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Experimental investigations on performance improvement and emission control of a single cylinder diesel engine by using trinary blends with nano additives

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Abstract: The significant search in exploration of renewable fuel for IC engines is due to energy crisis (rapid exhaustion of fossil fuels), energy security, and increasing cost of fuel, environmental degradation and CO_2 emission which contribute to rise of global warming. Several researches have been done by researchers with different types of alternate fuels. Eucalyptus oil is one such alternate fuel which is being tried due to its properties. Eucalyptus has low viscous and high calorific value that assists maintenance of stability in diesel – alcohol blends as a fuel in engines. As eucalyptus oil has higher flash point and cetane number with reduced viscosity, it improves the mixture formation and quality of the ignition by reducing delay period. This study investigates the impact of blending diesel with propanol, eucalyptus oil, and 40 ppm of Graphene Oxide nano additives on the performance and emissions of a single-cylinder engine. The addition of GO to various blends of eucalyptus, diesel, and propane with 40 ppm of GO led to an increase in brake thermal efficiency. Meanwhile, the emission of Carbon Monoxide, Hydrocarbon, and Carbon dioxide (CO_2) decreased. However, the addition of GO resulted in an increase in Oxides of nitrogen compared to diesel fuel.

1. Introduction

In general, the supply of fuels derived from crude oil is declining every day and could eventually become scarce. As the population of automobiles increases, demand and

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supply cannot coexist in the future. Upsurge usage of fossil fuels may lead to their complete exhaustion. However, the use of fossil fuel has created inflation number of pollutants like CO, CO_2, HC, and NOx are released into the atmosphere. Such a hazardous situation indirectly pushes researchers to develop innovative replacements for fossil fuels that use environmentally beneficial energy sources. Since the supply of non-renewable fossil fuels like oil and gas has become extremely scanty, people feel the need to find sources for alternative, renewable, and non-fossil fuels. In Internal Combustion (IC) engines, the fuel used for combustion has turn up inside the cylinder and in the case of External Combustion (EC) engines, the fuel used for combustion occur outside the cylinder. The benefits of an IC engine over an EC engine are better BTE, high power produced per unit weight with low cost.

Researchers find the inability of vegetable oil for direct use as fuel. Transesterification is the best method for producing biodiesel with properties similar to diesel. Biodiesel engines emit lower levels of CO, smoke, and HC but may increase NO_X emissions. Biodiesel has higher viscosity and lower heating value, but it is a good alternative to diesel. Triglycerides from biomass substances and micro-algal oil can be used for producing biodiesel via transesterification. [1]

Research by Santos ND et al showed idling, which consumes a rich Air-Fuel Ratio (AFR), can lead to increased fuel consumption and emissions of HC and CO. Automatic engine start-stop technology was introduced two decades ago to avoid this mode of operation, but it has not resulted in any significant performance improvements due to frequent start-stop cycles, which can lead to increased wear over time and emissions when the engine starts from a stop. [2]. The work of on Sanli et al. research on low viscous micro-emulsification fuels, showed compression ignition (CI) engine has utilized alcohol in improving the combustion process due to oxygen enrich additive which assist in co-combusting with biodiesel or diesel engine. However, alcohol is utilized in terms of additive for the diesel fuel but complexness in miscible of both primary and secondary fuel in which the phase separation has been ensued [3]. According to Liang et, al, different kinds of stabilizers, including tetrahydrofuran and n-pentanol are employed for production of a stable combination [4]. The research found alcohol percentage in the blend diesel fuel combination can be controlled in term of volume by 20% [5]. Alcohols have identical molecular structure to biodiesel and combine with it better [6]. A study by Tutak et al related the combustion of different reactivity fuel mixtures in a dual fuel engine and found saturated HC propane having high calorific value and energy value. Dual-fuel engines with co-combustion of alcohol fuel and diesel or biodiesel injected separately have been developed as a solution to these challenges. In this technology, alcohol fuel was poured into the intake manifold through PFI during the intake stroke, and diesel or biodiesel is then injected directly into the chamber during engine starting. [7]. One of the best methods for utilizing an alternate fuel for operation of an industrial engine is the dual-fuel system. Based on the engine's load or resources, this method permits approximately of any fuel supply proportion [8]. Kuszewski [9] conducted research on the effect of alcohol fuel percentage on the combustion, phases, timing, and emissions. They found that the amount of alcohol in mixture has a significant impact on these parameters. The high heat of vaporization of alcohol injected through the intake manifold causes the temperature of the fuel to decrease before combustion, resulting delay in ignition [9]. Increased ignition delay in the combustion chamber can raise temperature and pressure, leading to more efficient combustion in industrial engines. Propanol has a high-octane number of 118, but high manufacturing makes it less commonly used in SI engines. It contains 26.6% oxygen and acts as an oxygenated fuel similar to other alcohols. Arkadiusz Jamrozik et al. investigated the Proponal as a fuel in PFI-powered engines. The study found increase in propanol's proportion in the fuel mix causing increase in the cooling effects and maximum pressure (Pmax), and also a reduction in combustion duration and increased ignition delay time. A 50% proportion of propanol in diesel fuel combustion resulted in maximum engine efficiency 5.5% higher than diesel combustion. [10].

The direct injection diesel engine's efficiency and emissions characteristics by using different eucalyptus-diesel blends have been researched by Rajesh Kumar et al. Eucalyptus oil is added to diesel mixes and has properties similar to plain diesel, such as density (q), flash point, calorific value, and viscosity. The results showed that when eucalyptus oil was added to diesel fuel, the engine's efficiency (BTE) rise and emissions were reduced in comparison to when diesel fuel was used alone. [11]. Sivakumar ellaiyappan et al. studied the operation and emission features of a diesel engine using a blend of biodiesel and eucalyptus oil as secondary fuel. Diethyl ether (DEE) was additional to the mix to increase its cetane index and density. According to the findings, using a eucalyptus-biodiesel blend with DEE increased the engine's BTE and reduced emissions when compared to diesel fuel. In particular, the BTE was increased by 3.5%, while the CO and HC emissions were decreased by 25% and 20%, separately. Nitrogen oxide (NOx) emissions, however, rose by 5%. [12]. Rickwinder Singha et al. examined the effects of butanol adding to eucalyptus biodiesel-diesel blends on an engine's performance and emission characteristics. Results showed that a base-catalyzed transesterification process at a predetermined an approximate 92% yield of biodiesel was generated using an 8:1 methanol to oil ratio with a 0.1% (wt) NaOH catalyst at 65°C reaction temperature for three hours. With butanol-biodiesel-diesel fuels, BTE dropped but braking power (BP) and BSFC somewhat increased. For B20 and B100, respectively, the average reduction in CO emissions at full load was 10% and 20%, while the average reduction in unburned hydrocarbon (HC) emissions was 36.7% and 46%. When compared to diesel, it was shown that the CO_2 and NOx and emissions were higher. Due to the butanol's cooling impact, B20-5Bu, B20-10Bu, and B20-15Bu showed average values of 23.55 percent, 21.9%, and 25.16% decrease in NOx emission, respectively. Overall, the research points to butanol-diesel-biodiesel as a probable alternative fuel to diesel [13]. Eucalyptus biodiesel is being looked at by L Tarabet et al. by means of a substitute fuel for diesel engines. According to the study, eucalyptus biodiesel in its pure form and in mixes with diesel fuel significantly reduced exhaust pollutants, especially under heavy loads, while exhibiting similar performance to diesel fuel. At high power levels, the unburned hydrocarbons (HC) emissions reduction can reach up to 52% when compared to plain diesel fuel. When power output increases, the exhaust gas temperature (EGT) rises linearly. EGT for pure diesel is somewhat lower than for neat biodiesel or its mixes [14]. Puneet Verma and colleagues looked at the viability of utilising eucalyptus biodiesel in a compressed ignition engine as an alternative to regular diesel fuel. According to the study, the BSFC of the B10 blend of eucalyptus biodiesel, which is nearly identical to diesel, was the best among the various ratios. B10 blends' Brake Thermal Efficiency (BTE) was shown to be 0.52% and 0.94% lower than diesel, suggesting that it may be a viable alternative to diesel. Utilizing biodiesel enhanced the engine's emission characteristics, with cleaner smoke produced than when using diesel. Eucalyptus biodiesel has a lower HSU for a 10% mix than conventional diesel, indicating that the smoke from biodiesel is clearer or cleaner [15].

The impact of incorporating metallic as well as carbon based nano-additives for the blends of diesel as well as biodiesel fuel has been studied by researchers in this domain. Several researchers have reported the complete performance enhancement because of complete fuel combustion [16, 17]. Asymmetric GO nanoparticles have been found to be highly successful than their metal-based equivalents at lowering fuel emissions and enhancing performance an outcome in their superior properties of physical and chemical as well as behaviors and phenomenon of droplet combustion [18].

M.E.M.Soudagar et al., did experiments on improvement of CN, calorific value, oxygen content, reducing the period of ignition delay, increasing micro explosion, etc. Many experts made blends of biodiesel fuel with nano-additives and found nano-additives based on metal are assisting in collection, clustering as well as set up nanoparticles because of their limited stability. This research work has beneficially undertaken the usage of carbon based nanoparticles as GO over biodiesel blends with choice of an anionic surfactant from the experimental approaches for additional stability enhancement. The distribution stability reduction in by surfactant concentrations above or below 1:4 ratios was seen. Applying an ultrasonication process, the biodiesel and GO nanoparticles were combined at parts per million (ppm) ratios of 20, 40, and 60. At a steady speed, this experiment was run while changing the load as well as braking power conditions. The BTE increased by more than 11% BSFC is decreased by 8%, UHC declined with 21%, CO increased by 38.662% and smoke decreased by 24.88%, for the DSOME blends with nano-fuel with 40ppm of GO nano-additives [19]. The study related to the harmful emissions generated from diesel engines, including emission. These pollutants were difficult to control in traditional diesel combustion due to an emissions tradeoff with reduction in one pollutant leading to increase in the other. Engine manufacturers rely on after treatment systems for meeting emission requirements.

2 Materials and Methods

2.1 Eucalyptus oil as biodiesel

One of the non-edible oil is eucalyptus oil with source as potential as other biodiesel product because of widespread availability in India. Eucalyptus oil as biodiesel has high CN and with sulphur absence which is the major criterion for choice as an alternate fuel to diesel. The usage of biodiesel has generated less pollutant composition in their exhaust. This paper focuses on the examination of the influence of the eucalyptus biodiesel on engine efficiency as well as emission properties. Eucalyptus plant seeds are depicted in Fig.1 and the extraction of oil from seed by a mechanical expeller. However, the oil essence available in the seed consists of nearly 60% of cineole essence. Its primary characteristics include a quick growth rate, the capacity to loom weeds, coppice adequately, fatigue resistance, browse resistance, and climatic adaptability. Eucalyptus trees vary greatly in height as well as diameter. Three year old eucalyptus tree in agroforestry system reaches a height of around 12 m and a circumference of 40–45 cm.

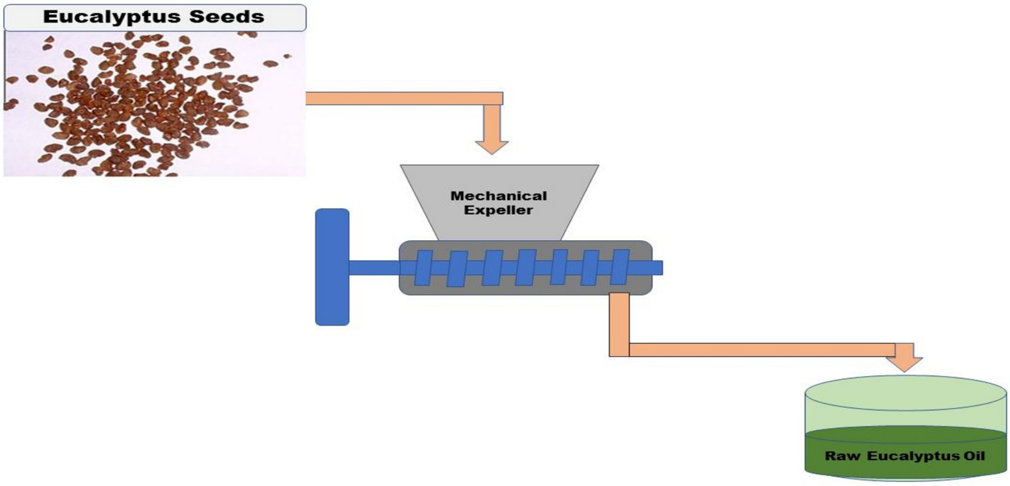

Fig. 1. Eucalyptus oil extraction.

Essential oils were produced from a plant's non-fatty portions inclusive of seeds, leaves, root, flowers and stems. This kind of oil is mainly utilized in the domain of natural medicine in view of health benefits claimed and the sector of fragrance and flavoring. Similarly, the market has seen rapid growth over current years. The essential oil benefit over CI engine is a concept not explored completely. This study has analyzed the relevent literature on the essential oil influence as well as its blend on performances, emission metrics of the diesel engine.

2.2 Physical and chemical properties

Eucalyptus biodiesel has physical and chemical properties that make it a good alternative fuel, with high volatility and less viscosity. When blended with biodiesel, the properties of the blend oil are nearly identical to those of diesel, with high flash point and high viscosity balancing out other lower properties. The low heating value of biodiesel can be improved by blending it with diesel fuel, resulting in better fuel efficiency and reduced emissions. The properties of physical and chemical in eucalyptus oil as essential oil, propanol as alcohol and diesel are shown in table 1.

Table 1. Properties of proposed fuels

Sl.No	Properties	Eucalyptus oil	Propanol	Diesel
1	Cetane Number	47	12	52
2	Molecular weight	154.2	60.1	142
3	Density @ 15ºC	905	803.7	831
4	Viscosity @ 40ºC	1.68	1.74	2.82
5	Specific gravity @ 15ºC	0.92	0.804	0.81-0.89
6	Boiling point in ºC	200	90	195
7	Self-ignition temperature in ºC	290	350	250
8	Flash point in ºC	54	22	69
9	Latent heat of vaporization	305	720	270

The University of Malaya's Nanocat Research Center created GO nanoparticles using the Chemical Vapor Deposition (CVD) production method. Synthesized GO NPs have an average size of 23–27 nm (0.5 nm), inherent mobility of 200,000 cm^2 v^{-1} s^{-1}, thermal conductivity of 3300 W m^{-1} K^{-1}, Young's modulus of 1.0 TPa and surface area of 2630 m2 g1. Purity of 99% GO with 40 ppm is highly soluble which increases the performance in biodiesel which improves the high surface area and rapidly mixed with different polymers may assist to reduce harmful emission such as HC, CO and NOx. Essential oils are similar to diesel in terms of their characteristics. Many essential oils and its combinations have enhanced BTE and lower the BSFC while used in blend biodiesel engines.

2.3 Biodiesel production and properties

This study focuses on biodiesel that produced from eucalyptus oil muddle with constant 30% of propanol which significantly less toxic as well as volatile than methanol. The flash point of propanol is 22°C, with benefits in fire safety with less carbon. Moreover, the GO at 40PPM as nano-additive has been considered along with propanol for preventing nanoparticles from collection over base fluid of propanol. GO was used as the doping agent in this current study. Figure 3 illustrates the 70% of eucalyptus oil with 30% of propanol with GO at 40PPM which is represented as blend-1.

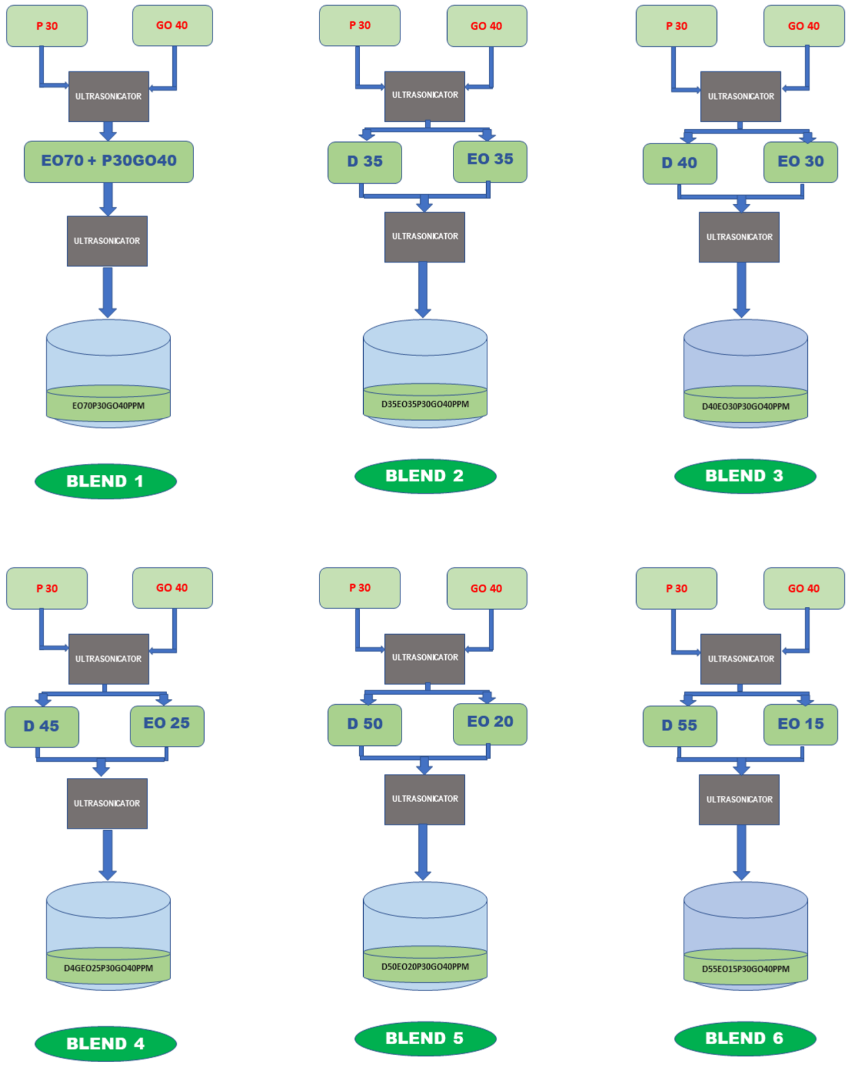

Fig. 2. Preparation of various blends using diesel with eucalyptus and propanol with GO.

Figure 2 illustrates the combination of diesel blends with eucalyptus and inclusive of 30% of propanol and 40ppm of GO, which is common for all blends from blend-2 to blend-6, with variations in diesel blends with eucalyptus varies from 35%-35% combination to 55%-15% from blend-2 to blend-6 respectively. Table 2 has provided details of the collected combination blends are heated as fuel preparation and segregated in individual container by representing blend names.

Table 2. Types of fuel blend with ratio

Blend Type	Blend Name	Fuel Bend ratio in %		
		Diesel	**Eucalyptus**	**Propanol with GO @40 PPM**
Diesel	Diesel	100	-	-
Blend 1	EO70P30GO40	-	70	30
Blend 2	D35EO35P30GO40	35	35	30
Blend 3	D40EO30P30GO40	40	30	30
Blend 4	D45EO25P30GO40	45	25	30
Blend 5	D50EO20P30GO40	50	20	30
Blend 6	D55EO15P30GO40	55	15	30

The combination of P30GO40 as constant for all the blends is expressed as Proponal with 30% and GO at 40PPM. Ultrasonic homogenizers or sonicators were used for fuel preparation to for a reduction in the size of particles for better dispersion and stability. This method is effective in reducing hard and soft particles and is used for both batch and inline processes.

In general, the density of eucalyptus is high in comparison with diesel but the viscosity is less in eucalyptus. Table 3 illustrates the blend-1 that has better fire and flash point compared to the other blends and the pure diesels but the calorific value of blend-1 is very less with 39.7MJ/Kg when compared with other blends. According to the properties of fuel blends, the blend-4 has high calorific value as 45.6 MJ/Kg with flash point as 51ºC and fire point as 58ºC followed by blend-6 and blend-5. These blends calorific value is better than diesel's CV which is 44.8 MJ/Kg which mentioned benefit of fuel with better BTE.

Table 3. Properties of various fuel blends

Properties	Diesel	Blend 1	Blend 2	Blend 3	Blend 4	Blend 5	Blend 6
Density (Kg/m3)	860	865	843	840	836	833	829
Calorific Value (MJ/Kg)	44.8	39.7	42.8	43.9	45.6	45.1	45.3
Viscosity @ 40ºC	2.73	1.76	2.14	2.19	2.25	2.27	2.31
Flash point ºC	62	39	47	49	51	54	58
Fire point ºC	69	43	52	56	58	61	67

2.4 SEM Analysis

The presence of oxygen functional groups like epoxides, hydroxides, and carboxylates in graphene oxide nanoparticles (GO NPs) promote chemically active areas that result in complete fuel combustion and management of carbon depositions. Unlike metal-based nanoparticles used in fuel blends, GO NPs and their effects on biodiesel blends are less understood. TEM and SEM imaging showed the accuracy of GO interspacing and its crystalline order. Raman spectrum of GO was also collected to determine its characteristics.

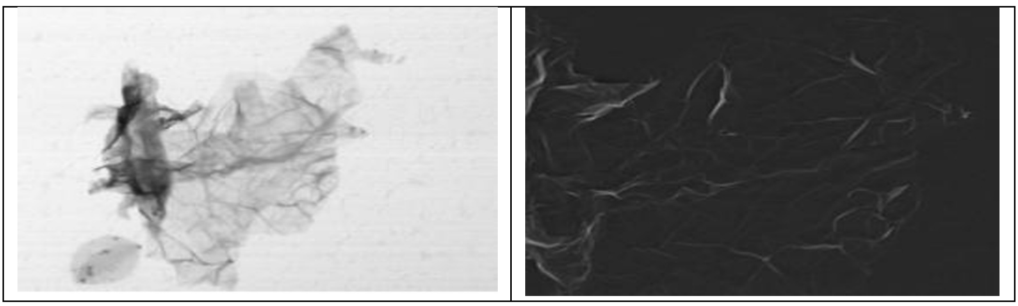

Fig. 3 (a) GO nano-particle TEM image, (b) GO nano-particle SEM image.

2.5 FTIR image of graphene oxide

Figure 4 illustrates the Fourier transform infrared FTIR picture of graphene oxide provides crucial information on the molecular structure and existence of functional groups in the material. FTIR spectroscopy, which analyses the absorption of infrared light, is widely used to assess the chemical makeup of materials. GO is an oxidised version of graphene, and the FTIR picture helps to detect and understand the oxygen-containing functional groups introduced during oxidation.

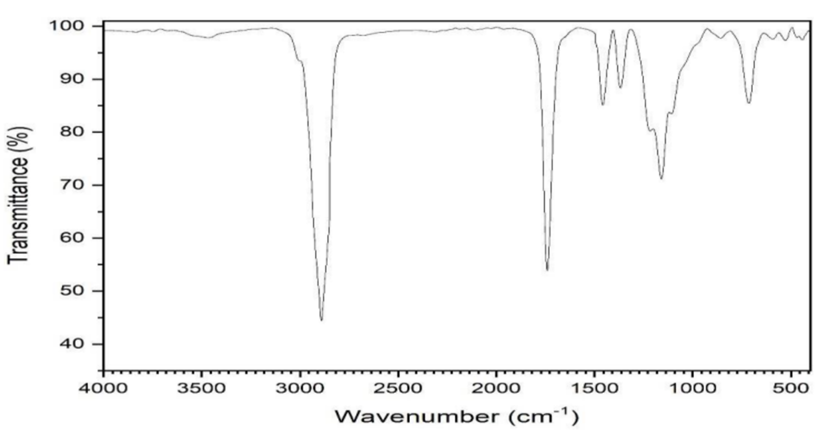

Fig. 4. FTIR image of graphene oxide.

These functional groupings exert a considerable effect on the characteristics and applications of GO. Oxidation adds functional groups to the graphene lattice, such as carboxyl (-COOH), carbonyl (C=O), and hydroxyl (-OH). FTIR spectroscopy may be used to locate and analyse these functional groups. In the FTIR picture, they are represented as discrete absorption peaks. The positions, forms, and intensities of these peaks provide information about the types and quantities of functional groups. Hydroxyl groups (-OH), for example, often show a wide absorption peak between 3200 and 3600 cm-1. While carbonyl groups (C=O) have absorption peaks in the 1600–1800 cm-1 range, carboxyl groups (-COOH) have peaks in the 1700–1800 cm-1 range. By examining the FTIR picture, researchers may estimate the quantity of various functional groups and ascertain the level of oxidation in GO samples. Understanding the chemical changes that occur during the production of GO and adjusting its characteristics need this knowledge. Information on other properties of GO, such as the existence of impurities or residual solvents, may also be obtained from the FTIR picture.

3. Experimental Setup

This experimental system makes use of a 4-stroke single cylinder engine that is water cooled, rated at 1500 revolutions per minute (rpm), with a rated BP of 5.2 KW. Table 4 shows Specifications of the test engine. The crank angle, temperature, combustion pressure, load, fuel flow, and air flow were all measured using an eddy current dynamometer mounted to the VCR engine. The configuration, however, was the solitary panel box seen in figure 5, and to interface the signal that was collected with the computer, a high-speed data collection procedure was used. In order to conduct this experiment, a number of equipment was used, including two fuel tanks, a fuel measuring unit, a transmitter for monitoring both fuel and air flow, a piezo powering unit, and a process indicator. Numerous measures, including braking power, BTE, and BFSC, were used to analyse the performance of blend fuel diesel engines. The AVL 437C smoke metre was used to measure exhaust gases and smoke from the engine for combustion and emission analysis using PC connection as a data acquisition, as illustrated in figure 5. The AVL-444N DI gas analyzer and smoke are also measured by this device.

Table 4. Specification of Test Engine

Parameter of Test Engine	Description
Engine	Water cooled Four stroke
Make	Kirloskar
Engine speed in RPM	1500
Rated Brake power @1500 RPM in KW	5.20
Cylinder Bore in mm	87.50
Swept volume in CC	661
Stroke in mm	110
Length of Connecting rod in mm	238

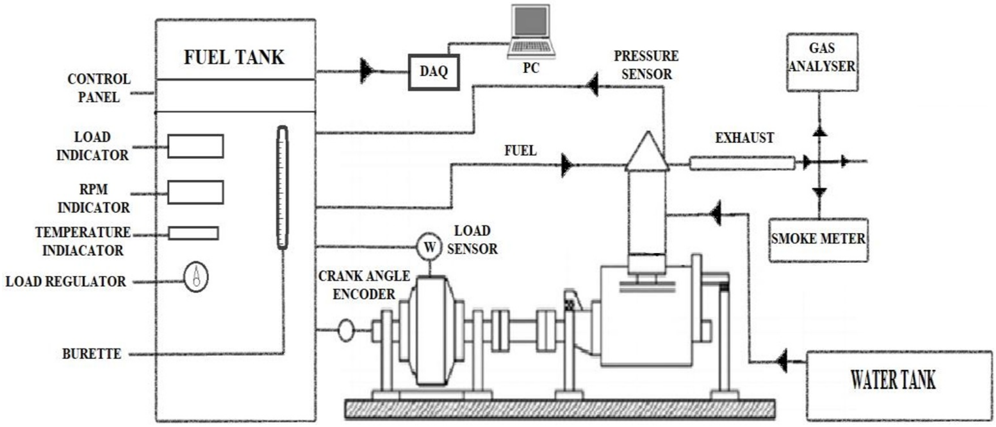

Fig. 5. Setup of Kirloskar TAF1 single cylinder for test engine.

The model describes the flowchart's operation. The AVL-444N DI gas analyzer and the AVL-437C smoke meter take exhaust air as inputs, respectively. Emission data for a range of IC engine loads has been collected. The data preprocessing module receives the results of the data acquisition process and uses them to carry out the feature extraction procedure.

3.1 Uncertainty analysis

According to the experimental procedure, the predicted uncertainty for this current measurement was done as a quantitative evaluation. The uncertainty factors present in the BTE, BP, BSFC, torque and BMEP were 1.3%, 1.9%, 2.01%, 1.81%, and 0.5%, correspondingly. Based on the diffusion error principle, during the current measurement for the entire experimental, it was with uncertainty 6.53%. Table 4 illustrates the accuracy and uncertainty value for the measured quantity measured at the experiment.

Table 5. Uncertainty and accuracy for measured Instrument

Parameters	Measurement Accuracy of the Instrument	Uncertainty in %
Fuel flow	±0.030 (L/h)	±0.37
Engine speed	±2.1 rpm	±0.16
Temperature	±1.1 ◦C	±0.19
Torque	±5.0 N/m	±0.05
BP	±0.030 kW	±0.15
BTE	±4.01%	±1.90
BSFC	±4.04 g/kWh	±2.01

4. Result and discussion

This research focuses on an alternate fuel as biodiesel with less emission pollutant. The initial research focuses on the Ignition Delay (ID), a parameter that is among the key parameters that has a serious influence. This may affect the fuel mixture of pressure and temperature during the time of fuel injection as well as engine operating conditions namely engine speed, fuel injection timing, and load. The combustion characteristic analysis, performance analysis and emission are discussed for diesel as well as all six types of blends. The respective results are discussed below

4.1. Performance analysis

Analysis of diesel engine performance helped determination through BTE and in all the blend fuel as well as diesel fuel cases, the BTE got increased with increase in the load. However, increase of BTE was due to minimization in the heat loss as well as incremental in the power progressed with increase over load. In the case of less biodiesel concentration in the blend, the engine BTE gets improved compared to the condition when engine runs on the biodiesel.

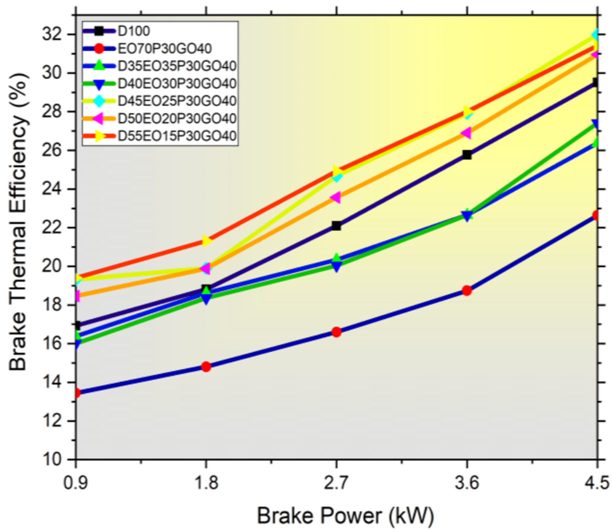

Fig. 6. BTE of Biodiesel blends.

Fig. 6, shows blend 1 has low BTE in all loads distinguished to diesel fuel due to its decrease in CN. Blend 2 and 3 has slightly increased BTE due to the addition of eucalyptus oil, propanol, and GO of 40ppm, but still lower than diesel. However, blends D45EO25P30GO40, D50EO20P30GO40, and D55EO15P30GO40 have higher BTE values (31.98%, 30.96%, and 31.41%, respectively) compared to diesel fuel (29.52%). This suggests that adding surplus lubricity from biodiesel may improve BTE by adding more oxygen to the fuel combustion process.

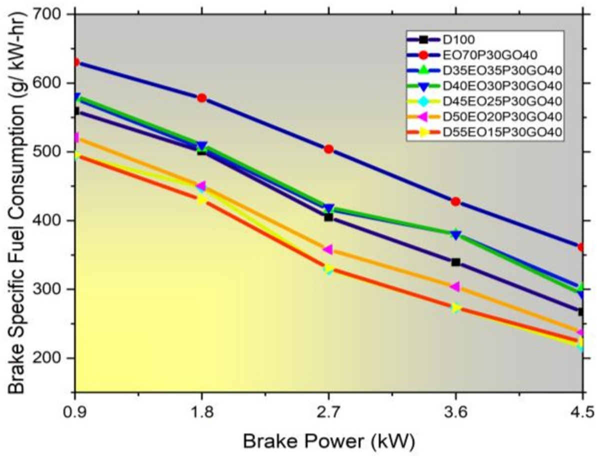

Fig. 7. BSFC of different biodiesel blends.

Fig. 7 illustrates the BSFC for different blends in which the BSFC gets decreased as with increase in BP. According to the full load in BP, the D45EO25P30GO40 has better efficient BSFC with less consumption of fuel followed by D55EO15 P30GO40 blend whereas the BSFC value is 216.96 kg/Kwh and 223.37 kg/Kwh respectively.

4.2. Combustion characteristic analysis

The cylinder pressure values for diesel fuel and different blends, which is significant for engine indication and measured combustion analysis. Peak cylinder pressure was observed for each fuel; with diesel fuel having a peak of 63.46 bar at 7º CA. D45EO25P30GO40 and D55EO15P30GO40 had higher peak cylinder pressures than diesel fuel, while EO70P30GO40, D35EO35P30GO40, and D40EO30P30GO40 had lower peak cylinder pressures. D50EO20P30GO40 had a peak cylinder pressure similar to diesel fuel, but at 2º CA.

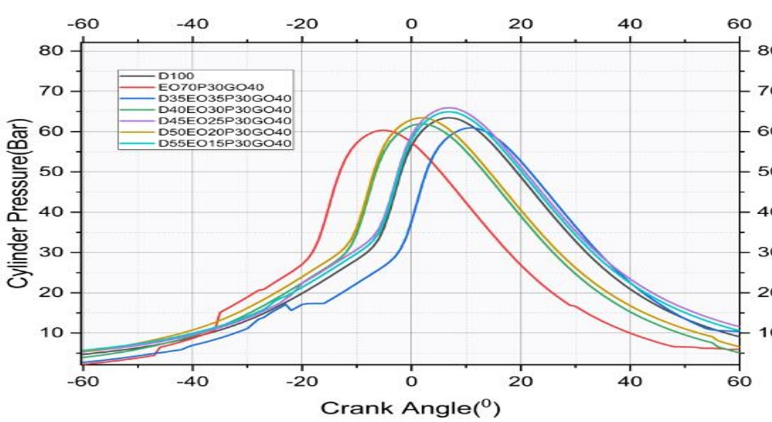

Fig. 8. Cylinder pressure for full load Vs CA to various biodiesel blends and diesel fuel.

Peak pressure was determined by participation of the fuel over combustion phase has been controlled by the delay period as well as spray surrounds the fuel. Except blend 1, blend 2 and blend3, the other blend produced somewhat more torque and power than diesel fuel. This outcome is determined through high combustion in blend as well as high viscosity and density. Hence, the blend 4 followed by blend 6 performed high peak cylinder pressure and combustion characteristic than diesel fuel.

Fig. 9 illustrates the variations in HRR with CA for tested blends at full load in which biodiesel fuels are represented in term of blends. It is seen that the blend 1 of HRR is higher than diesel fuel due to less CN. Occurrence of maximum HRR was seen at the premixed combustion phase. Longer elongation in ignition delay may have resulted in higher HRR during premixed combustion phase. The remaining blends of biodiesel are lower in HRR than diesel fuel due to combination of diesel fuel mixture of eucalyptus oil along with propanol and GO of 40ppm. This assisted in improving the CN and calorific value of the blends. Thus, the least HRR occur in the blend 4 followed by blend 6 and blend 5. Thus, maximum HRR generated from blend 4 is 0.72 KJ/Degree but in the case of diesel and blend 1 is 0.81 KJ/Degree and 0.93 KJ/Degree respectively.

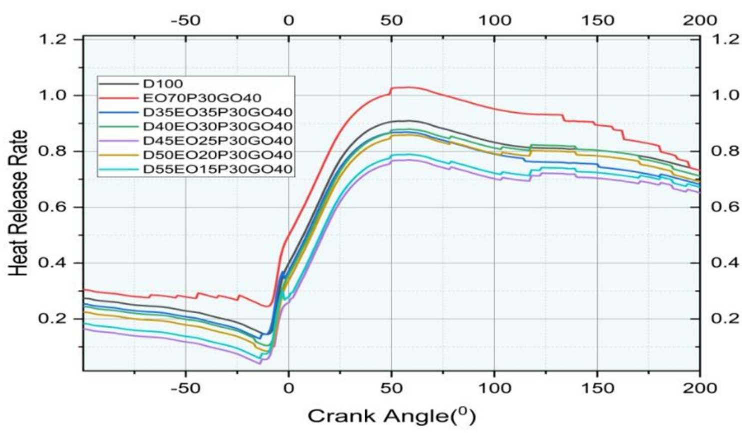

Fig. 9. Cylinder pressure for full load Vs CA of various biodiesel.

4.3. Emission Characteristics tests

NO_X emission of biodiesel blends with diesel fuel and pure diesel fuel is shown in Fig. 10. Biodiesel mixes emit was seen with less NO_X than diesel. One of the primary causes of NO_X generation has increases the combustion gas temperature. Propanol's higher LHV causes a cooling effect that might decrease combustion gas temperature as well as result in lesser Nox. The NO_X value for full load in diesel was 1356.3 PPM was less than the best performed blends namely D45EO25P30GO40 and D55EO15P30GO40 are 1379.1 PPM and 1456.6 PPM. Moreover, the blend D50EO20P30GO40 is also higher than diesel fuel such as 1428.9 PPM which is not suitably good for environment. Hence, NO_X need addressing for reducing the emission that need to be adequate for environment.

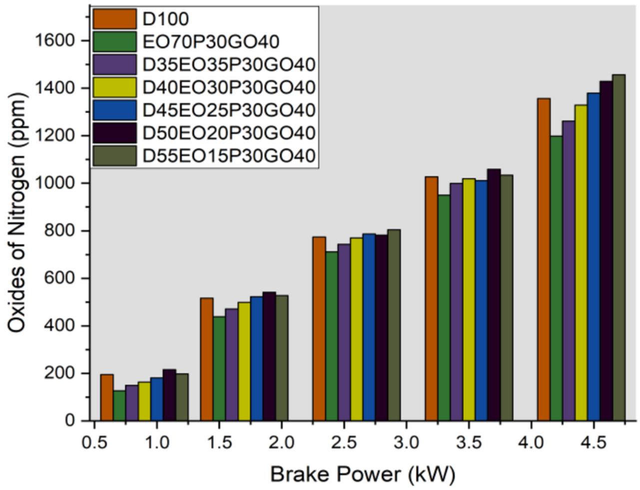

Fig. 10. NO_X emission of different biodiesel.

In Fig. 11, shows a comparison between HC emissions for different blends are showing that an increase in HC emissions increase with engine load due to higher combustion temperature. Biodiesel blends have lower as the proportion of biodiesel in the blend increases. The HC emissions for full load are discussed, with D45EO25P30GO40 blend having the highest emissions at 91.9 PPM, followed by D50EO20P30GO40 and D55EO15P30GO40 with lower emissions of 89.1 PPM and 87.8 PPM, respectively. Decrease in HC was because of decrease in eucalyptus oil proportions and the increase in diesel proportions. The presence of more oxygen in eucalyptus oil causes the fuel to combust quickly.

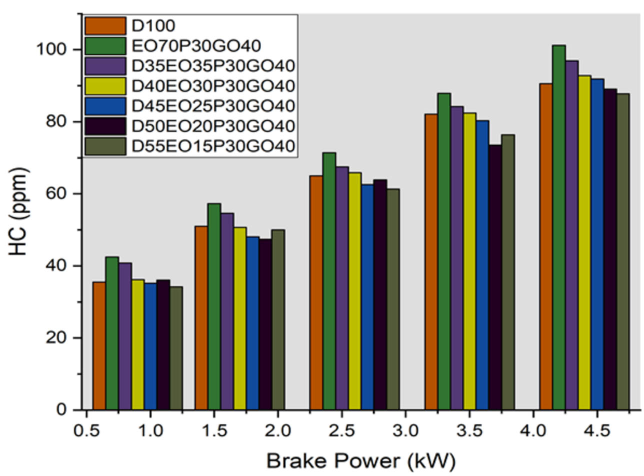

Fig. 11. HC emission of different biodiesel blends.

Fig. 12, shows increase in the CO emission for various biodiesel increases with engine load due to the rise in combustion temperature. However, CO emission was less for biodiesel blends than diesel, with decrease with increase in the proportions of eucalyptus oil in the blends. At full load, the CO emission was below at 0.9 KW, and decreases as the eucalyptus oil blend proportion decreases. Diesel fuel has a higher CO emission of 0.152% compared to D45EO25P30GO40 and D55EO15P30GO40 blends, which have CO emissions of 0.145% and 0.141% respectively. The pure eucalyptus oil blend (blend 1) has a CO emission 1.68% higher than diesel fuel.

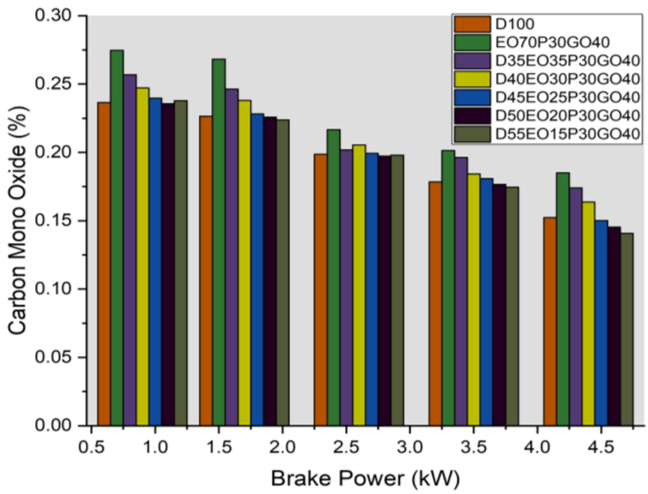

Fig. 12. CO emission of different biodiesel blends.

Fig. 13 illustrates the CO_2 emission for different biodiesel blends in which the CO_2 increases with increase in engine load because of increase over combustion temperature associated with increase in engine load. In the case of biodiesel blends, the CO_2 emission was less and reduces with increase in biodiesel fuel. The CO_2 emission of full load (4.4 kW) was lower than 2.6kW load whereas the biodiesel blended fuel with the CO_2 emission increased compared to diesel fuel by 8.87%, 10.08% and 8.66% of CO_2 for blend 4, 5 and 6. Compared to diesel, the Blend 4, 5 and 6 was better in emission. The CO_2 emission of pure eucalyptus oil blend (blend 1) was very lower than diesel by 8.12% and the blend 3 had very high CO_2 emission by 11.45%.

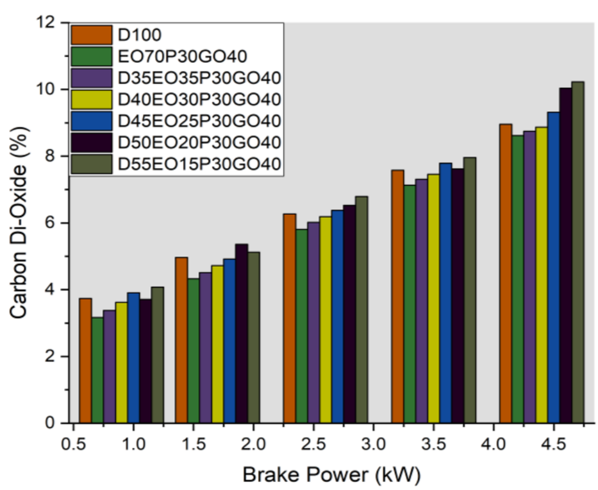

Fig. 13. CO_2 emission of different biodiesel blends.

Fig. 14 illustrates the smoke generated on different blends with increase in while engine load increased as the result of an increase in combustion fuel based on BP and the higher engine load is discussed for an instance. Generally, the smoke from diesel engine represents the condition of the engine. When the smoke is high, the engine condition is poor and vice versa. In this scenario, the complete diesel fuel consumed highest smoke as 68.1 HSU and the least smoke generated from D45EO25P30GO40 is 50.7 HSU followed by D55EO15P30GO40 is 51.6 HSU.

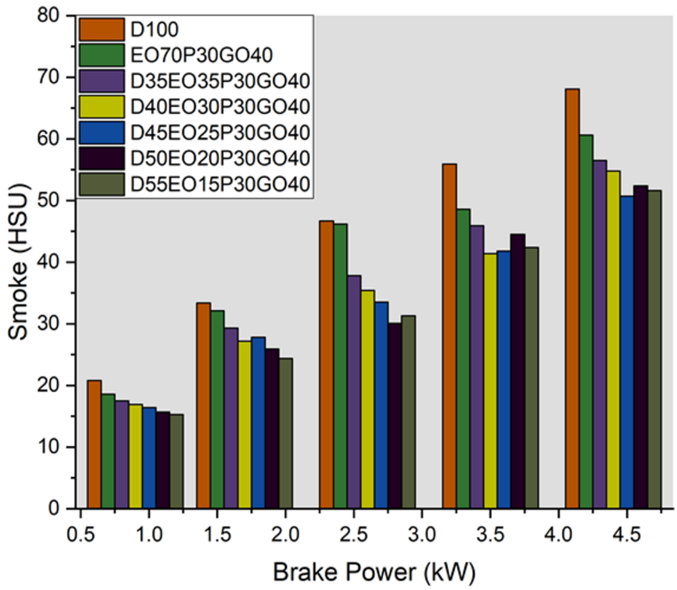

Fig. 14. Smoke for different biodiesel blends.

5. Conclusion

The study is focused on the usage of reduced volume of fossil fuel that is usage of diesel fuel. Fuel concentration was replaced by propanol and low viscous biofuel eucalyptus oil with nano additives. The blends were prepared in five various inclusive of diesel, eucalyptus oil, and propanol with 40 ppm of Graphene oxide nano additive concentrations. The results showed the usage of GO nano additive causing increase in BTE and HRR of the engine. However, it should increase the emission of NOx.

- As a result, blends 4 and 6 had higher peak cylinder pressure and better combustion characteristics than diesel fuel.
- Therefore, the highest HRR produced by blend 4 is 0.72 KJ/Degree, whereas diesel and blend 1 are respectively 0.81 KJ/Degree and 0.93 KJ/Degree.
- However, compared to diesel fuel, blends D45EO25P30GO40, D50EO20P30GO40, and D55EO15P30GO40 have higher BTE values.
- Diesel fuel emits more CO_2 than the blends D45EO25P30GO40 and D55EO15P30GO40. Blend 1 (pure eucalyptus oil) emits CO at a rate that is 1.68% greater than diesel fuel.

- ➢ The NO_X value for diesel at full load was lower than the values for the best-performing blends, D45EO25P30GO40 and D55EO15P30GO40. Additionally, the D50EO20P30GO40 mix has a higher level of NO_X, which is greater than that of diesel fuel and is not environmentally friendly.

The study's findings support the use of trinary blends, which are diesel-biodiesel mixtures containing 30% propanol and 40 ppm of GO nano additives. These blends have positive impacts on the engine's performance parameters. In terms of emissions, mixes with better performance than diesel had somewhat higher NO_X emissions. To lower emission levels to a level that is suitable for the environment, NO_X must thus be addressed.

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