Volume: 4 Issue: I Month of publication: January 2016
DOI:

International Journal for Research in Applied Science & Engineering Technology (IJRASET)

Use of Straight Vegetable Oil in Single Cylinder Diesel Engine Using Waste Heat Recovery System

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Abstract--The world is being modernized and industrialized day by day. As a result vehicles and engines are increasing. But energy sources used in these engines are limited and decreasing gradually. The rapidly depleting conventional petroleum resources have promoted research for alternative fuels for diesel engines. Bio-fuel, a promising substitute as an alternative fuel has got significant attention due to the limited sources of conventional fuels and environmental concern. From different possible options, fuels derived from vegetable oil present promising renewable substitutes for fossil fuels. The utilization of Straight vegetable oil fuel in diesel engine fuel has main the advantage of eliminating the energy, cost and time consumed in biodiesel production. Oil derived from Jatropha curcas plant has been considered as a sustainable alternate fuel for diesel engine. The use of straight vegetable oil encounters problem due to its high viscosity, poor volatility and cold flow. The purpose of this review is to reduce the viscosity of oil by effectively utilization of waste heat from exhaust gases before fed to inlet.
Keywords— Diesel Engine, Jatropha, Straight vegetable oil

I. INTRODUCTION

In our present day lifestyle, the internal combustion engines have already become an indispensable and integral part, particularly in the transportation and agricultural field. CI engines are the most trusted power sources which are preferred in the transportation industry also. Due to the problems of fuel crisis and environmental pollution, the survival of these engines has been threatened. Therefore to protect the global environment, it's become necessary to search an alternative of oil as energy source. Among different clean burning sources, bio-fuel obtained from vegetable oils seems to be more efficient because of its renewable and clean burning property similar to mineral diesel. The use of edible vegetable oils for bio-fuel production has recently been of great concern because they compete with food materials. As the demand for vegetable oils for food has increased tremendously in recent years, it is impossible to justify the use of these oils for fuel use purposes such as bio-fuel. Moreover, these oils could be more expensive to use as fuel. Hence, the contribution of non-edible oil will be significant as a non-edible plant oil source for biodiesel production.

A. Why "Bio Fuels"?

Nowadays, research have been made to use vegetable oil, animal fats as an alternate source of renewable energy known as bio-fuel that can be used as fuel in CI engines. Bio-fuels appear to be a potential alternative "greener" energy substitute for fossil fuels. It is renewable and available throughout the world. The idea of using vegetable oils as fuel for diesel engines is not new. Bio-fuels are generally considered as offering many properties, including sustainability, reduction of greenhouse gas emission regional development, social structure and agriculture, security of supply. Vegetable oils are considered as most sustainable alternative fuels for CI engines as they are renewable, biodegradable, non-toxic, environmental friendly, a lower emission profile compared to diesel fuel and most of the situation where conventional petroleum diesel is used. Non edible vegetable oils are the most significant to use as a fuel compared to edible vegetable oils as it has a tremendous demand for using as a food and also the high expense for production. Therefore many researchers are experimenting on non-edible vegetable oils. In India the feasibility of producing bio diesel as diesel substitute can be significantly thought as there is a large junk of degraded forest land, unutilized public land, and fallow lands of farmers, even rural areas that will be beneficial for overall economic growth. . The use of vegetable oils, such as palm, soya bean, sunflower, peanut, and olive oil, Jatropha curcas etc. as alternative fuels for diesel is being promoted in many countries. Only a very few and non-edible type such as Jatropha oil, karanja oil, etc. can be considered to be eco nominally afford able to some developing countries like India in particular.

B. Jatropha Plant

The Jatropha curcas Linnaeus plant (J. curcas L.) belongs to the family Euphorbiaceae. The genus name Jatropha derives from the Greek jatros (doctor), trophe (food), which implies medicinal uses, hence the plant is traditionally used for medicinal purposes. It is a hardy shrub that can grow on poor soils and areas of low rainfall (from 250 mm a year) hence its being promoted as the ideal plant

Volume 4 Issue I, January 2016
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

for small farmers. It is a drought-resistant, perennial plant and living up to fifty years and has capability to grow on marginal soils. It requires very little irrigation and grows in all types of soils (from coast line to hill slopes). It is a rapidly growing tree and easily propagated. Jatropha usually grows below 1400 meters of elevation from sea level and requires a minimum rainfall of 250mm, with an optimum rainfall between 900-1200mm. It is non-edible oil being singled out for large-scale for plantation on waste lands Jatropha plant can thrive under adverse conditions. The production of Jatropha seeds is about 0.8 kg per square meter per year. The oil content of Jatropha seed ranges from 30% to 50% by weight and the kernel itself ranges from 45% to 60%. Fresh Jatropha oil is slow-drying, odor less and colour less oil, but it turns yellow after aging. [5]

Fig. 1 Jatropha Plant [8]

C. The Cultivation Of The Jatropha Plant

Jatropha curcas L. has various socio-economic benefits which makes it more economical when cultivated on commercial scale. Jatropha can be propagated from seeds as well as from cuttings. Seeds or cutting can be directly planted in the main field. Otherwise, seedlings grown in poly bags are transplanted in the main field. A hectare of Jatropha plantation is reported to yield 2.5-3.5tonnes of seeds in the third year and increases sharply to 5000-12,000 tonnes per hectare from the sixth year onwards. [7]

D. Jatropha As A Plant Of Many Uses

Rural energy problems in developing countries and are linked with other rural problems. These problems need an integrated approach to reach solutions. The Jatropha plant has four main contributions to rural development and poverty eradication in general: Renewable energy, promotion of women, poverty reduction and soil erosion control. The Jatropha Curcas has many products and potential contributions to rural community development. The products of the Jatropha plant are the plant itself, fruits, leaves, and latex. The fruits comprise of seeds and fruit hulls. The seeds produce seed oil, seed cake, and seed shells. The oil processes also produce sediments from oil purifications. The Jatropha plant itself can be used in erosion control if planted across the hills and against the wind. The plant can also be used as firewood. The fact that it grows very fast means Jatropha can be used to solve the problems of deforestation in many developing countries. The toxicity of the plant deters animal browsing. The leaves are used as a medicine and could also be used to develop Silkworm. The leaves can also be used as an anti-inflammatory substance. The Jatropha plant also provides a source of employment to many rural areas, which in turn helps to reduce urban migration in developing countries. [1]

E. Toxicity Of The Jatropha Plant

The toxicity of the Jatropha Curcas is an advantage on one side and disadvantage on the other. The advantage emanates from the fact that the plant leaves cannot be browsed by animals and could act as an excellent fence. The disadvantage comes from the fact that the equipment, such as ram presses that are used to press Jatropha seeds, could not be used to press other edible seed oil from plants like sunflower unless a thorough cleaning is done which would take a lot of environmental resources. The claims that there are some varieties of non-toxic Jatropha plants need more investigation. [8]

F. Characterization Of Jatropha Oil

Non-edible oil generally contains about 3-4 %wax and gum. De-waxing and degumming of plant oils is required not only for smooth running of the CI engine but also to prevent engine failure even if plant oils are blended with diesel. It is therefore necessary

Volume 4 Issue I, January 2016
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to remove wax and gum from the fresh oil before it could be used in CI engine. Analysis of Jatropha seeds revealed that the percentage of crude protein, crude fat and moisture were 24.60, 47.25 and 5.54% respectively Characterization of diesel and Jatropha oil is as per the Table–I

TABLE I: PHYSICAL AND CHEMICAL PROPERTIES OF DIESEL AND JATROPHA OIL BLEND [3]

Properties	Diesel	Jatropha OIL
Density , g/cc, 30 0C	0.836-0.850	0.93293
Kinematic viscosity, cSt, 30 0C	04-04	52.76
Cetane No.	40-55	38
Flash point, 0C	45-60	210
Calorific value, MJ/Kg	42-46	38.2
Saponification value	---	198
Iodine No.	---	94

From the above table, Density, cloud point and pour point of Jatropha oil are found to be higher than diesel. Higher cloud and pour point reflect unsuitability of Jatropha oil as diesel fuel in cold climatic conditions but the flash and fire points of Jatropha oil is very high compared to mineral diesel. Hence, Jatropha oil is extremely safe to handle. Higher carbon residue from Jatropha oil may possibly lead to higher carbon deposits in combustion chamber of the CI engine. Low sulphur content in Jatropha oil results in lower SOX emissions. Presence of oxygen in fuel improves combustion properties and emissions but reduces the calorific value of the fuel. Jatropha oil has approximately 90% calorific value compared to diesel. [3]

G. Advantages Of Jatropha [1]

Hardy shrub which grows in semi-arid conditions and poor soils.

Can be intercropped with high value crops such as sugar, coconut palm, various fruits and vegetables, providing protection from grazing livestock and phyto-protection action against pests and pathogens.

It is easy to establish and grows relatively quickly.

Yields around 4 tons of seed per hectare in unkept hedges are achievable.

Has a low nutrient requirement.

Requires low labor inputs.

Bio-fuel almost completely eliminates life cycles CO_2 emission.

Production of 1t / ha / year of high protein seed cake that can be used as animal and fish feeds and organic matter that can be used as organic fertilizers.

Various other products from the plant (leaf, bark and seed extracts) have various other industrial and pharmaceutical uses.

Restoration of degraded land over a period of time.

The highest cetane no. of bio-diesel compared to petro diesel indicates potential for higher engine performance.

The superior lubricating properties of bio-diesel increases functional engine efficiency.

Their higher flash point makes them to safer to store.

The bio-diesel molecules are simple hydrocarbon chains, contains no sulfur or aromatic substances associated with fossil fuels.

H. Economics Benefits [1]

Increase employment activity and increase Employment on the countryside.

Emits up to 100% less sulphur dioxide.

Reduces smoke particulates at about 75%.

I. Disadvantages Of Jatropha [1]

Low volatility.

High pour points, cloud points and cold filter plugging.

Higher NOX emissions at elevated temperatures.

Incomplete combustion.
Seeds and leaves are toxic to human beings and animals
Toxicity is based on several components (phorbol esters, curcains, trypsin inhibitors and others) which make complete detoxification a complicated and difficult process.
Competes with food production for land use.

II. LITERATURE REVIEW

A. Kazi Mostafijur Rahman Et Al. "Biodiesel From Jatropha Oil As An Alternative Fuel For Diesel Engine" [1]

They were investigates the prospect of making of biodiesel from Jatropha oil. Jatropha curcas is a renewable non-edible plant. Jatropha is a wildly growing hardy plant in arid and semi-arid regions of the country on degraded soils having low fertility and moisture. The seeds of Jatropha contain 50-60% oil. In their study the oil has been converted to biodiesel by the well-known Trans esterification process and used it to diesel engine for performance evaluation

TABLE II: THE OBSERVED ENGINE PERFORMANCE USING DIESEL AND BIODIESEL [1]

Performance	Diesel	Biodiesel	50% Biodiesel & 50% Diesel
Brake power, kw	0.466	0.895	0.339
Specific fuel consumption, g/kw-hr	784	629.74	1298
Mass of fuel, kg/hr	0.712	0.62	0.44
Brake thermal efficiency	11.76	24.09	10.8
Mass of air, kg/hr	7.94	5.52	8.49
Air fuel ratio	31.15	8.9	19.3

From their research they were conclude that the calorific value of biodiesel was almost same as the diesel. It has been found that the performance of biodiesel, mixture of 50% biodiesel & 50% diesel and compared with diesel and found that the brake power, brake thermal efficiency was greater than diesel and mass of air, fuel consumption, mass of fuel of biodiesel and air fuel ratio was less than diesel. It had also found that brake power, brake thermal efficiency, mass of fuel of biodiesel is greater than 50% biodiesel & 50% diesel and mass of air and air fuel ratio of biodiesel is less than mixture of 50% biodiesel & 50% diesel. From the analysis of exhaust gas it is observed that %of CO_2 gas of biodiesel was very lower than the diesel and also from the mixture of 50% biodiesel & 50% diesel. The % of $O_2$of biodiesel is very higher than the diesel and nearly with mixture of 50% biodiesel & 50% diesel. And the % of CO is zero for biodiesel & one for other two compositions.

B. Pramanik, "Properties And Use Of Jatropha Curcas Oil And Diesel Fuel Blends In Compression Ignition Engine"[3]

The main aim of the present investigation was to reduce the viscosity of Jatropha curcas oil close to that of conventional fuel to make it suitable for use in a C.I. engine and to evaluate the performance of the engine with the modified oils. Significant reduction in viscosity was achieved by dilution of vegetable oil with diesel in varying proportions. Among the various blends, the blends containing up to 30% (v/v) Jatropha oil have viscosity values close to that of diesel fuel. The blend containing 40% (v/v) vegetable oil has a viscosity slightly higher than that of diesel. The viscosity was further reduced by heating the blends. The viscosity of the blends containing 70 and 60% vegetable oil became close to that of diesel in the temperature ranges of 70–75 and 60–65 °C, respectively. The corresponding temperatures were found to be 55–60 and 45 °C for 50 and 40% blends, whereas only at 35–40 °C did the viscosity of the 30:70 J/D blend become close to the specification range. Acceptable brake thermal efficiencies and SFCs were achieved with the blends containing up to 50% Jatropha oil. Blends with a lower percentage of vegetable oils showed slightly higher exhaust gas temperatures when compared to an engine running with diesel but they were much lower than the Jatropha curcas oil in all cases. Therefore, from the engine test results, It has been established that up to 50% Jatropha curcas oil can be substituted for diesel for use in a C.I. engine without any major operational difficulties. However, the properties of the blends may be further improved to make use of higher percentage of Jatropha oil in the blend using Jatropha oil of purer grade which may be obtained by pre-treatment of the oil. Moreover, the long term durability of the engine using bio-diesel as fuel requires further study

C. Deepak Agarwal And Avinash Kumar Agarwal, "Performance And Emission Characteristics Of Jatropha Oil (Preheated And

Blends) In A Direct Injection Compression Ignition Engine" [2]

In their study they were designed the experiments to study the effect of reducing Jatropha oil's viscosity by increasing the fuel temperature (using waste heat of the exhaust gases) and thereby eliminating its effect on combustion and emission characteristics of the engine. They were also conduct the Experiments using various blends of Jatropha oil with mineral diesel to study the effect of reduced blend viscosity on emissions and performance of diesel engine. They were used A single cylinder, four stroke, constant speed, water cooled, direct injection diesel engine for their experiments. They were analyze the various parameters like thermal efficiency, brake specific fuel consumption (BSFC), smoke opacity, CO_2, CO and HC emissions. From their experiment they were conclude that if the viscosity of Jatropha oil reduced to that of conventional diesel than it is suitable for use in a C.I. they were found that viscosity was reduced by (i) preheating the oil (Jatropha oil) and (ii) by blending the Jatropha oil with diesel. Diesel and Jatropha oil were characterized for their various physical, chemical and thermal properties. They were found that heating the Jatropha oil between 90 ^{0}C and 100 ^{0}C is adequate to bring down the viscosity in close range to diesel. Viscosity of Jatropha blends (up to 30%) was also found close to diesel.

D. M. C. Navindgi, Maheswar Dutta And B. Sudheer Prem Kumar, "Prformance Evaluation, Emission Characteristics And Economic Analysis Of Four Non-Edible Straight Vegetable Oils On A Single Cylinder CI Engine" [4]

They were carried out experimental investigations in a single cylinder DI diesel engine to examine the suitability of different vegetable oils such as Neem, Mahua, Linseed and Castor as alternate fuels. Further the performance and emission characteristics of these oils are evaluated and compared with diesel and optimum fuel is determined. From the above investigations, following conclusions are drawn. The properties viz. density, viscosity, flash point and fire point of above vegetable oils are higher and calorific value is lower than that of diesel. Viscosity at 30°C of diesel is very close to the viscosity at 80^{0}C of neat Neem, Mahua and linseed oil, and that at 120^{0}C for Castor. Hence preheating of oils is required to attain the smooth flow. Performance and emission characteristics of Neem, Castor and Mahua are better than other fuels. The maximum brake thermal efficiency and minimum BSFC of Neem, Mahua and Castor are well comparable with diesel. Smoke emission of Castor and Mahua followed by Neem are lower compared with other oils. For Linseed oil smoke emission is on higher side for entire range of operation. Hence from above conclusions it may be stated that Neem, Mahua and Castor oils with preheating has acceptable performance with lower emissions. Hence these neat oils with preheating can be substituted as fuel for diesel engine without any modification in the diesel engine.

TABLE III: FUEL PROPERTIES OF FOUR NON-EDIBLE OILS AND DIESEL.[4]

Properties	Diesel	Neem	Linseed	Mahua	Castor
Viscosity, cSt(@ 40^0 C)	5.032	29	16.23	34	78
Calorific value, kj/kg	42707	39400	40374	38000	36000
Sp. Gr. At 25^{0}C	0.834	0.919	0.8645	0.917	0.956
Density, kg/m3	834	919	874	917	956
Flash point, ^{0}C	78	178	108	277	320
Fire point, ^{0}C	85	195	---	298	345

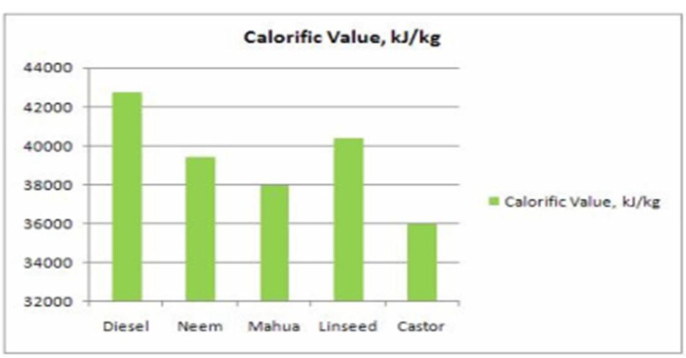

Fig. 2- Calorific value of diesel with different neat vegetable oils [4]

III. METHODOLOGY

A naturally aspirated direct injection diesel engine is more sensitive to fuel quality. The main problem of using Jatropha oil in unmodified form in diesel engine is its high viscosity. Therefore, it is necessary to reduce the fuel viscosity before injecting it in the engine. High viscosity of Jatropha oil can be reduced by heating the oil using waste heat of exhaust gases from the engine and also blending the Jatropha oil with diesel. Several tests were conducted to characterize Jatropha oil v/s diesel in order to compare various physical, chemical, and thermal properties. Viscosity of Jatropha oil and diesel was measured at different temperatures to find the effect of temperature on viscosity. [2]

A typical engine system widely used in the agricultural sector has been selected for present experimental investigations. A single cylinder, four stroke, constant speed, water cooled, direct injection diesel engine was procured for the experiments. The engine operated at a constant speed of 1500 rpm. Fresh lubricating oil was filled in oil sump before starting the experiments. The engine is coupled with a single phase, 220 V AC alternators. The alternator is used for loading the engine through a resistive load bank. The load bank consists of eight heating coils (1000 W each). A variac was connected to one of the heating coils so that load can be controlled precisely by controlling voltage in one of the coils of load bank. [2]

The schematic layout of the experimental setup for the present investigation is shown in Figure 3. The main components of the experimental setup are two fuel tanks (Diesel and Jatropha oil), fuel conditioning system, heat exchanger, exhaust gas line, by-pass line, and performance and emissions measurement equipment. Two fuel filters are provided next to the Jatropha oil tank so that when one filter gets clogged, supply of fuel can be switched over to another filter while the clogged filter can be cleaned/replaced without stopping the engine operation. The engine is started with diesel and once the engine warms up, it is switched over to Jatropha oil. [2]

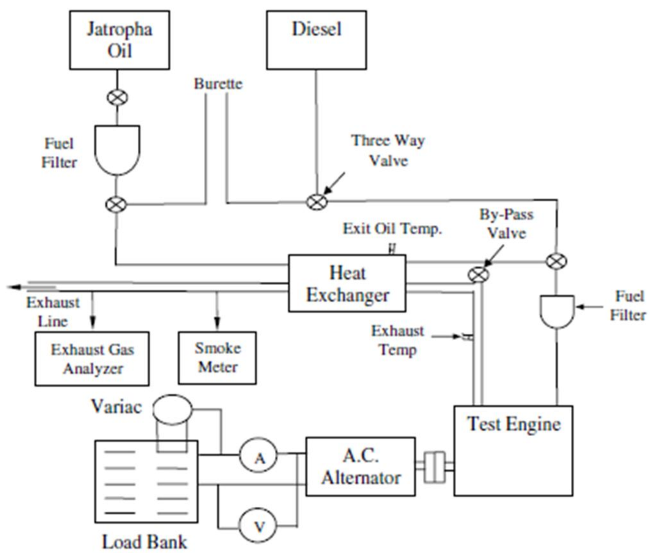

Figure 3 Schematic diagram of experimental setup. [2]

IV. RESULTS

Viscosity of Jatropha oil decreases remarkably with increasing temperature and it becomes close to diesel at temperature above 90 ^{0}C (within ASTM limits). Viscosity of diesel was 2.44 cSt at 40 ^{0}C. For Jatropha oil, viscosity was found below 6 cSt at a temperature above 100 ^{0}C. Therefore, Jatropha oil should be heated to 100 ^{0}C before injecting it into the engine in order to bring its physical properties close to mineral diesel (at 40 ^{0}C). The viscosity of various blends of Jatropha oil and diesel was also evaluated at 40 ^{0}C. Viscosity of Jatropha oil decreases after blending. The viscosity of 30:70 and 20:80 blends was slightly higher than diesel but these blends are within ASTM limits for viscosity of diesel fuels. For these two Jatropha oil blends, corresponding viscosity was found to be 5.35 and 4.19 cSt @ 40 ^{0}C respectively. [2]

V. CONCLUSION

The main objective of the present review paper was to reduce the viscosity of Jatropha oil close to that of conventional diesel in order to make it suitable for use in a C.I. engine and to evaluate the performance of the engine with new alternate fuels. From the available literature, viscosity was reduced by (i) preheating the oil (Jatropha oil) and (ii) by blending the Jatropha oil with diesel. Diesel and Jatropha oil were characterized for their various physical, chemical and thermal properties. It was found that heating the Jatropha oil between 90 ^{0}C and 100 ^{0}C is adequate to bring down the viscosity in close range to diesel. Viscosity of Jatropha blends (up to 30%) was also found close to diesel. Optimum fuel injection pressure was evaluated, which was found to be 200 bars for diesel and preheated Jatropha oil. Preheating the Jatropha oil reduces the viscosity. Therefore, preheating the Jatropha oil does not lead to change in optimum fuel injection pressure. So that we can use straight Jatropha oil in single cylinder diesel engine by using waste heat recovery system.

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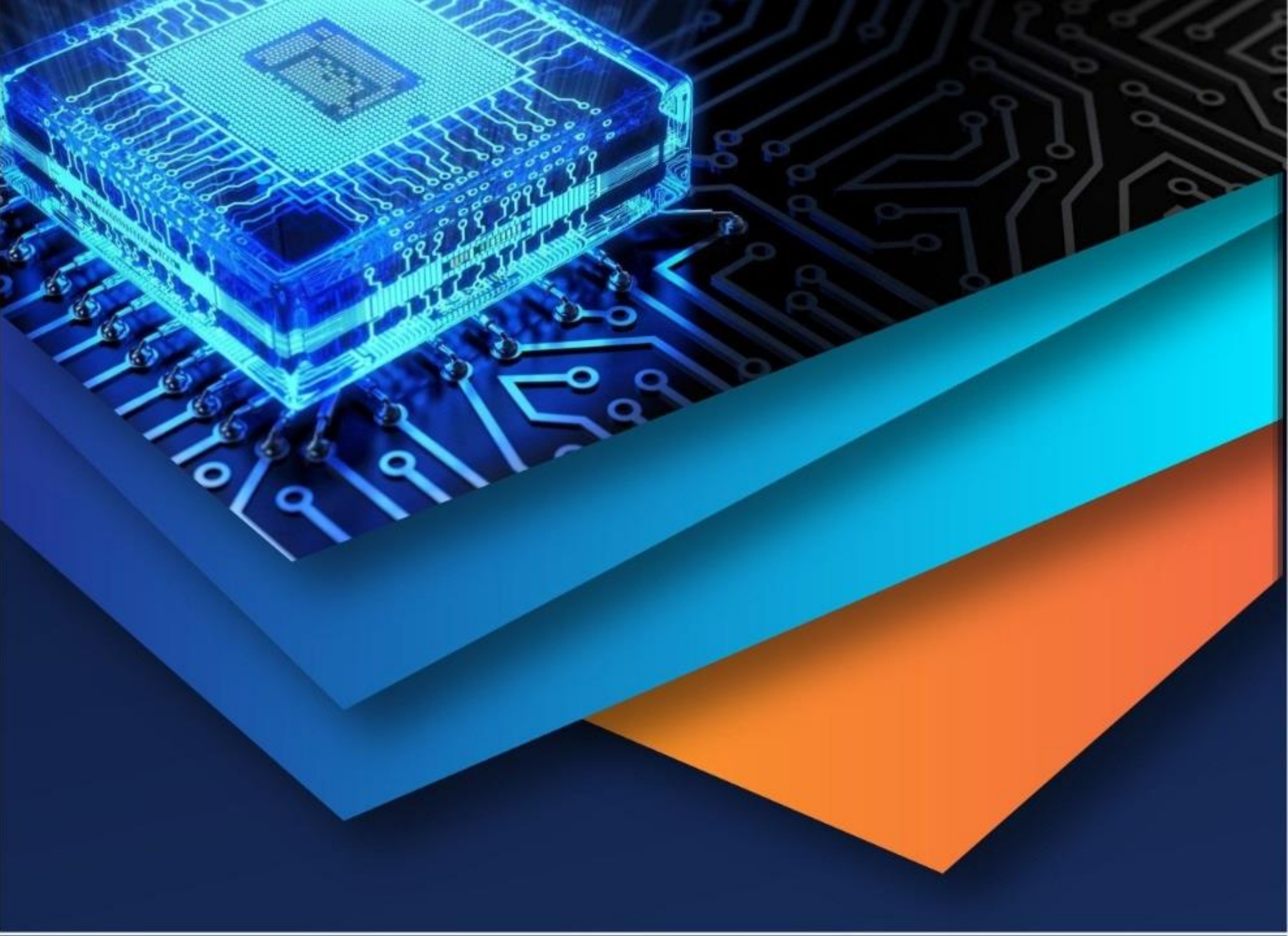

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