Exhaust Emission Studies of Diesel and Soybean Oil Blends as CI Engine Fuel

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Abstract

A study was conducted on fuel blends prepared using diesel and refined soybean oil combinations compatible with diesel fuel as used in CI engines. A stationary 3.73 kW Kirloskar make single cylinder compression ignition diesel engine having 27° BTDC (standard injection timing) was tested as per IS 10000 - 1980 on diesel and prepared diesel blends. The performance tests of the engine were carried on at no load, 25, 50, 75, 100 and 110 % brake load conditions and emission of CO, UBHC and NO_x was evaluated for each fuel blends. The emission of CO, UBHC, nitric oxide and nitrogen dioxide from the engine on diesel - refined soybean oil blends was in the range of 0.21 to 0.85%, 0.01 to 0.16%, 12.7 to 317 ppm and 3.8 to 41 ppm, respectively. The results indicated that the emission of CO and UBHC on the selected blends was found comparable but the NOx level was found to be higher than the diesel. A blend having diesel - refined soybean oil mixed in 80:20 proportion replacing 20 percent diesel may be selected for fuel use in CI engines.

Keywords : Alternate fuel, Vegetable oil, Diesel engine, Emission, Blend

Introduction

In the present age of energy crisis researchers all over the world are paying attention on the development of various alternative fuels using renewable as well as blends of renewable and non-renewable fuels. This includes biogas, producer gas, methanol, ethanol, vegetable oils apart from liquefied petroleum gas (LPG) and compressed natural gas (CNG). The world wide emphasis on the use of alternative liquid fuels of renewable nature in engines has also acquired attention in India because of rising fuel prices, limited resources of petroleum based fuels and environmental pollution caused by them. India has incurred an expenditure of Rs 70,442 crore in the year 2000-01(India, 2002) which was about 6.56 % of its NNP. Thus, search for alternative fuels for internal combustion engines both automobile applications and stationary motive power is equally important for India as they consume more than one third of our crude oil import.

In the recent past vegetable oils (Peterson, 1986), alcohols (Gupta, 1983) and biogas have been found to be promising fuels for compression ignition (CI) engines. However, problems of transportability to distant use points of biogas, high viscosity and gumming tendency of crude vegetable oils have limited their capabilities to supplement diesel fuel in a large way. Vegetable oils, straight or modified are known to offer several advantages as engine fuel. These include better self-ignition characteristics, compatibility with fuel injection system of the CI engines, high-energy content along with safe processing and handling. Based on simple calculations researchers have indicated that one hectare of an oil seed crop can fetch adequate oil to meet the energy needs of 8 to 10 hectare of agricultural farm (Bruwer el al., 1980).

It has been reported that in diesel engines, crude vegetable oils can be directly used as fuel or it can be blended with the diesel (Shyam et al., 1984). This idea dates back to early part of last century in 1900 when Rudolph Diesel, the inventor of the diesel engine used Peanut oil to fuel the engine (Clevenger et al., 1988). The higher viscosity of vegetable oils when injected into the cylinder does not atomize properly for combustion. It results into incomplete combustion of the fuel and build-ups of the carbon deposits on the injector head and piston (Bruwer et al., 1980).

Therefore, several techniques are being used to reduce the viscosity. But amongst them the blending has given quite satisfactory results

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without involving major conversion techniques and has low processing cost. The most popular diesel–vegetable oil fuel combinations have been resulted from the blending of the vegetable oils with conventional diesel fuels as they improve fuel properties, give better engine performance than using vegetable oils alone as engine fuel.

The present study has been conducted on assessing feasibility of liquid renewable fuels using diesel and refined soybean oil combinations in internal combustion (IC) engines. The performance of the engine in terms of emission of carbon monoxide (CO), un-burnt hydrocarbon (UBHC) and nitrogen dioxide (NO_2) were evaluated.

Materials and methods

The performance evaluation of a 3.73 kW engine commonly used in Indian agriculture for different farm works such as operation of irrigation pumps, power threshers, rice and pulse milling machine, floor mills, cane crushers and also for electric generators was made on different diesel and refined soybean oil blends.

Engine performance test

The performance test of the engine was conducted as per I.S. standard (Bureau of Indian Standards, 1980). Initially the engine was run on no load condition and its speed was adjusted to 1600 ± 10 rpm by adjusting the screw given with the fuel pump rack. The selection of blended fuels was carried out on the basis of the blends reported in the past studies and proportion of replacement of diesel by renewable fuels, stability of blends based on homogenous mixing and solubility of different constituents. The fuels as shown in Table I were selected for study.

Exhaust Emissions Measurement

The emissions of carbon monoxide, un-burnt hydrocarbons, nitric oxide and nitrogen dioxide in exhaust by different fuel blends at various loads were measured.

Carbon monoxide emission

The CO content of exhaust gases emitting from burning of different fuel types at different load conditions were analyzed using a Nucon–5700 gas-liquid chromatograph. In order to determine the CO content at different load conditions, the exhaust gas samples were collected in 20 ml syringe. The gas chromatograph was calibrated by injecting 1 ml standard CO sample having 1.05 percent CO in nitrogen using a Hamilton make gas tight syringe. The elution time as well as peak obtained was recorded. Thereafter, 1 ml from the exhaust gas samples already collected in 20 ml syringe was injected in to the chromatograph. The elution times as well as peak obtained were again recorded. The amount of CO in the unknown sample was determined by comparing the peak of unknown sample with that of standard one. Each sample was replicated thrice and the average was calculated.

Un-burnt hydrocarbon emission

The measurement of un-burnt hydrocarbon in the exhaust gases was made using a Nucon make, model 4900 hydrocarbon analyzer. The exhaust gas sample was fed in to the analyzer through a pump. The analyzer has an electrochemical sensor and indicates the percent un-burnt hydrocarbon in exhaust gas. The total range of the analyzer was 0–10 percent. The measurements of un-burnt hydrocarbon were made at different load conditions.

Nitric oxide emission

A Nucon make nitric oxide analyzer, model 500–NO was used for the measurement of nitric oxide in the exhaust gas. The instrument uses an electrochemical transducer that operates on 230V AC. It has a range of 0 –1999 ppm. The exhaust gas sample was directly drawn from exhaust gas manifold using a 3 mm PVC pipe and fed to analyzer for all the selected load conditions.

Nitrogen dioxide emission

The nitrogen dioxide content in engine exhaust gas emitting from burning of different fuels samples was measured with the help of a Nucon make NO_2 analyzer- model 500. The samples were drawn from the exhaust pipe of the engine using 3 mm diameter PVC pipe through a pump operating on 230V AC and fed in to the electrochemical sensor of the analyzer. The analyzer used had a range of 0 – 199.9 ppm. The measurements were carried out under different load conditions.

Results and discussions

Effect of fuel types on exhaust emissions

The emission of carbon monoxide (CO), un-burnt hydrocarbon (UBHC), nitric oxide (NO) and nitrogen dioxide (NO_2) from the engine at different load conditions on the selected fuel blends was measured.

Carbon monoxide emission from the engine

The carbon monoxide emission from the engine on diesel and the selected blends at different load conditions is shown in Table 1. The figure shows the variation in emission of CO from the engine with change in brake load. The table indicates that the emission of CO from the engine on diesel was in the range of 0.25 to 1.03 percent. It was also observed that the emission of CO varied in the range of 0.21 to 0.73, 0.40 to 0.91 and 0.54 to 0.85 percent on diesel - refined soybean oil blends mixed in the proportion of 90:10, 80:20 and 70:30 respectively between no load and 110 percent load conditions. The comparison of CO emission from the engine when developing its rated power indicates that it was lowest (0.21 to 0.73 percent) on the diesel - refined soybean oil blend mixed in 90:10 proportions. The comparison of CO emissions on different fuel types at full load conditions reveals that lower emission was recorded on the blend containing diesel-refined soybean oil (90:10). It is also evident from the result that the emission of CO was found to increase with an increase in content of refined soybean oil in a fuel blend. The above findings are in consistent with that of Clark et al., 1984 and Peterson and Reece, 1996 which showed lower emission of CO from a diesel engine operating on vegetable oils as fuel.

Emission of un-burnt hydrocarbon

The variation in UBHC emission with load is presented in Table 2. It has been observed that on diesel fuel, the emission of UBHC was 0.01 percent between no load to 75 percent load, 0.03 percent on full load and 0.05 percent on 110 percent load. Further, the UBHC emission from the engine between no load and 110 percent load ranged between 0.01 to 0.07 percent, 0.03 to 0.07 percent and 0.03 to 0.16 percent on the diesel-refined soybean oil blends having 10, 20 and 30 percent refined-soybean oil with diesel respectively. The results further indicated that at rated power, the emission of UBHC was higher on the blends having higher content of refined soybean oil.

Emission of nitric oxide

The level of nitric oxide emitted from the engine at different loads and the variation is presented in Table 2. The emission of nitric oxide from the engine on diesel fuel was found to be in the range of 9 to 216 ppm between no load to 110 percent load. The blends of diesel - refined soybean oil mixed in the proportion of 90:10, 80:20 and 70:30 were observed to have emission of nitric oxide in the range of 12.7 to 196, 13 to 218.3 and 19 to 317 ppm respectively between no load to 110 percent load conditions. Further, the results indicate that emission of NO at full load i.e. when the engine developed its rated power was lowest (164 ppm) on the fuel having diesel-refined soybean oil mixed in 90:10 proportions. The results also indicated that emission of NO on all fuel types gradually increased with increase in brake load. It is evident from the observed results that blending of refined soybean oil results into reduction of NO emission. These results are in accordance with the findings of Faletti et al., 1984 who reported that the emission of NO was lower on the fuel having vegetable oil.

Emission of nitrogen dioxide

It is evident from the Table II that the emission of NO_2 gradually increased with increase in brake load on all fuel types and was observed to be highest at 110 percent load. The results indicate that the level of NO_2 on diesel fuel varied between 4.5 to 22 ppm. The level of NO_2 emission was found to vary between 3.8 to 26, 5.6 to 30.9 and 8.2 to 41 ppm between no load and 110 percent load on diesel - refined soybean oil blends mixed in the proportion of 90:10, 80:20 and 70:30 respectively. It is evident from the observed results that at rated power, the emission of NO_2 was lowest (12.5 ppm) on diesel and was highest (40.6 ppm) on the blend having diesel-refined soybean oil- mixed in proportions the of 70:30.

The emission of NO_x from diesel engines depends on iodine number of fuel. The emission of NO_x increases with increase in iodine number. The iodine number of diesel as reported is 5.97 and that of soybean oil varies in the range 189-195 (Peterson et al., 2000). Due to this emission of NO_x (combination of NO and NO_2) was found higher on the blends compared to diesel particularly at part load conditions.

The emission of CO, UBHC and NO_x from a diesel engine may be around 0-2 percent, <100 to 2000 ppm and a few ppm to <1000 ppm respectively (Mathur and Sharma, 2001). The results indicate that the emission of CO and UBHC on the selected blends was found comparable but the NO_x level was found to be higher than the diesel. Based on above observation it may recommended that a blend having diesel - refined soybean oil mixed in 80:20 proportion replacing 20 percent diesel be selected for fuel use in CI engines. However, long duration tests of an engine on above fuel may be performed to establish effect of high carbon content of refined soybean oil on the performance of the engines and its component.

The study was conducted on fuel blends prepared using diesel and refined soybean oil combinations compatible with diesel fuel in a stationary 3.73 kW Kirloskar make single cylinder compression ignition diesel engine having 27° BTDC (standard injection timing). The emission of CO, UBHC, nitric oxide and nitrogen dioxide from the engine on diesel - refined soybean oil blends was in the range of 0.21 to 0.85%, 0.01 to 0.16%, 12.7 to 317 ppm and 3.8 to 41 ppm, respectively. The results indicated that the emission of CO and UBHC on the selected blends was found comparable but the NOx level was found to be higher than the diesel. Based on the results it may be concluded that a blend having diesel - refined soybean oil mixed in 80:20 proportion may replace 20 percent diesel for fuel use in CI engines.

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Table 1: Emission of Nitric Oxide and Nitrogen Dioxide from Kirloskar AVI engine on selected fuels

Sl. No.	Fuel Type	Brake Load (%)					
		No Load	25	50	75	100	110
		NO (ppm)					
1	Diesel	9.0	19.7	37.0	115.7	191.3	216.0
2	Diesel-Refined Soybean Oil Blend (90:10)	12.7	24.0	49.0	111.3	164.0	196.0
3	Diesel-Refined Soybean Oil Blend (80:20)	13.0	45.3	66.7	146.7	187.0	218.3
4	Diesel-Refined Soybean Oil Blend (70:30)	19.0	60.0	113.3	221.7	260.3	317.0
		NO_2 (ppm)					
1	Diesel	4.5	4.9	5.2	10.0	12.5	22.0
2	Diesel-Refined Soybean Oil Blend (90:10)	3.8	5.5	5.7	15.3	24.0	26.0
3	Diesel-Refined Soybean Oil Blend (80:20)	5.6	8.4	12.4	20.1	29.6	30.9
4	Diesel-Refined Soybean Oil Blend (70:30)	8.2	11.7	10.5	16.4	40.6	41.0

Table 2: Emission of Carbon Monoxide and Unburnt Hydrocarbon from Kirloskar AVI engine on selected fuels

Sl. No.	Fuel Type	Brake Load (%)					
		No Load	25	50	75	100	110
		CO (%)					
1	Diesel	0.25	0.32	0.32	0.59	0.72	1.03
2	Diesel-Refined Soybean Oil Blend (90:10)	0.21	0.28	0.36	0.52	0.60	0.73
3	Diesel-Refined Soybean Oil Blend (80:20)	0.40	0.56	0.61	0.85	0.76	0.91
4	Diesel-Refined Soybean Oil Blend (70:30)	0.54	0.68	0.49	0.57	0.84	0.85
		UBHC (%)					
1	Diesel	0 .01	0.01	0.01	0.01	0.03	0.05
2	Diesel-Refined Soybean Oil Blend (90:10)	0.01	0.01	0.01	0.01	0.04	0.07
3	Diesel-Refined Soybean Oil Blend (80:20)	0.03	0.01	0.01	0.01	0.04	0.07
4	Diesel-Refined Soybean Oil Blend (70:30)	0.03	0.04	0.02	0.05	0.08	0.16