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Performance and Emission Characteristics of a CI Engine Fueled With Diesel- Waste Fried Oil Blend with Dee as Additive

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Abstract— An experimental study is conducted to evaluate the effects of using diethyl ether as additive to waste fried oil/diesel blend on the performance and emissions of a direct injection diesel engine. The waste fried oil and diesel blending with diethyl ether (DEE) in the ratio of 0:100:0, 20:80:0, 30:70:0, 40:60:0, 15:80:5, 25:70:5 and 35:60:5 by volume were tested in CI Engine. The results shows that compared with neat diesel, there is slightly lower brake specific fuel consumption (BSFC) for diesel-waste fried oil -DEE blend. Strong reduction in emission is observed with diesel-bio waste fried oil-DEE at various engine loads. waste fried oil at 25% and DEE 5% blend with diesel gave best performance in terms of low smoke intensity, emissions of HC,CO,CO_2,and NO_x.

Keywords— Diesel, waste fried oil, diethyl ether, performance, emission.

I. INTRODUCTION

Several alternative fuels have been studied to either substitute the diesel fuels partially or completely. Alternative fuels derived from biological sources provide a means for sustainable development, energy conservation, energy efficiency and environmental protection [1,2]. Some of the alternative fuels explored are biogas, ethanol, vegetable oils etc. The high viscosity of vegetable oils and their low volatility affects the atomization and spray model of fuel, leading to incomplete combustion and severe carbon deposits, injector choking and piston ring sticking [3]. The various methods used to reduce the viscosity are pyrolysis, blending with diesel, transesterification, and emulsification. In particular, biodiesel has received broad attention as an alternate for diesel fuel because it is biodegradable, nontoxic and can significantly reduce exhaust emissions from the engine when burned as a fuel [4,5]. Many researches show that using biodiesel in diesel engines can reduce hydrocarbon (HC), carbon monoxide (CO) and opacity emissions, but nitrogen oxide (NOx) emission may increase [6]. Biodiesel can be used in the existing engines without any modifications and the biodiesel obtained from vegetable sources does not contain any metals, Aromatic hydrocarbons and sulfur or crude oil residues. Biodiesel is an oxyfuel; emissions of carbon monoxide and soot tend to reduce. The oxygen content of biodiesel is an important factor in the NOx formation, because it causes to high local temperatures due to excess hydrocarbon oxidation [7]. The problem with WFO is that it's a dirty product. It's full of food particles, fats, water and many impurities. These must be removed from the WFO before it is clean enough to use in the vehicle and the cleaning process is time-consuming. Depending on the quality of the used oil, it is often found that up to 50% of the waste oil collected is unusable as a fuel. Although the little higher cetane numbers and the absence of aromatics components tend to contribute to less NOx production. On the other hand biodiesel has some disadvantages such as higher viscosity, pour point and lower volatility compared with neat diesel. The poor cold flow property of biodiesel is a barrier to the use of biodiesel-diesel blends in cold weather [8]. Fuel additives become essential tools not only to improve performance and combustion of diesel engines but also produce slighter emissions that meet the international standards. Additional research needs to develop diesel specific additives for better performance, combustion and emissions of diesel engines [9]. DEE posses required characteristics and expected to improve low temperature flow properties. Earlier studies have recommended that the weight percent of oxygen content in the fuel is the most important factor for opacity reduction [10]. DEE has high cetane number of >125. The latent heat of vaporization is higher than diesel. DEE is liquid at room temperature which reduceses handling and storage problems. DEE is also non-corrosive properties compared to alcohols. Ohta and Takahashi [11] reported the flame propagation stages for DEE. DEE has low heat release rates (HRR) during early cool flame generation, but has typical heat release rates for mid stage blue flame oxidation. The blue flame is followed by a conventional red flame with constant

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

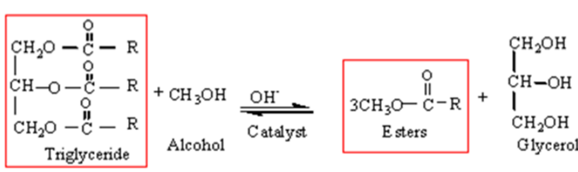
HRR during full combustion. P.Q.E Clothier et al.,[12] reported that adding DEE to diesel fuel will increase the cetane number of the diesel fuel. Used as a cold starting aid, DEE apparently acts as a neat fuel and not in combustion with the diesel fuel. Addition of diethyl ether to biodiesel and diesel blends can increase the oxygen contents, which may further improve the opacity emissions. Investigations have been carried out on different approaches for improving exhaust emission when biodiesel is used. T.K.Kannan et al. [13] studied an oxygenated additive DEE was blended with biodiesel in the ratios of 5%, 10%, 15% and 20% and carry out their performance. Reduction of 14.63% of opacity and 15% of NOx emissions was observed for 20% DEE blends at full load which was the highest reduction among the blends. Some authors says, when the DEE composition increased beyond 24% the engine become unstable and heavier smoke observed [14].BTE observed 30% which was 5% higher than biodiesel [15-17]. The objective of the present work is to investigate the effect of DEE additive on the performance of Diesel engine. In the present work different blends of biodiesel, diesel without/with DEE additive are prepared and their comparative performances are evaluated with neat diesel.

II. MATERIALS AND METHOD

A. Experimental Fuels

Larger organisations such as Hotel chains, Bakery, etc. already have an infrastructure in place to deal with their waste fried oil (WFO), so obtaining used vegetable oil from these places is difficult. However, smaller establishments don't have such infrastructures (local restaurants, family run hotels, etc.). For these people WFO is usually something they are keen to get rid of. Flash point and fire point was determined by using of fire point apparatus. The viscosity was determined at different temperatures using redwood viscometer to find the effect of temperature on the viscosity of waste fried oil. The viscosity of waste fried oil was found to be approximately 5 times higher than that of diesel fuel. The flash point of waste fried oil was higher than diesel and hence it is safer to store. It is seen that the boiling range of waste fried oil was different from that of diesel [18-20].

These waste fried oil, trans-esterified before it blended with diesel because of the oils have glycerol. It must extract from the bio-fuel because it will affect the engine performance. Among these, the trans-esterification is the most commonly used commercial process to produce clean and environmental friendly fuel. Methyl/ethyl/butyl esters of WFO oil have been successfully tested on C.I. engines and their performance has been studied. Trans-esterification is the process of conversion of triglyceride to glycerol and ester in the presence of alcohol and catalyst. This reaction, also known as alcoholics in whom the displacement of alcohol from an ester by another alcohol in a process similar to hydrolysis except that an alcohol is used instead of water. This reaction has been widely used to reduce the viscosity of the triglycerides [21-22]. Experimental study shows that the major variables affecting the trans-esterification reaction are: The free fatty acid (FFA) and the moisture content. Properties of diesel, biodiesel, DEE and fuel blends are given Table-1 and Table-2. Then with the help of washing remove the catalyst, soap and excess methanol from bio diesel. Trans-esterification process for waste fried oil:



B. Experimental Setup

Test has been conducted on a Kirloskar Engine, four strokes, single cylinder, water-cooled direct injection, and naturally aspirated diesel engine with a bowl in piston combustion chamber. The specification data of the engine used are given in Table-3 and block diagram for the experimental set up is shown in Fig.1. For fuel injection, a high-pressure fuel pump was used, a three hole injector nozzle. The injector nozzle was located at the center of the combustion chamber and has an operating pressure of 220bar. The engine was coupled to an eddy current dynamometer set and loaded by electrical resistance to apply different engine loads. The specification of the dynamometer is demonstrated in Table-4. Smoke meter model AVL437C made by AVL India Pvt. Ltd. Gurgaon is used in this experimental study. The measurement is based on the principle of light absorption by particle. Photo electronic smoke detection is based on the principle of optical detection. It is also known as the "scattered" light principle. Exhaust gas analyzer used for this experiment is AVL DI 444 model made by the AVL India Pvt. Ltd. In this cable one end is connected to the inlet of the analyzer and the other end is connected at the end of the exhaust gas outlet. Continuous charging of the analyzer is essential to work in an effective way. The measuring method is based on the principle of light absorption in the infrared region, known as "non-dispersive infrared absorption". The broadband infrared radiation produced by the light source passes through a chamber filled with gas, generally methane or carbon dioxide.

C. Experimental Procedure

To estimate the performance parameters i.e operating parameters such as engine speed, power output, and fuel consumption were measured. Significant engine performance parameters such as brake specific fuel consumption (BSFC) and brake thermal efficiency (BTE) for the test fuels were calculated. Emission parameters i.e. CO, CO_2, HC, NOx and opacity were observed for various fuel blends.

In the first phase experiments were conducted with neat diesel

In the second phase of the work, the engine was operated diesel- waste fried oil blend ratio of 80: 20, 70:30 and 60:40.

In the third phase, waste fried oil and diesel blend with DEE in the ratio of 15:80:5, 25:70:5 and 35:60:5.

III. RESULT AND DISCUSSIONS

A. Brake Specific Fuel Consumption

The BSFC variation of the test fuels with respect to load is shown in Fig.2. The fuel mass flow rate is calculated from the respective measured volume flow rate value and the fuel density. BSFC of D80+M20 oil blend is 1.6% lower than neat diesel at load 4kg and D80+M20 blend is approximately same with diesel ant 6kg load. BSFC of D80+M15+A5 is 1.3% lower than that of neat diesel at 4kg and almost similar to neat diesel in remaining loads. D70+M25+A5 fuel has similar BSFC values up to 4,8kg load and slightly higher for higher loads compared to neat diesel. The main reason may be due to the higher volatility of DEE which speeds up the mixing velocity of air/fuel mixture, improves the combustion process and increases the combustion efficiency.

B. Brake Thermal Efficiency

The variations of BTE at different loads and various fuel blends have been shown in Fig.3. BTE for diesel is higher than that of all other blended fuels up to 4kg applied load. BTE for D70+M25+A5 blend has 5%, 2% higher than neat diesel at 6kg, 8kg load. This is due the addition of DEE reduces the viscosity which in turn increases the atomization and leads to the enhancement of combustion.

C. Opacity

The smoke is produced due to incomplete combustion of fuel. The variation of opacity with load for the fuels is shown in Fig. 4. It can seen that higher load, the smoke intensity for blended fuels lower comparing to neat diesel. D70+M25+A5 blend has 24%, 19% lower opacity than neat diesel at 6kg, 8kg load. The improvement in spray atomization and air fuel mixing with the addition of DEE decrease the rich mixture and also smoke emission. However DEE added blends, the smoke intensity also increase but it is still lower than biodiesel-diesel, diesel. This may due to phase separation of the blends which results in incomplete combustion.

D. Carbon Monoxide (Co)

The variation of CO emissions with load is shown in Fig.6. At full load, the CO emission decreases by 30% for D70+M25+A5 blend compared to neat diesel. The improvement in spray atomization and fuel air mixing reduces the rich region in cylinder and reduces the CO emission. The high temperature promotes the CO oxidation in the cylinder. Biodiesel-diesel blend has slightly higher CO emissions due to poor atomization and do not have time to undergo complete combustion.

E. Carbon Dioxide (Co_2)

Fig.6 shows the variation of CO_2 with respect to load. As could be seen CO_2 emissions increase when increases of biodiesel in diesel- biodiesel blends. At lower engine loads CO_2 is lower than neat diesel and higher loads it becomes higher than neat diesel. At 6kg load, D70+M25+A5 blend has approximately 13% higher CO_2 values than neat diesel. This may due to better combustion taking place in higher loads because of fine atomization and very high CO_2 emissions are undesirable.

F. Oxides Of Nitrogen (Nox)

Nitric oxides emission is shown in Fig.7. The NOx emission is function of lean fuel with higher temperature, high peak combustion temperature and spray characteristics. A fuel with high HRR at rapid combustion and lower HRR at mixing controlled combustion will causes of NOx emission. NOx emission increases with increase in load for all experimental fuels. D70+M25+A5 blend has 37%, 28%, 13% lower NOx emissions than neat diesel corresponding to 4, 6, 8kg loads. The addition of DEE in blends increases the evaporation and lowers the charge temperature. It makes beneficial effect on NOx emission level. In biodiesel- diesel blends, NOx emission is higher due to high HRR and excess oxygen supplied by biodiesel.

G. Hydrocarbon (Hc)

Fig.8 shows the variation of HC with respect to load. It can seen that the HC emission for all the fuel blends are lower than diesel for medium and higher loads. The addition of DEE in blends, HC emission is reduced. Initially, the increase of HC may be due to higher latent heat of evaporation of DEE causes lower combustion temperature, especially the temperature near the cylinder walls during the mixture formation. In this case higher HC will be produced from the cylinder boundary. D70+MA25+A5 blend has approximately 20% lower HC emission throughout the engine operation comparing to diesel.

IV. CONCLUSION

In the present investigation, the addition of DEE into biodiesel-diesel improves the physical and chemical properties of engine fuels. With the addition of DEE into biodiesel-diesel, the BTE and BSFC is improved with the use of D70+M25+A5. The opacity and CO are 17% and 38% lower for D70+M25+A5 blend comparing to neat diesel at peak load. The HC, NOx emissions are 18% and 26% lower for higher load compared to neat diesel. Hence, the addition of DEE can be a promising technique for using biodiesel-diesel efficiency in diesel engines without any modification in the engine.

TABLE 1
Properties of diesel, WFO biodiesel and DEE

Property	Diesel	Biodiesel	DEE
Chemical structure	$C_{16}H_{34}$	$C_{17}H_{34}O_2$	$C_2H_5OC_2H_5$
Density (kg/m^3)	830	878	713
Kinematic vis. 35 ^{o} C (cS)	2.7	10.4	0.23
Auto ignition point (^{o} C)	200-400	-	160
Cetane number	48	50	>125
Boiling point (^{o} C)	180-330	-	35
Pour point (^{o} C)	-20	-4	-110
Lower heating value ((MJ/kg)	43.0	40.0	33.9
Stoichiometric A/F ratio	14.9	13.5	11.1

TABLE 2
Properties of fuel blends

Blend	Flash point ^{0}c	Fire point ^{0}c	Density in g/cc at 32^{0}c	Calorific value MJ/kg
Diesel (100%)	68	78	.8880	43.00
Biodiesel (100%)	142	151	.8920	40.00
D80+B20	70	80	.8900	42.55
D70+B30	74	84	.8915	42.18
D60+B40	82	93	.8940	41.30
D80+B15+A5	41	50	.8902	42.34
D70+B25+A5	44	53	.8907	42.00
D60+B35+A5	48	59	.8920	41.70

Volume 3 Issue V, May 2015
ISSN: 2321-9653

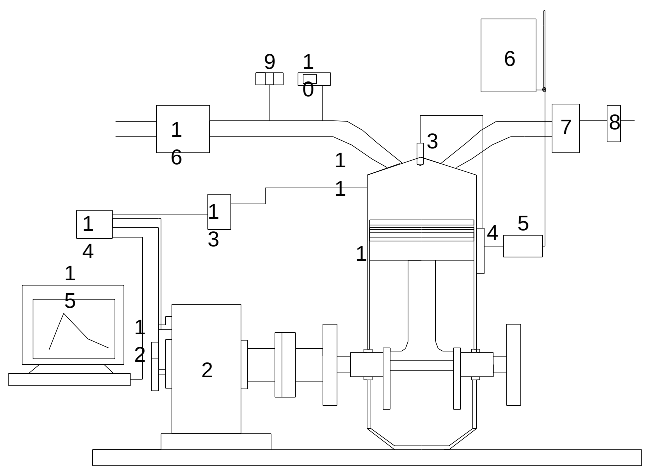
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

TABLE 3
Specification details of kirloskar TV1 engine

Type	Vertical, water cooled
Number of cylinders/ Number of strokes	01/04
Rated power	3.7 kW/ 5 hp @ 1500rpm
Bore (m)/Stroke(m)	0.08/.11
Piston offset (m)	0.00002
Con-rod length (m)	0.235
Compression ratio	16.7
Speed	1500 Rev/min

TABLE 4
Specification details of dynamometer

Dynamometer type	Eddy current
KVA	3.5 KVA
Current /voltage	14.6 A / 240V
Phase	Single
Speed	1500 rpm
Power factor	0.8
Frequency	50 Hz
Model	DI



1.Kirloskar TV1 engine
2.Eddy current dynamometer
3.Injector
4.Fuel injection pump
5.Fuel filter
6.Fuel tank
7.Air stabilizing tank
8.Air filter
9.AVL smoke meter
10.AVL Di-gas analyser
11.Pressure gauge
12.Pressure transducer
13.Charge amplifier
14.Indi meter
15.Monitor
16.Exhaust siliencer

Figure 1: Block diagram of experimental setup

Volume 3 Issue V, May 2015
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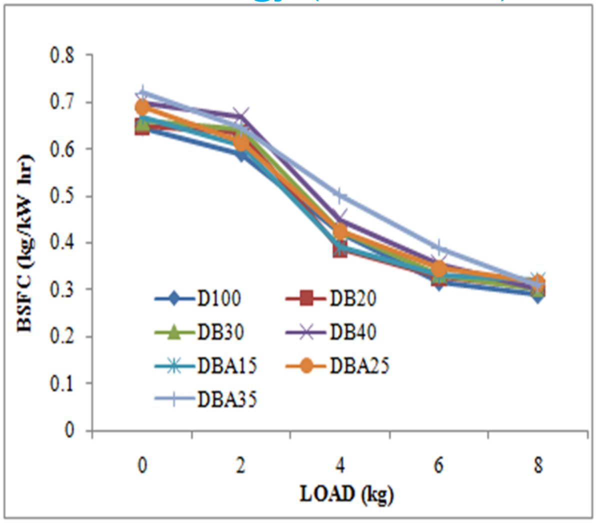

Figure 2: Brake specific fuel consumption Vs. load

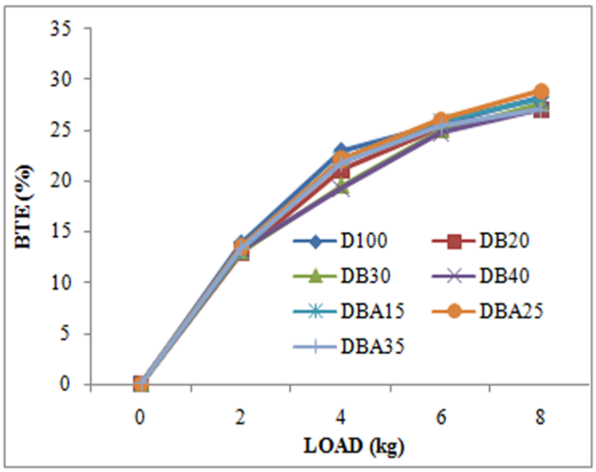

Figure 3: Brake thermal efficiency Vs. load

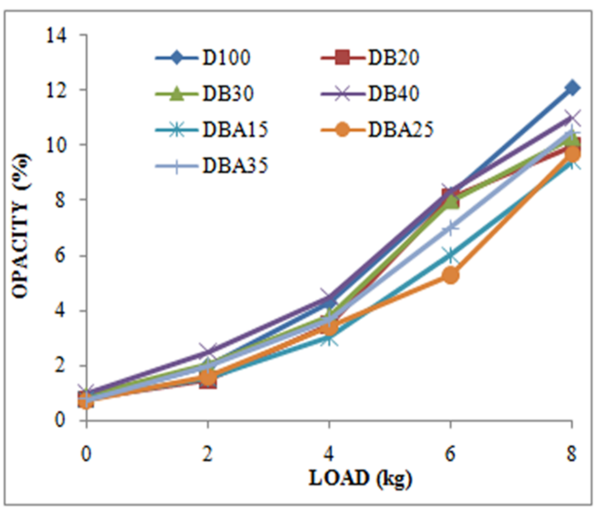

Figure 4: Opacity Vs. load

Volume 3 Issue V, May 2015
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

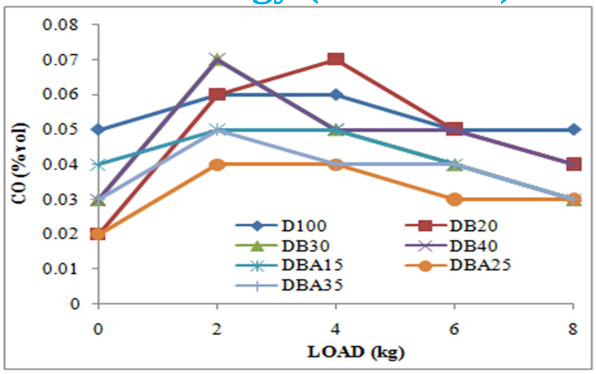

Figure 5: Carbon monoxide Vs. load

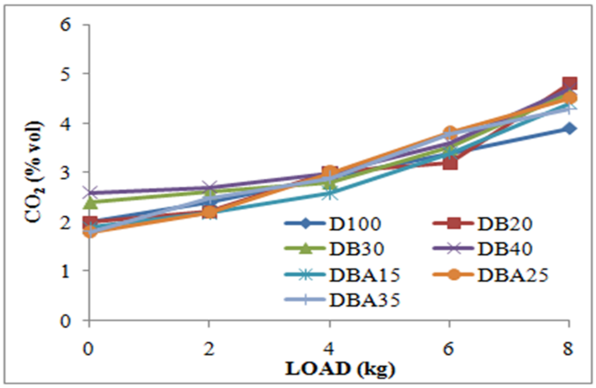

Figure 6: Carbon dioxide Vs. load

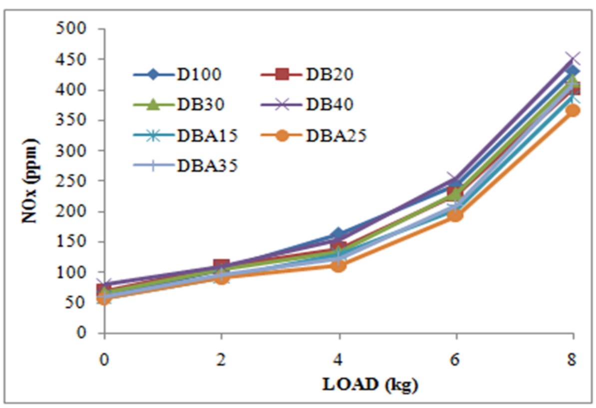

Figure 7: Oxides of nitrogen Vs. load

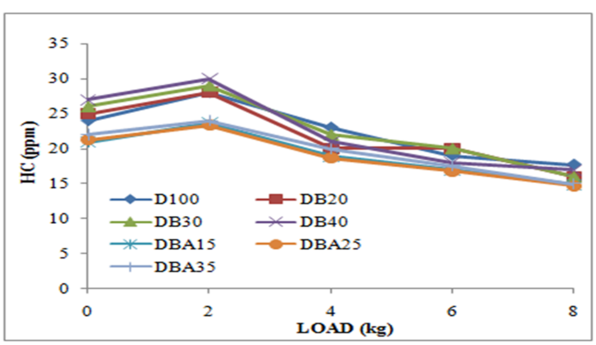

Figure 8: Hydrocarbon Vs. load

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

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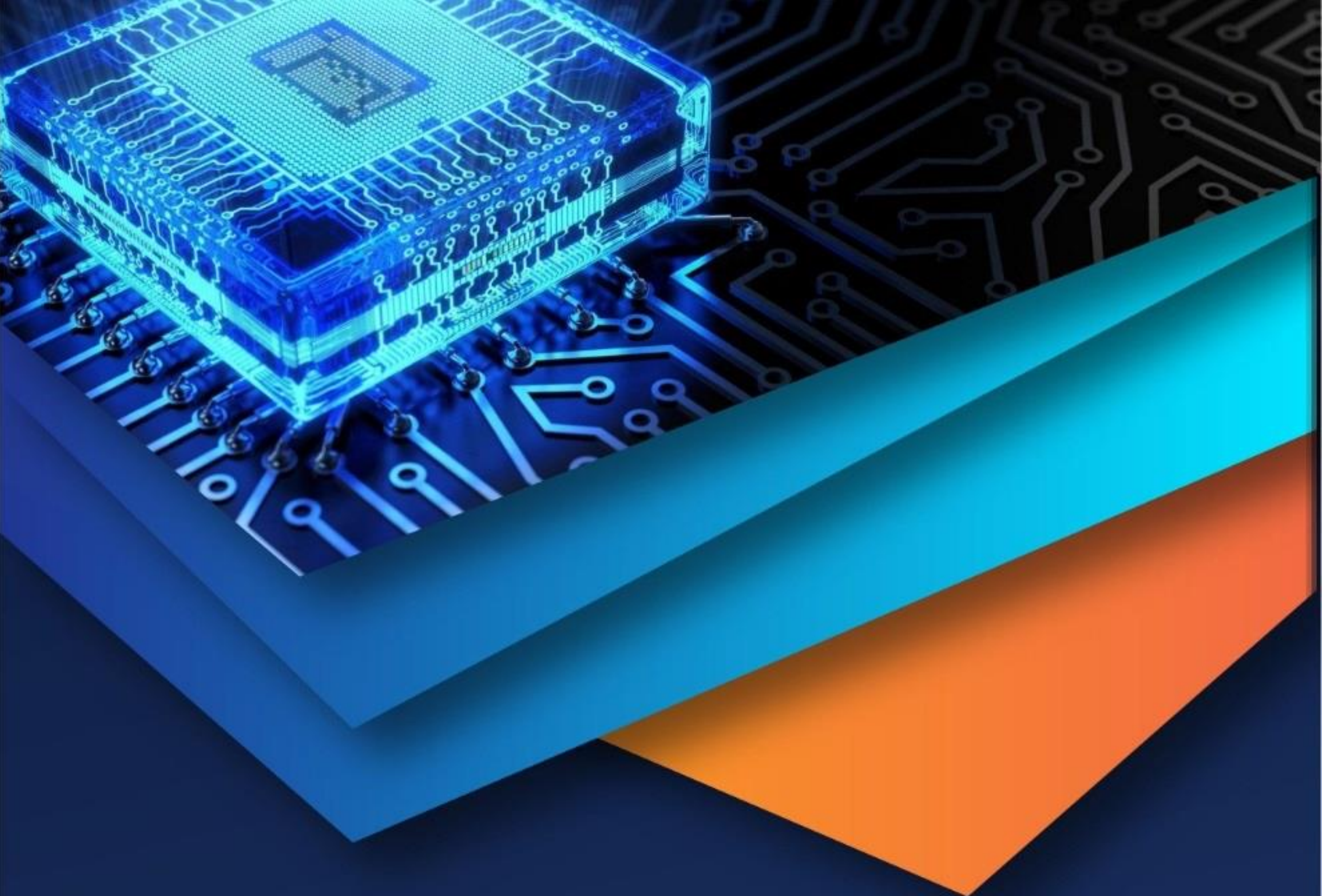
APPENDIX 1: Nomenclature

BSFC	Brake Specific Fuel Consumption
BTE	Brake Thermal Efficiency
DEE	Diethyl ether
DB20	80% diesel + 20% WFO biodiesel
DB30	70% diesel + 30% WFO biodiesel
DB40	60% diesel + 40% WFO biodiesel
DBA15	80% diesel + 15% WFO biodiesel+5 DEE
DBA25	70% diesel + 25% WFO biodiesel+5DEE
DBA35	60% diesel + 35% WFO biodiesel+5DEE



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