Impact Analysis of the CI Engine Emission and Performance Characteristics for Biodiesel from Calotropis Root Oil

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Abstract. The contraction of fossil fuels increasing demand for petroleum fuels precipitate extensive research on substitute sources of energy for internal combustion enginesin terms of energy efficiency, the increase in fuel costs and severe emission standards have quite a substantial impact on the economic prosperity of a nation like India, leading experts to look for innovative substitute for diesel fuel. The research presented here focuses on the impact of additives such dimethyl carbonate to 2%, 6%, and 8% Calotropis Root oil and methyl carbonate (CRDC20) biodiesel mix of varied percentages (20% and 2% on volume basis to study engine characteristics. The test findings showed that the braking thermal efficiency of CRDC20 with 6% dimethyl carbonate added is significantly improved and is 5.36% greater than the mix of biodiesel and Calotropis Root oil. Similarly, when compared to diesel fuel at full load, CRDC20 has demonstrated considerable reductions in hazardous engine passage emissions such as carbon monoxide, hydrocarbon, oxides of nitrogen, and smoke opacity, which are observed to be roughly 12.36%, 25.33%, 12.63%, and 27.72% correspondingly. Additionally, findings are contrasted with experimental values obtained under identical operating circumstances.

Keywords: Brake power · Emission · Calotropis root · Specific fuel consumption · Dimethyl carbonate

1 Introduction

Islam et al. [1]. The studied the viability of tamarind seed biodiesel and the feasibility of extracting biodiesel from spent tamarind seeds using a fixed bed fire-tube heating pyrolysis process. Researchers looked into the tamarind seed oils pyrolysis kinetics. Hniu et al. [2]. A simple equation is sufficient to forecast the rate at which oil will be produced from the tamarind biomass wastes. The findings of this study may be used to boost a pyrolysis system's effectiveness in the thermal conversion of biomass

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solid wastes into befouls. Similar investigations into the physicochemical properties of tamarind seed oil have been carried out. Sharma Munish et al. [3]. The performance of the thermal brake could be dramatically increased and the engine's harmful exhaust emissions could be significantly reduced by adding nanoparticles as fuel-born catalysts to a mixture of 20% tamarind biodiesel, according to research on the use of tamarind biodiesel as an alternative fuel for diesel engines.

Kishore PS et al. [4]. Nagarajan G et al. [5] Studying the physical and chemical characteristics of biodiesel made from rice bran oil revealed that it complies with all ASTM requirements. Diesel fuel has a somewhat higher heating capability than rice bran oil. It burned entirely when there was a higher cetane number and more oxygen present. Atmanli A et.al [6] employed pentanol-diesel-biodiesel tertiary mixes as an alternate feedstock in a standard diesel engine. When diesel engines employed ternary mixes, the specific fuel consumption and brake thermal efficiency both went up. Longanathan et al. [7] showed that when ethanol was added to biodiesel at lower percentages, thermal efficiency rose somewhat, while emissions suchcarbon monoxide, hydrocarbons, and oxides of nitrogen were dramatically decreased entailer all load activities.

Agarwal AK [8] hasshown that the use of oxygenated fuel-added chemicals in biodiesel blends results in considerably reduced tailpipe emissions compared to regular diesel fuel, with no detectable change in engine performance over a broad range of load situations. Lingfa D et al. [9] examined how different nahar oil-to-diesel blends—5%, 10%, 20%, 30%, and 40%—affected the efficiency of diesel engines. Results showed that adding a 10% mix significantly reduced hydrocarbon emissions by 9.71% and carbon monoxide emissions by 9.13% as compared to mineral diesel fuel when operating at full load. Kuleshov A [10] used the simulation program to evaluate the efficiency and emissions of a hypothetical diesel engine operating under typical circumstances. They also claimed that this software was one of the best tools for adjusting variables including piston bowl shape, EGR ratio, fuel injection pressure, and nozzle count to achieve maximum engine efficiency. There has been a lot of study on other biofuels like a Jatropha oil, Mahua oil, and cotton oil and so on, but there hasn't been much done on tamarind oil yet.

Further research into tamarind's potential as a renewable fuel source is warranted given its abundance in India and other Asian nations. Using biodiesel blends with oxygenated additives may significantly reduce the exhaust emissions of diesel engines, including carbon monoxide (CO), hydrocarbons (HC), and smoke opacity. Dimethyl carbonate (56% O_2), Diethyl ether (24% O_2), and dimethyl ether (38% O_2), and are all oxygenated additives that are often added to biodiesel because of their ability to promote quick, full combustion by igniting fractional combustion at the fuel's center. This research seeks to answer this question by examining the impact on emission, and performance characteristics of adding DMC oxygenated additives to a CRDC 20 mix at 2% and 6% concentrations. To guarantee a totally homogeneous solution, we make different blend on a volumetric basis, mix them using a magnetic stirrer, and then homogenize the mixture using an Ultrasonicator.

Only peanut biodiesel has never been used in the Rudolf Diesel original diesel engine due to worries about the declining availability of liquid petroleum. Due to its ability to be produced from plants and vegetables other than food as well as its environmental friendliness, biodiesel has quickly gained popularity as one of the most popular alternative fuels. The low cost and wide availability of biodiesel may be responsible for its ten-year success in the transportation and industrial sectors. To lessen our reliance on fossil fuels, biodiesel was created.

2 Testing Material and Experiment Methods

2.1 Oil Extracted from the Root Oil Calotropis

Because of its potential to lessen our reliance on fossil fuels and increase our access to cleaner forms of energy, biodiesel has recently gained in favor as a viable alternative fuel. There is no net increase in atmospheric carbon dioxide since the carbon dioxide that was sequestered during the feedstock's growth is burned during combustion. Due to its cheap cost, environmental friendliness, and long-term viability throughout India, tamarind seed is a potential candidate for broad usage in compression ignition engines. India now produces more tamarind fruit than any other country. The tamarind seed is thrown away during processing of the tamarind fruit.

Production of biodiesel from tamarind seed incorporates waste reduction steps from the outset. This crude oil does not have enough calorific value to fulfill the need for biodiesel because of its high viscosity with increased density. The transisterification procedure is the powerful tool for improving the biodiesel characteristics. The primary downsides of unrefined tamarind seed oil are its increased viscosity and greater density Sorenson SC [11].

Transisterification has the potential to decrease the viscosity of raw vegetable oils and enhance the ignition quality of biodiesel. Biodiesel may be made from tamarind seeds by heating crude tamarind oil in the presence of methanol and a catalyst such potassium hydroxide (KOH).Three chemical processes, collectively known as transisterification, are required to transform vegetable oil into biodiesel and glycerol. Triglycerides may be broken down into triglyceride and then further into monoglycerides. The transisterification procedure that is used to make Calotropis root biodiesel is shown in Fig. 1. In terms of its physical and chemical qualities, biodiesel becomes significantly more similar to diesel fuels after transisterification.

Chemical the physicochemical attributes of vegetable oils obtained from various sources may differ significantly due to differences in atomic structure and free fatty acids (FFA). In particular, the characteristics of the unsaturated fats present in the preferred biodiesel have a significant impact. The features of biodiesel are significantly influenced by the atom chain structure of the fatty acids in vegetable oil. Monounsaturated, polyunsaturated, and saturated triglycerides are all present in the lipid composition of Calotropis biodiesel. The Calotropis Root biodiesel blend incorporated 2% and 6% volumetric concentration of these additives. Biodiesel's initial fractional combustion occurs at the droplet's center, and the addition of oxygenated additives dimethyl carbonate (56% of O_2) speeds up the spread of this combustion and ensures complete combustion. Table 1 details the chemical and physical properties of additives DMC. Most fuel additives have larger cetane numbers, enhanced volatility, and low viscosities, and this property is a prevalent theme in the extant literature on the topic of improved atomization of biodiesel-diesel blends. As a rule, ternary mixes (diesel, biodiesel, and oxygenated additives)

(a) Raw material (b) small pieces (c) extract oil

Fig. 1. Calotropis Root Oil

Table 1. Properties of blends

Properties	Diesel, Bio-diesel (B20)	Diesel Biodiesel (B40)	Diesel, Bio-diesel (B60)	Diesel, bio-diesel (B80)	Diesel, bio-diesel (B100)
Density (gm/cc) @ 38 ˚C	961	925	894	879	832
Fire point (˚C)	69	71	79	86	92
Flash point (˚C)	74	82	105	119	125
Viscosity (cst) @ 38 ˚C	3.69	4.15	5.93	6.38	7.12
Calorific value (lKj/kg)	42.36	44.12	45.95	47.32	49.52
Cetane number	54	57	61	64	67

employed in a CI engine exhibit superior combustion and performance characteristics. Table 1 shows in properties of Calotropis Root oil.

3 Establishment of an Experiment

Using Calotropis root biodiesel mix and certain oxygenated fuel additives, the present Kirloskar study develops a water-cooled, direct injection, compression ignition diesel engine ideal for the applications of agricultural. Figure 2 displays a diagram of the experimental testing equipment. Due to their increased thermal efficiency and endurance, single-cylinder diesel engines are becoming more and more used in the agricultural, industrial, and automotive sectors. The diesel engine is connected to an eddy current dynamometer and controlled by a dynamometer controller to maintain a constant speed of 1500 rpm under varying loads of 0%, 20%, 40%, 60%, 80%, and 100%. Combustion analysis requires a large amount of data, which is collected using a data gathering system that includes sensors for measuring heat release rate, in-cylinder pressure, and fuel % burned mass.

An AVL multi-gas analyzer measures the levels of gases like CO_2, NO_X, HC, CO, and O2 in the exhaust. Carbon dioxide and carbon monoxide in exhaust can be found using non-dispersive infrared (NDIR) sensors. Flame ionization detectors (FIDs) are used to measure emissions of unburned hydrocarbons, while chemiluminescence detectors (CLDs) are used to measure nitrogen oxides.

Huang Z et al. [12] the amount of soot in a vehicle's tailpipes is measured using an AVL 437C smoke meter. The diesel engine was ran on diesel fuel for 10 min after starting to obtain perfect running conditions. The engine was then put through with a number of Calotropis root oil biodiesel mixes that contained oxygenate additives DMC. To assure complete ignition of the remaining fuel, the diesel engine is permitted 8 min to operate on diesel fuel in between each series of tests. The amount of thermal energy created when fuel and air are burned is measured by the rate at which heat is released Manickam AR et al. [13] (Table 2).

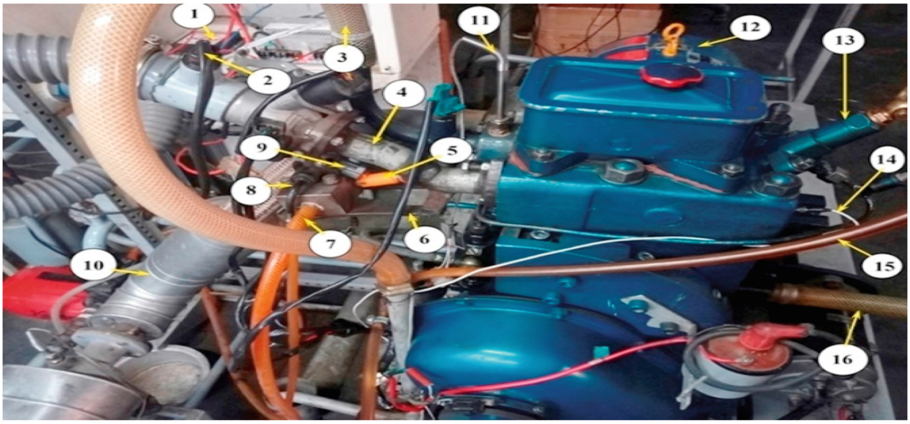
4 Performance Characteristic

4.1 Brake Thermal Efficiency (BTE)

The ability of a diesel engine to transfer heat from the fuel to the crankshaft is gauged by the thermal efficiency of the brakes. Fuel properties including kinematic viscosity, the amount of oxygen it contains, cetane index, and calorific value are some of those that affect BTE. Using data from a variety of tests (Table 1), we were able to determine that diesel; CRDE 20 Dimethyl Carbonate all had BTE values show in Fig. 3, which was significantly different from one another (DMC). We find that, for all tested fuel types, raising the brake implies enough pressure increases BTE. Under full load, the efficiency of diesel, CRDC20, CRDC20 with 2 percent and 6 percent with DMC ranges from 38.45 percent to 339.15 percent. Diesel's superior thermal efficiency may be attributed to its greater heating value in comparison to the other fuels considered. The BTE is significantly enhanced by the addition of dimethyl carbonate at a concentration of 6%, especially when compared to the other oxygenated additives assessed under full load. Under full load circumstances, the difference in BTE between the CRDC 20 biodiesel mix and the CRDC 20 biodiesel blend with 6% DMC added is about 4.22 percent. Due to the increased oxygen availability, decreased viscosity, and high volatility of DMC, a better fuel/air combination is produced in the combustion chamber, increasing BTE. A minor reduction in BTE at 75% load is caused by a reduced surplus air ratio, higher lubricating oil temperature, and slower combustion according to Jiang X et al. [14].

4.2 Fuel Use in Relation to Braking (FURB)

How much of the gasoline is utilized as a brake is mostly determined by its calorific value, viscosity, cetane index, and fuel density. Fuel required to provide one braking power for



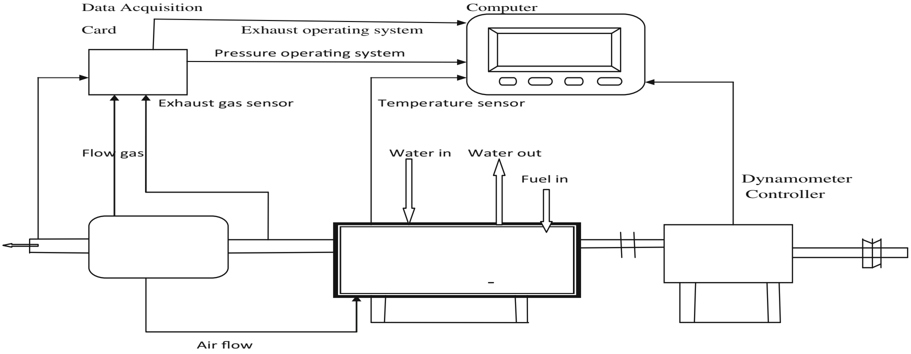


Fig. 2. Line Diagram of CI Engine

one second is indicated by the FURB value. The variation in fuel usage around the brake mean sufficient pressure is graphically shown in Fig. 4. Diesel, CRDC 20 DMC 2%, and CRDC 20 DMC 6% have FURB values of around 0.321 kg/kWh, 0.364 kg/kWh respectively. At maximum engine load. As load rises, FURB decreases in all tested fuels. Because of their more concentrated heating value, DMC fuel-enhanced compounds have greater BSFCs. However DMC was included to CRDC 20, FURB constantly decreased. For all fuel types considered. Weird tendencies were seen in the diesel engine at all fuel loads tested Udaya kumar M et al. [15].

4.3 Heat Release Rate (HRR)

Figure 5 illustrates how the rate of heat emission varies depending on the fuel type and crank angle. The figure illustrates how all of the tested fuels behave fairly similarly across the engine's whole load range. Full throttle contributes the maximum heat with the TSME 20 mixture that contains 6% DMC, producing 77.28 J per degree of crank angle (CA) before TDC. The HRR values for diesel at full load are 76.15 J/CA, CRDC 20 at 6 percent,

Table 2. Engine specification

Engine	Kirloskar Diesel Engine
Type	Tv-1, 2-stoke, water cooled
No. of Cylinder	Single- cylinder
Bore	70 mm
Stroke	120 mm
Length of connecting rod	210 mm
Speed(Rpm)	1500
Maximum load capacity	60 Kw
Fuel consumption of the engine	1.25 kg/hr
Compression ratio	16.5:1
Lubricant oil	SAE 40
Orifice diameter	20 mm

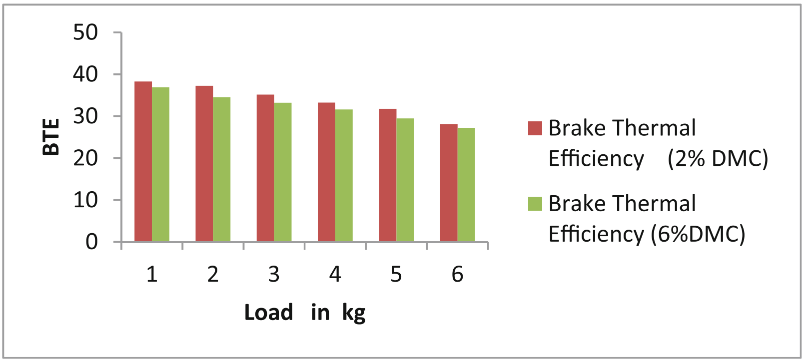


Fig. 3. Variation BTE with Load

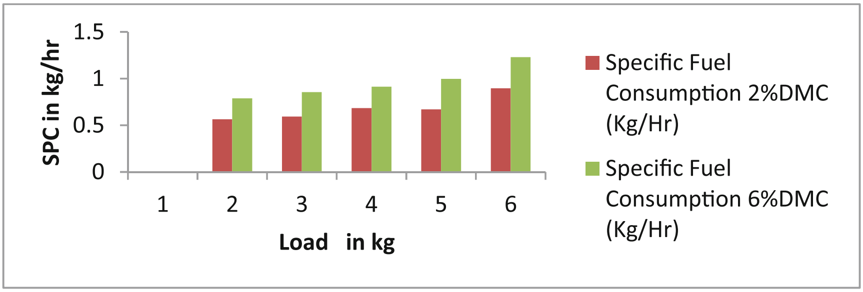


Fig. 4. Variation of SPC with Load

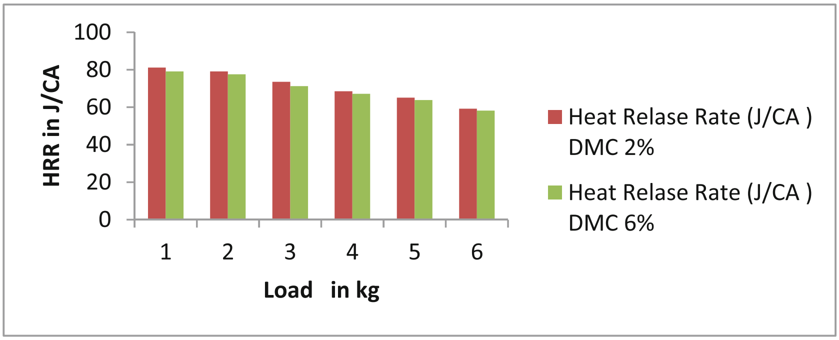


Fig. 5. Variation of HRR with Load

and the oxygenated additives DMC at 6% are, 75.23 J/CA and 83.12 J/CA. Relatively to DMC, A 20:1 blend of CRDC resulting in significantly more desirable combustion phenomena. When 6% DMC is added to the standard fuel, the HRR is increased by 10.35% in comparison to the CRDC 20 blend.Improved combustion is facilitated by the reduced viscosity and greater cetane number. Findings from the present investigation are in line with those from previous studies utilizing oxygenated additives, such as those by Saravanan S et al. [16].

4.4 Rise of Pressure Within the Cylinder

In Fig. 6 the in cylinder pressure fluctuation for allbiodiesel mix fuels evaluated in this research, across all crank angles, while operating at full loadcondition. In-cylinder pressure increases as a result of the production of the fuel/air combination and the progression of the combustion event inside the cylinder. The efficiency of the fuel/air mixture's combustion may be measured by how quickly the cylinder pressure rises. The greatest pressures for all fuels used at full load, as shown in the figure, have been reached at 100 to 250 after top dead centre. Cylinder pressures of around 73.49 bars, and 66.88 bar are produced at full speed by diesel, CRDC 20 with 2% and 6% concentrations of oxygenated additives such DMC. Tests conducted at full power revealed that diesel fuel blended generated the greatest peak in-cylinder pressure. The CRDC 20 DMC 6percent mix costs 1.88 percentage points more than the CRMC 20 when both are operating at full capacity, Dhana Raju V et al. [17] all found that using too much fuel at the start led to an uncontrolled combustion phase.

4.5 Ignition Delay Period (IDP)

The time it takes for the fuel to be fully injected and for combustion to start is known as the ignition lag or delay period. For a variety of loads, the range of ignition delay time for the fuels under consideration is illustrated in Fig. 7. For diesel, CRDC 20, and full-load operation, respectively, the oxygenated additives of DMC applied to CRDC20 at concentrations of 2% and 6% provide IDP values of roughly 17.7oCA and 21.4oCA.Compared to other oxygenated fuels with additional chemicals to CRDC20, the IDP for the biodiesel

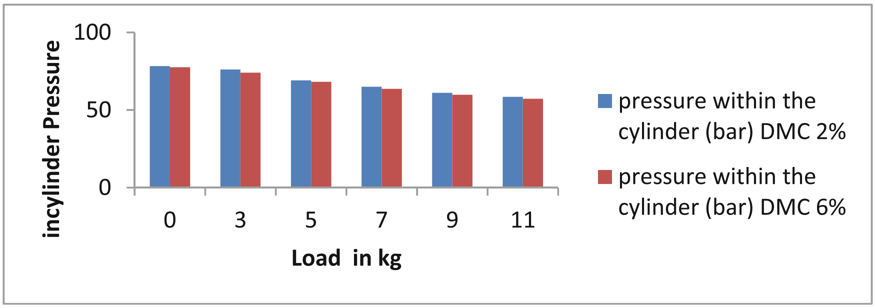


Fig. 6. Variation in cylinder pressure with load

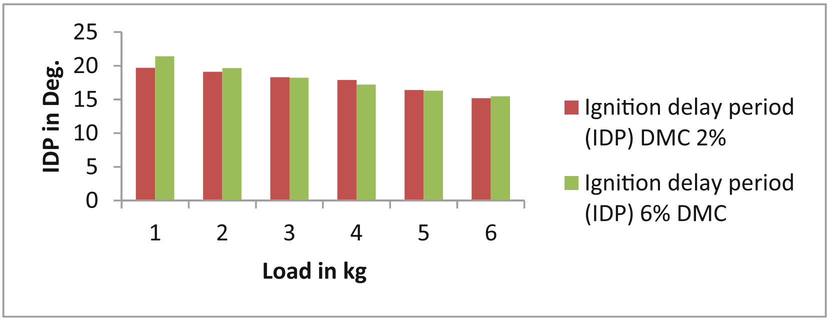


Fig. 7. Variation of IDP with load

combination percent discovered in the test exhibited a shorter delay time. Reduced delay times in oxygenated biodiesel blends with DMC are the result of higher cetane numbers and lower viscosities. Optimal combustion occurs when the fuel blend is exposed to the right amount of air Saravanan et al. [18] provided compelling evidence that oxygenated fuel is more efficient at converting fuel heat energy into useful mechanical work, which improves biodiesel mixed performance comparative to full load of diesel fuel. The present results agree with those of Reddy et al. [19].

5 Emission Characteristics

5.1 Gaseous Discharges of Hydrocarbons (HC)

The nozzle sac region, crevice volumes, and quench regions are all contributors to the engines unreached hydrocarbon emissions during the exhaust stroke. The effect of the brake mean sufficient pressure on the HC emissions from the various fuels utilized in the experiment is seen in Fig. 8. In contrast to diesel fuel, the addition of oxygenated additives to the CRDC 20 mix dramatically reduced hydrocarbon emissions. Hydrocarbon emissions at maximum load were DMC added at 2 and 6 percent respectively show in Fig. 8. In addition, as compared to diesel fuel, HC emissions are reduced by 24.36 percent when using the CRDC 20 blend with 2 percent DMC, and 6 percent when using

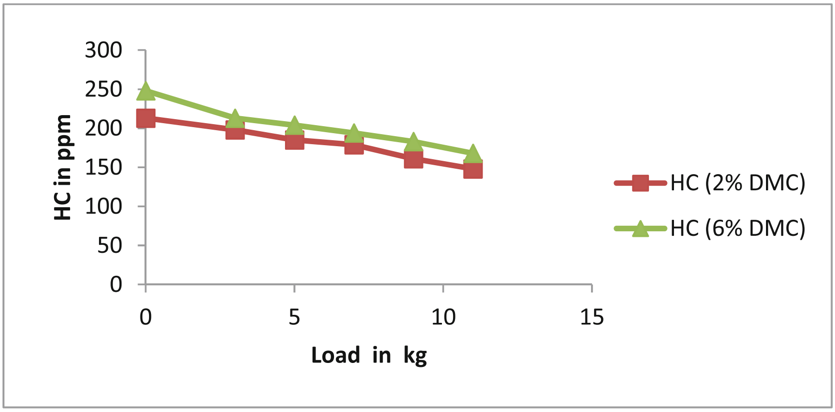


Fig. 8. Variation of load with HC levels

the CRDC 20 blend at maximum load by 27.77. Use of DMC to CRMC 20 resulted in a discernible decrease in HC pollutants as compared to diesel fuel and a Calotropis biodiesel mixed Vijayabalan P et al. [20]. The main reason for the increased HC emissions for the oxygenated fuel added substance biodiesel blend is the improved ignition air-fuel blend in the engine cylinder, which is a result of the increased igniting nature of the additives.

5.2 Gaseous Carbon Monoxide (CO)

Figure 9 illustrates how the CO emissions alter depending on the braking mean sufficient pressure for different fuel types. The most common cause is an improper mixture of gasoline and air in the engine's combustion chamber. At 75% of maximum load the CO emissions of a biodiesel mix with fuel-added compounds and diesel are found to be lowest. However, while running at full capacity, CO emissions increase for all fuel sources. Carbon monoxide emissions at maximum engine RPM are 0.131 for diesel, 0.154 for CRDC 20, and 0.123 for fuels with oxygenated additives DMC at 6% and 12% concentrations, respectively. Our calculations show that the CO creation for DMC 6% CRDC 20 is 0.889 percent at maximum load, which is 19.25 percent reduced for CRDC 20 and 15.84% reduce the CO emissions from diesel fuel. The earlier complete ignition is mostly caused by the greater cetane number and inherited oxygen in DMC Manoharan N et al. [21].

5.3 Smoke Opacity (SO)

Figure 10 shows diesel, a Calotropis root biodiesel blend, and biodiesel blends with additives of DMC at 2 percent and 6 percent volume additions to show the range of smoke opacity as a function of braking mean adequate pressure. It is a measurement of the smoke density in automobile tailpipes. Percentages are used to express values for the smoke's opacity. Smoke's opacity is decreased by complete burning in the combustion chamber. Under peak load conditions, the diesel CRDC20 Fig. 10 findings with 2% and

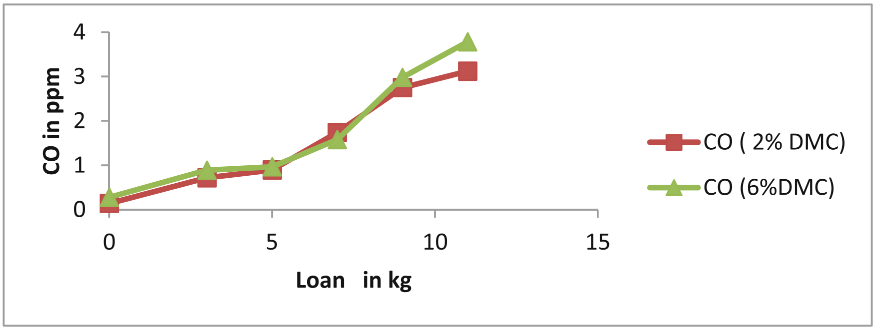


Fig. 9. Variation of CO with load

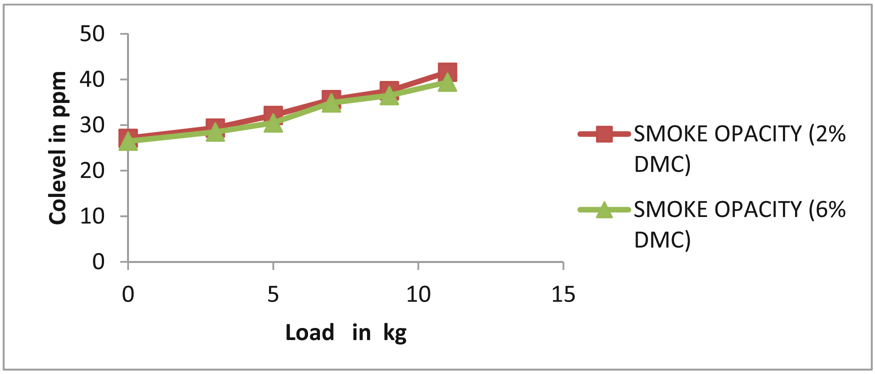


Fig. 10. Variation of smoke with load

6% DMC are approximately 41.34 and 39.12, respectively. When compared to diesel fuel at full load, testing showed that CRDC 20 with fuel additives dramatically reduced smoke output (by 27.72 percentage points for DMC 6 percent for DMC). Additionally, CRDC 20 DMC 6% reduces smoke opacity by 22.67% compared to CRDC 20 operating at peak load.

5.4 Exhaust Gas Containing Nitrogen Oxide (NO_X)

Lack of oxygen and higher combustion temperatures in the air/fuel mixture are 2 key factors that influence nitrogen oxide generation. NO_X emissions are produced as a result of the Zeldovich process between nitrogen and oxygen. The original study used fuel sample emissions from various loads are shown in Fig. 11. At high speed, their nitrogen oxide emissions are 982 ppm and 915 ppm, respectively, in comparison to diesel, CRDC 20, and DMC. According to the emission analysis, NO_X emissions from DMC 2 percent and DMC 6% were reduced by around 10.33% and 6.06%, accordingly, in comparing to fossil diesel at full load. These results support the oxygenated fuel additives' superior heat of vaporization. NO_X emissions for CRDC 20 at full power have been compared to diesel fuel.

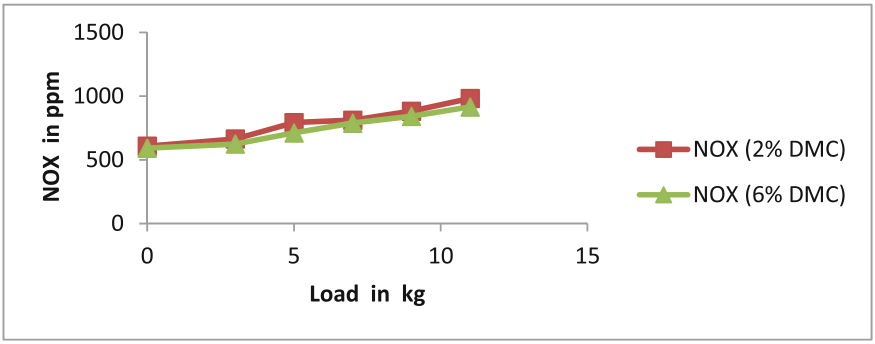


Fig. 11. Variation of load with NO_X level

6 Conclusion

This research looked at how a diesel engine using a CRDC 20 mix of oxygenated fuel performed in comparison to a regular diesel engine in terms of combustion, performance, and emissions. Oxygenated gasoline additives, including DMCwere added to CRDC 20 at concentrations between 2% and 6% (Volumetric Basis). Here are the most important things we learned from the experiments:

- The diesel-biodiesel-oxygenated additive mixes performed favorably in terms of performance, combustion, and emission characteristics in the diesel engine.
- A 6% DMC addition to CRDC 20 greatly increased BTE in comparison to other oxygenated additives tested at all loads. While the engine is running at full power, the CRDC 20 biodiesel blend with 6% DEE has a 5.96 percentage point higher BTE than the CRDC 40 biodiesel blend without DMC. However, compared to diesel, its BTE is a little lower.
- A diesel engine running on CRDC 20 with 2% and 6% DMC reduced tailpipe emissions by 12.54% and 15.74%, respectively, in comparison to a diesel engine running on base diesel fuel at maximum power. Diesel emissions are slightly reduced by gasoline additives DMC.
- In comparison to other fuel additive blends and CRDC 20, diesel was shown to have improved combustion parameters, including heat release rate and in-cylinder pressure. When compared to the CRDC 20 blend under full load conditions, the inclusion of 6% DMC has caused the HRR to rise by approximately 9.25 percent.

After comparing experimental data for the optimised fuels with the results from the engine simulation, it is discovered that the CRDC 20 with a DMC 6% biodiesel blend has the best overall engine characteristics. When there is a strong correlation between theoretical predictions and experimental data, our numerical predictions will be accurate.

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