Emission characteristics study of Gasoline-Diesel and Gasoline-Diesel/pentanol blend

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Abstract. Increase in vehicular emission affects the environment due to air pollution. Emission laws are formulated to control vehicular emission and all nations show their intensive interest in alternative fuel for pollution reduction and fuel economy. In the present work, experiment was carried out in a direct diesel inject 4-S engine; for diesel, Gasoline-Diesel and Gasoline-Diesel/pentanol blend (D70/P30). For dual fuel mode, Diesel is supplied from main injection and Gasoline was injected into the port at 5 bar. The result indicates high hydrocarbon emission at no load condition for both Gasoline-Diesel (1200 PPM) and Gasoline-Diesel/Pentanol blend (1170 PPM). Maximum NOx emission was observed for D70-P30 blend. Low CO emission (<2%), CO2 emission (<6%) and smoke emission (<70 PPM) was observed in blended fuel up to 60% load condition.

1. Introduction
The interest in renewable fuels has enhanced dramatically in recent years because of high demand of energy and the limitation of fossil fuels. A large number of research focuses on the emissions reduction and improvement of fuel economy. Some of the most predominant combustion Strategies was Homogeneous Charge Compression Ignition (HCCI), Premixed Charge Compression Ignition (PCCI), Reactivity Controlled Compression Ignition (RCCI). Running an engine in dual fuel mode with blended fuel will reduce the fuel dependency and alleviate the fuel economy and availability. The study of an engine emission decides the usage of dual fuel in with blend. Pentanol is one of the next generation biofuel with five-carbon subatomic structure, which can be produced from renewable feedstock. Pentanol has higher energy density than butanol directs to fuel economy. Pentanol has higher cetane number, makes it trouble-free for auto ignition. Diesel–pentanol blend significantly reduces the concentration of particulate emission and improves the brake thermal efficiency. Low viscosity and high volatility of pentanol enhances the atomization quality and high oxygen content in pentanol reduces soot emission.

2. Literature Review
Kavuri et al. (2016) compared RCCI and Gasoline Compression Ignition (GCI) strategies at high load, low speed conditions. RCCI strategy was found to have more control over combustion phase due to the shorter ignition delay of diesel than gasoline. Soot emission was increased as the combustion occurs near the TDC injection. The longer ignition delay of the GCI strategy results in less control over combustion phase and very low soot emission was observed.
Li et al. (2016) investigated the influence of fuel properties on the combustion characteristics of a RCCI engine. The combustion rate of methanol/diesel is higher than gasoline/diesel for the same premixed ratio and inlet valve closing (IVC). Fuel with simple molecule provides higher ignition rate due to the improved homogeneous fuel/air mixture and longer ignition delay supports the combustion. The NOx emission of methanol/diesel is lower than gasoline/diesel due to the decrease of maximum local combustion temperature and equivalence ratio in the cylinder.

Pedrozo et al. (2016) investigated potential of internal exhaust gas recirculation (iEGR) and throttled operation for low load extension of ethanol-diesel dual fuel RCCI combustion on a heavy duty engine. The experimental results shown the introduction of hot residuals into the intake manifold increased the specific volume of inlet charge and decreased the fresh air inducted.

Tong et al. (2016) investigated the RCCI combustion and load extension in CGI and Polyoxymethylene dimethyl ether (PODE). Result indicates, peak pressure rise rate (PPRR) of PODE is slightly higher than diesel and less energy was required to maintain the same combustion phase. The high cetane number and increased injection duration is responsible for better PRRR value.

Paykani et al. (2015) analyzed the effects of diesel injection strategy on natural gas/diesel RCCI combustion. The Result indicates longer ignition delay and lower combustion rate leads to decreased peak heat release rate (HRR) and shorter reaction time affects hydrocarbon (HC) and carbon monoxide (CO) emission. Reduction of combustion temperature substantially increases the HC and CO emission. Retarded ignition time, decreases the residence time of the mixture and reduces the NOx formation.

Prabhu and Venkata raman et al. have conducted experiments on Pentanol is blended with neat diesel at different measured volumes of 15%, 25% and 35%. Three blended fuels prepared by volume of 85% of diesel and 15% of pentanol (D85P15), 75% of diesel and 25% of Pentanol (D75P25) and 65% of diesel and 35% of Pentanol (D65P35) respectively. Effect of emission and performance parameters have been studied in an unmodified diesel engine propelled with pentanol-diesel blends at various proportions.

Li et al. (2015) evaluated the potential of pentanol addition to diesel for engine performance improvement. The addition of pentanol lowers viscosity and improves volatility leads to better atomization quality of blend and high HRR was observed during combustion. Higher oxygen content in pentanol reduces soot emission. The pentanol addition can effectively reduce the soot and CO emission without serious impact on NOx and total hydro carbon emission (THC) for wide load range.

In this study Gasoline-Diesel/pentanol blend (D70/P30) have been investigated to find the emission characteristics of hydrocarbon, carbon monoxide, oxides of nitrogen, smoke and carbon dioxide. The emission results compared with 100% diesel and Gasoline-Diesel operation mode. Methanol, ethanol and butanol are the commonly used fuel blend for diesel because of their matching characteristics and their production from renewable biomass. In the present work pentanol was used as blend fuel because of its better fuel property-high energy density, low viscosity and high volatility. Tamilmagan et al. have conducted a comparative study of biodiesel production from waste cooking oil using green synthesized nano Fe2O3 and CuO impregnated nano Fe3O4 was carried out. Mahesh Kumar et al. have assessed the single-cylinder, diesel engine fueled with nano-emulsion of orange peel oil biodiesel. The orange oil was elicited from orange peels through solvent extraction method then converted into methyl ester.

3. Experimental setup

The diesel engine used for testing is single cylinder, four stroke and air cooled, direct fuel injection type. The engine was manufactured by KIRLOSKAR TAF1 with common rail injection system of BOSCH. Engine specification is shown in Table 1. Eddy Current Dynamometer is used to measure the torque of the engine; it has rated torque and speed of 28 N-m and 1500 rpm respectively. The engine was controlled by Electronic Control Unit (ECU); injection parameters - injection pressure, injection timing and the quantity of the fuel to be injected are controlled by ECU. Experimental setup and Schematic view of the test engine is shown in Figure 1 and Figure 2 respectively.
Table 1. Engine Specification

| Specification            | Value                        |
|--------------------------|------------------------------|
| Number of Engine cylinder| 01                           |
| Number of Stroke         | 04                           |
| Compression ratio        | 17.5                         |
| Bore X Stroke            | 87.5 X 110 (mm)              |
| Capacity                 | 662 CC                       |
| Rated power              | 4.41 kW                      |
| Rated torque             | 28 Nm                        |
| Rated speed              | 1500 rpm                     |
| Injection system         | Common rail type             |
| Injection Pressure       | 2000 bar                     |
| Dynamometer              | Eddy Current                 |

Figure 1. Experimental setup of the Test Engine
1. Compressor, 2. Bypass Valve, 3. Air Flow Meter, 4. One Way Valve, 5. Intake Intercooler, 6. EGR Valve, 7. EGR Cooler, 8. Pressure Transducer, 9. Charge Amplifier, 10. Direct Injector, 11. Port Injector, 12. Back Pressure Valve, 13. Exhaust Gas Analyzer, 14. Smoke Meter, 15. Encoder.

**Figure 2.** Schematic Layout of the Test Engine

Fuel is supplied from tank using low pressure pump with filter. Fuel is injected to the cylinder by injector at a pressure of 2000 bar and injector has 6 nozzles. For dual mode operation gasoline is injected into the port at 5 bar. Based on the input signal from the crank sensor, fuel injection and ignition time were controlled by ECU. Exhaust gas analyzer is used to measure the HC, CO, CO₂ and NOₓ emission. Smoke meter is used to measure the smoke level in engine exhaust. Engine parameters and gas quality details are recorded in a data logger connected with the system. The engine is operated in three condition, 100% Diesel, Gasoline-Diesel and Gasoline-Diesel/pentanol blend (D70/P30) for finding the emission characteristics at different load conditions. The properties of Diesel, Pentanol and blend (D70/P30) are shown in Table 2.

| Particulars                      | Diesel  | Pentanol | D70/P30 |
|----------------------------------|---------|----------|---------|
| Chemical Formula                 | C₁₅H₂₈  | C₅H₁₂O   |         |
| Viscosity@20°C (mm²/s)           | 4.127   | 2.89     | 3.2     |
| Lower Heating Value (MJ/kg)      | 42.68   | 35.06    | 40.42   |
| Oxygen content (% weight)        | 0       | 18.15    | 5.5     |
| Cetane number                    | 56.5    | 20–25    | -       |
| Density @ 20°C (kg/m³)           | 830.5   | 815      | 825     |
| Surface tension @ 20°C (10⁻³ N/m)| 27.5    | 24.7     | 26.2    |
| Boiling point (°C)               | 223     | 138      | 135     |
4. Results and Discussion

In the present work Diesel/pentanol blend emission characteristics was analyzed for loading conditions of 0%, 20%, 40% & 60% in a Gasoline-Diesel engine. Hydrocarbon emission (HC), CO, CO\textsubscript{2}, NO\textsubscript{X} and smoke level were measured.

4.1. Hydrocarbon Emission

At no load condition HC emission was low in 100% Diesel supply, only 10 PPM was observed. Maximum HC emission value of 1201 PPM was observed in Dual fuel mode. HC emission of diesel, dual fuel and Diesel/ pentanol blend is shown in Figure 3.

![Figure 3. Hydrocarbon emissions](image)

In Diesel/ pentanol blend 1120 PPM was observed. Increase in load decreases the HC emission for Dual fuel and Diesel/ pentanol blend due to increase in cylinder temperature and better mixing of fuel and air. At 20% loading condition 480 PPM was observed which corresponds to 57.14% reduction in HC emission. At 40% load maximum HC emission reduction of 74.79% was observed. At 60% load HC emission was 100 PPM. HC emission from dual fuel and Diesel/ pentanol blend are comparable, maximum difference of 81 PPM was observed at no load condition.

4.2. Carbon monoxide emission

For diesel, increase in load increases the CO emission; maximum CO emission of 5.2% was observed at 60% load. CO emission of diesel, dual fuel and Diesel/ pentanol blend is shown in Figure 4.

![Figure 4. Carbon monoxide emissions](image)
High CO emission is due to the rich fuel and incomplete combustion. For dual fuel, a fluctuation in CO emission was observed up to 40% load. In Diesel/ pentanol blend CO emission is low due to complete combustion.

4.3. Carbon dioxide emission

Increase in load increases the CO$_2$ emission for all the fuels, high release of CO$_2$ indicates the better combustion. CO$_2$ emission of diesel, dual fuel and Diesel/ pentanol blend is shown in Figure 5.

![Figure 5. Carbon dioxide emissions](image)

A high increase in CO$_2$ emission release was observed at 40% loading condition except diesel. CO$_2$ emission is in the order of diesel, dual fuel and Diesel/ pentanol blend for all the loading condition.

4.4. NOX emission

Diesel has highest NO$_X$ emission up to 40% load compared to other fuels; at 60% load condition Diesel/ pentanol blend has maximum emission of 1702 PPM shown in Figure 6.

![Figure 6. NO$_X$ emissions](image)

Duel fuel run has lowest NO$_X$ emission for all loading conditions due to gasoline addition. The NO$_X$ emission was significantly higher from 40% load and it increased 4.35 times for the load change from 20% to 40%.
4.5. Smoke emission
Smoke is collection of particulate matter and soot. Except 20% load condition, for all the load dual fuel run has maximum smoke emission is shown in Figure 7.

![Figure 7. Smoke emissions](image)

Diesel/ pentanol blend has lower smoke emission compared to diesel for all the loads. For all the fuels, maximum increment in smoke emission occurs for load change from 40% to 60%. Increment in load increases the smoke emission level due to the fuel spray deposition on engine cylinder head.

5. Conclusion
In the present work emission characteristics of diesel, Gasoline-diesel (dual fuel) and Diesel/ pentanol blend are studied. From the experimental results, addition of pentanol to diesel reduces the smoke by 8.33% - 44.44% at different loading condition and 97.62% of CO emission was reduced at 40% load. From 40% load, maximum NO\textsubscript{X} emission was observed with Diesel/ pentanol blend. High HC emission was observed for dual fuel and Diesel/ pentanol blend because of running the engine at constant compression ratio. CO\textsubscript{2} emission of diesel and Diesel/ pentanol blend are comparable.

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