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AN EXPERIMENTAL STUDY OF THE PERFORMANCE OF A CI ENGINE USING ETHANOL AS A FUEL STABILIZER

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ABSTRACT

Ethanol is a promising alternative fuel owing to its renewable bio-based origin and lower carbon content, as well as its ability to significantly reduce particle emissions in diesel engines. To evaluate the particulate matter emissions and performance of ethanol-diesel blends, researchers conducted experiments using mineral blends of 5% and 10% ethanol with 95% and 90% diesel fuel, respectively, as well as biodiesel blends with 25% biodiesel and 75% diesel fuel, and 100% diesel as a baseline. These blends were tested in a CI engine with a constant RPM of 1350 and variable loads from 0.0 to 1.6 at intervals of 0.2 kg-m. The study found that biodiesel blends reduced exhaust particulate emissions compared to diesel fuel, while the brake specific fuel consumption decreased with increasing brake power, and the brake thermal efficiency increased as brake power increased. The sound pressure level was measured from different locations of the engine, and the results indicated that increasing the percentage of biodiesel led to a decrease in the sound pressure level. Overall, the study concluded that ethanol-blend fuel improved both brake and engine thermal efficiency while reducing particulate matter emissions. The engine experiments evaluated engine brake torque, braking power, brake specific fuel consumption, brake thermal efficiency, and particulate matter emissions under a variable load and a constant engine speed.

Keywords: CI engine, diesel fuel, ethanol, particulate matter, thermal efficiency.

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1. INTRODUCTION

The widespread use of diesel engines, also known as CI engines, in the transportation and power generation sectors, has raised concerns due to their significant contribution to pollution, waste heat, and hazardous pollutants, such as Particulate Matter. The emissions from diesel engines, particularly the particulate matter, are harmful to human health. In response, there has been a growing interest in finding substitutes for diesel fuel, either partially or entirely, to reduce PM emissions [1]. Researchers have explored multiple oxygenates, considering factors such as availability, cost, toxicity, safety, and compatibility with diesel fuel. Biodiesel and ethanol are among the most researched alternatives, with ethanol blended diesel emerging as a cleaner-burning choice for both heavy-duty and light-duty compression ignition engines found in buses, trucks, off-road equipment, and small cars [2].

The use of ethanol in diesel engines has led to a significant reduction in particulate matter emissions. Ethanol is also renewable and has a high-octane number, making it an attractive option for reducing the environmental impact of diesel engines [3]. The global petroleum crises of the 1970s made several countries aware of their vulnerability to oil embargoes. The shortage of petroleum and its high price, along with global climate change concerns, have further fueled the interest in renewable fuels [4]. Fossil fuels used in cars release carbon dioxide, making them the largest source of greenhouse gas emissions in the US [5]. Therefore, renewable energies have become a prominent research topic, aiming to reduce reliance on hydrocarbons. Methanol, ethanol, vegetable oils, and biodiesel fuels have been investigated and tested in compression ignition engines to determine their performance and emission characteristics [6, 7].

To find a substitute for any fuel, the engine must be modified. While fuel can be largely replaced, an additive can also be blended into it to reduce noise, global warming, and greenhouse gas effects, and boost the engine's performance [8]. Blending different fuels, such as two or more coals, one or two coals plus biomass (e.g., wood waste, corn Stover), opportunity fuel (e.g., petroleum coke), or industrial or municipal waste fuel (e.g., refuse-derived fuel, or RDF, hazardous waste), requires a thorough understanding of the fuel to achieve the desired outcomes. Blending is a promising method for converting less expensive feedstock into biodiesel [9, 10]. When ethanol is blended with diesel, thermal efficiency improves by up to 31.12% [11, 12]. While ethanol is less dense than gasoline and contains 30% less energy, it has a larger oxygen concentration that leads to complete combustion, which is not essential in low-alcohol gasoline blends [10, 13].

Diesel engines contribute significantly to pollution and hazardous emissions, prompting the search for substitutes. Ethanol blended diesel has emerged as a cleaner and renewable alternative to regular diesel fuel. Renewable energies have become a significant research topic due to the need to reduce reliance on hydrocarbons, which are major contributors to greenhouse gas emissions. Fuel blending, in which different fuels are mixed, offers a promising method for converting less expensive feedstock into biodiesel, and when ethanol is blended with diesel, it can improve thermal efficiency. However, understanding

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the fuel is essential when blending different fuels to achieve the desired outcomes.

The emission of greenhouse gases (GHG) is responsible for the acceleration of sea level rise caused by melting glaciers [14]. Biofuels have the potential to increase agricultural value and wealth, provide energy independence, and reduce dependence on imported petroleum products [15, 16]. Additionally, biofuels have a variety of applications, such as producing chipboards and methane gas from wastewater, animal waste, and landfills. Methane gas can also be produced through the gasification process of wood, which is also known as paralysis. Methanol can be obtained from plant oils or biomass and is considered a type of biofuel [17]. Biofuels are generally viewed as more environmentally friendly than conventional fuels because they emit fewer greenhouse gases, such as methane (CH4), carbon dioxide (CO2), and nitrous oxide (N2O), which contribute to global warming and environmental degradation [18].

Fatty acid methyl ester (FAME), also known as pure biodiesel (B100), is a type of biodiesel fuel. Biodiesel blends with lower concentrations are referred to as "biodiesel blends," with B25 indicating 25% biodiesel in diesel fuel [19, 20]. Biodiesel is considered a green fuel due to its similarity to diesel fuel and its ability to blend in any proportion with diesel fuel [21, 22]. However, biodiesel does not have the same properties as diesel fuel, which can affect engine efficiency and emission characteristics [24]. The viscosity of biodiesel is a significant property that affects engine performance, as high fuel-air ratios lead to increased fuel consumption (smoke), causing the brake-specific fuel consumption (BSFC) of compression ignition (CI) engines to increase at high loads. Lower loads also result in decreased mechanical efficiency and increased BSFC [25, 26]. Biodiesel's higher oxygen content, cetane number, and proper spray timing, on the other hand, lead to improved thermal efficiency [27, 28].

In this study, two fuel samples were tested in a CI engine to analyze parameters such as engine performance, exhaust gas emissions, and noise emissions. The fuel properties were initially tested using ASTM (American Society of Mechanical Engineering) standards. The engine performance, exhaust gas emissions, and sound pressure level tests were analyzed under variable loading conditions and constant speed. It was observed that vegetable oil blends result in lower thermal efficiency than diesel fuel [29, 30]. However, with a limited amount of methanol and ethanol, an increase in the combustion chamber's temperature improves thermal efficiency.

In summary, the use of biofuels is gaining attention due to their potential to reduce greenhouse gas emissions, increase agricultural value and wealth, and reduce dependence on imported petroleum products. Biodiesel is a type of biofuel that can be blended with diesel fuel in any proportion, but its properties can affect engine efficiency and emission characteristics. The physicochemical properties of biodiesel, such as kinematic viscosity, calorific value, and lubricity, are important factors that affect brake power. Engine performance, exhaust gas emissions, and noise emissions can be analyzed using ASTM standards under variable loading conditions and constant speed.

2. METHODOLOGY

This study aims to investigate the particulate matter emissions from a CI engine fuelled by ethanol blended gasoline. The research methods employed in this study involve testing three different fuel samples and examining two separate characteristics, namely engine performance and particle matter emission. The testing will be carried out under various loading conditions and constant speed (constant RPM) to check the exhaust, particularly the PM pollution.

To collect the PM emissions, a particulate matter emission device will be installed at the exhaust of the diesel engine, specifically the backside of the diesel engine's silencer. The device will collect PM emissions at different sizes, including pm-1 mg/l, pm-2.5 mg/l, and pm-7 mg/l, and we will acquire varied particulate matter emission sizes at mixed fuels by altering the load through the load cell. The amount of pollution produced by an engine is determined by its speed, load, fuel characteristics, and injection timings.

To achieve this goal, two gasoline tanks are mounted on the diesel engine test platform. A single pipe is used to provide fuel to the engine, and flow can be controlled by two distinct valves, although a single line connects dual petroleum tanks. One tank is filled with diesel (D100), and the other is filled with ethanol blended fuel based on fuel preferences.

The engine performance will be assessed by measuring torque, brake power, brake thermal efficiency, and brake specific fuel consumption at constant RPM, changing load, and constant RPM. These parameters are crucial indicators of the engine's efficiency and will help determine the best fuel sample to use in the CI engine.

This study employs various research methods, including testing three different fuel samples and examining engine performance and particle matter emission. The particulate matter emission device will be used to collect PM emissions at different sizes, and the engine's performance will be assessed by measuring various parameters, including torque, brake power, brake thermal efficiency, and brake specific fuel consumption. By employing these methods, this study aims to determine the best fuel sample to use in the CI engine.

3. RESULT AND DISCUSSIONS

The study analyzed three different fuel samples in a CI engine to investigate their impact on engine performance and particulate matter emissions. The diesel fuel D100 was found to produce more particulate matter compared to E05 and E10, as shown in Figures 1 to 3 and Table-1. However, blending ethanol with diesel in a ratio of E10 (90% diesel and 10% ethanol by volume) resulted in decreased particulate matter emissions, as seen in Figure-4, especially at varying load conditions.

The study found that ethanol, which has higher oxygen content, reduces particulate matter emissions.

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Additionally, the study evaluated brake thermal efficiency (BTE), which is a measure of the heat engine's brake power as a proportion of the fuel's heat supplied. Table 02 shows that increasing the proportion of ethanol in the blend leads to a decrease in the calorific value, resulting in increased fuel consumption for the same power output. The study also detected differences in BTE, as shown in Figure-4 and Figure-5. The BTE of D100, E5, and E10 engines were similar at idling to 1 KW of the load. However, the BTE of D90E10 gasoline increased from 1 KW to 10 KW of engine load regularly, mainly due to the increased percentage of oxygen in the air aiding the combustion process.

Furthermore, when ethanol is mixed with diesel, it results in leaner combustion due to a lower stoichiometric air/fuel ratio than diesel, which increases the amount of oxygen in the air and accelerates the combustion process. The results suggest that blending ethanol with diesel reduces particulate matter emissions and improves BTE, making it a viable alternative to diesel fuel in terms of engine performance and emissions.

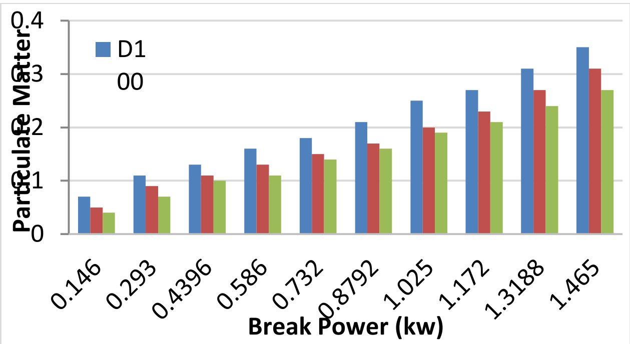

Figure-1. Particulate matter emission of size 1 mg/l at different loads.

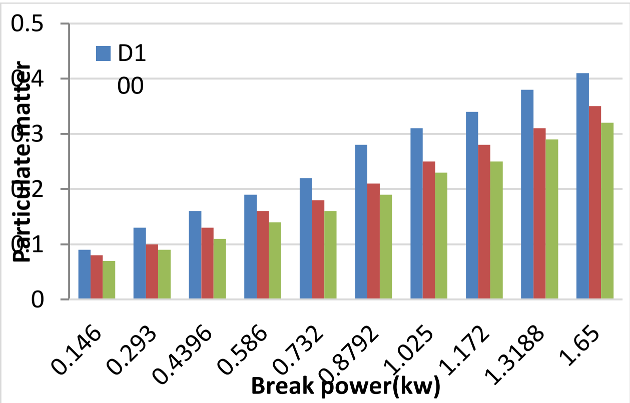

Figure-2. Particulate matter emission of size 2.5 mg/l at different loads.

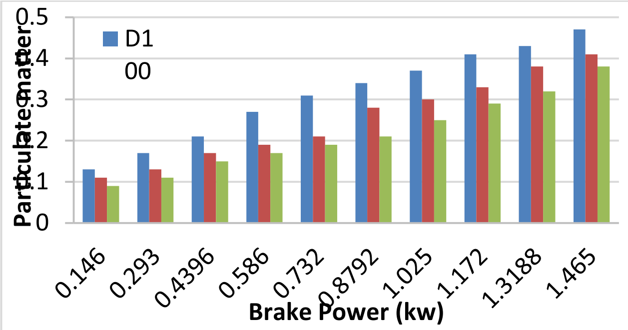

Figure-3. Particulate matter emission of size 7 mg/l at different loads.

The experimental setup for diesel engines includes the brake specific fuel consumption (BSFC) component, which is influenced by engine speed, loads, and ethanol blending ratios. The results presented in Figure-4 and Figure-5 reveal that the BSFC of E10 is higher than that of D100 and E5 when no load is applied. Higher BSFC values are observed for prepared fuel samples than diesel fuel due to their higher oxygen concentration, resulting in a lower heating value. The fuels' lower densities and heating values require more mass fuel for the same energy output from the engine. Additionally, the degree of unsaturation has a significant impact on density and calorific value, with unsaturated esters having lower heating values and mass energy content (MJ/kg) than saturated esters.

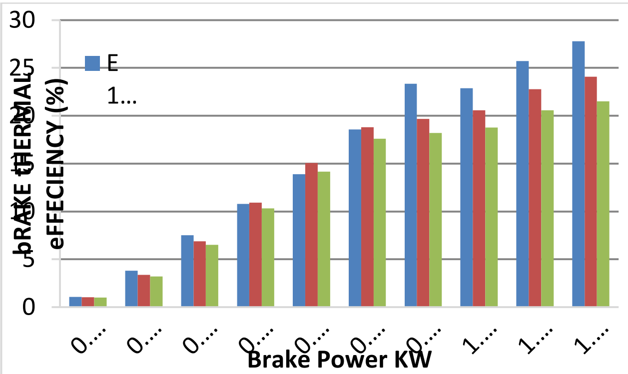

Figure-4. Break thermal efficiency measurement.

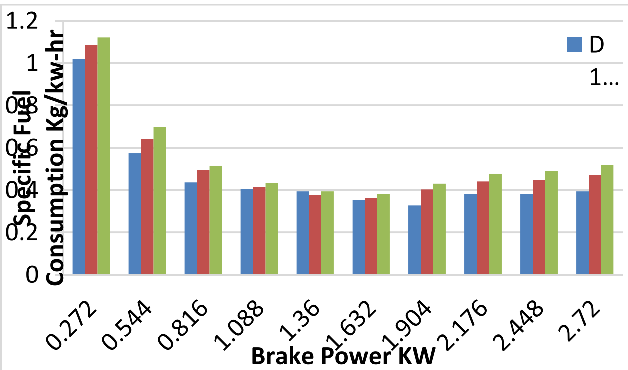

Figure-5. Break power and BSFC analysis on all fuel samples.

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Table-1. The blended ethanol fuel in an engine calculates the particulate matter emissions.

BREAK POWER	7 mgl			2.5 mgl			0.1 mgl		
	D100	D95 E5	D90 E10	D100	D95 E5	D90 E10	D100	D95 E5	D90 E10
0.146	0.13	0.11	0.09	0.09	0.08	0.07	0.07	0.05	0.04
0.293	0.17	0.13	0.11	0.13	0.1	0.09	0.11	0.09	0.07
0.4396	0.21	0.17	0.15	0.16	0.13	0.11	0.13	0.11	0.1
0.586	0.27	0.19	0.17	0.19	0.16	0.14	0.16	0.13	0.11
0.732	0.31	0.21	0.19	0.22	0.18	0.16	0.18	0.15	0.14
0.8792	0.34	0.28	0.21	0.28	0.21	0.19	0.21	0.17	0.16
1.025	0.37	0.3	0.25	0.31	0.25	0.23	0.25	0.2	0.19
1.172	0.41	0.33	0.29	0.34	0.28	0.25	0.27	0.23	0.21
1.3188	0.43	0.38	0.32	0.38	0.31	0.29	0.31	0.27	0.24
1.465	0.47	0.41	0.38	0.41	0.35	0.32	0.35	0.31	0.27

Table-2. Break thermal efficiency (BTE) calculation for energy extraction from fuels to change in mechanical energy.

fuels	Torque(Nm)	Brake power (Kw)	3600*bp	BSFC	FC*Cv	BTE	BTE(%)
E10	1	0.136	489.6	1.019608	45678.43	0.010718	1.071841
	2	0.272	979.2	0.573529	25694.12	0.03811	3.810989
	3	0.408	1468.8	0.436975	19576.47	0.075029	7.502885
	4	0.544	1958.4	0.404844	18137.02	0.107978	10.7978
	5	0.68	2448	0.393277	17618.82	0.138942	13.89423
	6	0.816	2937.6	0.352941	15811.76	0.185786	18.57857
	7	0.952	3427.2	0.367731	16474.35	0.208032	20.80324
	8	1.088	3916.8	0.382353	17129.41	0.228659	22.86593
	9	1.224	4406.4	0.382353	17129.41	0.257242	25.72418
	10	1.36	4896	0.393277	17618.82	0.277885	27.78846
E5	1	0.136	489.6	1.085549	46895.7	0.01044	1.044019
	2	0.272	979.2	0.672006	29030.67	0.03373	3.372984
	3	0.408	1468.8	0.495163	21391.02	0.068664	6.866432
	4	0.544	1958.4	0.415063	17930.71	0.10922	10.92204
	5	0.68	2448	0.376324	16257.18	0.15058	15.05797
	6	0.816	2937.6	0.37185	16063.9	0.18287	18.28697
	7	0.952	3427.2	0.392204	16943.2	0.202276	20.22758
	8	1.088	3916.8	0.421004	18187.38	0.215358	21.53581
	9	1.224	4406.4	0.428004	18489.78	0.238315	23.83154
	10	1.36	4896	0.430404	18593.47	0.263318	26.33182
D100	1	0.136	489.6	1.121107	49104.5	0.009971	0.997057
	2	0.272	979.2	0.697274	30540.6	0.032062	3.206224
	3	0.408	1468.8	0.515103	22561.53	0.065102	6.510198
	4	0.544	1958.4	0.433155	18972.19	0.103225	10.32248
	5	0.68	2448	0.39432	17271.24	0.141739	14.17385
	6	0.816	2937.6	0.381176	16695.53	0.175951	17.59513
	7	0.952	3427.2	0.409898	17953.54	0.190893	19.08927
	8	1.088	3916.8	0.416471	18241.41	0.21472	21.47202
	9	1.224	4406.4	0.428688	18776.52	0.234676	23.4676
	10	1.36	4896	0.439786	19262.63	0.254171	25.41709

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Table-3. BSFC calculation for a performance metric of an engine with different fuel samples.

fuels	Torque(Nm)	Brake power (Kw)	FC /sec	5ml/sec	ml/min	l/hr	Value of ρ (kg/l)	Fc*ρ(kg/h)	BSFC = FC/Pb (kg/kw-hr)
BSFC for Diesel	0	0	62	0.080645161	4.838709677	0.290322581	0.832	0.241548387	0
	2	0.272	54	0.092592593	5.555555556	0.333333333	0.832	0.277333333	1.019607843
	4	0.544	48	0.104166667	6.25	0.375	0.832	0.312	0.573529412
	6	0.816	42	0.119047619	7.142857143	0.428571429	0.832	0.356571429	0.43697479
	8	1.088	35	0.142857143	8.571428571	0.514285714	0.832	0.427885714	0.393277311
	10	1.36	31	0.161290323	9.677419355	0.580645161	0.832	0.483096774	0.355218216
	12	1.632	28	0.178571429	10.71428571	0.642857143	0.832	0.534857143	0.327731092
	14	1.904	22	0.227272727	13.63636364	0.818181818	0.832	0.680727273	0.357524828
	16	2.176	17	0.294117647	17.64705882	1.058823529	0.832	0.880941176	0.404844291
	18	2.448	15	0.333333333	20	1.2	0.832	0.9984	0.407843137
	20	2.72	13	0.384615385	23.07692308	1.384615385	0.832	1.152	0.423529412
BSFC for B 5	0	0	60	0.083333333	5	0.3	0.853	0.2559	0
	2	0.272	52	0.096153846	5.769230769	0.346153846	0.853	0.295269231	1.085548643
	4	0.544	44	0.113636364	6.818181818	0.409090909	0.853	0.348954545	0.641460561
	6	0.816	38	0.131578947	7.894736842	0.473684211	0.853	0.404052632	0.495162539
	8	1.088	34	0.147058824	8.823529412	0.529411765	0.853	0.451588235	0.415062716
	10	1.36	30	0.166666667	10	0.6	0.853	0.5118	0.376323529
	12	1.632	26	0.192307692	11.53846154	0.692307692	0.853	0.590538462	0.361849548
	14	1.904	20	0.25	15	0.9	0.853	0.7677	0.403203782
	16	2.176	16	0.3125	18.75	1.125	0.853	0.959625	0.441004136
	18	2.448	14	0.357142857	21.42857143	1.285714286	0.853	1.096714286	0.448004202
	20	2.72	12	0.416666667	25	1.5	0.853	1.2795	0.470404412
BSFC for B 10	0	0	59	0.084745763	5.084745763	0.305084746	0.864	0.26359322	0
	2	0.272	51	0.098039216	5.882352941	0.352941176	0.864	0.304941176	1.121107266
	4	0.544	41	0.12195122	7.317073171	0.43902439	0.864	0.379317073	0.697274032
	6	0.816	37	0.135135135	8.108108108	0.486486486	0.864	0.420324324	0.515103339
	8	1.088	33	0.151515152	9.090909091	0.545454545	0.864	0.471272727	0.43315508
	10	1.36	29	0.172413793	10.34482759	0.620689655	0.864	0.536275862	0.394320487
	12	1.632	25	0.2	12	0.72	0.864	0.62208	0.381176471
	14	1.904	19	0.263157895	15.78947368	0.947368421	0.864	0.818526316	0.429898275
	16	2.176	15	0.333333333	20	1.2	0.864	1.0368	0.476470588
	18	2.448	13	0.384615385	23.07692308	1.384615385	0.864	1.196307692	0.488687783
	20	2.72	11	0.454545455	27.27272727	1.636363636	0.864	1.413818182	0.519786096

The emission of particulate matter (PM) from diesel engines was studied in this research, where different blends of diesel fuel and biodiesel were used. The PM emission from the engine was found to depend on various factors, such as engine speed, load, fuel properties, and injection timing. A dynamometer coupled with the engine shaft was used to control the engine load, while the instrumentation on the test bed was manually controlled. Three particle sizes were analyzed, namely PM 1.0, PM 2.5, and PM 7.0, using both diesel fuel and biodiesel blended fuel.

To achieve the aim of the study, two fuel tanks were connected to the diesel engine test bed. Fuel was delivered to the engine through a single pipeline, and the flow could be regulated by two separate valves connected to each tank. One tank was filled with diesel fuel (D100), while the other was filled with biodiesel blended fuel. The engine torque, brake strength, brake thermal efficiency, and brake specific fuel consumption were all measured to analyze the engine performance. Variable loads were also applied to calculate the separate RPM on each load.

The engine noise level (sound pressure level) of the compression ignition (CI) engine was also calculated using both diesel fuel and biodiesel blended fuels. These fuel samples were tested at different loading conditions and constant speeds. CI engines are known for being fuel-efficient and robust, but unfortunately, they are also responsible for generating particulate matter emissions that deplete the environment and can cause human diseases. Biodiesel produces less PM emissions, but there are various reasons why particulate matter is generated from diesel engines. One reason is the incomplete combustion of diesel fuel due to temperature variations and fuel pyrolysis. Particulate matter is formed from fossil fuels due to improper combustion. The results of the study showed that diesel fuel was responsible for generating the majority of the PM 1.0 emissions, which were higher during idling conditions with D100. In comparison, biodiesel blend B25 produced less PM emissions than diesel fuel. The thermal efficiency of the brake increased with an increase in the proportion of biodiesel blend. However, as the calorific value of biodiesel decreased, fuel consumption increased for the same power output, as shown in Figure-4. The brake thermal performance of D100 increased with an increase in load from 0.2KW to 1.6KW of the engine, as shown in Figure-5. The brake specific fuel consumption (BSFC) varied depending on the engine load, RPM, and biodiesel blending ratio. It was observed that the BSFC of B25 was higher than D100, as B25 had a higher oxygen content, which resulted in a lower heating value. The lower density and heating values of the fuels required a higher mass of fuel to produce the same energy output from the engine. The degree of unsaturation also had a significant impact on the density and calorific value, with unsaturated esters having lower heating values and mass energy content (MJ/kg) than saturated esters.

This study focused on the emission of particulate matter (PM) from diesel engines using diesel fuel and biodiesel blended fuels. The PM emissions were affected by various factors such as engine speed, load, fuel properties, and injection timing. The results of the study showed that biodiesel blend B25 produced less PM emissions than diesel fuel. However, the thermal efficiency of the brake decreased with an increase in biodiesel blending ratio, as the calorific value of biodiesel decreased. The BSFC of B25 was also higher than D100 due to the higher oxygen content, which resulted in a lower heating value. The study highlighted the importance of considering the impact of fuel properties on engine performance and emissions.

4. CONCLUSIONS

The study investigated the impact of biodiesel blends on engine performance and emissions. It was observed that B25 (a 25% blend of biodiesel with diesel fuel) produced lower particulate matter emissions than D100. This is because biodiesel generates less particulate matter than fossil diesel due to its more complete combustion. The thermal efficiency of the engine was found to increase with an increase in the proportion of biodiesel in the blend. However, as the calorific value of biodiesel decreases, the fuel consumption increases for the same power output.

The density and calorific value of the fuels were found to have a significant impact on the degree of unsaturation, which affects the mass energy content of the fuel. Unsaturated esters have a lower heating value and mass energy content than saturated esters. This could lead to higher fuel consumption in engines using unsaturated ester blends.

The study investigated the noise emission levels of the engine using different fuel blends. It was observed that the noise levels were affected by the fuel type and loading conditions. Biodiesel blends were found to produce lower noise levels than diesel fuel.

In conclusion, the study highlights the potential of using ethanol and biodiesel blends to reduce particulate matter emissions and improve engine performance. However, the fuel properties of the blends must be carefully considered to ensure optimal engine operation and fuel efficiency. Further research is needed to investigate the long-term effects of using these blends on engine performance, emissions, and durability.

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