Effect of Sunflower Biodiesel Blended Fuels with Ignition Improver on Engine Performance and Emission Characteristics of a Diesel Engine

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Abstract:
Alternative fuels have received much attention due to the depletion of world petroleum reserves and increased environmental concerns. Thus processed form of vegetable oil (Biodiesel) offers attractive alternative fuels to compression ignition engines. The aim of the present work is to evaluate the fuel properties and investigate the impact on engine performance using sunflower oil biodiesel and their blends with diesel. The performance and emission characteristics of a direct injection diesel engine when fueled with sunflower oil methyl ester and its 5%, 10%, 15%, 20% blends with diesel (on a volume basis) are investigated and compared with standard diesel. Experiments were conducted at constant speed of 1500 rpm. The results show that better performance and lower emissions were found with 15% blend at full load condition. For the 15% blend, ignition improver (Isopropyl alcohol -2%, 4%) by volume proportions added and the tests were performed. The results indicated that higher brake thermal efficiency and lower brake specific fuel consumption were observed when operating with 15% blend with ISO 4%. It is finally observed from the experimental results that sunflower methanol blends have maximum efficiency and minimum emissions at optimized engine parameters and it is a suitable alternative fuel for diesel and could help in controlling air pollution.

Keywords: Bio-diesel, Ethanol, Ignition Improver, NOx, Sunflower seed oil

1. INTRODUCTION:

From previous studies, straight vegetable oils used in engine lead to various problems like fuel filter clogging, poor atomization and incomplete combustion because it is highly viscous, high density and poor non volatility. In order to reduce the viscosity of the straight vegetable oil the following four techniques are adopted; namely heating/pyrolysis, dilution/blending, micro-emulsion and transesterification. Among all these techniques the transesterification is an extensive, convenient and most promising method for reduction of viscosity and density of the straight vegetable oils [1].

Due to excess use of the petroleum based fuel for industry and automobile application in the present time the world is facing several problems like global energy crisis, environment pollution and global warming. Therefore global consciousness has started to grow to prevent the fuel crisis by developing alternative fuel sources for engine application. Vegetable oils from plants both edible and non-edible and ethyl ester (Biodiesel) are used as alternate source for diesel fuel. Biodiesel was found to be the best alternate fuel, technically, environmentally acceptable and easily available. There are more than 350 oil bearing crops that have been identified among sunflower, soybean, cotton seed, mango seed, rapeseed and peanut oil are considered as potentially alternative fuel for diesel engines [2]. Advantages of biodiesel are high oxygen content, higher flash point higher lubricity that produce complete combustion with comparison of conventional diesel fuel. And another environmental benefit is less green house effect less air pollution. The long chain hydrocarbon structure vegetable oil have good ignition characteristics how ever they cause serious problems such as carbon deposits buildup, poor durability, high density, high viscosity lower calorific value and more molecular weight. These problem leads to poor thermal efficiency while using vegetable oil in the engine. These problems rectified by different methods that are used to reduce the viscosity of the vegetable oil the methods are transesterification, dilution and cracking method. The transesterification of vegetable oil gives better performance when compared to the other methods [3]. Vinay kumar conducted experiments to apply Thermal Barrier Coatings (TBC) onto engine parts for improving engine performance when biodiesel is used palm oil as alternative fuel. For this purpose, a Direct Injection (DI) diesel engine was converted to a LHR engine by applying Al₂O₃-TiO₂ (TBC) on the Piston Crown and the effects of biodiesel (produced from panama oil) usage in there engine, performance and emission characteristics have been investigated experimentally with injector pressures of 180 bar & 250 bar. Panama oil having high viscosity and low volatility makes the oil unsuitable for a diesel engine. By transesterification process the fuel properties are closer to diesel fuel. At 250 bar injection pressure, the thermal efficiency improved with increased emissions [4].

From the literature review it can be inferred that a lot of research work has been carried out on evaluating the performance and emission characteristics of different grades of vegetable oils and biodiesel at a standard compression ratio but very little work has been done in evaluating the...
performance of sunflower oil. This oil has the potential to become an alternate for conventional diesel oil. Hence, the study of the characteristics of sunflower oil on diesel engine is very essential[12]. In the present work, effect of ignition improver with sunflower ethyl ester oil – diesel blended fuels on the performance and emission characteristic of fuel has been studied. It was found that the sunflower ethyl ester oil blends with diesel are obtaining better performance and lower emission characteristics results in a diesel engine without any modification [5]. Biodiesel is an oxygenated, renewable, biodegradable and environmentally friendly bio-fuel with low emission profile[15]. Pure coconut oil usage in diesel engine shows lesser smoke, carbon monoxide (CO), hydrocarbons (HC) emissions compared to diesel fuel since it has oxygen molecules which results in enhanced oxidation [6]. Also, neat vegetable oil usage tends to create operational and durability problems for long-term operation in diesel engine. These problems can be solved by converting vegetable oil into biodiesel as it has similar characteristics like diesel fuel. The present study is focused on sunflower seed oil [18].

1.1 Sunflower Seed Oil

Sunflower oil, also known (Helianthus Annuus) oil is a clear to yellowish drying oil derived from the dried ripe seeds of the sunflower plant. It is obtained by pressing, followed by an optional stage of cold pressing. The sunflower (Helianthus annuus) is an annual plant in the family Asteraceae, with a large flower head (capitulum). The stem of the flower can grow up to 3 metres tall, with a flower head that can be 30 cm wide. Other types of sunflowers include the California Royal Sunflower, which has a burgundy (red + purple) flower head. Sunflower was probably first introduced to Europe through Spain, and spread through Europe as a curiosity until it reached Russia where it was readily adapted. Selection for high oil in Russia began in 1860 and was largely responsible for increasing oil content from 28% to almost 50%. The high-oil lines from Russia were reintroduced into the U.S. after World War II, which rekindled interest in the crop. However, it was the discovery of the male-sterile and restorer gene system that made hybrids feasible and increased commercial interest in the crop. Sunflower oil can be extracted using chemical solvents (e.g., hexane), or expeller pressing (i.e., squeezed directly from sunflower seeds by crushing them). “Cold-pressing”/expeller-pressing sunflower seed oil under low-temperature conditions is a preferred method, for those seeking an extraction process that does not involve chemical solvents, as well as for people following a raw foods diet. Sunflower seed oil is a triglyceride, like other fats. Sesame oil is distinctive in terms of fatty acid constituents of the triglyceride, which contain an unusually large amount of α-linoleic acid, which has a distinctive reaction toward oxygen in air. Specifically, the constituent fatty acids in a typical sunflower seed oil.

Table 1. Chemical aspects of sunflower seed oil.

<table>
<thead>
<tr>
<th>Oil crop</th>
<th>Oil (%)</th>
<th>Palmitic acid (%)</th>
<th>Stearic acid (%)</th>
<th>Oleic acid (%)</th>
<th>Linolenic acid (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sunflower</td>
<td>40-42</td>
<td>3-10</td>
<td>1-10</td>
<td>14-72</td>
<td>20-65</td>
</tr>
</tbody>
</table>

1.2 Sunflower Seed Oil Ethyl Esters

Among the non-edible seeds produced in India, sunflower is one of the preferred seed because of its oil content and biodiesel yield. The research work related to the use of ethyl esters obtained from the sunflower oil in direct injection engines established different results. However the availability of seed is limited, discouraging the use of biodiesel [9, 10]. As the availability of sunflower seed is found to be less at this time, a certain percentage of biodiesel can be replaced by some other second generation biofuels such as ethanol which is commonly used in transesterification. In this process catalysts such as KOH are used to increase the reaction to quickly break the triglycerides into glycerol and methyl esters. So, far the major focus on biodiesel research has been mainly of transesterification process. Two distinct layers are formed, the lower layer is glycerin and the upper layer is ester. The upper layer (ester) is separated and moisture is removed from the ester by using calcium chloride. It is observed that 90% ester can be obtained from vegetable oils. Blends of biodiesel and conventional hydrocarbon-based diesel are products most commonly distributed for use. Much of the world uses a system known as the “B” factor to state the amount of biodiesel in any fuel mix.

- 5% biodiesel, 95% petro diesel is labelled B5
- 10% biodiesel, 90% petro diesel is labelled B10
- 15% biodiesel, 85% petro diesel is labelled B15
- 20% biodiesel, 80% petro diesel is labelled B20

Table 2. Properties of SFOEE and Diesel Fuel

<table>
<thead>
<tr>
<th>S. No</th>
<th>Type of Oil</th>
<th>Notation</th>
<th>Specific Gravity</th>
<th>Calorific Value (KJ/kg)</th>
<th>Kinematic Viscosity (cst)</th>
<th>Flash Point °C</th>
<th>Fire Point °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Diesel</td>
<td>D100</td>
<td>0.830</td>
<td>42500</td>
<td>3.05</td>
<td>56</td>
<td>63</td>
</tr>
<tr>
<td>2.</td>
<td>Sunflower seed Oil Crude</td>
<td>B100</td>
<td>0.864</td>
<td>38769</td>
<td>4.5</td>
<td>254</td>
<td>279</td>
</tr>
<tr>
<td>3.</td>
<td>Blends With Biodiesel (SFOEE)</td>
<td>B5</td>
<td>0.860</td>
<td>41980</td>
<td>5.1</td>
<td>115</td>
<td>196</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B10</td>
<td>0.858</td>
<td>41570</td>
<td>5.9</td>
<td>78</td>
<td>84</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B15</td>
<td>0.850</td>
<td>40970</td>
<td>6.4</td>
<td>65</td>
<td>73</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B20</td>
<td>0.843</td>
<td>40865</td>
<td>7.0</td>
<td>62</td>
<td>69</td>
</tr>
</tbody>
</table>

2. EXPERIMENTAL SETUP AND PROCEDURE:
Experiment were conducted on Kirloskar, four stroke, single cylinder, water cooled diesel engine. The rated power of the engine was 3.7kw at 1500 rpm. The engine was operated at a constant speed of 1500 rpm. The fuel flow rate was measured on volume basis using a burette and a stop watch. A smoke analyzer was used for the measurement of smoke in the exhaust. The performance and emission tests were started using 100% diesel and then fuel was replaced by blended fuels. This is a water cooled single cylinder vertical diesel engine is coupled to a rope pulley brake arrangement to absorb the power produced necessary weights and spring balances are induced to apply load on the brake drum suitable cooling
water arrangement for the brake drum is provided. Separate cooling water lines are provided for measuring temperature.

Fig: 1 (a) 4-Stroke diesel engine.

<table>
<thead>
<tr>
<th>Make</th>
<th>Kirloskar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power</td>
<td>5hp</td>
</tr>
<tr>
<td>Speed</td>
<td>1500rpm</td>
</tr>
<tr>
<td>no. of cylinders</td>
<td>1</td>
</tr>
<tr>
<td>compression ratio</td>
<td>16.5:1</td>
</tr>
<tr>
<td>Bore</td>
<td>80mm</td>
</tr>
<tr>
<td>orifice diameter</td>
<td>20mm</td>
</tr>
<tr>
<td>type ignition</td>
<td>compression ignition</td>
</tr>
<tr>
<td>method of loading</td>
<td>rope brake</td>
</tr>
<tr>
<td>method of starting</td>
<td>crank shaft</td>
</tr>
<tr>
<td>method of cooling</td>
<td>Water</td>
</tr>
</tbody>
</table>

Fig: 1(b) Engine specifications

3. RESULTS AND DISCUSSIONS

The performance and emission characteristics of an unmodified diesel engine with sunflower oil and its biodiesel blends are studied. The engine performance characteristics include variation of brake specific fuel consumption; brake thermal efficiency and emission characteristics (NOx, CO, HC, CO2) for different brake power are analyzed and studied. The results show that better performance and lower emissions were found with 15% blend at full load condition. For the 15% blend, ignition improver (isopropyl alcohol -2%, 4%) by volume proportions added and the tests were performed.

3.1 BRAKE THERMAL EFFICIENCY:

Fig 3.1 show variation of brake thermal efficiency with the load. It shows clearly brake thermal efficiency increase at full load. From fig observed diesel have lowest brake thermal efficiency and B15 have height efficiency than that of other blends. This is due to increase in brake power the brake thermal efficiency also increases. This was due to reduction in heat loss. Increase in thermal efficiency due to present of oxygen presence in the biodiesel the extra oxygen leads to better combustion inside the combustion chamber. The reason may be the leaner combustion of diesel and extended ignition delay resulting in a large amount of fuel burned. By adding ignition improver isopropyl alcohol (2ml, 4ml) by volume proportions the brake thermal efficiency is increased when compared with the diesel and biodiesel blend. The increment of BTE was observed with B15 at full load is 7.58% higher than that of diesel fuel. Because, The increment in brake thermal efficiency due to better combustion because of adding ignition improver it effects to decrease the viscosity and due to increase % of oxygen presence to the biodiesel-diesel blend, the extra oxygen leads to causes better combustion inside the combustion chamber.

3.2 MECHANICAL EFFICIENCY:

Fig 3.2 variation of mechanical efficiency with load
From the plot it is observed diesel and its blends like B15 nearly equal at full load conditions. But considerable improvement in mechanical efficiency was observed by the blends B15 is 6.03% because of lowest frictional powers compared to diesel. Because of sufficient lubricating property of this blend frictional powers are reduced drastically and considerable improvement in mechanical efficiency has been observed and calorific value of this blend is more compared to after other blends and compared to other blends B15(69.69) it gives maximum efficiency. By adding the ignition improver the efficiency is increased shown in the fig 3.2 the blend B15D81ISO4% is higher.

3.3 BRAKE SPECIFIC FUEL CONSUMPTION:

The variation in BSFC with brake power for different fuels is presented in Fig.3.3 Brake-specific fuel consumption (BSFC) is the ratio between mass fuel consumption and brake effective power, and for a given fuel, it is inversely proportional to thermal efficiency. BSFC decreased sharply with increase in brake power for all fuels. The main reason for this could be that the percent increase in fuel required to operate the engine is less than the percent increase in brake power, because relatively less portion of the heat is lost at higher loads. It can be observed that the BSFC of 0.289 kg/kW-hr were obtained for diesel and 0.238 kg/kW-hr B15 at full load. It was observed that BSFC decreased compared to other blends.

3.4 CARBON MONOXIDE:

Fig 3.4 variation of emission with load

The comparison of carbon monoxide for various biodiesel blends with respect to brake power shows in Fig.3.4. Carbon monoxide (CO) occurs only in engine exhaust, it is a product of incomplete combustion due to insufficient amount of air or insufficient time in the cycle complete combustion. It is observed that the CO emissions for SFOEE and its blends are lower than for diesel fuel. These lower CO emissions of biodiesel blends may be due to their more complete oxidation as compared to diesel. Some of the CO produced during combustion of biodiesel might have converted into CO2 by taking up the extra oxygen molecules present in these- chain and thus reduced CO formation. It can be observed from figure that the CO initially decreased with load and later increased sharply up to full load. This trend was observed in all the fuel blends tests. The CO content is decreased for B15 blend with ignition improver at full load compared with diesel.

3.5 HYDROCARBON:
The hydrocarbons (HC) emission trends for blends of ethyl ester of sunflower oil and diesel are shown in Fig.3.5. That the HC emissions decreased with increase in brake power for all biodiesel blends (B5, B10, B15 and B20) at all loads. In case of diesel fuel HC emissions are decreases with load, because of there is oxygen content present in diesel fuel. At full load diesel contains 58ppm where as in case of B15 it is 43 ppm at same load. So there is a reduction from 58 ppm to 43 ppm at full load these reductions indicate a more complete combustion of the fuel. The presence of oxygen in the fuel was thought to promote complete combustion. As the cetane number of ester based fuel is higher than diesel, it exhibits a shorter delay period and results in better combustion leading to low HC emission. Also the intrinsic oxygen contained by the biodiesel was responsible for the reduction in HC emission. Therefore the decreased in HC emissions is 34.8% in case of B15 at full load.

3.6 OXIDES OF NITROGEN:

Variation of NOx with engine brake power for different fuels tested are presented in Fig.3.6 The nitrogen oxides emissions formed in an engine are highly dependent on combustion temperature, along with the concentration of oxygen present in combustion products. The amount of NOx produced for B15 is 974 ppm where as in case of diesel fuel is 872 ppm for diesel fuel. From figure it can be seen that an increasing proportion of biodiesel in the blends was found to increase NOx emissions slightly increased. This may be due to higher combustion temperature inside the cylinder at higher load. In general, the NOx concentration varies linearly with the load of the engine.

4. CONCLUSION:

The performance and emission characteristics of conventional diesel, biodiesel blends and optimum blend with 1 -Hexanol as fuel additive were investigated on a single cylinder diesel engine. The conclusions of this investigation are as follows:

- The brake thermal efficiency increases with increase biodiesel percentage. Out of all these, B15 shows best performance.
- As a CI engine fuel, B30 blend results in an average reduction of smoke density, CO emissions reduced, with a marginal decrease in NOx emission when compared with diesel. Brake specific fuel consumption is decreases in blended fuels.
- In B15 fuel the BSFC is lower than the diesel and Reductions in unburned hydrocarbon emissions were compared to diesel.
- The ignition improver of Isopropyl alcohol of 4% shown the best performance in the sense of brake thermal efficiency and BSFC. The maximum brake thermal efficiency obtained is 37.57%.
- The increased amount of ignition improver to B15 blends increased, brake thermal efficiency, and decreased in emissions CO, NOX and HC observed. So it concluded that using ignition improver for optimum blend its performance increased and emissions were decreased.

5. REFERENCES


