Experimental Investigation of Performance and Emission Characteristics of Single Cylinder Diesel Engine using Jojoba Biodiesel and their Blends with Diesel

Manjunatha[1], Dr. C.H. Biradar[2]

[1]M.Tech Scholar in Thermal Power Engineering, Department of Mechanical Engineering, PDA College of Engineering, Kalaburagi-585102, Karnataka, INDIA
[2]Head Department of Automobile Engineering, PDA College of Engineering, Kalaburagi-585102, Karnataka, INDIA

Abstract - *In this study the Jojoba oil was extracted from Jojoba seeds by mechanical expeller and Jojoba oil was transesterified with methanol using Sodium Hydroxide as a Catalyst to obtain Jojoba Biodiesel (Jojoba methyl Ester). A four stroke single cylinder water cooled constant speed diesel engine with different load conditions is used for the performance and emission characteristics of Jojoba biodiesel and their blends with diesel for injection pressure of 200 bar and injection timing of 23°bTDC maintained constant throughout the experiment. Diesel and Jojoba biodiesel blends (10%, 20%, 30%, and 40%) are used for the experiment of performance and emission characteristics at various engine loads (0%, 25%, 50%, and 75%). The variations of all engine performance parameters and exhaust emissions were plotted with respect to Brake Power. Among the blends JB20 (Jojoba biodiesel 20%+Diesel 80%) shows better performance with Brake Thermal Efficiency and Brake specific fuel consumption. Among the blends JB100 shows higher HC emission 92ppm at 50% load. The JB30, JB40 shows lower CO emissions at no load and 75% load when compared to diesel. In case of NOX emissions JB30 has lesser NOX emissions of 28, 572, 828, 967ppm respectively at 0%, 25%, 50%, and 75% load compared to diesel fuel.*

Key Words: Jojoba Biodiesel, Transesterification, Performance, Emissions characteristics.

1. INTRODUCTION

1.1 Fossil Fuel Scenario

The consumption and demand for the petroleum products are increasing every year due to the increase in population and urbanization. For the industrial and economic growth of country will depend on electricity supply and transport facility. Economic development and political factors has led to a high demand for energy. The energy as we demand is mainly derived from fossil fuels that are going to be depleted. Due to globalization in developing countries like India, china the consumption of petroleum products increases year by year. The increase in crude oil import affects the country's economy and development this will lead to increase in import bill [1]. The world will need 50% more energy in 2030 than today of which 45% will be accounted for China and India. Thus the search for alternative fuel for IC engines for automobile applications and for stationary motive power has become important [2]. At present India is producing only 30% of the total petroleum fuels. India is the fifth largest energy consumer and imported nearly 70% of its crude oil requirement (90 million tonnes) during 2003-2004, which costs about 80000 crore every year [3]. The combustion of fossil fuels is the dominant global source of CO_2 emissions. Hence renewable energy options have been discovered in the area of solar, wind, biomasses have been discovered and those are eco-friendly than conventional energy fuels [4]. Diesel fuels have an essential function in the industrial economy of a developing country and used for transport of industrial and agricultural goods and operation of diesel tractor and pump sets in agricultural sectors [5]. Moreover, the depleting resources of petroleum based fuels, the increasing threat to the environment from NO_X, CO, and hydrocarbon emissions and global warming to which automotive engines are the main contributors have given momentum to the search for alternative fuels which are renewable [6]. The vegetable oils cannot be used directly in diesel engines as they have higher viscosity than diesel fuel. Hence viscosity of vegetable oils can be done by using chemical treatment like transesterification. Non edible oil sources are suitable for biodiesel production. Among the non edible oil sources Jatropha, Neem, pongamia, Mahua, Kusum, Jojoba etc are perfect replacement or alternatives for the diesel engines. Biodiesel has attracted wide attention in the world due to its renewability, biodegradability, non toxic and environmental benefits [7]. The production of biodiesel can be obtained by the simple process called transesterification in which the reaction of a fat or vegetable oil with an alcohol in presence of catalyst to form esters and glycerol. A catalyst is used to improve the reaction rate and yield [8].

K.sureshkumar et al have tested single cylinder diesel engine by using pongamia biodiesel and its blends with diesel. It is found that blends up to B40 will give the less emissions and better performance and this could fulfill the economical and environmental conditions [9]. Swarupkumar nayak et al are carried out the mahua biodiesel using additive (Di-methyl carbonate) in a single cylinder, four stroke, water cooled diesel engine. Their results reveal that increasing in the brake thermal efficiency with the increasing in additive percentage in the biodiesel blends. However, CO and HC, emissions increases while, smoke and NOx emissions are reduced with increase in additive percentage in biodiesel [10]. R.D.Misra et al conducted an experiment on performance and emission characteristics of single cylinder direct injection diesel engine using karanja oil and karanja biodiesel. From this experiment shows that at all load higher percentage blends gives the lower brake thermal efficiency due to the higher viscosity, incomplete combustion and spraying problems. The brake specific energy consumption increases due to the low heating value and higher density [11]. R.D.Misra et al conducted experiment on performance, emission, combustion evaluation of soapnut oil- diesel blends in CI engine. SNO 10 has an overall better performance with respect to both engine performance and emission characteristics [12]. P.K. Devan et al conducted experiment on performance and emission characteristics of Eucalyptus oil and diesel blend at various injection timing in a diesel engine. The brake thermal efficiency increases with increase in the eucalyptus oil blend is due to increase in 2calorific value with respect to increase in eucalyptus oil proportion in blend and brake specific energy consumption decreases due to increase in density and calorific value [16].The objective of the present work is to study the performance and emission characteristics of single cylinder diesel engine using jojoba biodiesel and its blends with diesel. In this jojoba biodiesel and its blends with diesel are chosen as test fuels. Initially the raw jojoba oil is converted to biodiesel and various blends of biodiesel and standard diesel fuel are prepared. Then the investigation is carried out on the performance and emission characteristics of single cylinder diesel engine at 200 bar injection pressure. The tests were carried out at a constant speed under variable load conditions.

2. Materials and methodology

2.1. Materials

The jojoba plant seed (Simmondsiachinensis) contain 40-45% of oil content which is non-edible oil suitable for production of biodiesel. The jojoba seeds were purchased from Santo group store, Rajasthan, India. The Methanol, NaOH and Phenolphthalein indicator were purchased from Shree venkatesh chemicals store, kalaburagi, Karnataka, India.

2.2 Oil Extraction

The jojoba seeds are initially dried for the removal of moisture content. The dried seeds are crushed by using mechanical expeller.

2.3 Transesterification

The Jojoba oil was heated in order to remove moisture content before reaction. The NaOH is used as catalyst. Initially the sodium methoxide solution was prepared by dissolving 6.5g of NaOH pellets in 300ml of methanol in separate beaker and stirred up to complete dissolving of NaOH for 15 min. The resultant Methoxide solution was put into one litre of Jojoba oil, the mixture was heated at 60° c and with stirring for 2 hours at 500 rpm using magnetic stirrer. Then the reaction mixture was cooled to room temperature and allowed to settle down resulting in separation of two phases. The upper phase contained biodiesel and lower phase contained glycerine as byproducts which were separated by simple decantation. The biodiesel layer contains excess methanol, catalyst, and soap formed glycerides. These are removed by successive washing. After washing process biodiesel is heated at 110°c for 30min in order to remove complete water droplets from prepared jojoba biodiesel.

2.4 Characterization of Test Fuels

The physico-chemical properties of diesel, jojoba biodiesel and diesel-biodiesel blends were determined and depicted in Table.1. The bomb calorimeter was used to determine the calorific value of prepared test fuels. The Cannon - Fensky viscometer was used to determine the viscosity of diesel and jojoba biodiesel blends. The Pensky Marten's apparatus is used to determine flash and fire points. These tests were carried out as per ASTM and other standard procedures.

Table.1 Physical properties of test fuels

Properties	unit	JB10	JB20	JB30	JB40	JB100	DIESEL	CRUDE
Density	g/cm³	0.840	0.853	0.860	0.865	0.876	0.833	0.920
Viscosity	cSt	2.77	2.96	3.26	3.74	6.26	3.23	33.85
Flash point	°c	75	98	115	130	160	60	-
Fire point	°c	86	110	125	140	170	70	--
C.V	Mj/kg	42.98	41.64	40.9	40.5	39.88	43.30	--

2.5 EXPERIMENTAL SET UP

The specifications of the test engine are given in the Table 2. Figure1. shows the schematic diagram of the test engine. The setup consists of a single cylinder four stroke water cooled diesel engine developing a power of 3.5 kW at rated speed of 1500 rpm was used for the experiment. The engine was coupled to eddy current dynamometer was used for the of engine loading. An infrared AVL5 exhaust gas analyzer was used for the measurement of CO, CO_2, HC and NO_X emissions and smoke opacity was measured using an AVL 437 smoke meter.

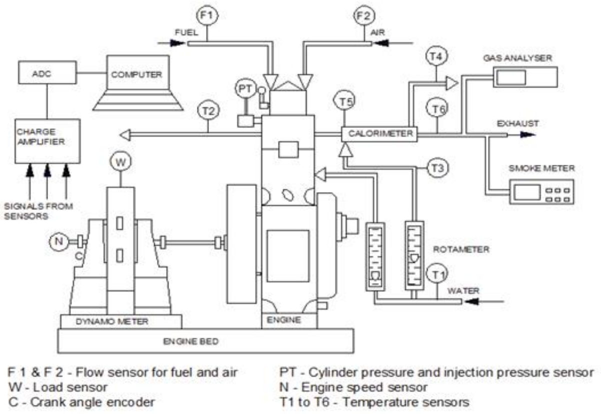

Fig.1. Schematic diagram of the Experimental Set up

Table 2 Specifications of Test Engine

Model and Make	TV1, Kirloskar
No. of cylinders	One
Cycle of operation	Four stroke
Dynamometer	Eddy current
Rated power output (kW)	3.50
Rated speed (rpm)	1500
Bore × stroke (mm)	87.5 × 110
Compression ratio	17.5:1
Cooling system	Water cooled
Displacement volume (cc)	661cc
Injection Pressure (Bar)	200
Injection Timing	23^0 BTDC

2.5 EXPERIMENTAL PROCEDURE

The engine performance tests were carried on a single cylinder four stroke water cooled diesel engine by using diesel, jojoba biodiesel and diesel- biodiesel blends. Before starting the engine checking roto meter level and fuel flow meter and lubrication. Initially engine is started by using diesel and when engine reaches some operating temperature 25% load will be applied. Then load is increased to 50% to 75% gradually. The tests were conducted at rated speed of 1500 rpm. The same procedure will be repeated for other blends of test fuel. In every test brake thermal efficiency, specific fuel consumption, brake power, brake mean effective pressure and exhaust gas temperature. Engine exhaust emissions such as CO, CO2, HC, OPA and NOx are recorded. Same procedure will be repeated for other test fuels also.

3. Results and Discussion

Engine tests were carried out at different engine load (0%, 25%, 50%, and 75%) respectively by different brake power. The performance and emission characteristics of diesel engine with diesel, jojoba biodiesel and diesel-biodiesel blends. The obtained results are compared with base diesel.

3.1. Performance Characteristics

The Performance parameters like Brake Thermal Efficiency, Brake Specific Fuel consumption and Exhaust Gas Temperature are discussed.

3.1.1 Brake thermal efficiency

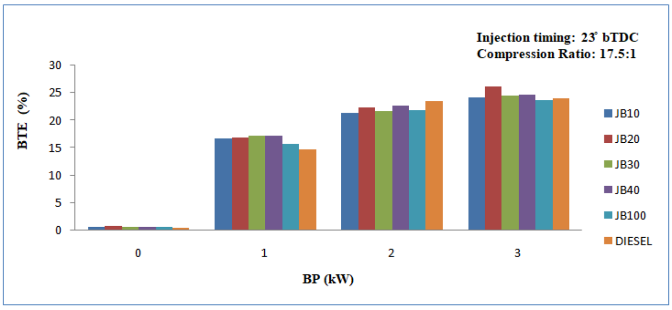

Fig.3.1 Variation of BTE with respect to brake Power

The variations of brake thermal efficiency with respect to brake power for different fuel blends as shown in figure 4.1. It is observed from the graph that with increasing brake power the BTE of jojoba biodiesel blends increases. The brake thermal efficiency indicates the conversion of fuel energy into useful work. The BTE of pure biodiesel is lower than neat diesel due to higher viscosity, specific gravity and lower heating value of fuel. The maximum BTE, 26.05, 24.59, and 24.38% observed for JB20, JB40 and JB30 at 3kW BP.

3.2.2 Brake specific fuel consumption

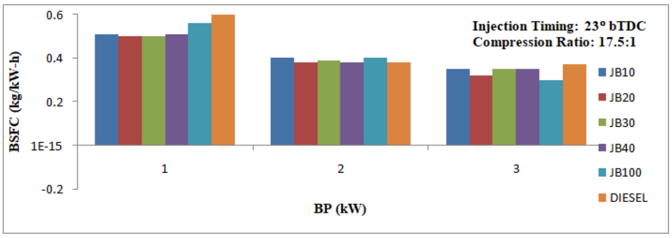

Fig.3.2 Variation of BSFC with respect to brake power

The figure 3.2 shows the variation of specific fuel consumption with respect to brake power for different fuel blends. The specific fuel consumption of all fuels decreases with increasing load. It is observed that BSFC is highest for pure biodiesel (JB100) as compared to all prepared fuel blends. At 1kW brake power the diesel fuel shows higher BSFC compared to other test fuels. Whereas JB10, JB30, JB40 shows similar fuel consumption at 75% load. The maximum BSFC, for JB10, JB20, JB30, JB40, JB100 and diesel were found to be 0.35, 0.32, 0.35, 0.35, 0.37 and 0.35kg/kW-h respectively.

3.1.3 Exhaust Gas Temperature

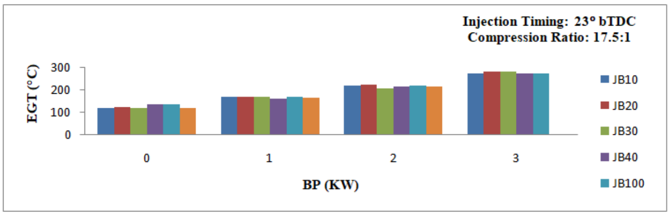

Fig.3.3 Variation of EGT with respect to brake power

The variations of exhaust gas temperature with respect to brake power for different fuel blends as shown in figure 3.3. It can be seen from graph that exhaust gas temperature is increased along with the increase in engine load for all prepared blends. The EGT increases due to increase in fuel consumption. The increase in EGT with increase in brake power. At higher load the exhaust gas temperature of all other fuels has less compared to diesel. At no load the diesel has less EGT than other blends. At 3kW BP, the EGT of Diesel was 284.39c higher than all test blends.

3.2 Emission characteristics

3.2.1 Hydrocarbon emissions

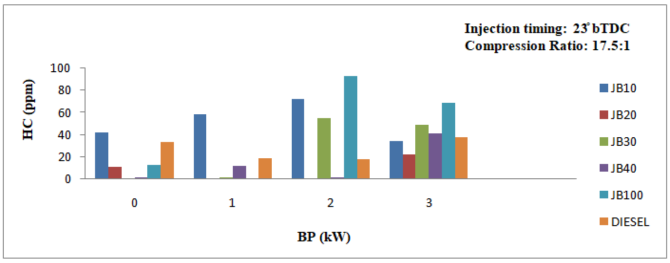

Fig3.4 Variation of HC emissions with respect to brake Power

Figure 3.4 shows the variation of unburnt hydrocarbon emissions with respect to brake power. A minimum HC emission observed for JB20 and JB40 blends at 0%, 25%, and 75% load respectively. For JB20 and JB100 blends the HC emissions are nil at 25% load. At 3kW BP, minimum value of UHC emissions for JB20, JB10 and diesel were observed to be 22, 34 and 38ppm respectively. Among all the test blends JB100 gives highest UHC emissions i.e 92ppm at intermediate load. At 25% load JB10 has more HC emissions due to incomplete combustion and where as JB20, JB30, JB40, JB100 have less emissions. At higher loads the JB100 have highest HC emissions among all blends this may be due to the higher viscosity and poor atomization. The HC emissions increases for JB10 blend at 0%, 25%, 50% load respectively.

3.2.2 Carbon Dioxide Emissions

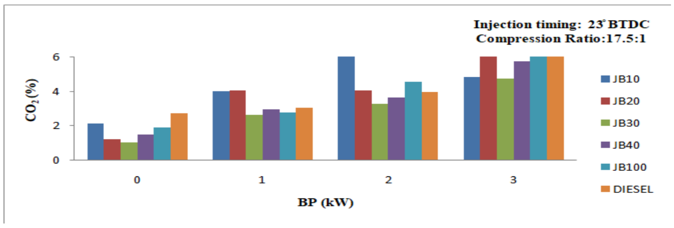

Fig.3.5 Variation of CO2 emissions with respect to brake Power

The figure 3.5 shows the variations of the carbon dioxide emissions with respect to brake power for jojoba biodiesel and diesel blends. The carbon dioxide emission increases with increase in brake power. At intermediate load JB10 has a highest CO_2 emission than compared to other prepared fuels. At 3kW BP, JB20 blend gives highest CO2 emission than all prepared test fuels. CO_2 emissions for JB20, JB40, JB100 and Diesel shows higher CO2 emission at 75% load. The maximum CO_2 emission observed at 75% load for JB100, Diesel and JB20 are 7.57%, 6.70% and 6.13% respectively. CO_2 emission of JB30 blend is lower than neat diesel and other test blends at all brake power.

3.2.3 Nitrogen oxide emissions

The figure 3.6 shows the variations of NO_X emissions with respect to brake power for jojoba biodiesel and diesel blends. It is observed from figure that the formation of NO_X emissions increases with increase in engine load for all blends and diesel because of maximum exhaust temperature. From graph JB10 blend gives higher NOX emissions than mineral diesel at 75% load. Among all blends JB30 has lesser NO_X emissions than all other prepared blends for all tested loads. Average value of NO_X emissions was observed as 1621, 1581, 967, 1426, 1433 and 1500 for JB10, JB20, JB30, JB40, JB100 and mineral diesel at 3kW BP.

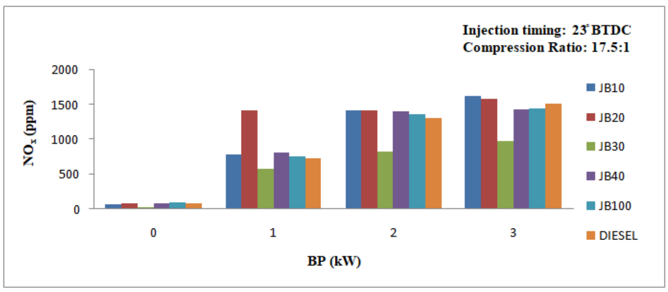

Fig.3.6 Variation of NOX emissions with respect to brake Power

3.2.4 Carbon Monoxide Emissions

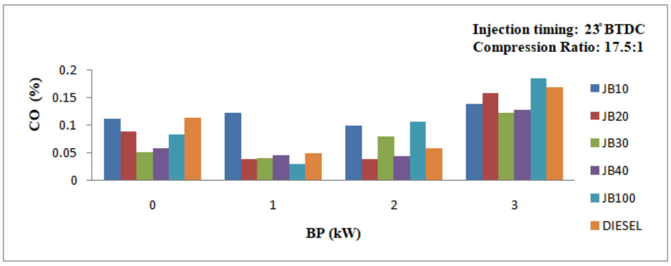

Fig.3.7 Variation of CO emissions with respect to brake Power

The variations of carbon monoxide emissions of jojoba biodiesel and diesel fuel operation at different load conditions are shown in figure 3.7. The blends of JB10, JB20, JB30, JB40 and pure biodiesel have lesser carbon monoxide emissions at no load condition as compared with petroleum diesel. At 75% load pure biodiesel has higher CO emission then diesel it may be due to improper combustion, higher viscosity. At higher load engine requires richer air-fuel mixture this resulting in more CO emissions. Higher viscosity, improper spray characteristics with higher percentage of blends resulting in the incomplete combustion may have increased the CO emissions.

3.2.5. Smoke Opacity Emissions

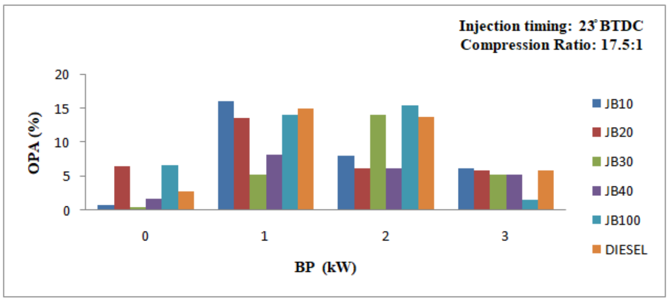

Fig.3.8 Variation of OPA emissions with respect to Brake Power

The figure 3.6 shows the variations of smoke level with respect to brake power for jojoba biodiesel and diesel blends. The smoke level is less for JB10, JB30, and JB40 blends at no load condition. At 75% load pure biodiesel has less smoke level then diesel and other blends due to complete combustion of fuel. Higher smoke opacity may be due to the poor atomization of fuel blends. The reason for the lesser smoke level due to the high heat combustion temperature and complete combustion. It is observed from Fig3.8 JB10 blends shows maximum smoke level as compared to base diesel.

4. CONCLUSIONS

The performance and emission characteristics tests of jojoba biodiesel and its blends with diesel were conducted in single cylinder diesel engine at different loads and at constant speed of 1500rpm. The brake thermal efficiency of blends increases as the load increases. The variation of brake thermal efficiency increases with increase in engine load this may be due to the increase of brake power. At maximum load JB20, JB40 exhibits higher BTE compared to diesel. Compared to diesel the pure biodiesel has quite higher specific fuel consumption values. The exhaust gas temperature is increased along with the increase in load for all blends. The increase in EGT is due to the more fuel is required for the higher loads.

The blends JB20, JB30, JB40, JB100 exhibits lower hydrocarbon emissions at lower load conditions due to the high oxygen content of biodiesel leads to complete combustion. At 75% load JB100 has more HC emissions. Among all blends JB20 has lowest HC emissions at 75% load and this will be good for diesel engine. The CO_2 emissions are lesser for the lower load conditions. But for JB100 the CO_2 emission is higher than diesel. The formation of NO_X increases with increase in engine load for all blends and diesel. For JB10 at lower load and for JB100 at 75% load the NO_X emissions are comparable to diesel. The NO_X emissions of diesel increasing gradually as load increases. Higher NO_X emissions are because of higher exhaust temperature. All fuels have lesser CO emissions than diesel at no load condition. At 75% load JB100 has higher CO emission than diesel due to improper combustion and higher viscosity. Higher viscosity, improper spray characteristics of higher blends resulting in the incomplete combustion. At lower loads JB30 has less CO emission than diesel and at higher load JB40 has less CO emission than diesel. In case of smoke opacity all the blends exhibit same smoke emission compared to diesel. Among all blends JB40 can use for the lesser smoke emission compared to diesel. Smoke opacity is less for the blends JB10, JB30, JB40 at no load condition. But at 75% load JB100 has least smoke emission than the diesel and other blends. Lesser smoke levels for some blends because complete combustion due to presence of oxygen and high heat combustion temperature.

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