Effect of Injection Pressure on the Performance and Emissions of Nerium Biodiesel Operated Diesel Engine

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ABSTRACT
Use of vegetable oil in unmodified diesel engines leads to lower thermal efficiency and higher smoke emission. In this project esterified Nerium oil is used as an alternate fuel. A single cylinder stationary kirloskar engine is used to compare the performance and emission characteristics between pure diesel and Nerium blends. In this project selection of suitable nerium blend and selection of optimized injection pressure for the blend is done. The Nerium oil blends are in percentage of 20%, 40%, 60%, 80%, and 100% of Nerium oil to 80%, 60%, 40%, 20% & 0% of diesel. From this project it is concluded that among all nerium and diesel blends 20% of nerium and 80% of diesel blend with injection pressure 220 bar gives better performance nearing the diesel. When comparing the emission characteristics HC, CO is reduced when compared to diesel, however NOx emission is slightly increased when compared to diesel. Hence Nerium blend can be used in existing diesel engines with minimum modification in the engine. It also describes the usage of non-edible oil to a greater extent. At present neither Nerium oil nor bio-diesel of Nerium oil is available in the market. Hence for our work, well grown Nerium seeds are collected in Salem District around 500kgs of Nerium seeds are collected. After the processing of these seeds, oil was extracted. Approximately 10 liters of oil is obtained from the 20 kg of nerium seed. Then after proper filtration, esters of Nerium oil are prepared using the bio-diesel plant available in the department.

Keywords: Nerium, Injection pressure, Esterification.

1. INTRODUCTION
Vegetable oils are considered as good alternative to diesel fuel due to their properties which are much closer to that of diesel. Thus, they offer the advantage of being readily used in existing diesel engines without much modification. They have a reasonably high cetane number. Vegetable oils have a structure similar to that of diesel fuel, but differ in the type of linkage of the chains and have a higher molecular mass and viscosity. The heating value is approximately 90% of diesel fuel. A limitation on the utilization of vegetable oil is its cost. In the present market the price of vegetable oil is higher than that of diesel. However, it is
anticipated that in future the cost of vegetable oil will get reduced as a result of developments in agricultural methods and oil extraction techniques. In India, forests and plants based non-edible oils are considered as the main sources for bio diesel production. Non – edible oils can be obtained plant species such as Jatropha, Karanja, Rubber, Mahua and Neem. However, it is not possible for us to get Nerium oil that much easily as that of other oils. Hence, in the present work, Nerium oil based bio-diesel is being considered as an alternate fuel for Diesel engines.

2. EXPERIMENTAL APPARATUS AND METHODS

2.1 TRANSESTERIFICATION OF NERIUM OIL
To reduce the viscosity of the Nerium oil, trans-esterification method is adopted for the preparation of biodiesel. The procedure involved in this method is as follows: 1000 ml of nerium oil is taken in a three way flask. 12 grams of Potassium hydroxide (KOH) and 200 ml of methanol (CH3OH) are taken in a beaker. The Potassium hydroxide and the alcohol are thoroughly mixed until it is properly dissolved. The solution obtained is mixed with Nerium oil in three way flask and it is stirred properly. The methoxide solution with nerium oil is heated to 60ºC and it is continuously stirred at constant rate for 1 hour by stirrer. The solution is poured down to the separating beaker and is allowed to settle for 4 hours. The glycerin settles at the bottom and the methyl ester floats at the top (coarse biodiesel). Methyl ester is separated from the glycerin. This coarse biodiesel is heated above 1000C and maintained for 10-15 minutes to remove the untreated methanol. Certain impurities like sodium hydroxide (KOH) etc are still dissolved in the obtained coarse biodiesel. These impurities are cleaned up by washing with 350 ml of water for 1000 ml of coarse biodiesel. This cleaned biodiesel is the methyl ester of Nerium oil. This bio-diesel of Nerium oil is being used for the performance and emission analysis in a diesel engine. For the present work N20, N40, N60, N80 and N100 blends of Nerium oil bio diesel are being used.

2.2 ENGINE SPECIFICATION

<table>
<thead>
<tr>
<th>Engine manufacturer</th>
<th>Kirloskar engines ltd</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bore&amp; stroke</td>
<td>87.5 x 110 (mm)</td>
</tr>
<tr>
<td>Number of cylinders</td>
<td>1</td>
</tr>
<tr>
<td>Compression ratio</td>
<td>17.5:1</td>
</tr>
<tr>
<td>Speed</td>
<td>1800 rpm</td>
</tr>
<tr>
<td>Cubic capacity</td>
<td>0.661 litres</td>
</tr>
<tr>
<td>Method of cooling</td>
<td>Water cooled</td>
</tr>
<tr>
<td>Fuel timing</td>
<td>-27º by spill (btcd)</td>
</tr>
<tr>
<td>Clearance volume</td>
<td>37.8 cc</td>
</tr>
<tr>
<td>Rated power</td>
<td>7 and 8 hp</td>
</tr>
<tr>
<td>Nozzle opening pressure</td>
<td>-200 bars</td>
</tr>
</tbody>
</table>

2.3 EXPERIMENTAL SETUP
The engine used for the investigation is kirloskar SV1, single cylinder, four stroke, constant speed, vertical, water cooled, high speed compression ignition diesel engine. The kirloskar Engine is mounted on the ground. The test engine was directly coupled to an eddy current dynamometer with suitable switching and control facility for loading the engine. The liquid fuel flow rate was measured on the volumetric basis using a burette and a stopwatch. AVL smoke meter was used to measure the CO and HC emissions from the engine. The NOX
emission from the test engine was measured by chemical luminescent detector type NOX analyser. For the measurement of cylinder pressure, a pressure transducer was fitted on engine cylinder head and a crank angle encoder was used for the measurement of crank angle. The sound from the engine was measured by Rion sound level meter. The experimental setup is shown in the Fig.1

2.4 TEST METHOD
The engine was operated initially on diesel for warm up and then with Nerium oil blends. The experiment aims at determining appropriate proportions of biodiesel and diesel for which higher efficiency was obtainable. Hence experiments were conducted for different proportions of biodiesel mixed with diesel. The blends were in the ratio 20%, 40%, 60%, 80%, and 100% with diesel. First these blends were tested at normal injection pressure 200 bar at constant injection timing 27° BTDC and with a constant compression ratio 17.5. Then for the best efficiency blend, the test were conducted at three different injection pressures 180 bar, 220 bar and 240 bar and above procedure was followed. An injector pressure nozzle was used to change the injection pressure.

1. Engine  
2. Fuel injection pump  
3. Fuel injection nozzle  
4. Intake manifold  
5. Intake air surge tank  
6. Air cleaner  
7. U-Tube Manometer  
8. Fuel tank  
9. Crank angle detector  
10. Electric dynamometer  
11. Exhaust manifold  
12. Compression pressure transducer  
13. Injector needle lift sensor  
14. Dynamometer control panel  
15. Exhaust gas analyser  
16. Smoke meter  
17. Digital scope recorder  
18. Exhaust gas temp sensor  
19. EGR system  
20. Exhaust pipe
3. PERFORMANCE ANALYSIS

3.1 BRAKE THERMAL EFFICIENCY

At normal injection pressure of 180 bar the brake thermal efficiency for neat diesel at full load is 26.48 %, where as it was 24.08% , 23.56% , 22.45% , 21.923% , 21.07% for N20,N40,N60,N80 and N100 as shown in Fig 2.1. The best thermal efficiency was obtained for N20 blend and was 2.4% less than that of diesel for full load. From the Fig 2.2 it was observed that brake thermal efficiency for different injection pressures for best efficiency blend (N20) at 180 bar was 20.09%, 220 bar was 25.12%, and 240 bar was 24.11%. For N20 at 220 bar it was found to be 1.04% higher than N20 at 200 bar.

This may be due to better spray characteristics and effective utilization of air resulting in complete combustion of the fuel. For 180 bar the brake thermal efficiency is 3.99% less than normal the efficiency of injection pressure. This is because of incomplete combustion due to retardation of injection pressure.

3.2 SPECIFIC ENERGY CONSUMPTION

Comparison of the specific energy consumption for the four different injection pressures for best efficiency blend (N20) is shown in Fig no.3. It can be seen that the SEC is the highest in
the case of the 240 bar and is least in the case of 220 bar. This is because at 220 bar the fuel is optimally injected such that proper diffusion of the biodiesel takes place.

**Figure 3 variation of SEC with BP for different injection pressures for best efficiency blend**

4. **EMISSION ANALYSIS**

4.1 **UNBURNT HYDROCARBON EMISSIONS & CARBON MONOXIDE**

**Figure 4 variation of UBHC with BP for different injection pressures for best efficiency blend**

**Figure 5 variation of CO with BP for different injection pressures for best efficiency blend**
Comparison of the UBHC emissions for the four different injection pressures for best efficiency blend (N20) is shown in Fig no.4. Comparison of the carbon monoxide emissions for the four different injection pressures for best efficiency blend (N20) is shown in Fig no5. In both cases it can be seen that the UBHC and carbon monoxide emission is the highest in the case of the 180 bar and is least in the case of 220 bar. This is because at 220 bar proper diffusion and combustion of the biodiesel takes place which results in lower emissions. At 180 bar and 200 bar there is very less time for the diffusion of the fuel to takes place which leads to increase in emissions.

4.2 OXIDES OF NITROGEN & CARBON DI-OXIDE
Comparison of the oxides of nitrogen emissions for the four different injection pressures for best efficiency blend (N20) is shown in Fig no.6. Comparison of the carbon di-oxide emissions for the four different injection pressures for best efficiency blend (N20) is shown in Fig no7. In both cases it can be seen that the oxides of nitrogen and carbon di-oxide emission is the highest in the case of the 220 bar and is least in the case of 180 bar. This is because at 220 bar the peak temperature in the combustion chamber increases due to the proper combustion which leads to increase in emissions. At 240 bar because of the advancement in injection pressure, the peak pressure is lowered due to poor combustion. At 180 bar and 200 bar due to the poor combustion and spray characteristics, the oxygen content in the fuel is not fully burnt which results in lower emissions.
4.3 SOUND CHARACTERISTICS

Comparison of the sound characteristics for the four different injection pressures for best efficiency blend (N20) is shown in Fig no.8. It can be seen that the sound characteristics is the highest in the case of the 240 bar and is least in the case of 220 bar. This is because at 220 bar the proper combustion takes places and due to this the power developed helps in smooth running which results in lower noise level. At 180 bar and 200 bar due to improper combustion the noise level is marginally greater. At 240 bar due to higher amount of fuel accumulation in the combustion chamber initially, the engine tends to knock and this leads to increase in noise level.

![Figure 8 Variation of noise level with BP for different injection pressures for best efficiency blend](image)

5. COMBUSTION ANALYSIS

5.1 PEAK PRESSURE RISE

Comparison of the peak pressure rise for the four different injection pressures for best efficiency blend (N20) is shown in Fig no.9. Peak pressure for pure diesel at 200 bar is 72 bar. Peak pressure of N20 for 220 bar is 68.4 bar, 240 bar is 66.5 bar, 200 bar is 66 bar and 180 is 60.2 bar. This is because complete usage of the fuel is observed at 220 bar which results in increase in the pressure as a result of proper combustion. At 240 bar due to increase in delay period, proper diffusion does not take place which results in lower pressure in the combustion chamber.

![Figure 9 variation of peak pressure with crank angle for different injection pressures for best efficiency blend](image)
5.2 INSTANTANEOUS HEAT RELEASE RATE
Comparison of the instantaneous heat release rate for the four different injection pressures for best efficiency blend (N20) is shown in Fig no.10. Instantaneous Heat release rate for pure diesel is 76.50 J/deg CA at 200 bar. Heat release rate of N20 for 220 bar is 79.1 J/deg CA, 240 bar is 80.10 J/deg CA, 200 bar is 80.23 J/deg CA, and 180 bar is 87.12 J/deg CA. This is because at 220 bar, the increase in thermal efficiency indicates the complete burning of fuel and lower release of the heat to the exhaust and this reduces the instantaneous heat release rate. At 240 bar because of poor combustion the heat release rate is marginally higher. At 180 bar and 200 bar because of poor diffusion which causes the hot exhaust gases to escape out at a higher rate.

![Instantaneous Heat Release Rate](image1)

Figure 10 Instantaneous heat release rate with crank angle for different injection pressures for best efficiency blend

5.3 CUMULATIVE HEAT RELEASE RATE
Comparison of the cumulative heat release rate for the four different injection pressures for best efficiency blend (N20) is shown in Fig no.11. Cumulative heat release rate for pure diesel is 329.04 J/deg CA at 200 bar. Cumulative heat release rate of N20 for 220 bar is 339.26 J/deg CA, 240 bar is 345.63 J/deg CA, 200 bar is 349.048 J/deg CA, and 180 bar is 371.2 J/deg CA. This is because at 220 bar due to proper combustion, the amount of heat released is lower as the heat is utilized to produce better efficiency resulting in lower cumulative heat release rate. At 240 bar the cumulative heat release rate is higher due to improper burning at different zones in the combustion chamber. At 180 bar and 200 bar because of poor combustion, which causes the cumulative heat release rate to rise higher.

![Cumulative Heat Release Rate](image2)

Figure 11 Variation of Cumulative heat release rate with crank angle for different injection pressure for best efficiency blend
6. CONCLUSION

From the above results and discussions, the following important points are observed and the effect of injection timing are listed,

- Nerium oil, being non-edible oil proves to be a very effective alternate fuel.
- After trans-esterification of Nerium oil, the kinematic viscosity and density is reduced while the calorific value is increased.
- For Nerium oil, fuel injection pressure at 220 bar results in approximately 1.04% rise in BTE when compared to 200 bar for N20 blend.
- The UBHC, CO is significantly reduced with biodiesels and its blends.
- Compared to diesel fuel, NOx emissions are high for nerium blends.
- Based on the engine performance and emission tests, at 220 bar, the 20% blends of methyl esters with nerium fuel have better performance and lower emissions characteristics compared to other injection pressures.
- From the above conclusions it can be concluded that a significant improvement in the performance and emissions are observed if the blend and injection pressure are properly optimized when a diesel engine is to be operated with methyl ester of nerium oil.

REFERENCES


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