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Research Article

# Experimental Investigation of Performance, Combustion and Emission characteristics of neat Lemongrass oil in DI Diesel engine

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***Abstract***

*An experimental investigation was carried out to evaluate the performance and Emission characteristics of neat lemongrass oil with diesel fuel in single cylinder direct injection diesel engine. The tests were conducted to measure Fuel consumption, indicated power, Brake thermal efficiency & Combustion characteristics and Exhaust gas emissions and compared with standard diesel fuel operation. The results indicated that the higher specific fuel consumption, the brake thermal efficiency was nearly equal to the diesel fuel, CO and smoke emissions are lower than the diesel fuel but $CO_2$ & NOx emissions are higher than that of standard diesel fuel emissions. The peak pressure and heat release rates were found to be higher for Lemongrass oil compared to diesel fuel performance.*

***Keywords:*** *Lemongrass Oil, Performance, Emission, Combustion*

## 1. Introduction

The world is facing oil crisis, depletion of fossil fuel and environmental degradations. A lot of research work is going on for an alternative fuel. One of the great potential alternative fuels is biodiesel which is produced from vegetable oil and animal fats. For long term, the usage of vegetable oils to produce biodiesel may compete with food supply and they are seasonal and far too expensive to be used as fuel at present. Zafer Uulu et.al [2008] investigated waste frying oil on direct injection diesel engine found that emission values are decreased by 17.4% for CO and 1.45% for NOx; the smoke intensity is increased by 22.46%. The exhaust temperature of Waste frying oil methyl ester is decreased by 6.5%. M.Pugazhvadivu et.al [2005] used preheated waste frying oil as fuel in DI diesel engine. The high viscosity of fuel was reduced by preheating by 135°C and showed by increasing in BSEC & BTE and reduction in CO & Smoke.

A.S. Ramadhas et.al [2005] tested the rubber seed oil and reported that more carbon deposits due to incomplete combustion. Jatropha oil in preheated and blends were used by Deepak Agarwal et.al [2007] and the results showed that BSFC and exhaust gas temperature for unheated Jatropha oil was found to be higher compared to diesel and heated Jatropha oil and also thermal efficiency was lower for unheated Jatropha oil compared to heated Jatropha oil and diesel. $CO_2$, CO, HC and smoke opacity were higher for Jatropha oil compared to that of diesel.

Jagadale S.S.et.al [2012] conducted performance test on single cylinder diesel engine using blend of chicken fat based biodiesel with diesel. Further the performance was equal to diesel fuel and smoke emission as well. Alp Tekin ERGENC et.al [2013] used Soybean ester blends and found that the maximum torque generated by the soybean ester blends (B20, B50) was higher than that of diesel fuel. CO, NOx and $CO_2$ emissions are nearly equal to those of diesel fuel. K. Anbumani et.al [2010] conducted performance test on mustard and neem oil blends in CI engine and found that 20% ester of mustard oil with diesel gave best performance and the emissions were equal to neat diesel fuel. Sudhir Ghai et.al [2008] tested Sunflower methyl ester in CI engine and found that the performance was higher than the diesel operation. Further UBHC emissions were less but NOx emissions were higher when compared to the diesel. Most of the experiments are conducted in different types of biodiesel prepared from different oils but some of the studies show that neat oils are mixed with diesel fuel and tested in diesel engine.

In the present study, neat lemongrass oil and its ratio with diesel is chosen as a fuel for direct injection diesel engine. The various ratio of neat lemongrass oil with standard diesel fuel are prepared and the following investigations were carried out.

- The performance and emission characteristics of direct injection diesel engine using various ratio of LGO: Diesel 25, 50, 75 and 100 at different loads (0%, 25%, 50%, 75% & Full load) and its comparison with the results of standard diesel fuel.

*Corresponding author Sathiyamoorthi.R is a Research Scholar

**Nomenclature**

| | | | | | |
|---|---|---|---|---|---|
| LGO | Lemongrass oil | PM | Particulate matter | SFC | Sp. Fuel consumption |
| D00 | 100% diesel | CO | Carbon monoxide | THC | Total unburned hydrocarbon |
| LGO25 | 25% LGO + 75% diesel | TFC | Total fuel consumption | DI | Direct Injection |
| LGO50 | 50% LGO + 50% diesel | NOx | Nitrogen oxide | BSFC | Brake sp. fuel consumption |
| LGO75 | 75% LGO + 25% diesel | $CO_2$ | Carbon dioxide | NA | Naturally aspirated |
| LGO100 | 100% LGO | TDC | Top dead center | BTE | Brake thermal efficiency |

- The combustion parameters such as variation of cylinder pressure, heat release rate and maximum rate of pressure rise are discussed with reference to the crank angle for different loads.

## 2. Test fuel-Lemongrass oil

Lemongrass (Cymbopogan citratus) is a plant in the grass family that contains 1 to 2% essential oil on a dry basis. Lemongrass oil has a lemony, sweet smell and is dark yellow to amber and reddish in color, with a watery viscosity. Lemongrass oil, often found in soaps and perfumes, is used for many beauty purposes. The main component in lemongrass oil is Cymbopogon Citral, or Citral. Lemongrass oil consists of 65 to 85 percent Citral. Citral is a pale yellow liquid, often colorless, with a strong fresh lemon smell. Citral is extracted from fresh leaves by using steam distillation. Lemongrass oil contains quantities of Farmesol, Nerol, Citronellal, Myrcene and Geranyl acetate. (Family: Poecea, Genus: Lemon Grass, Species: Cymbopogon Citratus, Parts used: Leaves, stems). The lemongrass oils were isolated by the steam-distillation method. They were extracted separately from leaves and stalks of lemongrass at certain temperature and extraction time based on the optimization range to give a mixture of water/ essential oil. Dichloromethane was used to separate the essential oil from the water layer.

## 3. Experimental setup and procedure for experimentation

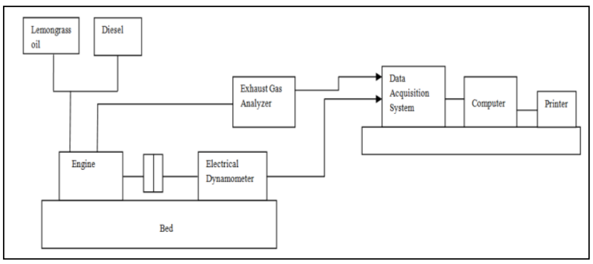


**Fig.1.** Schematic diagram of the Engine setup

The engine used in this experiment was a single cylinder, water cooled, NA, 4- stroke DI diesel engine, the Engine was coupled with an eddy current dynamometer through a load cell. The specifications of the engine are shown in Table 1. All the experiments were conducted at standard temperature and pressure. The engine is integrated with a data acquisition system to store the data for the off-line analysis. Cooling water is circulated separately to the engine and the dynamometer at the required flow rates. Necessary provisions are made to regulate and measure through electronic control unit of flow rates of air, fuel and coolant.

**Table.1.** Test Engine Specifications

| | |
|---|---|
| Model | Kirloskar AV1 |
| Type | Single Cylinder, 4 Stroke, Direct Injection |
| Power | 3.7 kW (5HP) |
| Bore | 80 mm |
| Stroke | 110 mm |
| Cubic capacity | 0.553 Litres |
| Compression ratio | 16.5 : 1 |
| Rated speed | 1500 rpm |
| Cooling type | Water cooling |

The engine is operated on diesel as baseline mode at a constant speed of 1500 rpm at no load to full load. The engine was loaded with eddy current dynamometer and the loads are applied in steps of 0, 25, 50, 75 and 100 percent of full load. For each load, the engine performance parameters and engine emissions were recorded; the dynamic fuel injection timing was set at 23° BTDC. Fuel consumption was measured by a burette attached to the engine and a stop watch was used to measure fuel consumption time for every 10 $cm^3$ fuel. Carbon monoxide, unburnt hydrocarbon and NOx emission were measured by Wahun Cubic Gas Analyzer. Smoke emissions were measured by means of Bosch smoke meter (GASBOARD-5020H). Chromyl-alumel (k-type) thermocouple was used to measure the exhaust gas temperature.

The engine is started by using standard diesel and the engine operating temperature was reached and then loads are applied. The warm up period ends when cooling water temperature is stabilized at 60°C. The tests are conducted at the rated speed of 1500 rpm. In every test, volumetric fuel consumption and exhaust gas emissions such as carbon monoxide (CO), hydrocarbon (HC), nitrogen oxides (NOx), carbon dioxide ($CO_2$) and oxygen ($O_2$) are measured. From the initial measurement, brake thermal efficiency (BTE), specific fuel consumption (SFC), brake power (BP), Indicated mean effective pressure (IMEP), mechanical efficiency and exhaust gas temperature for different ratios are calculated and recorded.

**Table.2** Comparison of neat Lemongrass oil with Diesel

| Properties | LGO | Diesel |
|---|---|---|
| Gross Calorific value (MJ/kg) | 36.279 | 43.35 |
| Kinematic viscosity (cst) at 40 ˚C | 4.18 | 3.25 |
| Specific gravity (g/cc) at 27 ˚C | 0.984 | 0.84 |
| Flash Point ˚C | 50 | 55 |
| Fire point ˚C | 58 | 63 |
| Total acidity (mg of KOH/g) | 0.26 | - |
| Sulphur content (% by mass) | Nil | 0.27 |
| Iodine value (wijs) | 74.96 | 95 - 125 |
| Cetane Index | 38 | 45 - 50 |

At each operating conditions, the combustion characteristics and exhaust emission levels are also processed and stored in personal computer (PC) for further processing of results. The same procedure is repeated for different ratio of neat lemongrass oil. The properties of the diesel and lemongrass oil are summarized in Table 2. The actual density, viscosity, fire point, flash point and gross calorific value were measured in the laboratory. The values are provided to comprehend the relative performance and emission activities of the different fuel ratios.

## 4. Results and Discussion

### *4.1 Performance analysis*

#### *4.1.1 Brake thermal efficiency*

Fig.2 shows the brake thermal efficiency for various ratios of LGO. For neat LGO, brake thermal efficiency is increased by 11 % (at 25% load), 11.7 % (at 50% load), 13.5 % (at 75% load) and decreased by 5.3% (at Full load) because of better vaporization and the combustion chamber surface is relatively hot and that would help in better air entrainment for better mixing.

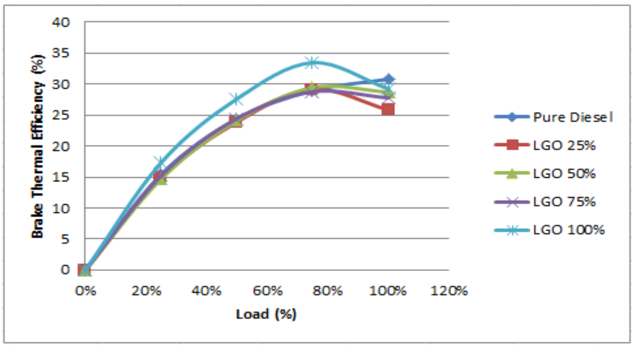


**Fig.2**.Variation of Brake thermal efficiency with load for different ratios

#### *4.1.2 Indicated thermal efficiency*

Fig.3 Shows the Indicated thermal efficiency for different ratios of LGO. The graph shows a similar trend for all the loads of operation. For the entire blending ratio, the Indicated thermal efficiencies are nearly equal to diesel fuel except neat LGO (at Full load). For LGO, ITE is increased by 7.3% (no load), 13.6% (at 25% load), 10.3 %( at 50% load), 17.4 %( at 75% load) but decreases at full load by 0.5%.

#### *4.1.3 Mechanical efficiency*

Fig.4. shows that variation of Mechanical efficiency for various ratios of LGO. For all the ratios, mechanical efficiencies are almost same. For neat LGO, Mechanical efficiency is decreased by 3 %( at 25% load), 4.7 %( at 75% load), 5.8 %( at full load) and increased by 1.5% (at 50% load).

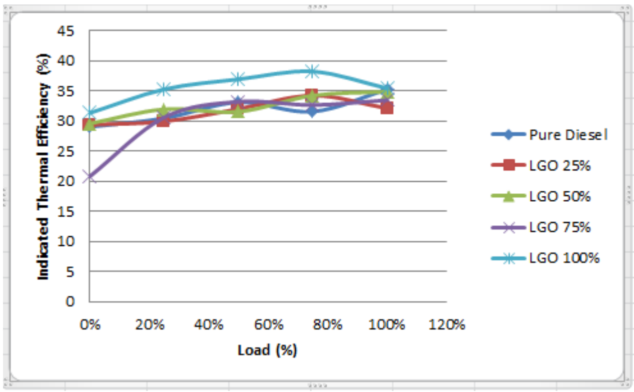


**Fig.3**. Variation of Indicated Thermal efficiency with load for different ratios

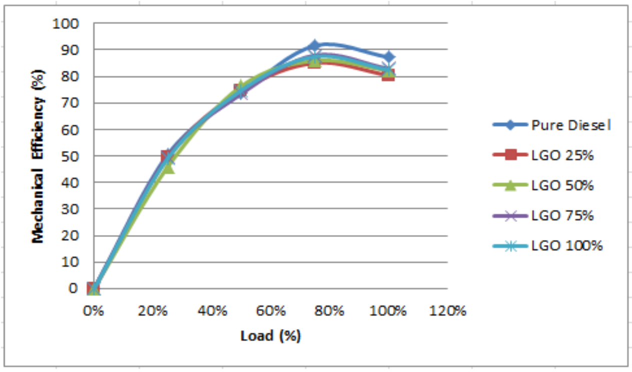


**Fig.4.**Variation of Mechanical efficiency with Load for different ratios

#### *4.1.4 Specific fuel consumption*

Fig.5. shows that variation of specific fuel consumption for various ratios of LGO. The graph shows a similar trend for all the loads of operation. For all the ratios, specific fuel consumption is increasing while comparing with pure diesel fuel. For LGO, SFC is increased by 6.25 %( at 25% load), 5.5 %( at 50% load), 3.57 %( at 75% load) and 20.8 %( at full load). This could be due to lower calorific value of higher ratios of LGO. But lower values of SFC are desirable one.

*4.1.6 Exhaust gas temperature*

The variation of exhaust gas temperature for different ratios of LGO is shown in fig.6. The results indicate that exhaust gas temperature is almost same as that of diesel fuel. The maximum temperature was measured for LGO: 50 at full load of operation (446°C) when compared with diesel fuel (433°C). For LGO: 25 & LGO: 50 the temperature values are lower than that of diesel fuel.

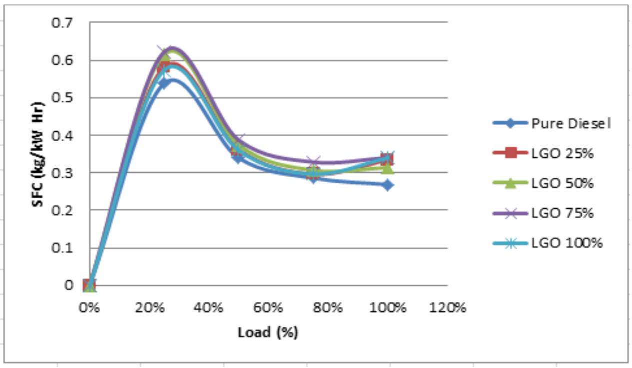


**Fig.5.** Variation of Specific fuel consumption with load for different ratios

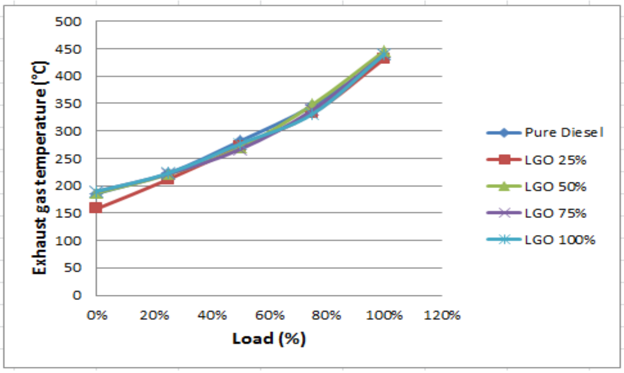


**Fig.6.**Variation of Exhaust gas temperature with load for different ratios

## 5. Emission Analysis

*5.1.1 Hydro Carbon (HC) Emission*

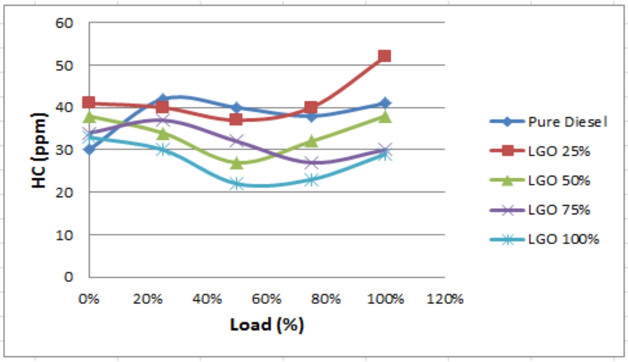


**Fig.7**.Variation of HC with different ratios

The variation of hydrocarbon emission with different ratios of LGO ratios is shown in Fig.7. It shows that the hydrocarbon emission of various ratios is lower than Diesel fuel except for LGO: 25. HC emission is higher by 26.8% for LGO: 25 when compared with diesel fuel. For all other ratios of LGO, the HC emissions are lower than the diesel fuel. This could be due to the longer ignition delay and the accumulation of fuel in the combustion chamber.

*5.1.2. NOx Emission*

The variation of NOx emission with various ratios of LGO is shown in fig.8. It is observed that the NOx emission is increasing trend than that of diesel. NOx emission is higher by 23.28% for LGO: 100 at full load condition when compared to diesel fuel and the maximum NOx emission is at 50% load condition (44.06 %) than that of diesel fuel emission. The reason for higher NOx emission could be due to higher peak flame temperature.

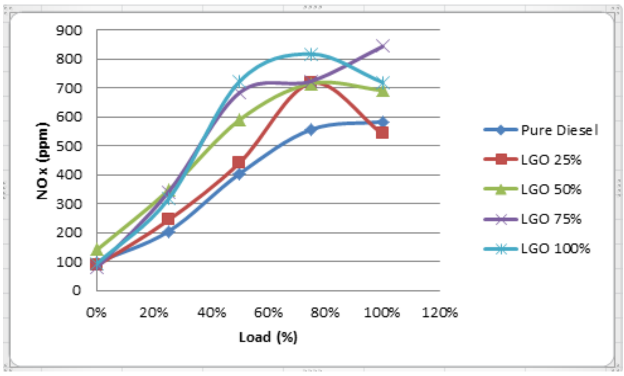


**Fig.8.** Variation of NOx emission for different ratios

*5.1.3. Carbon monoxide(CO) emission*

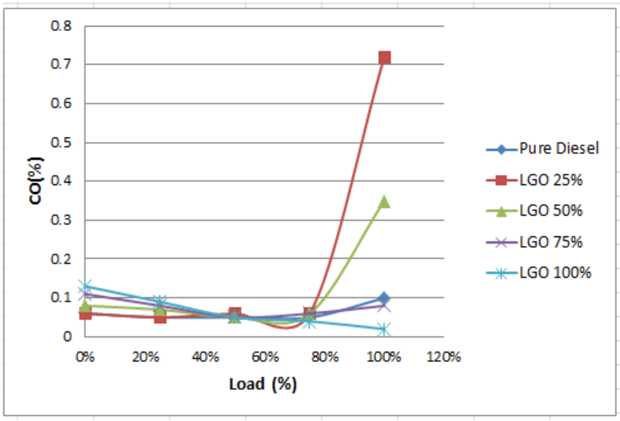


**Fig.9**. Variation of CO emission for different ratios

Fig..9. shows that the variation of CO emission for different ratios of LGO and diesel. CO emission for LGO:75 is very close to diesel fuel emission and it is found that for LGO:25 & LGO:50, the CO emission is higher by 86% and 71% respectively when compared with diesel fuel. This could be due the shortage of oxygen at high speed, and lesser amount of time available for complete combustion and further rising temperature in the combustion chamber, physical & chemical properties of the fuel and A/F ratio.

### *5.1.4. Carbon dioxide($CO_2$) Emission*

Fig.10. shows that the variation of $CO_2$ emission for various ratios. All the lemongrass oil-diesel fuel ratios give higher $CO_2$ emission when compared with standard diesel fuel $CO_2$ emission. The higher $CO_2$ emission indicates that the complete combustion of fuel in the combustion chamber. The ratio for LGO25 shows the lower $CO_2$ emission at low loads due to incomplete combustion and inadequate supply of oxygen for combustion process but increasing at higher loads.

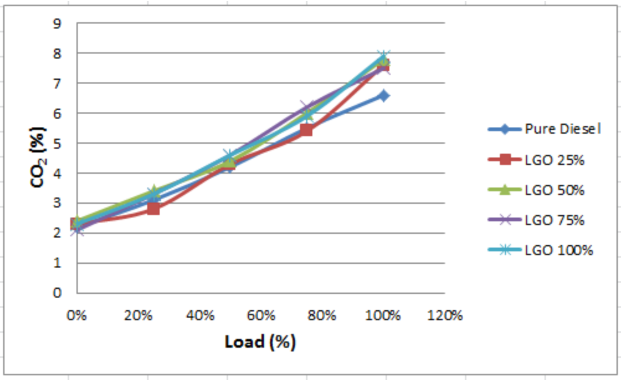


**Fig.10.** Variation of $CO_2$ emission for different ratios

## 6. Combustion Analysis

### *6.1.1. Combustion pressure*

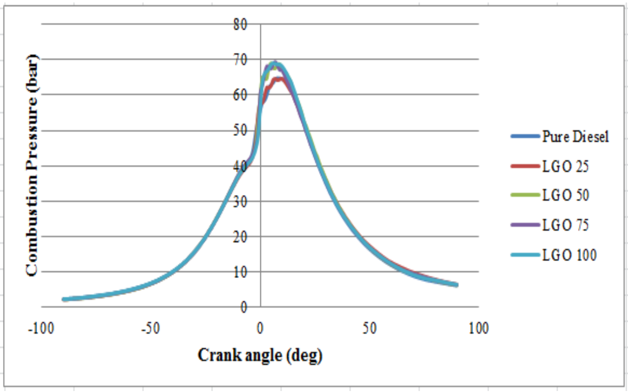


**Fig.11.** Variation of combustion pressure with crank angle for different ratios at Full load (100%)

The variations of combustion pressure with respect to crank angle for different ratios are shown in the Fig.11. It has been observed that the combustion pressures are higher than that of diesel fuel at full load for all the ratios of lemongrass oil. The combustion pressures are 64.64 bar, 68.68 bar, 69.32 bar & 69.02 for LGO: 25, LGO: 50, LGO: 75 & LGO: 100 respectively. The fuel absorbs more amount of heat from the cylinder immediately after injection and resulting in higher combustion pressure. This may be due to faster and complete combustion of fuel inside the combustion chamber.

### *6.1.2. Heat release rate*

The variation of heat release rate with respect to crank angle for different ratios of lemongrass oil with diesel fuel is given in the Fig.12. The heat release is analyzed based on the changes in crank angle variation of the cylinder. From the graph, it is observed that the heat release rates for LGO25, LGO50, LGO75 & LGO100 (at full load) are higher than that of diesel fuel by 34.85%, 56.06%, 59.22% & 64.74% respectively. This could be due to the better vaporization and atomization of lemongrass oil inside the combustion chamber and better spray formation.

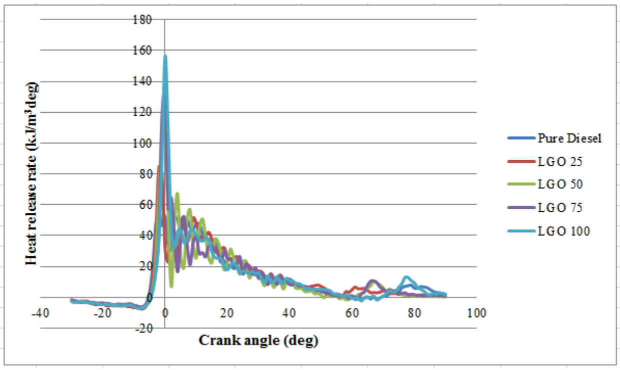


**Fig. 12** Variation of heat release rate with crank angle for different ratios at Full load (100%)

## Conclusion

The performance, emission and combustion characterstics of a direct injection diesel engine fuelled with neat lemongrass oil and diesel have been investigated and compared with that of standard diesel fuel. The following conclusions are drawn from this investigation.

1. The Indicated thermal efficiencies are nearly equal to diesel fuel except neat LGO (at Full load). The maximum temperature was measured for LGO 50 at full load of operation (446°C) when compared with diesel fuel (433°C).
2. The combustion pressures are increased because of the fuel absorbs more amount of heat from the cylinder immediately after injection and resulting in higher combustion pressure.
3. The heat release rates for LGO ratios are higher than that of diesel fuel. This could be due to the better vaporization and atomization of lemongrass oil inside the combustion chamber and better spray formation
4. For neat LGO, Brake thermal efficiency (BTE) is increased and SFC is increased. This could be due to lower calorific value of higher ratios of LGO. But lower values of SFC are desirable one and also Mechanical efficiency is decreased.

5. NOx emission is increased by 23.28% for LGO: 100 at full load condition when compared to diesel fuel. The reason for higher NOx emission could be due to higher peak flame temperature.
6. Results showed that at lower load conditions only, smoke emissions are higher than the diesel fuel. But for 75% & full load conditions, it is observed that lower smoke emissions. This is due to the complete combustion of lemongrass oil in the combustion chamber.
7. Hydrocarbon (HC) emissions are lower for all the different ratios except LGO25. HC emission is higher by 26.8% for LGO25 when compared with diesel fuel. CO emission for LGO75 is very close to diesel fuel emission and it is found that for LGO25 & LGO50, the CO emission is higher by 86% and 71% respectively when compared with diesel fuel. This could be due the shortage of oxygen at high speed, and lesser amount of time available for complete combustion
8. All the lemongrass oil-diesel fuel ratios give higher $CO_2$ emission when compared with standard diesel fuel $CO_2$ emission. The higher $CO_2$ emission indicates that the complete combustion of fuel in the combustion chamber. LGO25 shows the lower $CO_2$ emission at low loads due to incomplete combustion and inadequate supply of oxygen for combustion process but increasing at higher loads. Finally it is observed that without any engine modifications, neat lemongrass oil could be used as fuel in the direct injection diesel engine

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