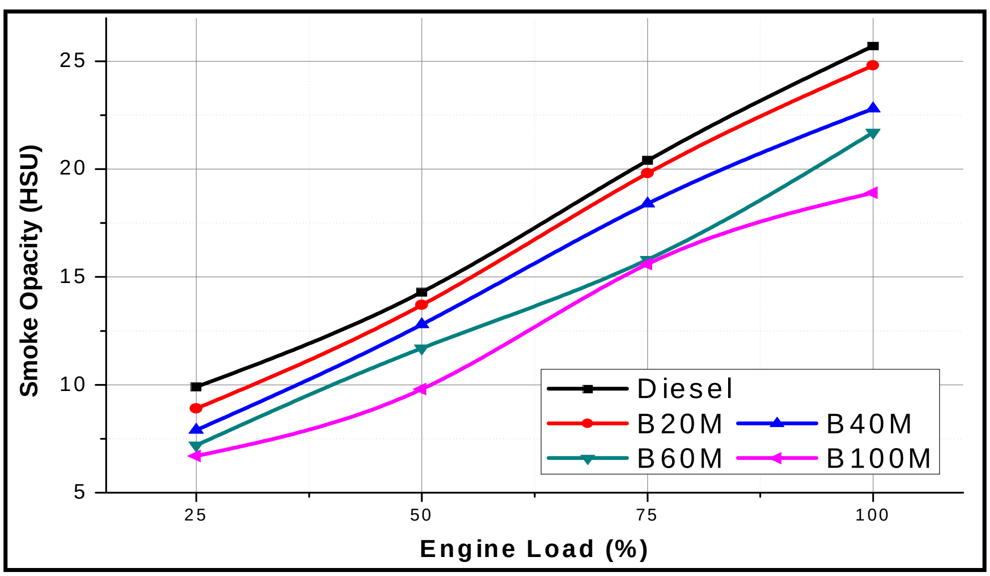

Fig. 4 Variations of Smoke Opacity with engine load for diesel and different biodiesel blends

IV. CONCLUSIONS

The Methyl Ester of Madhuca Indica Oil (MIOME) can be used as biodiesel and is a contemporary option instead of edible oils as feedstock of biodiesel. The experimental test results with a 4-stroke, single cylinder, water cooled DI compression ignition engine when fuelled with Madhuca indica methyl ester (MIOME) and various blends (B20M, B40M, B60M and B100M) of MIOME revealed that neat MIOME biodiesel has lower CO emission, smoke opacity, and particle pollution emission when compared to petro-diesel fuel. Biodiesels are generally oxygenated fuels which will help for better fuel combustion that causes less CO emission, low smoke opacity and low particulate matter .

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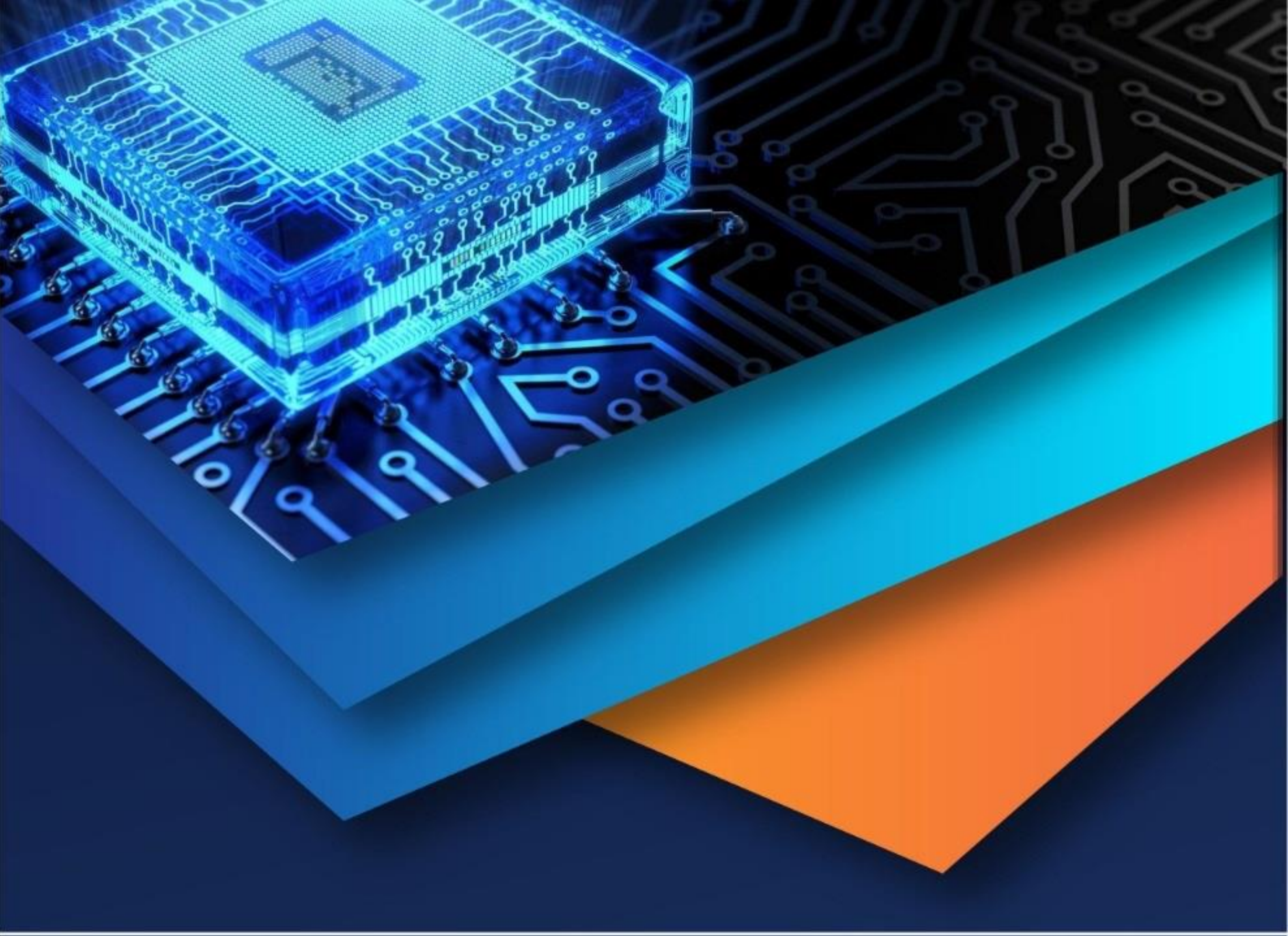

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