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EXPERIMENTAL STUDY ON PERFORMANCE AND EMISSION CHARECTERISTICS OF DIESEL ENGINE USING SOYBEAN OIL AS AN ALTERNATE FUEL

RAJENDRA KUMAR GANGANI[1], Dr. PRASHANT SHARMA[2], DHEERAJ SONI[3]
[1]M.Tech, Scholar, (Production Engineering) Pacific University, Udaipur
[2]Professor (Mechanical Engineering) & Principal, Pacific College of Engineering Udaipur, Rajasthan (India)
[3]Asst. Professor, (Mechanical Engineering), Pacific College of Engineering, Udaipur

RAJENDRA KUMAR GANGANI

Dr. PRASHANT SHARMA

ABSTRACT
Biodiesel, the methyl ester of vegetable oil is a renewable, low environmental impact and potential as a green alternative fuel for diesel engine. The aim of this present work is to compare the performance and emissions of a diesel engine run on soybean oil methyl ester (SOME) and diesel fuel. A 4-stroke single cylinder direct injection water cooled constant speed diesel engine was first run with diesel fuel and then bio-diesel. The performance of (SOME) and diesel is compared on the basis of brake thermal efficiency and exhaust gas temperature and the emissions compared are carbon monoxide and oxides of nitrogen. It is found from the results that biodiesels differ very little from diesel in performance and emission. However, oxides of nitrogen are found to be higher for biodiesels but not significantly higher when compared with diesel. It is concluded that the biodiesel can be used as alternative fuel in the Diesel engine without any engine modifications.

Keywords - Diesel engine, Emission, Soybean oil methyl ester, Pongamia methyl ester, Nitrogen.

I. INTRODUCTION

Petroleum products, the actual base of the world energy matrix, are causing serious problems to the environment. In search for alternative fuels which can be used as a substitute to conventional petroleum diesel fuels is in demand due to concerns about depletion of fossil fuel reserves and also growing worldwide environmental stringent of pollution**.** Fuels derived from renewable biological resources for use in diesel engines are known as bio-diesel. It is the mono alkyl esters of long chain fatty acids derived from renewable lipid sources [1]. Biodiesel is typically produced through the reaction of a vegetable oil or animal fat with methanol in the presence of a catalyst to yield glycerine and methyl esters [2]. The high value of soybean oil as a food product makes production of a cost–effective fuel very challenging. However, there are large amounts of low–cost oils, waste and animal fats that could be converted to bio-diesel [3]. With use of biodiesel, CO and HC emissions are reduced whereas N2O emissions increases with increase in biodiesel content [4]. The process of production of biodiesels is called transesterification which is catalyzed by chemical reaction of oil & alcohol [5]. There are several of species from which biodiesels can be made available. One of the main benefits of using a biodiesel fuel is its increased lubricity over regular diesel fuel and the potential benefits of reduced fuel consumption and engine wear that come with it[6]. Despite the success when diesel engines are operated on vegetable oil for short term performance tests, the real measure of success when using vegetable oil as a diesel fuel extender or replacement depends primarily on the performance of vegetable oils in engines over a long period of time[7].Biodiesel can be harvested and sourced from non-edible oils like Jatropha, Pongamia, Neem (Azadirachta indica), Mahua, castor, linseed, Kusum (Schlechera trijuga), etc and edible oils like coconut, palm, sunflower ,mustered, soybean etc[8-9]. Out of these plants, soybean and Pongamia Pinnata, which can grow in arid and wastelands [8].

Biodiesel has some important advantages when compared to diesel fuel. Biodiesel contains almost no sulphur; is biodegradable, nontoxic and a natural lubricant. Biodiesel has a high flashpoint, about 130ºC (266ºF), so it not explode spontaneously or ignite under normal circumstance. This feature makes biodiesel much safer to transport and store. Although biodiesel contains 10% less energy per gallon than convectional diesel fuel, it exhibits almost the same performance compared to diesel fuel, because, beyond reduces engine friction between engine parts, biodiesel useable energy is partially offset by approximately 7% increase in the combustion efficiency. Biodiesel has others advantages, compared to conventional diesel fuel, such as: ready availability, renewability, biodegradability, higher centane number, flash point, cloud point and cold filter plugging point [9]. Since biodiesel comes from a renewable energy source, its production and use as a replacement for fossil fuel provides three main benefits: reduces economic dependence on petroleum oil; decreases gas emissions that cause the greenhouse effect; and diminishes the proliferation of deceases caused by the pollution of the environment. The use of biodiesel in diesel engines require no hardware modification because vegetable oils have cetane numbers close to that of diesel fuel High viscosity of the vegetable oil leads to poor fuel atomization, which in turn may lead to poor combustion, ring sticking, injector cocking, injector deposits, injector pump failure and lubricating oil dilution by crank-case polymerization [10]. Canacki and J.Van.Gerpen conducted an experiment on a diesel engine and observed significant improvement in engine performance and emission characteristics for the biodiesel fuelled engine compared to diesel fuelled engine. Thermal efficiency of the engine improved, brake specific fuel consumption reduced and a considerable reduction in the exhaust smoke opacity was observed [11]. Jindal studied the effect of injection timing on combustion and performance of a direct inject diesel engine running on Jatropha methyl ester. Author reported that significant improvement in engine performance was observed compared to vegetable oil alone. The specific fuel consumption and the exhaust gas temperature were reduced due to decrease in viscosity of the vegetable oil and emission characteristics closer to the diesel fuel. Performance and emissions of the diesel–biodiesel–ethanol blends and comparing them with those of diesel fuel. They reported that, performances decrease, especially at low engine loads. CO emissions decrease significantly due to an increase of CO2 emissions, as a result of a prolonged oxidation process. The objective of the present study is to compare the performance and emission characteristics of a 4-stroke single cylinder water cooled constant speed diesel engine using soybean oil methyl ester (SOME), Pongamia piñata methyl ester (PME) and diesel [12].

II. EXPERIMENTAL SETUP

Straight vegetable oil is an important fuel resource. It is also an oxygenate fuel. In the case of Soybean oil methyl ester (SOME), its viscosity and low calorific values at same density as diesel makes it a poor alternative fuel but a good and easily available fuel. This experiments were performed at different loads at constant speed since this engine always operates at constant speed due to the restriction of producing the same amount of voltage across the alternator terminals. To characterize emissions, the engine was operated on some specific operating points [13]. Soybean oil methyl ester (SOME) and pure diesel were used to test a single-cylinder, four-stroke, and water cooled diesel engine with eddy current dynamometer having a rated output of 3.7

kW at a constant speed 1500 rpm. The schematic of the experimental setup is shown in Figure 1. The power output of the engine was measured by an eddy current dynamometer that was coupled with the engine. The exhaust emissions like HC, CO, and NOx were measured exhaust gas analyzer. The engine and dynamometer were interfaced to a control panel, which is connected to a computer. This computerized test rig was used for calculating the engine performance characteristics like brake thermal efficiency and for recording the test parameters like fuel flow rate, temperatures, air flow rate, load etc [14]. The engine was warmed up and before taking all readings the engine was allowed to come at steady state condition. All the observations are taken thrice to get a reasonable value. Properties of the fuel is shown in Table: 1

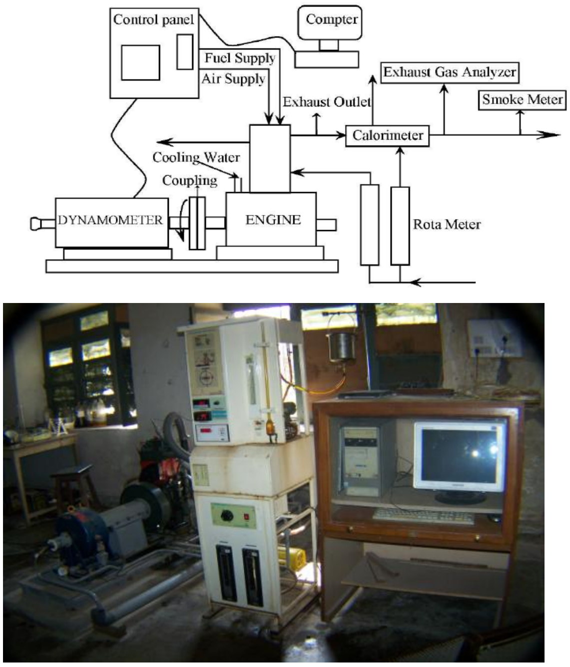

Fig.1: (a)Schematic diagram of experimental setup [13]and (b) actual Setup of Experiments

Table 1: Fuel Properties

Properties	Diesel	SOME
Fuel Density (kg/m^3)	835.8	904
Low heating value (kJ/kg)	42500	36200
Kinematic viscosity (mm^2/s)	3x10^{-3}	4.62x10^{-3}

III. EXPERIMENTAL ANALYSIS

The tests were conducted on a direct injection diesel engine for different loads, 10% and 20% soybean oil blended with diesel. Analysis of performance parameters and emission characteristics such as brake power, brake specific fuel consumption brake thermal efficiency, exhaust gas temperature, carbon monoxide, carbon dioxide and nitrogen dioxide are determined.

3.1. Brake thermal efficiency

The variation of brake thermal efficiency for different blends is presented in the Fig.2 .Brake thermal efficiency was found to increase with increase in load for all blends. This may be attributed to the reduction in heat losses and increase in power with increase in load. At lower loads,SB10 showed maximum BTHE(4.57%) as compared as compared to other blends and diesel(4.23%).This might be due to additional lubricity provided by the biodiesel and presence of oxygen in biodiesel resulted improved combustion as compared to diesel. It was also found that the thermal efficiency decreased as the amount of biodiesel increased in the blends beyond 10% at higher loads. It can be seen from the figure that brake thermal efficiency of the engine with biodiesel diesel blends is closed to BTHE with diesel.

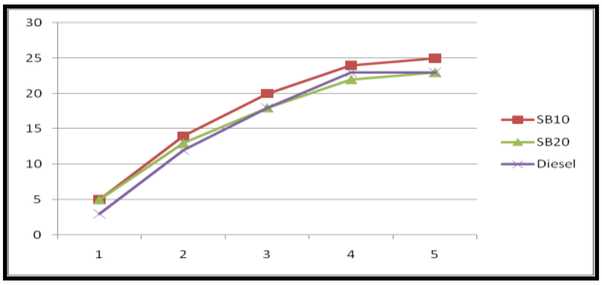

Figure: 2 Variation Of Brake Thermal Efficiency with Loads

3.2. Brake Specific Fuel Consumption

Fig.3 shows the BSFC of different SB blends at varying loads. The brake specific fuel Consumption decreased with load significantly for all blends. It is clear from the trend line that at lower loads there was significant change in BSFC.SB 20 had shown a higher BSFC with 6 kg/kw-h where as SB 10 was the lowest with 3 kg/kw-h with higher loads no changes in values were observed Brake specific fuel consumption (BSFC) was higher for Soybean biodiesel as compared to diesel for higher loads; this may be due to less heating value and higher density of biodiesel. Since biodiesel blends have different calorific values, viscosity and density, therefore BSFC cannot be a reliable tool to compare the fuel consumption per unit power developed. A better approach, brake specific energy consumption (BSEC) was used to compare the SB blends on the basis of energy required to develop unit power output.

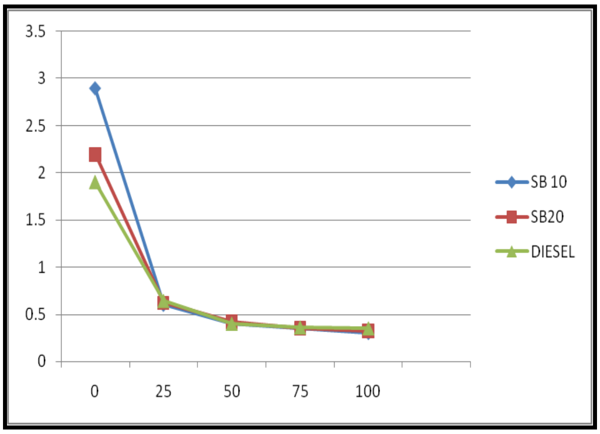

Figure 3: Effect of load on brake specific fuel consumption

3.3 Brake specific energy consumption

Fig4 represents trend lines for Break specific energy consumption at four different load cycles for different blends. The trend line depicts that BSEC of SB20 at lower loads is higher than other blends, while it shows a comparatively lower values at 25 and 50% loads. However with further increase in loads a straight line was achieved which illustrates that at higher loads BSEC of diesel and other SB blends are nearly equal. Brake specific energy consumption was found to be higher at low loads and eventually decreased at full load.SB20 blends showed a higher BSEC as compared to diesel and other blends, which is primarily because of lower calorific value and density of fuel. While SB showed a comparative results closer to diesel over entire range of varying loads. The brake specific energy consumption was slightly higher in case of SB blends as compared to diesel, which indicate that energy released by biodiesel, to develop unit power is more as compared to diesel.

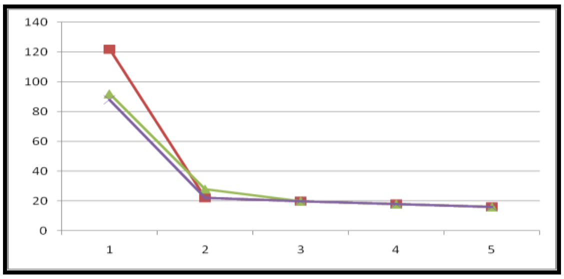

Figure 4: Variation of Brake Specific Energy Consumption with Loads

3.4 Brake Power

Relationship between brake power of engine at varying loads for different blends of soybean methyl ester is shown in figure 4.4 Brake power of the engine increased significantly with gradual increase in load for all blends, It is clear from the graph that the power developed by engine at varying load for diesel is maximum as compared to soybean methyl ester upper blends viz. (RB10, 20). This is primarily because of less heating value of biodiesel as compared to diesel. It can also be seen that RB 10 blend had a higher brake power as compared to diesel and other RB blends, both at lower and full load. This increase in brake power may be attributed to decrease in friction losses due to increased lubricity of fuel oils.

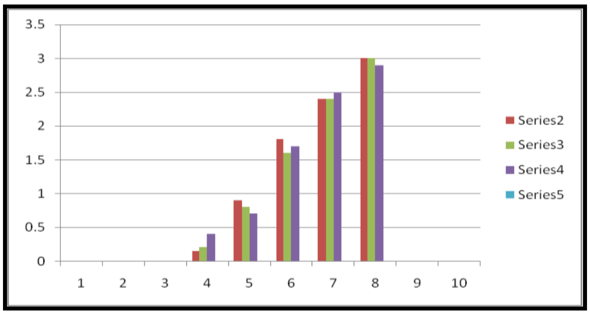

Figure 5: Variation of Brake Power with Load

5. Smoke opacity with diesel and biodiesel blends

Smoke opacity with different blends of soybean methyl ester is shown in Fig. 6. The smoke level increased sharply with increase in load for all blends. It was mainly due to the decreased air–fuel ratio at such higher loads when larger quantities of fuel are injected in to the combustion chamber, much of which goes partially burnt into the exhaust. The smoke opacity of SB blends was found be higher than diesel. The smoke opacity for SB10 was 38.15% higher than that of diesel fuel at full load of the engine. The smoke opacity was found maximum for SB10 blend and minimum for SB20 blend.

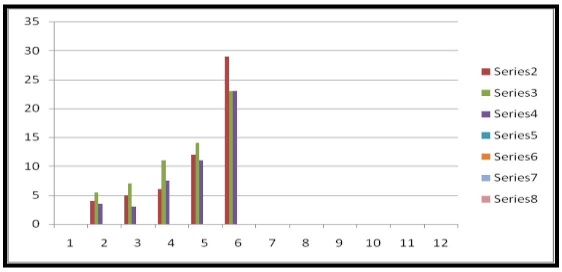

Figure 6: Effect of load on smoke opacity

3.6. NOX(PPM)

The effect of compression ratio on emissions of NOx for RB05 blend at different compression ratio is shown in Fig.7. The NOx emissions of diesel and biodiesel blend (RB05) were less at lower loads and more at medium and high loads than those of diesel fuel. It is due to the higher oxygen content and combustion temperature of the biodiesel at medium and high loads. The NOx emissions increased with the decrease in compression ratio. It is seen from the figure that the compression ratio 17.0 and 16.5 are found to have closer values to each other with rice bran as a fuel, whereas at a CR of 17.5 minimum NOx emission was observed.

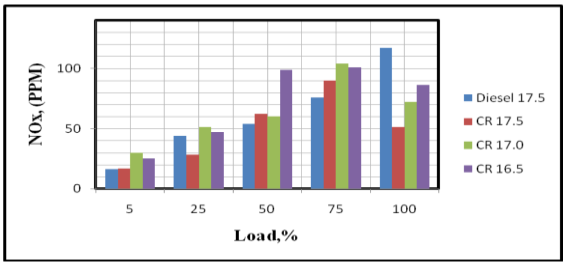

Figure 7: Effect of compression ratio on nitrous oxide at different loads

IV. CONCLUSION

A four stroke water cooled single cylinder direct injection diesel engine was run successfully using soybean oil methyl ester and diesel as fuel. The performance and emission characteristics have been analyzed and compared to baseline diesel fuel. The following conclusions are made with respect to the experimental results.

1. Similar brake thermal efficiency was observed for SB10 and SB20 as that of diesel at compression ratio of 12.At compression ratio 14 maximum brake thermal efficiency was observed for SB10 higher than that of compression ratio 12.
2. Nearly same brake specific fuel consumption was observed for SB10 and SB20 as that of diesel at compression ratio 12. A slight decrease in the specific fuel consumption was observed for SB10 at full load condition for compression ratio14.Maximum brake specific fuel consumption was observed for SB40 for both the compression ratio.
3. SB10 and SB20 showed better carbon monoxide and carbon di oxide emission than diesel at both compression ratios.
4. A higher NOx emission was observed as compared to diesel.

SOME is renewable and biodegradable can be successfully used as alternative fuels in existing diesel engine without any major modification of the engine hardware.

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