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Experimentation on Emission Analysis of a Compression Ignition Engine Run with Bio-diesel

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Abstract: In this research, esterified Rice Bran Oil (RBO) and non-esterified RBO was investigated for its performance as a compression ignition engine fuel. In this context experiments were conducted on single cylinder water cooled diesel engine with diesel, RBO, preheated RBO and Bio-diesel (esterified RBO). Performance parameters like thermal efficiency, specific fuel consumption and emissions such as smoke, particulate mater, unburned hydrocarbon, carbon monoxide and oxides of nitrogen have been measured. The performance of the engine with diesel has been used as the basis for comparison.

Key words: RBO, esterified RBO, emissions, diesel engine, particulate, cylinder

INTRODUCTION

Need for alternate fuel: The rapid depletion of non renewable petroleum fuel and the environmental pollution caused by the burning of petroleum fuels have directed to an intensive search for alternative fuels.

Types of alternate fuels: Out of the three specific alternative fuels solid, gaseous and liquid fuels, considerable work was done on gaseous and liquid fuels. Liquid fuels such like Bio-diesel, vegetable oils and alcohols and gaseous fuels like Compressed Natural Gas (CNG), Liquified Petroleum Gas (LPG), methane and hydrogen were found to be promising for the use in CI and SI engines.

Literature review: Tajoo and Keoti (2013) experimentally determined peanut oil-diesel fuel blends fundamental physical properties to support aptness for use in compression-ignition engines. For volumetric proportions of peanut oil ranging in 20% increments from 0-100%, the continuously varying properties at 21°C were found to range as follows: heating value 45.8-30.3 MJ/kg; specific gravity 0.848-0.915; surface tension 28.3-35.6 mN/m and kinematic viscosity 3.8-7.0 CS.

Shamim have studied chemical and fuel properties of some vegetable oils. Oil samples were subjected to ASTM tests suitable for diesel fuels. The tests recognized some problem areas that are found with vegetable oil fuels. The oil samples were also categorized chemically and thus certain fuel properties were correlated to chemical compositions.

A comprehensive review was attempted by Ziejewski *et al*. (1996) and Choi *et al*. (1997) on the use of vegetable oil as fuel for stationary CI engines. Specific vegetable oils were reviewed individually and a relative survey was presented. Normally short term engine tests have been positive with vegetable oil; long-term tests have revealed the fuel's limitations according to lubricant contamination, deposits on engine surfaces and injection issues which unfavourably affected engine durability and its performance in the long term. Trans-esterification of some oils was reported to gain better long-standing performance. Different blends with diesel oil and pure vegetable oil have been deployed as engine fuels for relative performance studies and the best mixes sought for dissimilar oils.

Choli have investigated the performance and exhaust emission of a DI tractor diesel engine using mustard seed oil as fuel. Two dissimilar Mustard Seed Oils (MSOs) were tested. The unesterized MSOs were cleaned by letting them stand and clear. There were no alterations made to the turbocharged diesel engine. The engine made brake torque with MSOs was moreover, the same to the Diesel

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Fuel Oil (DFO). Relatively comparable brake thermal efficiencies were measured with MSOs than being measured with DFO. Usage of MSOs decreased the exhaust smoke and NO_x emissions. There were no big differences among the fuels recognized when the exhaust HC emissions were determined.

Diesel fuel and oleic safflower oil of high 25-75 (v/v) blend, a non-ionic sunflower oil-aqueous ethanol microemulsion, a 25-75 blend (v/v) of refined-alkali sunflower oil as well as diesel fuel and a methyl ester of sunflower oil were evaluated by Lee as fuels in a DI Turbocharged intercooled, 4-cylinder Allischalmers diesel engine during a 200 h EMA cycle laboratory screening endurance test. Phillips 2-D mentioned fuels engine performance functioned as the standard line for these experimental fuels.

Beg *et al.* (2013) have studied the effect of compression ratio on the performance and exhaust emissions of an insulated piston head Ricardo variable compression diesel engine by using linseed oil. The piston head of the engine was insulated by using partially stabilized zirconia with a bond coat alumina-boro silicate in an indigenous process. Results show that for the coating thickness BSFC, exhaust gas temperature, CD level and smoke density were increased but brake thermal efficiency and NO_x level were decreased both in linseed oil blends and esterified linseed oil compared to 100% diesel operation at different compression ratios.

Tanner have studied on the performance of a single cylinder water cooled diesel engine using methyl ester of Jatropha oil as the fuel which was evaluated for its efficiency and exhaust emissions. Results of investigations shows that the Jatropha ester can be used as much in diesel engines with no major determination in performance.

Reitz *et al.* (2010) have conducted critical reviews on the different aspects of the vegetable oils as substitute fuel for diesel engines including vegetable oil composition, fuel properties of vegetable oil and their blends, viscosity reduction techniques, optimum blending ratios, performance of engine using various blends and emission characteristics of the diesel engines using vegetable oil based fuels have been presented in this study.

Zhu *et al.* (2013) have investigated on the suitability of vegetable oils for diesel engine operation with out any modifications in its existing construction. Earlier investigations revealed that 30-40% mix of vegetable oils with diesel gave satisfactory working of the engine without any considerable change in its performance. In this investigation effect of injection pressure on engine performance with 30% vegetable oil-diesel blends is reported. Poola have investigated on the performance and emissions characteristics of a diesel engine with diesel linseed oil blends and esterified linseed oil. Effect of variation in injection pressure on the engine performance with test fuels were also studied.

Table 1: Oil content of bran from different mills

Mill type/Grade	Oil content (%)
Huller	
Raw	4-6
Parboiled	4-6
Shelter	
Raw	12-15
Parboiled	15-20
Modern	
Raw	15-20
Parboiled	25-30

Bio-diesel: Clean-burning diesel fuel is otherwise called as Bio-diesel which was made from both natural and renewable sources like vegetable oil. It is also called as “mono alkyl esters”.

Properties of Bio-diesel: Bio-diesel is the only substitute fuel that can be utilized directly in any current, unchanged diesel engine. Since, it has comparative properties to petroleum diesel fuel, bio diesel can be combined in any percentage with petroleum diesel fuel. Pure Bio-diesel is nontoxic, biodegradable and really free from aromatics and sulphur. The engines tear and wear emissions have also been identified reducing with the usage of Bio-diesel.

Bio-diesel production: Bio-diesel is made by transesterification process. In this process triglyceride of vegetable oil is converted into glycerol and esters of fatty acid. This fatty acid ester is known as “Bio-diesel”. Glycerol is a by product of esterification process. Concentration ratio of alcohol to fuel, temperature, catalyst type and stirring rate impacts the esterification procedure to more noteworthy degree.

RBO: Rice contains only a lesser quantity of oil. The germ and bran layers are separated from the endosperm, when paddy is milled. The milling residue which is commonly formed is known as “Rice Bran”. The oil mined from Rice Bran is named as the “RBO”. The oil content of bran is specified in Table 1. Rice Bran Oil contains a high proportion of mono-unsaturated fatty acids (37-48%) and di-unsaturated fatty acids (30-41%).

Cost: Table 2 shows the cost of various fuels.

Chemical composition of RBO: Table 3 gives the chemical composition of RBO.

Table 2: Cost of various fuels

Fuels	Cost/L (Rs.)
Gasoline	66
Diesel	50
RBO	44
Bio-diesel	43

Table 3: Chemical composition of RBO

Fuels	RBO
Myristic	0.4-1.0
Palmitic	12-18
Stearic	1-3
Oleic	40-50
Linoleic	29-42
Linolenic	0.5-1.0
rachidic	0
Beberic and lignoceric	0.2

MATERIALS AND METHODS

Problems in direct use of RBO: The foremost problem with the direct usage of RBO as fuel in diesel engines is their greater viscosity. It interferes fuel injection and atomisation and contributes to incomplete combustion, nozzle clogging, excessive engine deposits, ring sticking, impurity of lubricating oil, etc. The problem of greater viscosity of vegetable oils can be overwhelmed to a larger extent by various techniques such as preheating, dilution, emulsification and esterification, etc.

Ester of RBO: Single mole of the RBO and another three moles of ethanol are taken in a round bottom flask. The mixture is stirred vigorously and heated to about 70°C for one hour, since, RBO and ethanol are immiscible liquids. Now, the mixture is cooled to 50°C and then sodium hydroxide and little amounts of ethanol are added. Here sodium hydroxide acts as a catalyst. Again the mixture is heated to about 70°C for one hour and stirred vigorously. Reaction takes place and three moles of fatty acids and one mole of glycerol are produced. Glycerol is valuable by product.

Now the solution is cooled to 50°C and some amount of concentrated hydrochloric acid and cool water are added. Then, it is permitted to cool full night at room temperature without stirring. Two layers are formed. The bottom layer consists of glycerol and top layer is the ester otherwise called Bio-diesel. It is separated from the glycerol and then used as fuel.

Chemical reaction in Bio-diesel production: BO when reacted with ethanol in the presence of NaOH gives glycerol and ethyl ester of RBO.

Properties of RBO Ester: Viscosity of RBO Ester is very low comparable to Raw RBO. Density of the Raw RBO Ester is also reduced and comparable one with #2 diesel. Calorific value of the ester is slightly reduced. But the cetane number of ester is increased from the raw RBO. Cetane number, flash point and carbon residue of the ester is decreased from the raw oil values. Table 4 gives the properties of RBO and its ester.

Table 4: Properties of RBO and its Ester

Properties	No. 2 diesel	Rice bran oil	Rice bran oil ester
Density	840	910	875
Calorific value (kJ/kg)	43000	39465	38190
Viscosity at 38°C	2.7	38.5	3.9
Cetane number	47	40-45	50
Flash point (°C)	52	240	180
Carbon residue (%W)	0.35	0.24	0.10

RESULTS AND DISCUSSION

Experimental programme

Experimental programme for emission measurement: This chapter describes the experimental techniques carried on how to work on engine with various fuels such as diesel, raw and as well preheated RBO and Bio-diesel (RBO Ester).

Base line testing: The cooling water flow, the level of lubricant and the fuel level are checked while starting the engine. The fuel used for this testing is diesel. The engine load is released and it is cranked by retaining the decompression lever and the fuel act off lever of the fuel pump in the ON position. Then times taken for 10 CC of fuel consumption and the hydrocarbon, CO, smoke, particulate matter, NO_x and exhaust temperature are measured. Then the load is changed in steps of 20% and after reaching the steady state condition all the above readings are taken. The test is repeated up to 100% load. Before stopping, all the loads are released and the engine is brought to zero load.

Testing with raw RBO: The cooling water flow, the level of lubricant and the fuel level are checked while starting the engine. Thus, the engine is allowed to run for 15 min to reach the steady state conditions. Then, the time taken for 10 CC of fuel consumption and the hydrocarbon, CO, smoke, particulate matter, NO_x and exhaust temperature are measured. Then, the load is changed in steps of 20% and after reaching the steady state condition all the above readings are taken. The test is repeated up to 100% load. Before stopping, the engine is brought to zero load, by releasing all the loads.

Testing with preheated RBO: RBO is found to be highly viscous oil and it will block the injector nozzle and may damage the fuel pump and the injector nozzle in long term operation. Heating process reduces the viscosity and decomposes the components in the composition of the RBO. The temperature of 100°C is found to be optimum and thus, maintaining the temperature of the fuel around 100°C is found suitable for the experiment.

Heating and testing procedure: Oil is filled in the fuel tank and the level of fuel in noted down. Heating is done electrically by an immersion heater. The thermometer is immersed in the burette till its bulb is inside the fuel column. The heater is switched on and the temperature rise was followed. A temperature control unit can be used for maintaining the temperature of the fuel around 100°C.

The cooling water flow, the level of lubricant and the fuel level are checked while starting the engine. For this testing preheated RBO is used as fuel. The load on the engine is released. The engine is cranked by keeping the decompression lever and the fuel act off lever of the fuel pump in the ON position. When the engine starts, the decompression lever is disengaged. The time taken for 10 CC of fuel consumption and the hydrocarbon, CO, smoke, particulate matter, NO_x and exhaust temperature are measured. Then, the load is changed in steps of 20% and after reaching the state of steady condition, all the above readings are noted. The test is repeated up to 100% load. Before stopping all the loads are released and the engine is brought to zero load. The constant temperature of the fuel is maintained in this whole process.

Testing with Bio-diesel: The flow of cooling water, lubricant level and the fuel level are checked while starting the engine. Bio-diesel is used as fuel for this testing. The engine is cranked by keeping the decompression lever and the fuel act off lever of the fuel pump in the ON position. When the engine starts, the decompression lever is disengaged. The time taken for 10 CC of fuel consumption and the hydrocarbon, CO, smoke, particulate matter, NO_x and exhaust temperature are measured. After that the load is changed in steps of 20% and after getting the steady state condition all the above readings are taken. The test is repeated up to 100% load. Before stopping all the loads are released and the engine is brought to zero loads.

Experimental uncertainity: The engine exhaust emission like CO, HC, NO_x, smoke and particulate mater is calculated by using appropriate instruments.

CO measurement: CO is measured by using exhaust gas analyser. The analyser is switched on and left for 5 min to warm up. From the main menu, reading option is selected. Then, the sample gas is admitted to the analyser by using probe. Finally, the readings are taken from creen display. CO is measured in percentage volume unit.

Exhaust gas analyser: It is a fully microprocessor controlled exhaust gas analyser employing Non-Dispersive Infra-Red (NDIR) technique. The analyser measures carbon monoxide, hydrocarbons, carbon dioxide and oxygen in exhaust. Zero calibration can be ordered at any wanted time by the operator and automatically executed by the analyser. An automatic auto zero check is performed every 30 min when the analyser is switched on.

HC measurement: The unburned hydrocarbon is measured by exhaust gas analyser. It is measured in ppm volume unit.

No_x measurement: NO_x is measured by using exhaust gas analyser. NO_x is measured in ppm volume unit.

Technovation-89 gas analyser: The heart of the instrument is an electrochemical sensor which converts the concentration of gas encountered around it into an electrical signal which is sensed, amplified, compensated and displayed by the instrument in terms of ppm on LCD.

Measurement of smoke intensity: Smoke intensity is measured by IIP smoke meter. The filter paper is placed on the filter paper disc. The gas trial is drawn through the filter paper. Then the filter paper is evaluated by means of photocell reflector meter unit to give a precise assessment of the intensity of the spot. The intensity of the spot is measured on a scale of 10 arbitrary units called Bosch Smoke Unit (BSU).

CONCLUSION

The brake specific fuel consumption of the engine with Bio-diesel is greater than that of diesel. The exhaust gas temperature of diesel is less than Bio-diesel at full load conditions. Brake thermal efficacy of Bio-diesel is less than diesel. Bio-diesel produces significantly less amount of hydrocarbons. Bio-diesel produces more smoke emission than that of diesel. Blending with standard diesel fuel is usually done to improve the engine performance. The ratio of the blend is based on their molecular weight. Micro emulsification is one of the processes of reducing vegetable oils viscosity. The property of the oil obtained by micro emulsified vegetable oil can be studied and its feasibility of using as a fuel in engines can be done in future. Oxygen enrichment at the inlet can be tried. The vegatable oil combustion characteristics can be studied by analysing P-θ diagram. Bio-diesel produced from other vegetable oils like jetropha, karanji, neem, sunflower, palmoil, carcus, punga can be tried.

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