Experimental investigation of performance and emission characteristics of dual fuel engine (petrol start) fuelled with waste vegetable oil biodiesel - diesel blend

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Abstract. The search for an alternate fuel has led to many findings due to which a wide variety of alternative fuels are available at our disposal now. The existing studies have divulged the use of biodiesel for engines as an alternative for diesel fuel. This paper deals with performance and emission characteristic of a single cylinder, naturally aspirated, four-stroke, and direct injection, water cooled petrol run/diesel run engine fuelled with diesel, Waste vegetable oil (Rape seed oil) with iso-butanol added additives and its different blends. In the present research three different blends were prepared in ASTM standards as B20 (Diesel 20%-Biodiesel 80%), B30 (Diesel 300%-Biodiesel 70%) and B50 (Diesel 50%-Biodiesel 50%). B20 shows the highest Brake power (BP) at full speed condition as compared to other blended fuel and diesel pursues the highest power at all speed condition. B20 shows 1.66% greater Brake specific fuel consumption (BSFC) than diesel and 11.66 % lower than other blends. The decrease in the exhaust gas temperature for B50 was 7.02% lower than diesel at full load condition. B50 shows the lower CO emission as compared to other fuels. It shows 33.33% reduction as compared to diesel. B20 is showing 1.25% higher CO2 emission at full load condition where as it is 6.9% and 11.11% lower than B30 and B50 respectively. B50 shows 6.52%, 10.41% and 18.865% reductions in HC as compared to B30, B20, and diesel respectively. Diesel shows the lowest NOx emission at full load whereas B20 shows 2.2% higher emission than diesel and 2.17% and 8.14% lower emission than B30 and B50 respectively. As seen Diesel is 25%, 35% and 50% lower than B20, B30 and B50 at full load condition. The present work contributes in using B20 as alternative fuel for Petrol start/diesel run engines without major change for engines parts.

Keywords. Biodiesel, Waste vegetable oil (rape seed oil), Brake specific fuel consumption (BSFC), Brake power (BP), Emission (CO, CO2, HC, NOx, O2), Exhaust Gas Temperature, Petrol start/ Diesel run engine.

1. Introduction
Various forms of energy became an inevitable need, since the industrial revolution. Energy demands increased by leaps and bounds and was mainly fulfilled by natural gas, coal and petroleum-based
liquid fuels. However, these fuels are expected to exhaust in the near future. Here arises the demand for clean, renewable and economically available energy sources. Biodiesel is a biofuel which is gaining worldwide popularity as it has many advantages over diesel because it is safe, biodegradable, produces lesser pollutants, emission characteristics and better lubricity. But the use of Straight vegetable oils on long-term leads to many functional problems in engines. The poor volatility, high viscosity and poly unsaturated characteristics of vegetable oils are the major factors which affects its usage. [1-4]. Vegetable oil with more viscosity causes ineffective pumping and forms large droplets. Since fuel and air are not properly mixed, combustion continues to be imperfect in the engine. Vegetable oil with their low volatility and capability to polymerize (due to unsaturation) produces undesirable carbon deposits in the injector coking and causes sticking problems in piston rings. There are various studies related to engine tests of biodiesel fuel blends.

A study about engine performance characteristics was proposed by Ashraful et al. [5] using various vegetable oils to form biodiesel. The analysis of biodiesel and their blends shows fluctuation of power , confirming that variation occurs based on raw materials, engine types and combustion conditions. Paulo et al. [6] used waste vegetable oil and showed in his study that best behaviour considering vegetable fuel consumption, power and emission was obtained for B20. Atmanl et al [7] shows that-butanol is added to biodiesel blends increasing oxides of nitrogen (NO and NOx) formations, while drastically decreasing formations of carbon monoxide (CO) and hydrocarbon (HC) emissions. Irimescu’s [8] Experiments showed that fuel conversion efficiency reduced when the engine was fueled with iso-butanol at different loads. It was identified that the decrease in engine efficiency was majorly due to incomplete fuel evaporation. [9] The results also shows that alcohol diesel blends also has a positive effect on the decrease of smoke opacity and particle concentration during warm engine start with similar nitrogen oxide (NOx) emissions and at cold start, the blends produced combustion instabilities.Atmanl et al [10] Experimented Cotton seed oil blended with n-butanol and Engine operation test result of DCtOnB shows average values of BT (2.6%), BP(1.6%), BTE (31.2%), BMEP (2.3%) and EGT (3.6%) are lower, while BSFC (34.1%) is high than those of diesel fuel. Ibrahim [11] performed the test on a single-cylinder direct-injection diesel engine at a speed of 1500 rpm and various engine load conditions and found that B50 blend was optimum among all the tested fuels . Tashtoush [12] In his experiments showed that, at the lower energy rate, the burning of biodiesel is more efficient with higher combustion efficiency and exhaust temperature . At the higher energy input, biodiesel combustion performance diminished and was inferior to diesel fuel due to its high viscosity, density and low volatility.Yang et al [13] experimented the blends of diesel, biodiesel, isobutanol at different proportions andproved that carbon monoxide (CO), nitrogen oxide (NOx), and other constituents are decreased by an average of 3.45, 32.5, and 38.5 vol%, respectively. Despite of the amount of work done on Waste vegetable oil blended with butanol, this is the new work which is implemented on Petrol start / Diesel run engine and the result justifies that there is tremendous scope for the usage of such engine with/ without minor changes.

2. Materials and methods
The main aim of this experiment is to explore the performance of the waste vegetable oil (rape seed oil) biodiesel with iso-butanol added as an additive. The final product Diesel50% - Biodiesel50% (BD50), Diesel70% - Biodiesel30% (BD30E) and Diesel80% - Biodiesel20% (BD20) will have the advantageous attributes of biodiesels. The biodiesel served for this purpose are waste vegetable oil (rape seed oil). The aim is to understand the properties of newly obtained biodiesel mixture and the variations in properties when mixed with diesel and iso-butanol additives in various proportions, and to determine the changes in emission characteristics and performance characteristics of the fuel used in a single cylinder, naturally aspirated, four –stroke and petrol start diesel run engine. Table 1 represents the properties of the Diesel and biodiesel for different blends and the ASTM standards used.
2.1 Experimental setup and testing
The experimental work was proceeded with a single cylinder, naturally aspirated, four-stroke, constant speed, petrol start diesel run engine, water cooled and coupled with an eddy current dynamometer. The detailed engine description is given in Table 2 and schematic representation is shown in Figure 1 and Figure 2. There were two different fuel tanks which contain petrol for the engine start and other for Biodiesel run. The fuel tank is connected to a graduated burette to obtain the fuel consumption of the engine. An orifice meter with U-tube manometer is provided along with an air tank on the suction line for measuring air flow rate. The consumption chamber pressure is obtained from AVL make water cooled piezoelectric pressure transducer place in the cylinder head of the combustion chamber. Various operating temperatures along with the exhaust temperature can be measured with the Chromel Alumel (k-type) thermocouples. The engine speed is measured by an in-house designed magnetic pick-up sensor connected to a frequency meter. AVL AMA-i60 Emission Analyser was used to measure the emission parameters like oxides of nitrogen (NOx), Carbon monoxide (CO2). Table 3. Represents the detailed of the Analyser used.

| Table 1. ASTM methods and various properties. |
|-----------------------------------------------|
| **Fuel Properties** | **ASTM method** | **Diesel** | **Rapeseed-oil** | **Isobutanol** | **B20** | **B30** | **B50** |
| Density (kg/m³) | D 1298 | 837 | 918 | 809 | 845 | 850 | 852 |
| Calorific Value (KJ/Kg) | D240 | 42500 | 37600 | 32500 | 42214 | 41458 | 41930 |
| Kinematic viscosity (mm²/s) | D 445 | 2.6 | 39.5 | 2.2 | 6.8 | 10.64 | 11.08 |
| Cetane Index | D613-16a | 45 | 42 | 17 | 44 | 44 | 43 |

| Table 2. Engine specifications. |
|---------------------------------|
| **Sr. No** | **Description** | **Specification** |
| 1 | Engine Make | MS. Greaves Cotton Ltd., |
| 2 | Engine Model | MK 20 HSPP |
| 3 | Fuel | Petrol Start / Diesel Run |
| 4 | Fuel Tank Capacity | Petrol - 0.5 Litters / Diesel- 3.5 Litters |
| 5 | Engine Type | Side Valve, 4 Stroke, Air Cooled, Horizontal Shaft, Single Cylinder |
|   | Feature          | Specification          |
|---|------------------|------------------------|
| 6 | Displacement     | 192 cc                 |
| 7 | Bore X Stroke    | 68 X 53 mm             |
| 8 | Rated Power      | (4 kW) @ 3600 rpm      |

**Figure 1.** Schematic representation of the Engine

**Figure 2.** Representation of the Engine used for the above process.
### Table 3. Emission Analyzer and accuracy of the instrument.

| Species to be measured | Type of analyser                  | Measuring range   | Accuracy                               | Percentage uncertainties |
|------------------------|-----------------------------------|-------------------|----------------------------------------|--------------------------|
| CO                     | Non dispersive infrared absorption (NDIR) | 0–10% vol         | < 0.6% vol: ± 0.03% vol<br>               > 0.6% vol: ±5%           | ± 0.3                    |
| CO₂                    | Non dispersive infrared absorption (NDIR) | 0–20% vol         | < 10% vol: ± 0.5% vol<br>               > 10% vol: ±5% vol         | ± 0.2                    |
| HC                     | Heated flame ionization detector (HFID) | 0–20000 ppm vol   | < 200 ppm vol: ± 10<br>                 ppm vol > 200 ppm vol: ± 5% ppm vol | ± 0.2                    |
| O₂                     | Paramagnetic (PMD), zirconia (ZRDO) | 0–100%            | ± 1%                                   | ± 1                      |

### 3. Results and discussion

#### 3.1 Brake Power comparison for different fuels at different RPM.

As we can see in the Figure 3 that diesel pursues the highest power at all speed condition. B20 shows the highest power at full speed condition as compared to other blended fuel, the reason may be due to less density and viscosity of B20 as compared to others which allows proper atomization at full load condition. Low viscosity and density also helps the fuel to inject keenly which increases the fuel and air to mix properly.

![Figure 3. BP (Brake power) vs. Speed for Diesel and biodiesel](image-url)
3.2 Brake Specific Fuel Consumption (BSFC)

BSFC is the major factor to be considered for the performance of the engine. The fuel consumption decreases with increasing the engine speed and increase at the last this is due to higher fuel requirement at the initial start of the engine where all the energy is wasted as heat and then remains nearly constant, but at higher speed fuel consumption increase due to increase in the envelope of the air-fuel requirement which enhances the fuel to be inserted in the engine. As we can see from the Figure 4 that diesel peruses the lowest fuel consumption as compared to others whereas B20 is 1.66% greater than diesel and 11.66 % lower than other blends. This may be due to reduced injection delay which allows lesser period of fuel air mixing and decreases the fuel consumption. The other reason may be due to amount of blending where the higher blending increases the amount of emulsion which increases the density and reduces the power requirement, to reach such requirement higher amount of fuel is required.

![Speed Vs BSFC (g/kW-hr)](image)

**Figure 4.** BSFC (Brake specific fuel consumption) vs. Speed for Diesel and Biodiesel

3.3 Exhaust Gas Temperature.

Figure 5 shows the influence of premixed ratio of waste vegetable oil/diesel on exhaust gas temperature. The intermixture ratio was varied from 20%, 30% and 50% and results were collated to 100% diesel operation. Because of audible knocking, measurement of emission was limited to premixed ratio of 50%. The rise in the amount waste vegetable oil decreases the exhaust gas temperature at all load condition. The reduction in the EGT for B50 was 7.02% lower than diesel at full load condition.
3.4 Emission.
3.4.1 Carbon monoxide (CO).
As seen from the Graph 4 that CO emission significantly decreases with increase in load. B50 shows the lower CO emission as compared to other fuels. It shows 33.33% reduction as compared to diesel. The unburned fuel and mixture temperature during combustion are the two factors which controls the formation of CO and also the rate of fuel decomposition and oxidation. Decrease in the CO emission is due to proper combustion as the injection timing in higher for B50 there is proper time for the fuel to combust. B50 contains higher amount of oxygen which may be other reason for the low CO emission.

Figure 5. Exhaust Temperature vs Speed for Diesel and Biodiesel

Figure 6. Carbon monoxide vs. Load For Diesel and Biodiesel
3.4.2 Carbon dioxide.
As from the Figure 7 we can there is subsequent decrease in the CO₂ as load increases. Carbon dioxide is formed when there is enough amount of oxygen present during formation of CO as combustion product. As we can see diesel has shown the least CO₂ emission as compared to others. B20 is showing 1.25% higher emission at full load condition where as it is 6.9% and 11.11% lower than B30 and B50 respectively. The reason may be due to most of the carbon bond is converted into CO due to which the CO₂ emission is reduced and the other reason may be due to increment of internal temperature of the core which intensifies the reaction for the formation of CO₂ at lower load.

![Figure 7. Carbon dioxide vs. Load for Diesel and Biodiesel](image)

3.4.3. Hydro carbon (HC)
HC emission presented in the Figure 8 shows that there is increase in HC emission with increase in load. B50 shows 6.52%, 10.41% and 18.865% reductions as compared to B30, B20, and diesel respectively. The probable cause for the lower emission at lower load may be due to lower temperature at lower load and as temperature increases the formation of HC bond from the premixed combustion increases.

![Figure 8. Hydro carbon vs. Load for Diesel and Biodiesel](image)
3.4.4 Oxides of Nitrogen.
As observed from the Figure 9 that the NO\textsubscript{X} increase as the load increases, this may be probably due to increase in temperature at higher load condition as we know that NO\textsubscript{X} is formed at higher temperature. Diesel shows the lowest NO\textsubscript{X} emission at full load whereas B20 shows 2.2% higher emission than diesel and 2.17% and 8.14% lower emission than B30 and B50 respectively. B20 shows lowest fuel injection timing as compared to other blend due to its less viscosity and density which do not allow NO\textsubscript{X} formation at that mixing condition.

Figure 9. Oxides of Nitrogen vs. Load for Diesel and Biodiesel

3.4.5 Oxygen.
As seen from the Figure 10 that as the load increases there is increment in oxygen emission. As seen from the graph Diesel is 25%, 35% and 50% lower than B20, B30 and B50 at full load condition, one of the reason may be due to structural composition of the biodiesel which prone to the formation of the oxides at higher temperature and other maybe due to petrol start which increases the temperature of the inner core of the engine which implies the temperature increase of the reaction and acts as an catalyst for the increment of oxygen at initial load condition.

Figure 10. Oxygen vs. Load for Diesel and Biodiesel

4. Conclusion
An experimental investigation was carried out for single-cylinder, four stroke, petrol start/Diesel run engine fuelled with Waste vegetable oil (Rape seed oil) blended with iso-butanol. The present
conclusion was based on performance and emission characteristics. B20 shows the highest power at full speed condition as compared to other blended fuel and diesel pursues the highest power at all speed condition. Diesel pursues the lowest fuel consumption as compared to others where as B20 is 1.66% greater than diesel and 11.66 % lower than other blends. The increase in the amount waste vegetable oil decreases the exhaust gas temperature at all load condition. The drop in the exhaust gas temperature for B50 was 7.02% lower than diesel at full load condition. CO emission significantly decreases with increase in load. B50 shows the lowest CO emission as compared to other fuels. It shows 33.33% reduction as compared to diesel. Diesel has shown the least CO2 emission as compared to others. B20 is showing 1.25% higher emission at full load condition where as it is 6.9% and 11.11% lower than B30 and B50 respectively. B50 shows 6.52%, 10.41% and 18.865% reductions in HC as compared to B30, B20, and diesel respectively. Diesel shows the lowest NOX emission at full load where as B20 shows 2.2% higher emission than diesel and 2.17% and 8.14% lower emission than B30 and B50 respectively. As seen Diesel is 25%, 35% and 50% lower than B20, B30 and B50 at full load condition. Despite of the amount of work done on Waste vegetable oil blended with butanol this is the new work which was implemented on Petrol start / Diesel run engine and the result specifies that B20 can be used on such engines with/ without minor changes.

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