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Research Article

Experimental Investigation on Performance, Combustion Characteristics of Diesel Engine by using Sunflower Oil

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Abstract

Biodiesel with fuel additives has been gaining increased attention from engine researchers in view of the energy crisis and increasing environmental problems. The present work is aimed at experimental investigation on bio diesel is the Sunflower oil which is obtained from the seeds by using the transesterification process. In the initial stage tests are to be conducted on the four stroke single cylinder direct ignition diesel engine and base line data is generated. Further in second stage the test was conducted on the same engine at same operating parameters by using the diesel blended with the sunflower oil esters with different blending ratios such as S10, S20, S30 and the performance parameters (Brake Thermal Efficiency, Brake Specific Fuel Consumption) and also emission parameters (CO, HC, NOx, CO2, unused oxygen and smoke density) are evaluated. Among all the blends S30 has shown the better performance in the parameters and also in the emissions. So S30 is taken as the optimum blend. Finally the performance and emission parameters obtained by the above test are compared with the base line data obtained earlier by using diesel.

Keywords: *Combustion characteristics, sunflower oil, Diesel-Biodiesel blends, Transesterification process, performance, emissions*

1. Introduction

Researchers have used different additives to petrol and diesel fuels for efficiency and emission improvement. The addition of alcohol based fuels to petroleum fuels has been increasing due to advantages like better combustion and lower exhaust emissions. Oxygenates like ethanol, I-propanol, I-butanol and I-pentanol improved performance parameters and reduced exhaust emissions (Ryo, 2011; Sivalakshmi, 2011). Gasoline-ethanol blends with additives such as cyclooctanol, cycloheptanol increased brake thermal efficiency when compared to gasoline with reduction in CO, CO2 and NOx while HC and O2 increased moderately (Ananda, 2010). Gasoline with additives like ethanol and ethanol-isobutanol increased the brake power, volumetric and brake thermal efficiencies and fuel consumption. The CO and HC concentrations in the engine exhaust decreased while the NOx concentration increased. The addition of 5% isobutanol and 10% ethanol to gasoline gave the best results (Balaji, 2010). Bio-additives (matter extracted from palm oil) as gasoline additives at various percentages (0.2%, 0.4% and 0.6%) showed improvement in fuel economy and exhaust emissions of SI engine (Yao, 2008). Methyl-ester of Jatropha oil diesel blends with Multi-DM-32 diesel additive showed comparable efficiencies, lower smoke, CO2 and CO (HanumanthaRao, 2009).

The addition of Di Methyl Carbonate (DMC) to diesel fuel increases efficiency marginally with reductions in NOx emissions while PM and soot emissions were reduced considerably (Zhang, 2005; Nibin, 2005). Biodiesel with Di Ethyl Ether in a naturally aspirated and turbocharged, high-pressure, common rail diesel engine reduced NOx emissions with slight improvement in brake thermal efficiency (Ni Zhang, 2011; Venkata Subbaiah, 2010). Ethanol addition to diesel-biodiesel blends increased brake thermal efficiency with reduction in carbon monoxide and smoke emissions and at the same time hydrocarbons, oxides of nitrogen and carbon dioxide emissions increased. Some researchers have used cetane improvers and some others have used additives in coated engines.

Biodiesel blended fuel, and a cetane improving additive (2-EHN) reduced PM emissions (12). Addition of di-1-butyl peroxide and the conventional cetane improver, 2-ethylhexyl nitrate additives to diesel fuel reduced all regulated and unregulated emissions including NOx emissions (13).Present work attempts to investigate performance, combustion and emission characteristics of diesel engine with the sunflower-biodiesel blends. The properties of sunflower oil are shown in Table 1.

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Table 1 Properties of Sunflower Biodiesel

Properties	S10	S20	S30	Diesel	Sunflower oil
Carbon %(w/w)	0.2325	0.2083	0.1666	0.2439	0.1369
Flashpoint(^{0}c)	58	62	64	60	141
Fire point (^{0}c)	68	70	72	62	173
Density (g/cm^3)	822.5	826	829	830	896
Kinematic viscosity (Centi Stroke) at 30 ^{0}c	3.575	3.96	4.3877	3.15	10.155
Specific gravity	0.8225	0.826	0.829	0.830	0.896
Calorific Value (kj/kg)	41.99×10^3	41.48×10^3	40.97×10^3	42.5×10^3	37.4×10^3

2. Experimental Set Up and Procedure

2.1 Experimental Set Up

The engine shown in plate.1 is a 4 stroke, vertical, single cylinder, water cooled, constant speed diesel engine which is coupled to rope brake drum arrangement to absorb the power produced. The engine crank started. Necessary dead weights and spring balance are included to apply load on brake drum. Suitable cooling water arrangement for the brake drum is provided. Separate cooling water lines fitted with temperature measuring thermocouples are provided for engine cooling. A measuring system for fuel consumption consisting of a fuel tank, burette, and a 3- way cock mounted on stand and stop watch are provided. Air intake is measured using an air tank fitted with an orifice meter and a water U- tube differential manometer. Also digital temperature indicator with selector switch for temperature measurement and a digital rpm indicator for speed measurement are provided on the panel board. A governor is provided to maintain the constant speed.

Table 2 Specifications of the Test Engine

Specifications of the Test Engine	
Particulars	Specifications
Make	Kirloskar
Rated Power	3.7 kw(5hp)
Bore	80 mm
Stroke Length	110 mm
Swept volume	562 cc
Compression ratio 16.5:1	Compression ratio 16.5:1

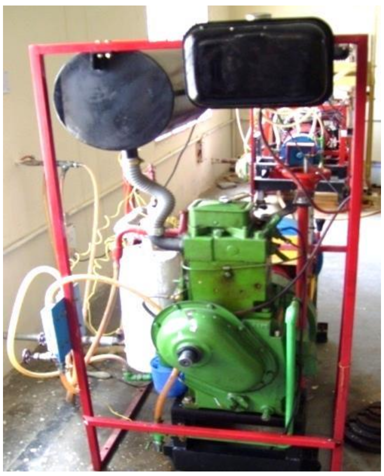

Plate 1 Diesel Engine Test Rig

3. Results and Discussion

3.1 Performance Analysis

The experiments are conducted on the four stroke single cylinder water cooled diesel engine at constant speed (1500 rpm) with varying loads. Various performance parameters such as, the variation of brake thermal efficiency with load for different fuels is presented in Fig. 1.1. In all cases, it increased with increase in load. This was due to reduction in heat loss and increase in power withincrease in load. The maximum thermal efficiency for S30 (34.01 %) was higher than that of diesel [32.82%]. This blend of 30% also gave minimum brake specific energy consumption. Hence, this blend was selected as optimum blend for further investigations and long-term operation. The variation of mechanical efficiency with brake power is shown in the Fig. 1.2. From the plot it is observed that there is slight variation of the mechanical efficiency for all the blends of sunflower oil compared to the diesel fuel. The variation of volumetric efficiency with Brake Power is shown in Fig. 1.3. From the plot it is observed diesel contains 78.42% at full load, but in case of sunflower oil blends it shown a slight decrement. The decrement in the volumetric efficiency is due to the decrease in the amount of intake air due to high temperature in the cylinder.

The variation in BSFC with load for diesel and sunflower oil blends is presented in Fig 1.4. In all cases, it decreased sharply with increase in percentage load for all fuels. The BSFC full load condition for the diesel is 0.26 and among all the blends S30 has taken minimum fuel my giving the value of 0.258. The main reason for this could be that percent increase in fuel required to operate the engine is less than the percent increase in brake power due to relatively less portion of the heat losses at higher loads. The BSFC for S30 was observed lower than diesel.The variation of Indicated Specific Fuel Consumption (ISFC) with Brake Power is shown in Fig. 1.5.From the plot it is observed that the indicated specific fuel consumption is slightly higher than the diesel for the blends of sunflower oil. At full load condition the ISFC for the diesel is 0.163 which is lower than the 0.188 for the blend S30. Initially it is higher than the diesel but coming to the full load condition it is coming closer to the diesel. The variation of Air-Fuel Ratio with Brake Power is shown in Fig. 1.6.

From the plot it is observed that air fuel ratio decreases compare with Diesel at full load condition for the different blends of sunflower oil. At the full load condition the air fuel ratio for the blend S30 is 22.05 which are lower than the diesel having 22.79. The air fuel ratio decreases due to increase in load because of the compensation of load can only be done with increasing the quantity of fuel injection to develop the power required to bare the load.

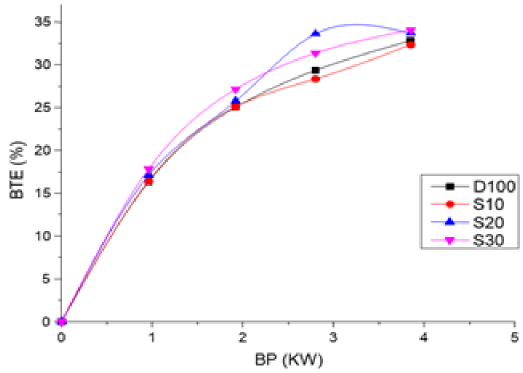

Fig. 1.1 Variation of Brake Thermal Efficiency with Brake Power Using SOME Blends

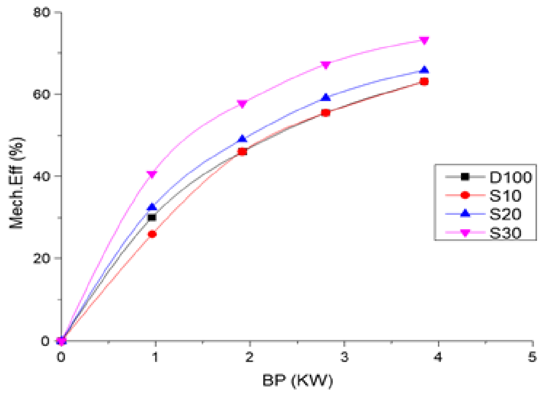

Fig. 1.2 Variation of Mechanical Efficiency with Brake Power using SOME Blends

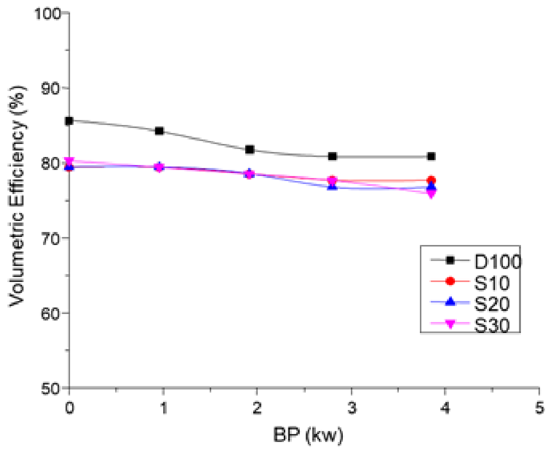

Fig. 1.3 Variation of Volumetric Efficiency with Brake Power using SOME Blends

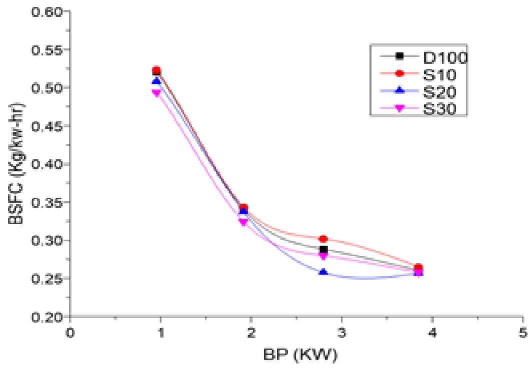

Fig. 1.4 Variation of Brake Specific Fuel Consumption with Brake Power using SOME Blends

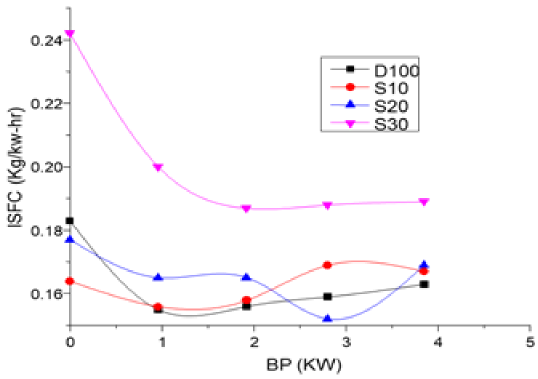

Fig. 1.5 Variation of Indicated Specific Fuel Consumption with Brake Power using SOME Blends

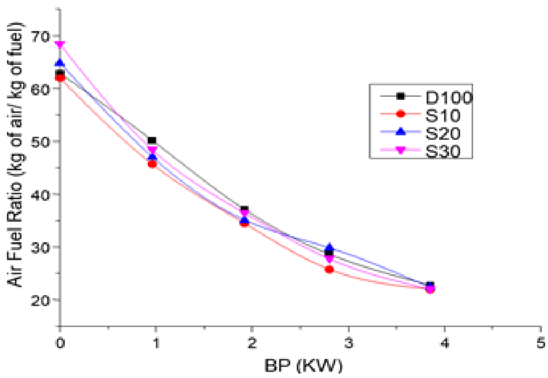

Fig. 1.6 Variation of Air Fuel Ratio with Brake Power using SOME Blends

3.2 Emission analysis using diesel and fish oil blends

The experiments are conducted on the four stroke single cylinder water cooled diesel engine at constant speed (1500 rpm) with varying loads. Various emission parameters in the sense of smoke density, unburned hydro carbons, carbon monoxide and nitrogen are discussed below. The variation of Smoke density with Brake Power is shown in Fig. 1.7. The Smoke is nothing but solid soot particles suspended in exhaust gas. Fig. 1.8 shows the variation of smoke level with brake power at various loads for different blends like S10, S20 and S30 tested fuels. It is observed that smoke is decreases for SOB-DIESEL blends at full load conditions. It is observed that the smoke density for the diesel fuel is 79.6 high compared to all blend and for the blend S30 smoke density is lesser compared to all the other blends by giving the value of 61.34.The variation of CO emission with Brake Power is shown in Fig. 1.9The plot it is observed that is interesting to note that the engine emits more CO for diesel as compared to biodiesel blends under all loading conditions. The CO concentration is decreases for the blends of S10, S20 and S30 for all loading conditions. At full load conditions the CO emissions for the diesel is lower than the other blends and at full load condition the blend S30 given the lower emissions compared to all blends. At lower biodiesel concentration, the oxygen present in the biodiesel aids for complete combustion.

However as the biodiesel concentration increases, the negative effect due to high viscosity and small increase in specific gravity suppresses the complete combustion process, which produces small amount of CO. The variation of carbon dioxide with brake power is shown in fig. 1.10. The plot is revels that different specified blends are indicated. The co_2 emission for all the fuels tested fallowed an increasing trend with respect to load. At full load condition the blend S30 has given the maximum CO_2 emission which is allowable. The reason could be the high amount oxygen in the specified fuel blends which is converting CO emission into CO_2 emission content. The variation in HC emissions with Brake Power is shown in Fig. 1.10. The plot it is observed that the HC emission variation for different blends is indicated. That the HC emission decreases with increase in load for diesel and it is drastic decreases for all biodiesel blends. Traces are seen at no load and full load. At full load condition the HC emissions for diesel is high compared to the all the blends, the blend S30 has shown the maximum reduction in the HC emissions. As the Catani 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.

The variation of NO_x emission with Brake Power is shown in Fig. 1.11. The plot it is observed that for different blends is indicated. The NO_x emission for all the fuels tested followed an increasing trend with respect to load. At full load condition the blend S30 has given the most decrement in the oxides of nitrogen compared to all the other blends of sunflower oil. The reason could be the higher average gas temperature, residence time at higher load conditions. A reduction in the emission for all the blends as compared to diesel was noted. With increase in the biodiesel content of the fuel, corresponding increment in emission was noted. The variation of unused oxygen emission with brake power is shown in Fig. 1.12. From the graph it is observed that as the load increases the unused oxygen decreases. At full load condition the unused oxygen obtained are 18.62%, 18.7%, 19.50% and 19.74% for the fuels of diesel, S10, S20 and S30 respectively. The decrement of unused oxygen due to CO emission converts into CO_2 emission.

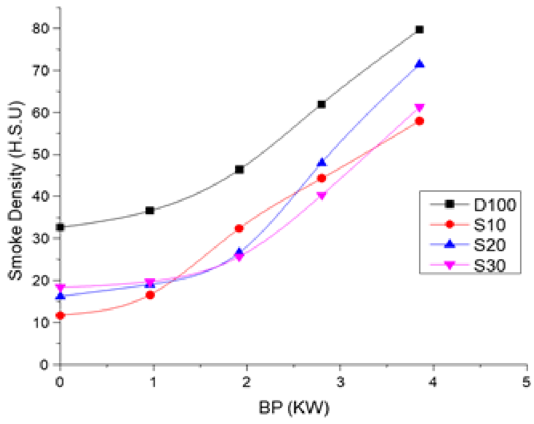

Fig. 1.7 Variation of Smoke Density with Brake Power using SOME Blends

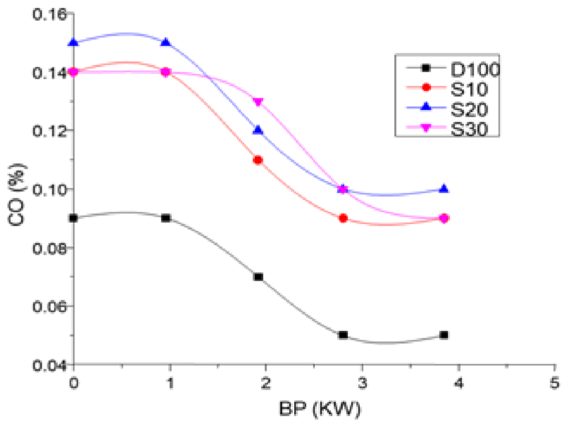

Fig. 1.8 Variation of Carbon Monoxide with Brake Power using SOME Blends

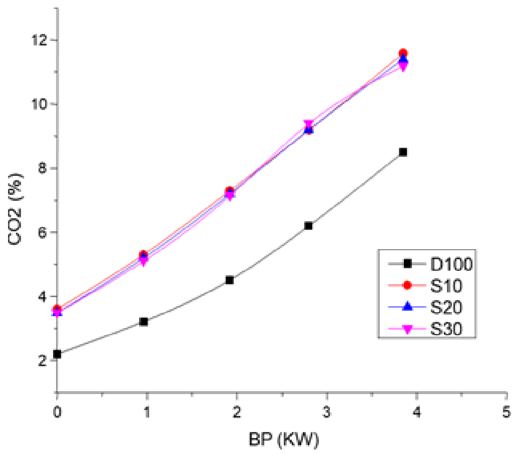

Fig.1.9 Variation of Carbon Dioxide with Brake Power using SOME Blends

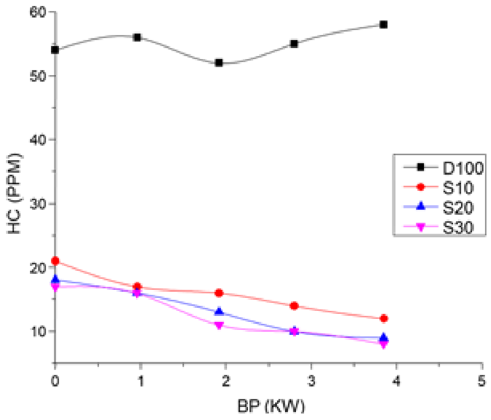

Fig. 1.10 Variation of Unburned Hydrocarbons with Brake Power using SOME Blends

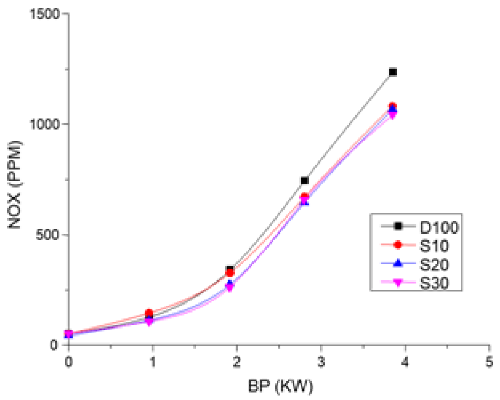

Fig.1.11 Variation of NOx Emission with Brake Power using SOME Blends

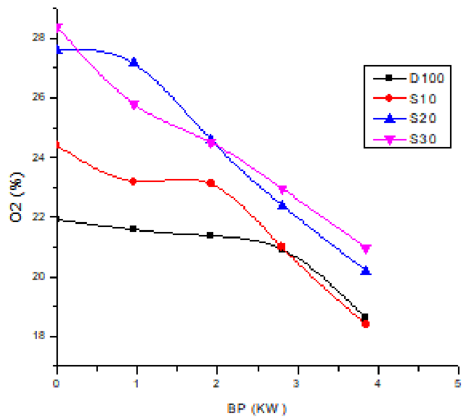

Fig. 1.12 Variation of Unused Oxygen with Brake Power using SOME Blends

Conclusions

The conclusions deriving from present experimental investigation to evaluate the experimental tests are conducted on 4-stroke, single cylinder, water cooled and direct injection diesel engine by using sunflower oil blends of S10, S20 and S30, pure diesel at constant speed of 1500 rpm. From the first set of results it can be conclude that the blend S30 has given the better performance in the sense of brake thermal efficiency, specific fuel consumption and emission parameters. No engine seizing, injector blocking was found during the entire operation while the engine running with different blends of sunflower oil and diesel are summarized as follows:

1) The BSFC obtained are 0.26 kg/kW-hr, 0.265 kg/kW-hr, 0.257 kg/kW-hr and 0.25 kg/kW-hr for fuels of diesel, S10, S20 and S30 respectively. The minimum fuel consumption is for S30 is 0.25 kg/kW-hr as to that of diesel are 0.26 kg/kW-hr. The BSFC of sunflower oil blend S30 is decreases up to 1.53% as compared with Diesel at full load condition.
2) The brake thermal efficiencies are obtained 32.82%, 32.33%, 33.71% and 34.08% for the fuels diesel, S10, S20 and S30 respectively, among the three blends of sunflower oil the maximum BTE is 34.08% which is obtained for S30. The BTE of sunflower oil is increases up to 0.46% as compared with Diesel at full load condition.
3) The smoke density obtained is 79.6 HSU, 58.05 HSU, 71.51 HSU and 61.34 HSU for the fuels of diesel, S10, S20 and S30. It is observed that smoke is decreases for sunflower oil blends at full load conditions as compared to diesel except S30 blend.
4) The unburned hydrocarbons are obtained 58ppm, 12ppm, 9ppm and 8ppm for the fuels of diesel, S10, S20 and S30 respectively.
5) The CO emission obtained is 0.05%, 0.09%, 0.1% and 0.09% for the fuels of diesel, S10, S20 and S30 respectively. The CO concentration is little increases for the blends of S10, S20 and S30.
6) The NOx emission obtained are 1236ppm, 1083ppm, 1068ppm and 1044ppm for the fuels of diesel, S10, S20 and S30 respectively. The reason could be the higher average gas temperature, residence time at higher load conditions. A reduction in the emission for all the blends as compared to diesel was noted.
7) Exhaust emissions like smoke density, unburned hydrocarbons, carbon monoxide and NOx are decreases of sunflower oil blends as compared to diesel fuel.

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