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Comparative Experimental Emission Analysis of a DI Diesel Engine using Madhuca Indica and Rice Bran Biodiesel and its Diesel Blends

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Abstract: The diesel fuel is most extensively used fossil fuel in automotives, construction and agriculture equipments and major source of hazardous environment pollutant across the globe. The increased utilization of fossil fuels and dwindling reserves caused to focus on alternative renewable energy sources to curb the exhaust emissions and reduce the consumption of fossil fuel as well. Recently, the research studies identified that plant based biodiesel are becoming a promising alternative renewable fuel and the edible/non-edible and animal fat oils can be used feed-stock in preparation of biodiesel, because its chemical properties almost similar to fossil diesel fuel, non-toxic, clean burning and renewable source. Hence, the objective of the present research work is experimentally evaluate the emission characteristics of direct injection (DI) diesel engine when blends of methyl esters of madhuca indica oil (MIOME) and rice bran oil (RBOME) used as fuel and compare their emissions to identify the blend that exhausts low emissions. The experimental study was conducted using a 4-stroke, single cylinder, direct injection (DI) diesel engine fuelled with different blends (B20, B40, B60 and B100) of MIOME and RBOME biodiesels. The experimental analysis identified that the emission of neat RBOME biodiesel has carbon monoxide (CO), particle pollution emissions and B100M biodiesel has lower smoke opacity when compared to other blends of tested biodiesel.
Keywords: Biodiesel, Methyl Ester, Mahuca Indica Oil, Rice Bran Oil, Emission Characteristics, Transesterification.

I. INTRODUCTION

The global warming, world's energy crisis, diminishing fossil fuel reserves are raising concerns and inevitability to find more economically feasible and more environmentally friendly solutions to satisfy the contemporary energy needs. In the recent times, the diesel engines became predominantly used engine than petrol engines as technology has improved and the invention of turbo-charged direct injection (DI) engines played a imperative role to extend the raise of its reputation in all sectors that includes personal automotives and agriculture machinery. Furthermore, massive usage of conventional fossil fuel in automotives and power production is the primary causes of environmental pollution and the major source of global warming. The chemical 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 [1-3]. In general, biodiesel is the predominantly appealing category of fuel that can be used directly in any diesel engine. Moreover biodiesel is the most enviable form of fuel that can be used directly in any existing, unmodified diesel engine. In addition, the biodiesel is more ecological friendly fuel than gasoline and other petroleum based fossil fuels. The biodiesel has many advantages as mentioned above over diesel fuel have rejuvenate the interest in renewable vegetable oil based biodiesel fuel [4,5].

In the last few decades, the past research reviews revealed that methyl/ethyl ester based biodiesels that were produced using vegetable oils and animal fat can be used as fuel in compression ignition engine [7-9]. Ekrem Buyukkaya has conducted experimental evaluation using methyl ester of soybean oil and its diesel blends in a diesel engine and his experimental results revealed that neat biodiesel has 6.9% higher brake specific fuel consumption (BSFC) than conventional petro-diesel fuel with less CO emission and smoke opacity [10]. Hanbey et al. used preheated rapeseed oil and its diesel blends as fuel in a one cylinder, 4-stroke, naturally aspirated, DI diesel engine and their experimental results showed that positive effects on engine performance and emission characteristics. This is because the viscosity was reduced that caused for smooth fuel flow [11]. Venkata et al. were conducted experimental analysis to evaluate the performance and emissions of CIDI engine fueled with rice bran oil methyl ester, its blends and blends of diesel-biodiesel-ethanol (DBE). They observed increase of brake thermal efficiency (BTE) and reduction of emissions such as carbon monoxide, smoke, and less engine noise with diesel-biodiesel-ethanol blends, the rice bran oil biodiesel. The highest BTE with 15% of ethanol in diesel-biodiesel-ethanol blends and reduction in exhaust gas temperature (EGT) and in engine noise was noticed with the increase of ethanol percentage in diesel blends. It was also confirmed that the increase of NOx,

CO_2 and hydrocarbons was with increase of ethanol percentage in diesel blends [12]. Goyal has conducted off-road test with rapeseed methyl ester of rapeseed oil in a 4239T model of Deere diesel engine and observed 6-8% of power loss with high carbon deposits in ports and piston rings for short-term operations. During the long-term engine operations, the damage of the test engine parts such as gaskets were noticed [13]. Spataru and Romig were carried-out experiments using blends of EPA #2 diesel, California ARB #2 diesel, methyl esters of canola oil and soya beans oil and their diesel blends in DDC 6V92TA model of Detroit MUI urban bus diesel engine and observed that the performance was satisfactory with reduced emissions [14]. Ramadhas et al. carried-out theoretical and experimental analysis using rubber seed oil biodiesel and its diesel blends and reported increased BTE, peak temperature in theoretical analysis when biodiesel used [15]. Stalin et al., have conducted experimental studies to evaluate the performance of a diesel engine using karanja oil biodiesel and its diesel blends. Their test results revealed that B40 blend has comparable performance and can be used in unmodified diesel engine [16]. Sirivella Vijaya Bhaskar has conducted experiments on a single cylinder, DI diesel engine and test results showed that jatropha biodiesel blends have emitted lower CO emission and smoke opacity when compared to diesel fuel and identified that engine has emitted lowest CO and smoke opacity emissions at 220 bar injection pressure [17]. Pandey and Nandgaonkar (2013) have studied the performance and emissions of diesel engine using a 585 kW military DI diesel engine was fuelled with petro-diesel, Karanja oil biodiesel and JP-8 and noticed slightly lower performance with JP-8 and pure methyl ester of karanja oil biodiesel when compared with diesel with reduced emissions of CO and UHC. But lower NOx with JP-8 and 10% higher NOx emission with Karanja oil biodiesel was observed [18].

II. MATERIALS AND METHODS

The rice bran and mahuca indica (mahua) oils were purchased from local vendor in Chennai, Tamilnadu, India and transesterified using methyl alcohol in presence of KOH. The reason for transesterification was crude oils have naturally higher viscosity and density that causing problems in diesel engine and therefore transesterification process was used to improve the properties and make it compatible for combustion as diesel fuel without any further problems. The figure 1 below shows the transesterification chemical reaction to in the production process of methyl ester biodiesel. After completion of transesterification process and the heavy glycerine was seperated, the producer is left with a light crude biodiesel phase. This neat biodiesel was filtered and further purified prior to use in diesel engine as fuel. The chemical properties of biodiesel and diesel fuel are presented in Table I.

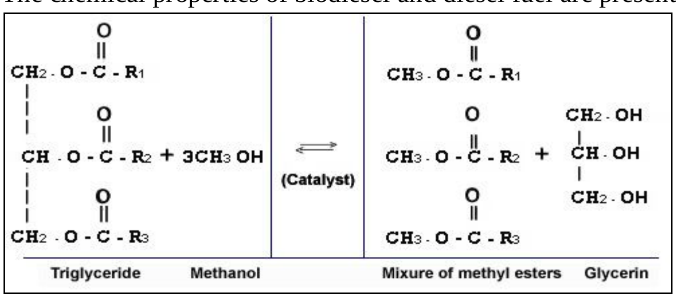

Fig. 1 Transesterification Process.

A. Fuel Properties of Diesel and Biodiesels

The methyl esters of madhuca indica (mahua) oil (MIOME), rice bran oil (RBOME) and their diesel blends were prepared by mixing with diesel in percentage of 20:80 (B20), 40:60 (B40), 60:40 (B60) and 100:0 (B100) on volume basis. The chemical properties of diesel fuel, MIOME and RBOME were evaluated . The properties of diesel and biodiesel blends are presented in Table

TABLE I.Properties of Diesel and Biodiesels

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

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B. Experimental Setup

The present experimental research study used a single cylinder, 4-stroke water cooled compression ignition direct injection (CIDI) for experimental evaluation of exhaust emissions of the engine when it is fueled with blends of MIOME and RBOME. The specifications of the test engine are presented in Table II. The experiment setup is illustrated as schematic diagram below at figure 2 and photographic view is presented in figure 3. The setup consists of 3.7 KW diesel engine, eddy current dynamometer, smoke meter, and exhaust gas analyser. The eddy current dynamometer was coupled with a test diesel engine to operate the engine at various loads such as 25, 50, 75 and 100% load conditions at rated speed of 1500 rpm with rated injection pressure of 200 bar. The engine was initially started with diesel and then repeated with blends of MIOME, RBOME biodiesel.

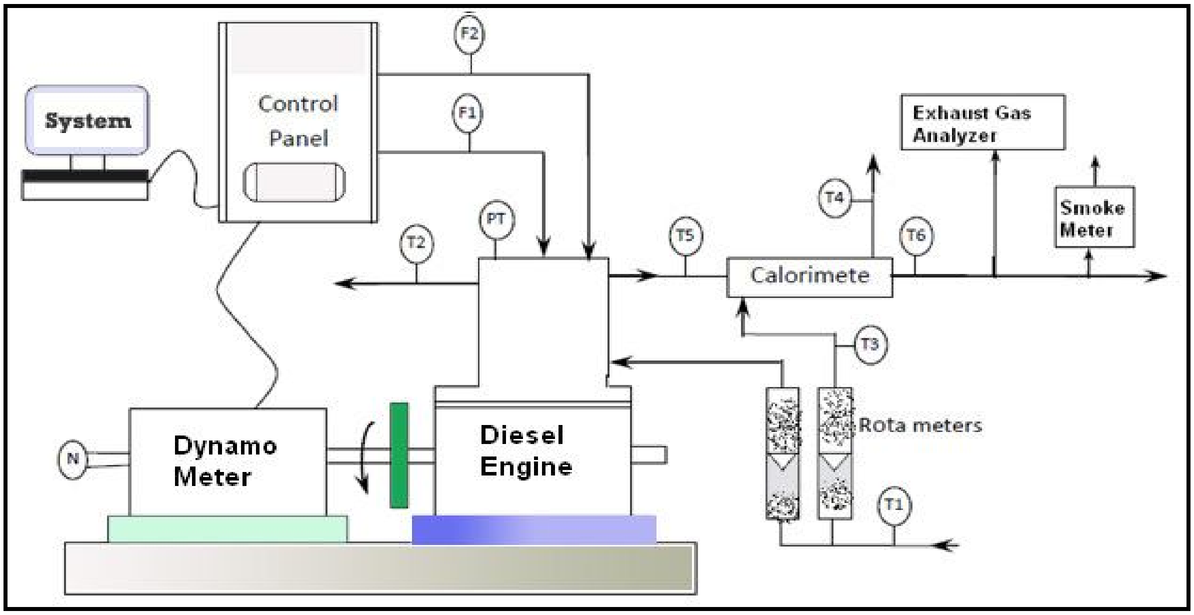

Fig. 2. Schematic Diagram of Experimental Setup

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		

Fig. 3. Photographic View of Engine Test Setup

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TABLE II 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 blends of diesel and methyl esters of Madhuca indica (Mahua) oil and rice bran oil were evaluated in terms of CO emission, smoke opacity and particle pollution. The test results and discussion was presented in below paragraphs.

A. CO Emission

The variation of carbon monoxide (CO) emission with the engine load for different biodiesel blends of MIOME, RBOME and diesel fuel is presented in Figure 5. The graph reveals that B100R blend of rice bran oil biodiesel has the lowest CO emission and the diesel has the highest CO emission at all loads. The B20M blend of MIOME shows closer, but lower CO emissions when compared to diesel, but higher among all other tested blends of both biodiesels. The engine has released lowest CO emissions at no load and has emitted highest emissions at full load conditions for all tested fuels. It was observed that the emission of carbon monoxide (CO) increased with the increase in engine load at all loads. This is because, when load increases the fuel pumped into combustion chamber increases and the insufficient combustion causes more release of carbon monoxide. was also observed that that the emission of CO from the test engine has decreased with increase in percentage of biodiesel proportion in blend.

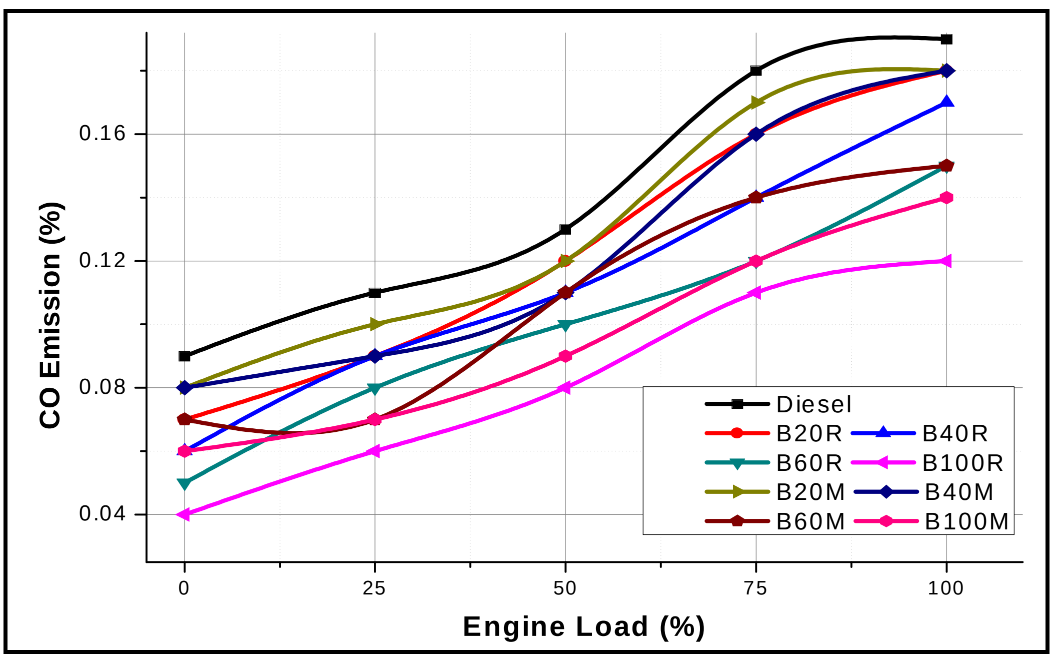

Fig. 4 Variation of CO with Engine Load for Diesel and Different Biodiesel Blends

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B. Smoke Opacity

The variation of smoke opacity (SOP) with engine load for diesel fuel, different biodiesel blends at constant rated speed of 1500 rpm is presented in Figure 5. From the collected test data and graph, it was observed that the smoke opacity emission increased with the increase of engine load. The engine with diesel fuel released highest and neat madhuca indica biodiesel released lowest smoke opacity among all tested fuels. The engine has lowest SOP at no load and highest at full load condition. The B20 blend of MIOME, RBOME biodiesel has nearer smoke opacity to diesel but higher to all other blends of biodiesel. It was noticed that the smoke opacity decreased with increase of biodiesel percentage in blend at all loads.

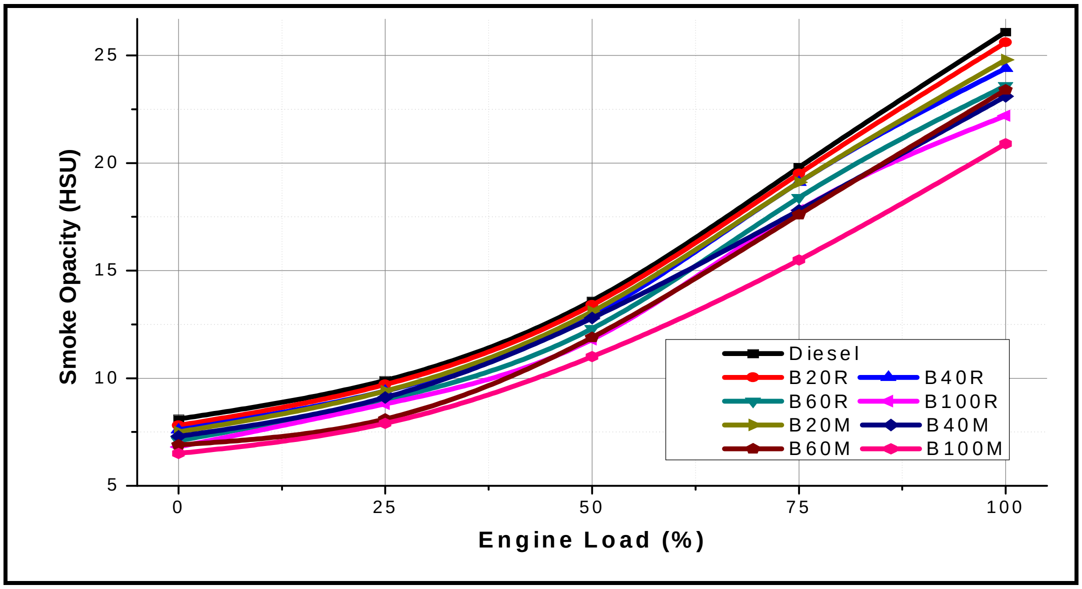

Fig. 5 Variation of Smoke Opacity with Engine Load for Diesel and Different Biodiesel Blends

C. Particle Pollution (PP)

Figure 6 shows the variation of particulate matter (PM) with the engine load for the selected biodiesel blends and the diesel fuel at rated engine speed of engine. As the load increases the PM emission has increased, but when the biodiesel content in blend increased, the PM emission has decreased. The B100R blend of methyl ester of rice bran oil has the lowest and B20R blend of RBOME has the highest PM emission among all tested biodiesel blends, but the diesel has the highest PM emission at all load conditions. The lower value of PM emission by biodiesel blends is due to higher oxygen content in the biodiesels. The engine has emitted lowest emissions at no load condition and higher PM emissions at full load condition.

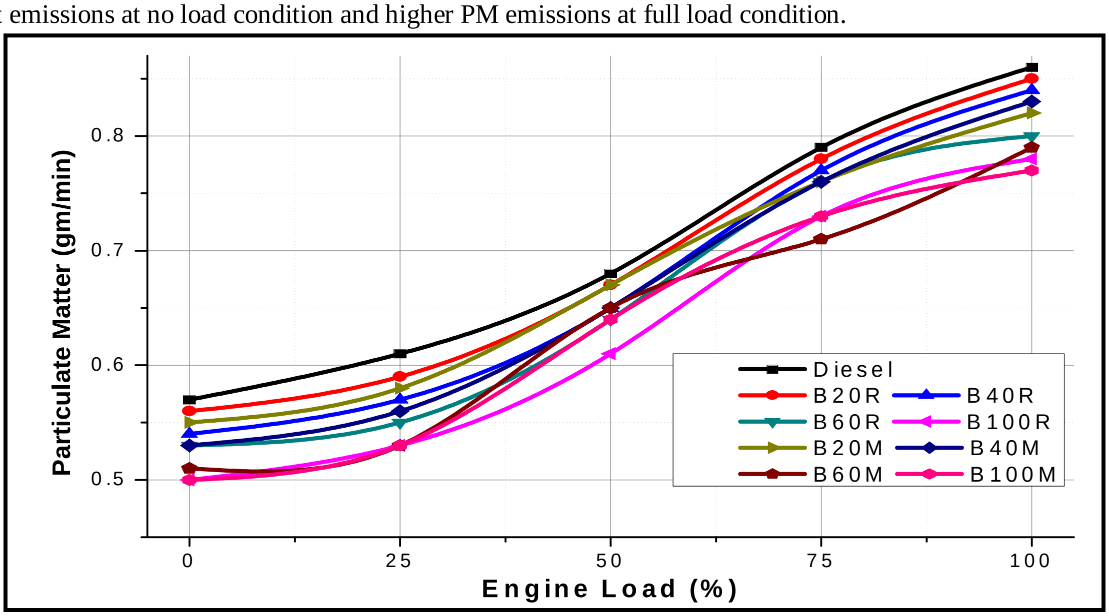

Fig. 6 Variations of Particulate Matter with engine load for diesel and different biodiesel blends

IV. CONCLUSIONS

The Methyl Ester of Madhuca indica oil (MIOME) and Rice bran oil (RBOME) can be used as biodiesel and is a substitute option instead of fossil diesel fuel. The experimental test results with a 4-stroke, single cylinder, water cooled DI compression ignition engine when fuelled with blends of MIOME and RBOME revealed that B100R blend of RBOME shown lower CO emission, B100M blend of MIOME has lower smoke opacity and B100R RBOME has lower PM among all blends of biodiesel and diesel fuel.

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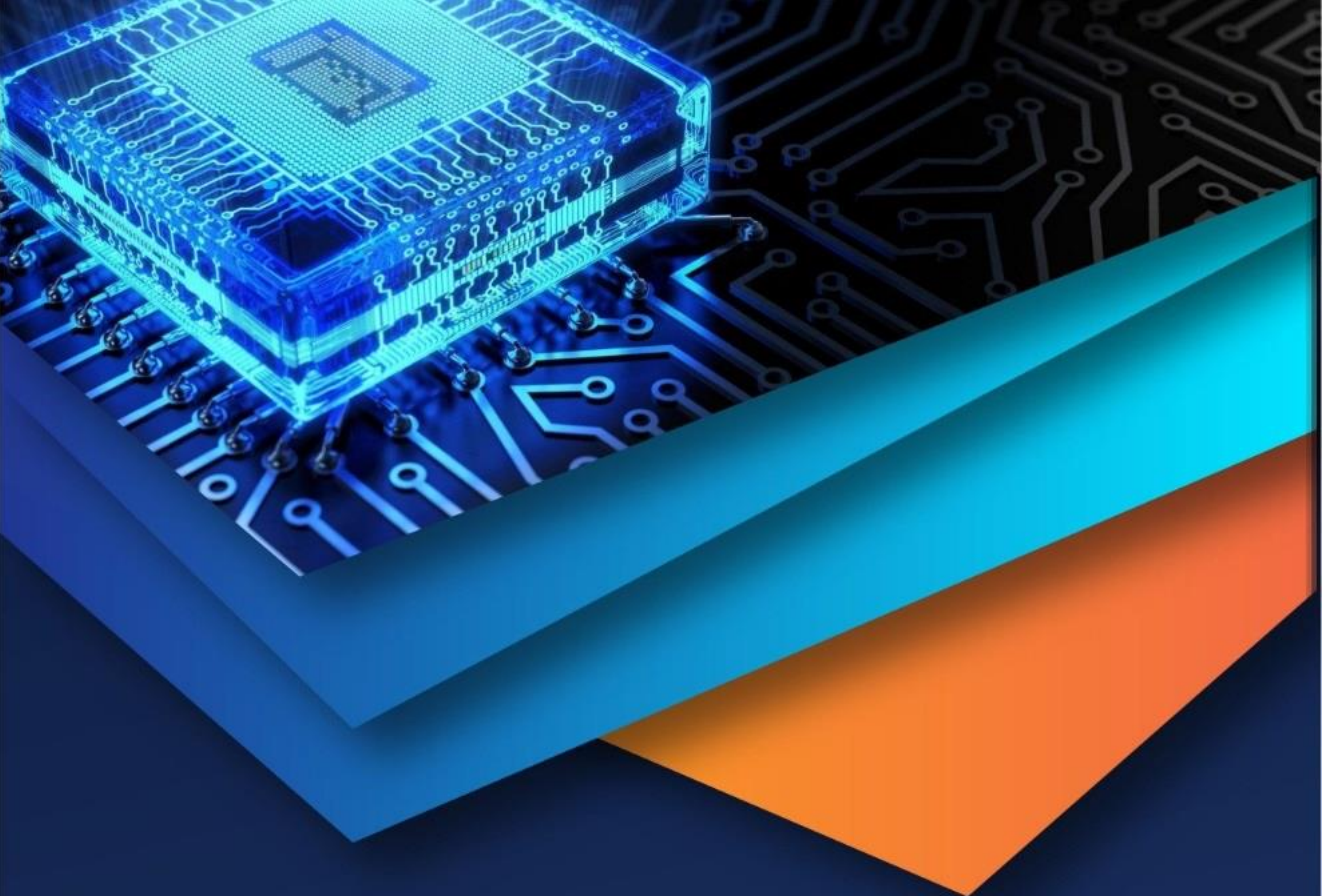

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