Experimental investigation of performance and emission characteristics of diesel engine with use of rape seed oil as biodiesel

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Abstract : In this paper, emission and performance characteristics of diesel fuel-engine was investigated using blending of diesel with bio diesel under steady state. Rape-seed oil was used as biodiesel and blended in diesel with different proportions of 10%, 20% and 30% by volume. The engine used in experiment was single cylinder 4-stroke diesel fuel-engine having water cooling system. Result shows that BTE decreases with more addition of bio-diesel in % fraction. For 10% blend, BTE of engine is almost same compared to diesel. The emission characteristics were remarkably improved by increasing volume fraction of rape seed oil except NOx emission. NOx emission was found maximum for 30% diesel-bio diesel blend.

KEYWORDS: Rape seed oil, Bio-diesel, Volume fraction, NOx emission

Nomenclatures:
- BTE : Brake Thermal Efficiency
- BSFC : Brake Specific Fuel Consumption
- CRDI : Common Rail Diesel Injection
- VCRDE : Variable Compression Ratio Engine
- CO : Carbon Monoxide
- HC : Hydrocarbon
- NOx : Nitrogen Oxide

1. INTRODUCTION

Fossil fuels are most popular as source of heat energy in automobiles, power generation, industries and agricultural sector. With increase in living standard of mankind, requirement of energy generation also increases day by day. On other side, reserve of petroleum resources is also limited and getting depleted progressively. In continuation with that, environmental pollution is one of the biggest challenge in current scenario. It is a high time to solve the issues related to reserve of fossil fuel and environmental pollution. The most convincing solution of above mentioned problem is use of alternative fuels along with conventional fuels. Bio-diesels are widely preferred among all the alternative fuels. Researchers around the globe proposed different techniques for use of vegetable oils in I.C. Engines includes esterification, direct blending with diesel, emulsification and pyrolysis. [1-2].

Sarvanan et al. have experimented on VCRDE using duel bio-diesel (Rape-seed oil and Mahua) blends. They concluded that BTE of engine decreases with increase in volume fraction of bio-diesel in diesel while emission characteristics got improved with increase in bio-diesel concentration. Raman et
al. had experimentally investigated effect of diesel-bio-diesel fuel on emission and performance characteristics of diesel fuel-engine and found 25% bio-diesel blended in 75% diesel may be used as fuel without any modification in diesel fuel-engine without compromising thermal efficiency and better emission characteristics [2]. Abu Zeid M. had used different bio-diesels extracted from palm, corn and sun-flower oils. He stated that blending of bio-diesel in diesel enhances emission characteristics of diesel fuel-engine without compromising performance [3]. Rajesh et al. had performed an experiment on multi cylinder CRDI diesel fuel-engine with blend of acid oil methyl ester, ethanol and diesel (EBD). Experiment was performed on different loads and different speeds (1200 RPM, 1500 RPM and 1800 RPM) and concluded that Knocking was observed at higher engine speed [4]. Rao & Reddy had blended Mahua bio-diesel with diesel along with diethyl ether additive and performed parametric optimization [5]. Haldar et al. blended the Jatropha, Putranjiva and Karanja oils with diesel and used in a VCRDE to investigate performance and emission characteristics of diesel fuel-engine. Experiment concluded that the Jatropha blend imparted best performance and emissions characteristics in comparison with other bio-diesels at all the load conditions [6]. A. Prabhu et al. have tested diesel fuel-engine with algae as a bio-diesel and concluded that without compromising performance much, better emission characteristics can be achieved with 20% of bio-diesel blend in diesel [7]. Venkatesan et al. tested twin cylinder 4-stroke diesel fuel-engine with methyl ester of soap nut oil and pine oil, found better performance and emission characteristics [8]. Many more researchers have investigated effect of bio-diesel in diesel fuel-engine and reported same conclusions [9–17].

2. BIODIESEL PREPARATION & PROPERTIES

Rapeseed consists of seeds having significant quantity of oil content. India is the 3rd largest country which produces rapeseeds around the globe. Rapeseed bio-diesel is extracted from rapeseed vegetable oil by transeserification process. In this process, one litter rapeseed oil is heated to 60°C and methyl alcohol (200 ml) and NaOH (5 mg) is added into oil. The mixture is then allowed to stirred constantly for half an hour. Then glycol was separated from rapeseed bio-diesel after 14 hours. Then by distillation method, methanol was separated from bio-diesel. Table 1 represents the comparison of different properties of rapeseed oil, bio-diesel and pure diesel.

| Properties                      | Rapeseed oil | Diesel | Rapeseed bio-diesel |
|---------------------------------|--------------|--------|---------------------|
| Density (kg/m³)                | 928          | 850    | 879                 |
| Calorific Value (kJ/kg)        | 36,500       | 42,000 | 37,400              |
| Kinematic Viscosity (mm²/sec)  | 33           | 2.9    | 4.9                 |
| Flash Point (°C)               | 229          | 66     | 148                 |
| % of Oxygen                    | 10.5         | -      | 10.3                |
| % of Ash Content               | 0.8          | 0.01   | 0.009               |

3. EXPERIMENTAL SET-UP

4-stroke single cylinder direct injection C.I. engine was used for experimentation. Rope brake dynamometer was used for applying load on engine. Rated loading capacity of engine was 5 HP.
All the experiments were performed at constant engine speed of 1500 RPM. Various thermocouples are provided to measure various temperatures like cooling water in and out temperature, temperature of exhaust gas etc. Lay out of experimental set-up is shown in figure 1. In this work, diesel is blended with rapeseed biodiesel in three different proportions of 10%, 20% and 30% of bio-diesel in diesel by volume. The load is applied gradually from 0% to 100% at the interval of 20%. The exhaust gas emissions were measured by Smoke meter (AVL-437) and Exhaust gas analyzer (AVL-444). Engine specifications is mentioned in table 2. The engine was allowed to run for 25 minutes at a particular loading condition to achieve the steady state condition. All the readings were repeated twice and average of two readings were taken for consideration. Experimental matrix was explained in table 3.

### Table 2. Engine Specifications

| Type                  | Single Cylinder, 4-stroke |
|-----------------------|---------------------------|
| Fuel                  | Diesel                    |
| Bore × Stroke         | 80 mm × 110 mm            |
| Cooling System        | Water cooled engine       |
| Rated Speed           | 1500 RPM                  |
| Rated Brake Power     | 5 HP                      |
| Method of Loading     | Rope brake current dynamometer |
| Injection Type        | Direct injection          |
| Injection Pressure    | 200 bar                   |

### Table 3. Experimental Test Matrix

| Test No. | Fuel used (% volume concentration) | Load (% of full load) | Abbreviation | Fuel Injection Pressure (bar) |
|----------|-----------------------------------|-----------------------|--------------|------------------------------|
| 1        | Diesel                             |                       | D100         | 200                          |
| 2        | Diesel 90%, Rapeseed bio-diesel 10% |                       | D90B10       | 200                          |
| 3        | Diesel 80%, Rapeseed bio-diesel 20% | 20%, 40%, 60%, 80%, 100% & 120% | D80B20       | 200                          |
| 4        | Diesel 70%, Rapeseed bio-diesel 30% |                       | D70B30       | 200                          |

4. RESULT & DISCUSSION

Various engine performance and emission characteristics were examined under different loading conditions and different blends of fuel.
4.1. Brake Thermal Efficiency
BTE indicates the conversion of heat energy into mechanical work. It depends on various factors like loading condition, injection pressure, combustion efficiency, angle of advance, compression ratio etc. According to results obtained during an experiment, BTE of engine at full load condition with diesel as a fuel is around 30%. With blending of bio-diesel in higher amount with diesel leads to decrease in BTE. The possible reasons may be lower heating value and higher viscosity of rapeseed bio-diesel compared to diesel. D90B10 and D80B20 blend gives compatible efficiency compared to diesel as oxygen content in fuel leads to improve combustion efficiency but D70B30 blend reports considerable drop of efficiency at all loading conditions. Figure 2 also describes that, BTE increases with load increases till full load condition and then decreases for overload condition.

![Figure 2. BTE vs. Engine Load](image)

4.2. Brake Specific Fuel Consumption (BSFC)
Quantity of fuel consumed to produce one kW brake power is termed as BSFC. With increase in load, BSFC decreases due to complete combustion at higher loading condition except overloading condition. Figure 3 clearly shows that BSFC increases with increase in concentration of bio-diesel in fuel. For 100% loading condition, BSFC for pure diesel, D90B10, D80B20 and D70B30 are 0.2811, 0.3129, 0.3223 and 0.329 kg/kW-hr respectively.

![Figure 3. BSFC vs. Engine Load](image)
4.3. CO Emissions
CO emissions generated in diesel fuel-engine due to incomplete combustion. The insufficient amount of oxygen presence in combustion chamber or non-uniform mixing of air with fuel is the main reason of CO emission. Figure 4 displays the deviation in CO emission with alteration in load and fuel content. D70B30 blend shows least CO emission compared to other blends because of higher amount of oxygen in rapeseed bio-diesel is available for combustion provides complete combustion. At full load condition, CO Emission with D70B30 blend is decreased by 52% compared to diesel. Figure 4 also express that CO Emission at full load and overload condition is higher than that at 80% load.

![Figure 4. CO Emissions vs. Engine Load](image)

4.4. HC Emissions
HC emission indicates the presence of unburnt hydrocarbon particles in exhaust gas coming out from engine due to various reasons like combustion chamber type, fuel air ration, design of fuel injector and spray pattern, viscosity of fuel, oxygen content in fuel blend and cetane number.

![Figure 5. HC Emissions vs Engine Load](image)

Figure 5 shows that HC emission increases with increases in load for all prepared fuels. HC emission decreases with percentage increase of rape seed bio-diesel in diesel for all the loading condition. The
reason may be due to presence of oxygen in bio-diesel provides uniform combustion and lesser HC emission. Percentage decrease in Hydrocarbon emission with D70B30 blend is around 20% compared to diesel.

4.5. Smoke Density
Presence of smoke in diesel fuel-engine may be due to improper particle size in combustion chamber causes enriched fuel zone and generates soot. Figure 6 shows the variation in smoke density with change in load for different blends.

![Figure 6. Smoke Density vs. Engine Load](image)

Smoke density increases with increase in load for all blends of fuel. Smoke emission is minimum for D70B30 blend at all loading condition may be due to occurrence of extra oxygen in combustion chamber provides complete combustion. Smoke density with D70B30 fuel blend is 69% of smoke density with diesel fuel.

4.6. NO\textsubscript{x} Emission

![Figure 7. NO\textsubscript{x} Emission vs. Engine Load](image)

NO\textsubscript{x} emission mainly depends on cylinder pressure and temperature and presence of oxygen concentration. Figure 7 displays that NO\textsubscript{x} emission rises gradually with increase in load due to higher
combustion temperature. It is also found that NOx emission increases with % increase in bio-diesel in diesel fuel for all loading conditions. It may be due to presence of oxygen in bio-diesel.

5. CONCLUSION

In current experiment, several tests were performed on single cylinder 4-stroke diesel fuel-engine. Esterified rape seed oil was used as a bio-diesel and blend in diesel with different proportion. Tests were performed under different loading conditions and following points were observed:

(i) Due to lower heating value of rape seed bio-diesel, with % rise in concentration of bio-diesel causes decrease in BTE of diesel fuel-engine. While on other side, oxygen enriched combustion provides complete combustion and ultimately increases thermal efficiency of engine. Both the factors are contradicting to each other but effect of first factor is more dominant. Hence, BTE decreases with increase in bio diesel concentration. Due to same reason, BSFC increases, with increase in % concentration of bio-diesel in diesel fuel.

(ii) Use of bio-diesel in diesel shows better emission characteristics due to better combustion efficiency. Experimental results show that CO, HC and smoke emissions decreases with increase in bio-diesel concentration due to oxygen enriched combustion. The same reason is responsible for increase in NOx emission.

(iii) Looking from both performance and emission prospective, it may be concluded that D80B20 blend shows preeminent emission performance without negotiating efficiency much.

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