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Experimental Study on Performance, Combustion and Emission Characteristics of Gossypium Hirsutum L. Biodiesel Fuelled with Single Cylinder 4-Stroke Diesel Engine

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Abstract - Gossypium Hirsutum L. also called as cotton is produced in more than 80 countries in the world. After harvesting process it will be traded as raw cotton, fiber as well as seeds. The oil will be used for producing biodiesel, manufacturing cosmetics and also used as insecticide. Gossypium Hirsutum L. seeds are having the oil yield of 25-30%. So the oil has been extracted using the mechanical expeller. Biodiesel production has done by using the transesterification process; got FFA content as 1.692 which is less than 4 %. So according to this value here alkali base transesterification has selected by using Sodium Hydroxide as catalyst and methanol as alcohol. It has selected ethanol as additive and adds it into the cotton seed biodiesel. Finally by conducting an engine test using single cylinder 4-stroke diesel engine, it has noted that the blend B20E10 has secured good performance at 100% load. And also noted that addition of ethanol will almost match the properties of cottonseed oil biodiesel with diesel and reduces the emission of NO_x and increases the emission of CO and HC by reducing combustion temperature.

Key words - Gossypium Hirsutum L., Biodiesel, Transesterification, Additive, Ethanol Blend, Performance, Combustion, Emission.

I. INTRODUCTION

Now a days, fossil fuels for fulfilling public's personal needs and they are polluting the environment and also they are limited to certain period of time and also they are very expensive. To replace the use of fossils fuels research fellows got a solution in the name of biodiesel. And they concluded that biodiesel is a good alternative fuel from the renewable energy source and can use them by blending with the diesel in regularly using vehicles. Biodiesel will be produced from vegetable oil, animal fats, tallow and leftover cooking oil by using the process called transesterification [1]. There will be two types of transesterification process one is catalytic and another one is non-catalytic process. In catalyzed transesterification process there will be two types of catalysts are used one is homogeneous and other one is heterogeneous. Under both homogeneous catalyst and heterogeneous transesterification there will be two types one is base and another one is direct acid catalyzed transesterification [2]. Homogeneous catalyst includes sodium hydroxide, sulphuric acid, oxides of tin, zinc, magnesium etc. Heterogeneous catalyst includes sulphates metal oxides, heteropolyacids, sulphonated amorphous carbon etc. as solid acid catalyst and metal oxides, zeolites, calcium oxide as solid base catalyst. Solid base catalysts are very much energetic than solid acid catalysts [3]. Hence the biodiesel will be produced from triglycerides with the help of catalyst and alcohols, resulting in the formation of glycerol and alkali esters by using the process called transesterification [4]. Addition of oxygenated additives like ethanol and methanol are very important because they reduce the main disadvantage of biodiesel like emission of some quantity of pollutants because the smoke emission depends on oxygen content and molecular arrangement of fuel. And they increases the octane rating and combustion quality and lower the ignition temperature of biodiesel and the properties such as viscosity, density, behavior at low temperature, volatility and cetane number are directly affected by oxygenated additives [5] [6]. So by adding ethanol as additive to the biodiesel will reduce the NO_x emission [7] [8] [9] [10].

II. GOSSYPIUM HIRSUTUM L. AS A FEEDSTOCK

Gossypium Hirsutum L. (Gossypium Hirsutum Linnaeus) is also called by the name upland cotton and has started growing cotton in 7000 years ago in the Indus valley in United States. Also currently in some places of North India and North Karnataka and very few places of south India are cultivating these cotton plants as a commercial crop. The specification of cotton has clearly mentioned in the Table I. The plant grows up to 2 m tall per annum. Leaves are heart shaped at base and grow up to 10 cm long; flowers are

yellowish white in colour; fruit capsules are up to 4 cm long and having 3 to 5 cells and each cell is having up to 10 hairy and fuzzy seeds. The seeds are ovoid in shape. The yield of cotton seed is around 1200 kg to 2450 kg per hectare. An oil yield of cotton seed is around 25 to 30 %. It is an annual crop and can get the seeds once in a year.

TABLE I
SPECIFICATION OF COTTON PLANT

Botanical Name	Gossypium Hirsutum Linnaeus
Kingdom	Plantae
Family	Malvaceae
Genus	Gossypium
Species	G Hirsutum

III. BIODIESEL PRODUCTION

Oil has been extracted using the mechanical expeller and got an oil yield of 25% (250 ml of oil per kg of Gossypium Hirsutum L. seeds). It is necessary to filter the crude oil because it contains some impurities. Next based on the FFA content, 1.692 which is less than 4 % the alkali base transesterification process has selected. The transesterification process will be carried out in the following way. 1 liter of filtered pure oil has measured and poured into the 3 necked flask. Fixed the condenser to the flask. Then prepared the solution by using 5.5 grams of NaOH and 250 ml of methanol. Heated the oil up to 60^0 C using heater by stirring uniformly by using magnetic stirrer by maintaining the speed around 600 rpm. Added the solution which has been prepared by using NaOH and methanol into the beaker. Allowed the reaction mixture for 120 minutes for taking proper reaction. After reaction takes place, poured the mixture into the separation tank and allowed it to settle for 120 minutes. After the settling time two phases will be formed in the separation tank one is at the top and other is at bottom. The top phase is methyl ester and bottom phase is glycerol. Then taken out the glycerol from the separation tank. Then only methyl ester has remained in the separation tank. After that, taken 1 liter of water and heated for about 60^0 C and poured into the separation tank which contains methyl ester to do water wash. Repeated the water wash process for around 4 to 5 times and removed catalyst residue or soap. Later taken out the methyl ester from the separation tank to the open beaker and heated it using electrical heater for around 120^0 C after that the remaining methanol has been vaporized and escaped from the methyl ester finally pure biodiesel has been remained in the beaker. Then measured the amount of biodiesel obtained to know the conversion yield. And it has been obtained 850 ml of biodiesel from 1 liter of cotton seed oil.

IV. ETHANOL AS ADDITIVE

The process of addition of additives is called as emulsification and the biodiesel called as emulsified biodiesel. The oxygenated additives like ethanol and methanol are very important because they reduces the main disadvantage of biodiesel like emission of some quantity of pollutants because the smoke emission depends on oxygen content and molecular arrangement of fuel. And they increases the octane rating and combustion quality and lower the ignition temperature of biodiesel and the properties such as viscosity, density, behavior at low temperature, volatility and cetane number are directly affected by oxygenated additives. Initially the physical properties of biodiesel are not same as diesel fuel so it is impossible to get the efficiency in the engine which is running by normal diesel fuel. By adding additives it is possible to match the physical properties of biodiesel with the standard diesel fuel so that can get the efficiency which is approximately equal to conventional diesel. The major problem using biodiesel is emission of harmful gases. So by adding ethanol and methanol as additive to the biodiesel can reduce the NO_x, CO and HC emissions. Here it has been selected ethanol as additive and adds it into the cotton seed biodiesel and diesel blends in varying proportions to check their effect on emission of pollutants.

V. BLENDING PROCESS

Blending means mixing of different liquids to form a homogeneous mixture. As mentioned in the objective of the project it is required to blend the biodiesel with diesel with some amount of ethanol. After blending it is required to keep the samples for minimum of 24 hours to bring it to homogeneous mixture. In this work 1000 ml blend samples have prepared as shown in Fig. 1 and Fig. 2. The details of different blending ratios which are used in this project are as follows: B20, B30, B40, B50, B20E5 and

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B20E10.

Fig. 1 Biodiesel blends of cotton seed oil

Fig. 2 Ethanol blends

VI. EXPERIMENTAL SETUP

To estimate the performance, combustion and emission characteristics of the various blends of biodiesel, an engine test should be conducted. Here the engine test has been conducted using single cylinder 4-stroke computerized diesel engine to analyse the performance and combustion parameters and exhaust gas analyser has been used to study about the emission of gases. The experimental setup is as shown in the Fig. 3.

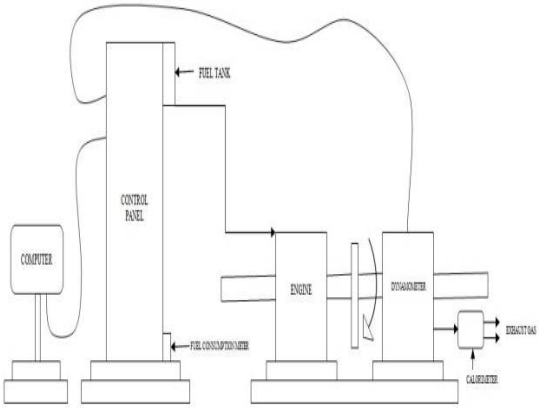

Fig. 3 Block diagram of experimental setup

A. Specification of Diesel Engine

Every engine is having different specification among them the Table II shows the specification of the computerized diesel engine which has been used in the experiment. Addition to the engine it has provided with control panel to vary the load and other useful parameter like fuel over ride and also to set the pressure and crank angle. It is having cooling water filtering unit also. The main components of engine are cylinder, piston, connecting rod, crank shaft, crank webs to for balancing purpose, main bearing, crank pin, fuel nozzle, piston rings, piston pins, Intake and exhaust valves, cam and cam shaft, valve springs, crankcase, flywheel, bed plate, cooling water jackets.

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TABLE II
SPECIFICATION OF COMPUTERIZED DIESEL ENGINE

Parameter	Details
Made	Kirloskar
Number of Strokes	4
Number of Cylinder	1
Fuel Used	Diesel
Diameter of Cylinder	0.0875 m
Cylinder Stroke	0.11 m
Cooling System	Water Cooled
Lubrication	Forced Type
Output	5.2 kW at 1500 rpm
SFC	251 g/(kW-h)

Fig. 4 Engine control panel

Fig. 5 Diesel engine

Once the initial conditions are satisfied to operate then start the engine by cranking with the help of decompressor lever and handle provided. Observe the fuel consumption indicator and maintain the minimum fuel consumption rate. Once the exhaust temperature indicator becomes steady press the log current data button then it will create a result sheet for the applied load by taking around 30 seconds of time. Then give save experiment option to save the results in the computer. And also save the pressure and crank angle diagram. Continue the same procedure for different loads as required by using dynamometer knob provided on the control panel as shown in the Fig. 4. Turn off the engine by cut-off the fuel supply pressing the lever provided in the engine. And finally stop the cooling water supply. The engine used in this work is as shown in the Fig. 5.

VII. RESULTS OF PERFORMANCE TEST

Engine performance test has been conducted using single cylinder 4-stroke diesel engine for different loads like 0% (0kg), 25% (3kg), 50% (6 kg), 75% (9 kg) and 100% (12 kg) for samples of D100, B20, B30, B40, B50, B20E5 and B20E10.

A. Influence of Load on Brake Thermal Efficiency (BTE)

The deviation of Brake Thermal Efficiency by varying the load as shown in Fig. 6. It shows that the Brake Thermal Efficiency increases as the load increase. And the BTE of ethanol blended samples is more than the blends without ethanol and it almost

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reached the BTE of Pure Diesel. The B20E10 is having highest BTE of 46.5 % at maximum load compare to all other blends. Finally the graph tells that as the addition of ethanol increases in the biodiesel blends increases the BTE of the fuel.

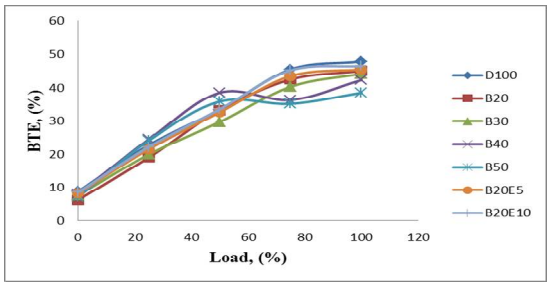

Fig. 6 Variation of BTE with respect to varying load

B. Influence of Load on Specific Fuel Consumption (SFC)

The Fig. 7 indicating that, the amount of brake specific fuel consumption decreases as load increases. And the BSFC decreases as increasing the addition of ethanol to the biodiesel blends at low loads. The very low BSFC of 0.0031 kg/kW-min has found to B20E10 sample at full load condition.

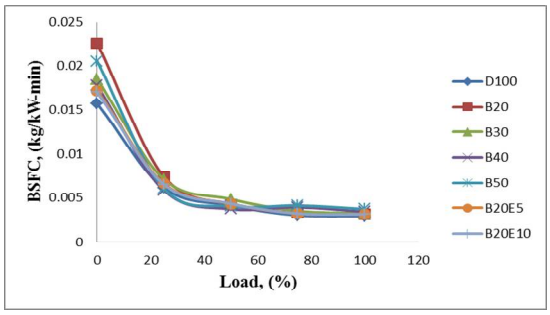

Fig. 7 Variation of BSFC with respect to varying load

C. Influence of Load on Exhaust Gas Temperature

The Fig. 8 indicates that the exhaust gas temperature rises as the load rises for all diesel and biodiesel samples. But the addition of ethanol to biodiesel blends will reduce the exhaust gas temperature for fraction. Due to minor heating value exhaust gas temperature of biodiesel and ethanol is more compare to diesel. Very low exhaust gas temperature of 158 ^{0}C has found to B40 at 0 % load and maximum of 376 ^{0}C has found to B20 at full load.

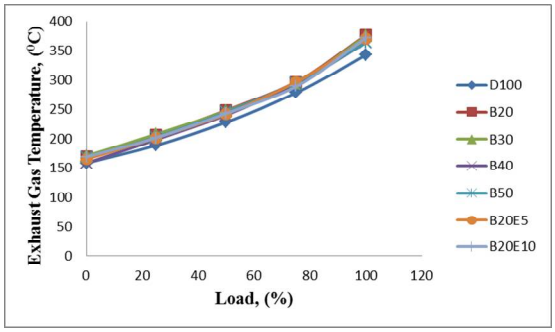

Fig. 8 Variation of exhaust gas temperature with respect to varying load

VIII. CHARACTERIZATION OF COMBUSTION PARAMETERS

The combustion quality can be characterizes by the parameters crank angle and pressure. The Fig. 9 shows the effect of pressure with respect to crank angle at 50 % load for all the blends. The pressure is almost same for the entire crank angles but at certain crank angle it reaches to peak position. It is showing that D100 is having low peak pressure and B20E10 is having high peak pressure at 50 % load.

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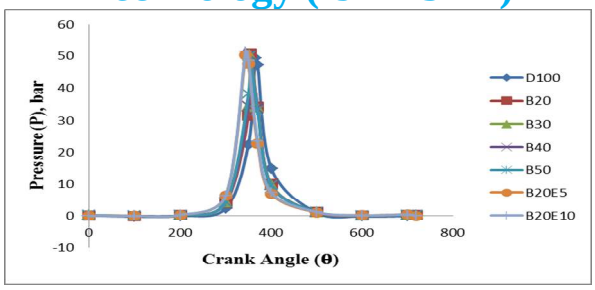

Fig. 9 P-**θ** diagram for 50 % load

The Fig. 10 indicates that B20 is having maximum peak pressure and the lowest peak pressure has obtained for B20E5 sample among all the samples at 100 % load condition. The variation in combustion for different loads has shown in the Fig. 9 and Fig. 10.

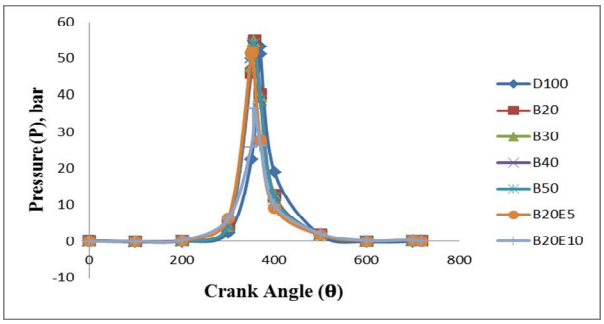

Fig. 10 P-**θ** diagram for 100 % load

IX. RESULTS OF EMISSION TEST

It is required to concentrate on the reduction of harmful emissions. So by conducting the emission test using gas analyser one can determine the amount of harmful gases present in the exhaust of any engine.

A. Effect of Load on Emission of CO

The amount of CO emitted for varying load of different blends has shown in Fig. 11. And from the graph it has noted that the emission of CO increases as the ethanol addition increase to biodiesel blends. Here the more CO of 0.21 % has found to B20E10 at 100 % load and less CO of 0.04 % has found to B40 at 25 % load condition because of cooling effect.

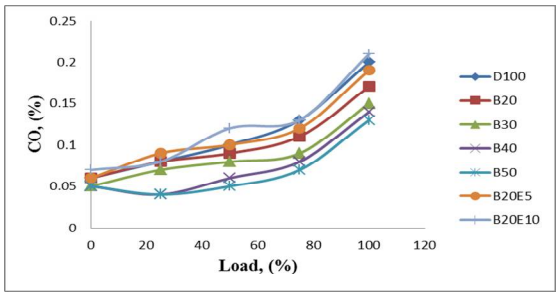

Fig. 11 Effect of load on CO

B. Effect of Load on Emission of HC

If amount of ethanol added to biodiesel blend increases then emission of HC also increases because addition of ethanol decreases the oxygen comfortable. The variation in emission of HC with respect to variation in load is as shown in the Fig. 12. The more HC of 62 parts per million has found to B20E10 at 100 % load and less HC of 4 ppm has found to B50 at 25 % load condition because of cooling effect.

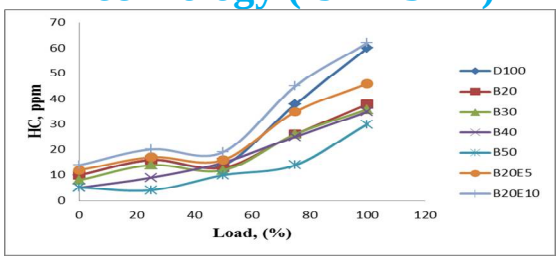

Fig. 12 Impact of load on HC

C. Effect of Load on Emission of NO_X

To reduce NO_X, if it reduces the addition of biodiesel to diesel then it is not possible to achieve economy. So the only way to control NO_X is the addition of ethanol to biodiesel blends so that it makes the NO_X reduction. The effect of varying load on NO_X emission is as shown in the Fig. 13. The more NO_X of 600 parts per million has found to B50 at 100 % load and less NO_X of 90 ppm has found to B20E10 at 0 % load condition because of cooling effect.

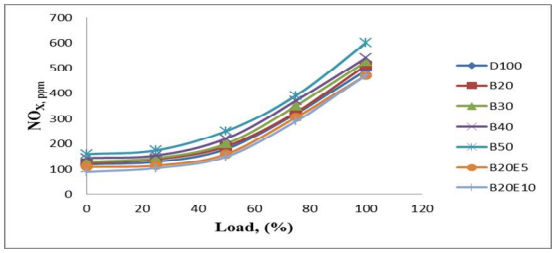

Fig. 13 Influence of load on NO_X

X. CONCLUSIONS

After conducting the experiment finally it can be concluded by the following points.

A. The cotton seed oil is having low FFA content. Hence it is easy to produce biodiesel using single step transesterification process.
B. The properties of cotton seed oil biodiesel are good so that it can be used in diesel engine as an alternative fuel without doing any alteration of engine.
C. The properties of B20 sample are closer to diesel properties and hence it gives better performance.
D. Addition of ethanol will still more improves the properties of biodiesel closer to the diesel properties.
E. Addition of ethanol upturns the brake thermal efficiency by reducing the specific fuel consumption.
F. There will be proper combustion occurred inside the engine cylinder due to addition of ethanol.
G. Addition of ethanol reduces the emission of NO_X and increases the emission of CO and HC.

XI. ACKNOWLEDGEMENT

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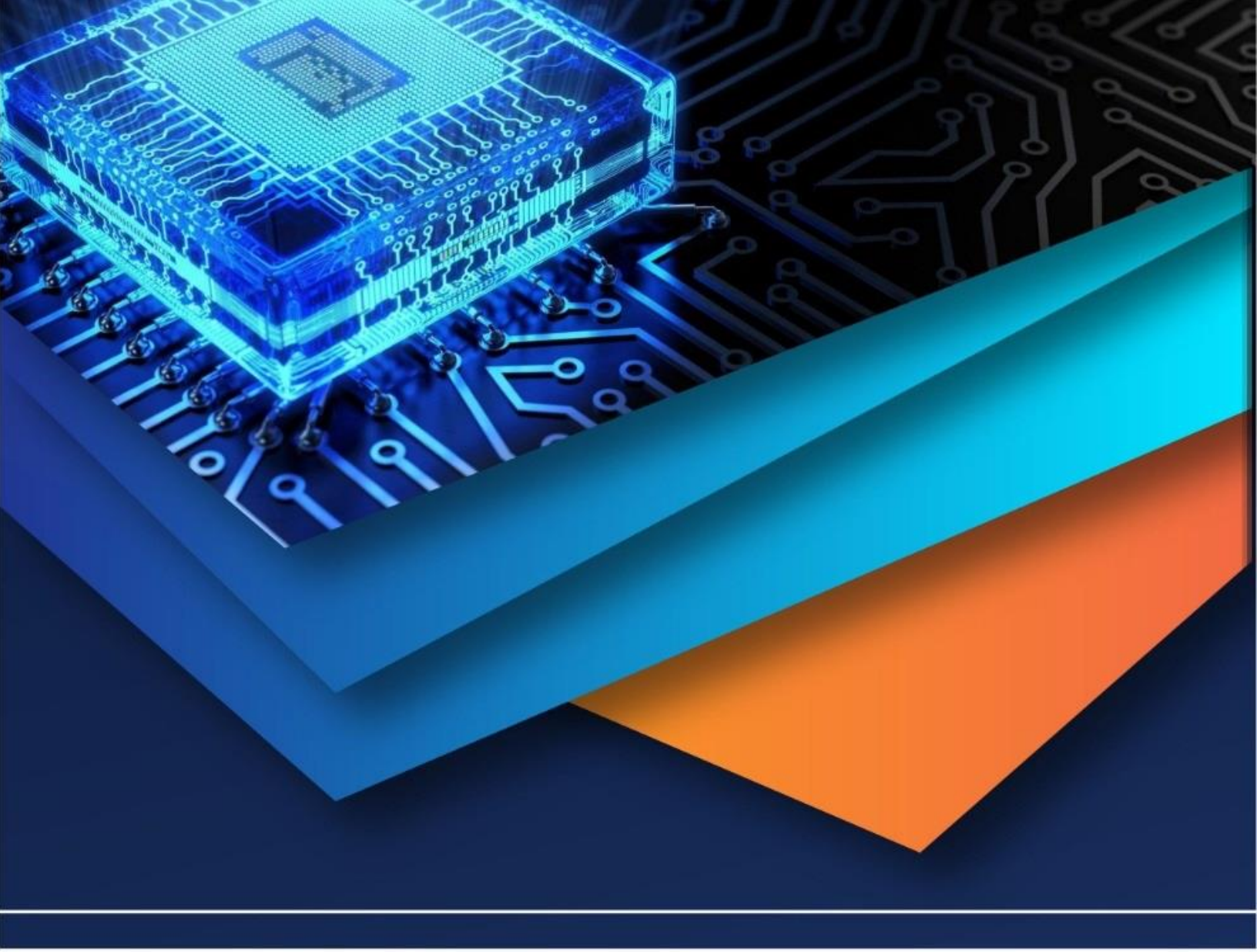

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