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Experimental Investigation on Compression Ignition Engine Fuelled by Biodiesel Blended With Diesel

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EXPERIMENTAL INVESTIGATION ON COMPRESSION IGNITION ENGINE FUELLED BY BIODIESEL BLENDED WITH DIESEL

Strictly as per the compliance and regulations of:

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S.K. Mahla[α] & S. Gomasta[σ]

Abstract - Increased environmental concerns and depletion of fossil fuel resources necessitates the search for a viable alternative fuel for diesel engine. Bio-fuels are renewable, can supplement fossil fuel, reduce green house gas emissions and mitigate their adverse effects on the climate changes resulting from global warming. However, further reduction in engine emission becomes one of major tasks in engine development. One promising approach to solve this problem is to add the oxygenated fuels in biodiesel. Biodiesel commands crucial advantages such as technical feasibility of blending in any ratio with petroleum diesel fuel. Superiority from the environment and emission front, its capacity to provide energy security to remote and rural areas and employment generation. In this paper, the investigation is made with addition of biodiesel in different proportion and effect on engine performance and emissions were computed. The emission is found to be reduced considerably while the engine performance is also improved marginally.

Keywords : Biodiesel, Rice Bran Oil, Diesel engine, Emission, Performance, Environment, Blending.

I. Introduction

The concept of using bio-fuels in diesel engine was originated from the demonstration of the first diesel engine by the inventor of diesel engine "Rudolf Diesel" at the world exhibition in Paris in 1900 by using peanut oil as a fuel. However, due to abundant supply of petro-diesel, R&D activities in vegetable oil were not seriously persuaded. It receive attention only recently when it was realized that petroleum fuels were dwindling fast, and environment friendly renewable substitute must be identified. In India, diesel engines being more efficient and sturdier than spark ignition engines are frequently used on Farms, in heavy trucks, city buses, locomotives, electricity generators farm equipments, underground mine equipments etc. Diesel used in diesel engine contains higher amounts of aromatics and sulphur, which causes environmental pollution. In recent years, serious efforts have been made by several researchers to use different sources of energy as fuel in existing diesel engines. Biodiesel is receiving increased attention as an alternative non-toxic, biodegradable and renewable diesel fuel. Properties of biodiesel are similar to mineral diesel and can be used in conventional diesel engines without significant modifications. It can be blended in any proportion with fossil based diesel to create a stable biodiesel blend. Therefore, the biodiesel has become one of the most common bio-fuels in the world.

The source of biodiesel usually depends on the crops amenable to the regional climate. Soybean oil in the United States and rapeseed oil in European countries are the most commonly used biodiesel. In tropical countries, palm oil and coconut oil are common sources of biodiesel. Rice bran is a by-product obtained from the outer layers of the brown rice kernel during milling to produce polished rice. In the present study rice bran Oil (RBO) is used for production of biodiesel. RBO is extracted from the rice barn, which is a by-product obtained during the grinding of paddy. Biodiesel from RBO offers significant potential as an alternative low cost feedstock for biodiesel production. Since rice is the staple diet in a large part of India, there is a huge potential to produce and utilize RBO. Though Indian is the second largest producer of paddy, hardly 50% of the barn is utilized for producing RBO and only 19% of edible grade RBO is consumed as a cooking media. Hence RBO is commercially feasible for biodiesel production.

Whole rice grain comprises Endosperm: 70- 72; Hull: 20; Barn: 7- 8.5; and Embryo: 2-3% (dry weight basis). Out of this 7- 8.5% of Barn contains: oil: 15- 20%; wax: 0.4- 1.5%; proteins: 5-8%; soluble carbohydrates: 40- 50%; fiber: 5- 8%; Typical composition of RBO is triglycerides: 81.3- 84.3%; diglycerides: 2- 3%; monoglycerides: 5- 6%; free fatty acids: 2 -3%; wax: 0.3%; glycolipids: 0.8%; and phospholipids: and unsaponifiables: 1.6%. The rice bran biodiesel is prepared in the laboratory through transesterification.

Biodiesel, which can also be known as fatty acid methyl ester (FAME) is produced by the transesterification (alcoholysis) of vegetable oil or animal fat and alcohol to yield fatty acid methyl ester (FAME) and glycerol, the key reaction is shown in Fig. 1.

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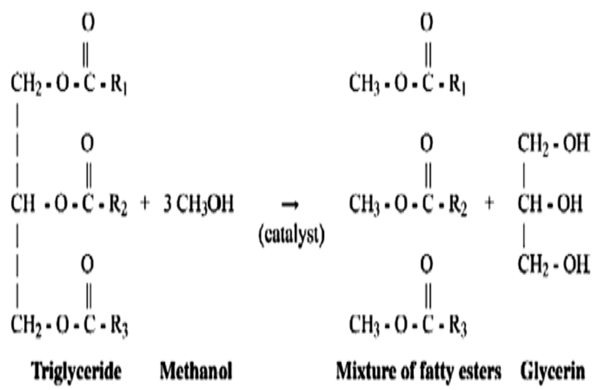

Figure 1 : Transesterification of triglycerides with methanol to FAME

The reaction is catalysed by alkali, acid or enzyme. When Triglycerides (TG) reacts with an alcohol, the three FA chains are released from glycerol skeleton and combine with the alcohol to yield FAME. Alkali (sodium hydroxide, potassium hydroxide), acids (sulphuric acid Hydro chloric acid) catalyze reaction. Alkali catalyzed transesterification is faster than acid catalyzed transesterification and is most used commercially. However, immediately following the milling process, rapid deterioration of the crude fat in the barn by lipase and to a lesser extent, oxidase makes the barn unfit for human consumption. Rice bran contains several types of lipase that are site specific and cleave the 1,3 site of triglycerols (TG). Depending on the nature of barn and the storage conditions, spoilage due to lipase continues after the milling [1]. Rapid increase in the free fatty acid (FFA) content in the rice bran occurs within hours, followed by about 5% per day increase in FFA content. The producing of an off flavour and soapy taste, and the change of functional properties of the barn were also reported [2]. Heating of barn immediately after milling inactivate the lipase and prohibit the formation of FFA. Various methods for the stabilization of rice barn have been described in the past [3]. However, due to the dispersed nature of rice milling, it is difficult to collect the barn continuously from the mills in large quantities, thus making central treatment impractical. Moreover, stabilization of barn results in additional cost. As a result, the utilization of rice bran is limited and is mainly used as animal feed and boiler fuel [4].

Haxane is commonly used as the solvent in the commercially extraction of oil from rice barn. RBO is one of the most nutritious oils due to its favourable fatty acid composition and a unique combination of naturally occurring biologically active and antioxidant compounds, such as ϒ- oryzanol, vitamin-E, Phytosterols, and tocotrienols [5]. In addition, rice bran also contains high molecular weight wax esters, which is a source of policosanols [6]. Although RBO is highly nutritional, it is not popular worldwide and its production is limited by several factors. Crude RBO has been difficult to refine because of its high content of FFA, unsaponifiable matter and dark colour [7]. The refining loss for RBO is particularly acute because of 2-3 times the percentage of FFA content in the oil. Due to the rapid splitting of lipid by active lipase present in the barn, RBO available in most Asian countries contain 40—50% FFA [8]. Crude RBO with less than 5% FFA is desirable for economic refining purpose. This leads to lack of widespread commercial use of RBO due to economic factors. As a result, only a small portion (<10%) of RBO is processed into edible oil. Hence RBO with high FFA content is potentially cheap feedstock for biodiesel production.

Alkaline – Catalysed Transesterification Alkali catalysed transesterifcation is used in the commercial production of biodiesel. Even at ambient temperature, the alkali catalysed reaction usually reaches 95% conversion in 1- 2 hour. On the other hand the acid catalysed reaction commonly requires temperatures above 100°C [9] and reaction times of 3- 48 hours have been reported, except when reaction were conducted in high temperature and pressure [10]. However for alkali-catalysed transesterification, the starting materials (oil or fat) must be dry and free of FFA. It is suggested that the FFA content of the refined oil should be as low as possible (below 0.5%) and Fuege and Grose also stressed the importance of oils being dry (<0.06%) and free of FFA [11].

II. Experimental Setup & Procedure

The present study was conducted on a single cylinder four stroke direct injection diesel engine of Kirloskar make, which is primarily used for agricultural purpose and house hold electricity generation as shown on figure 2.

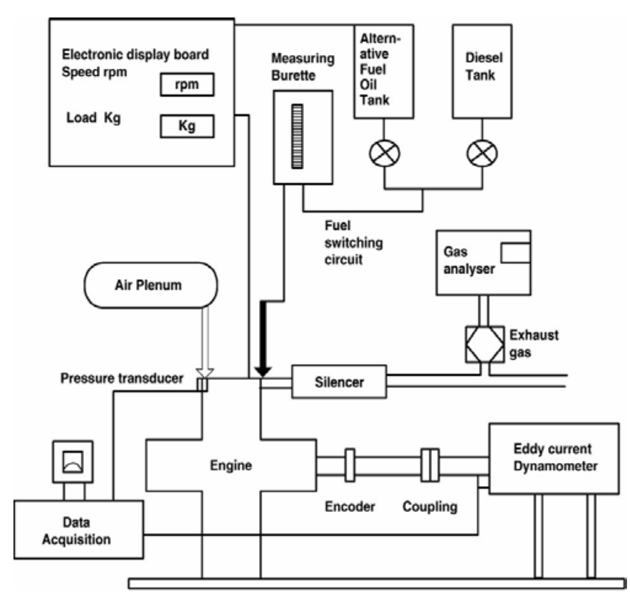

Fig. 2 : Experimental Setup

Engine was chosen as single cylinder because it was light and easy to maintain. Being air cooled means absence of radiator and water body and pump, made the system more suitable for the hot and arid conditions. The objective is to replace diesel fuel to the maximum without much loss of performance and significant reduction in emission. The compression ratio of 17: 1 and was normally aspirated and air cooled. The shaft of the diesel engine was coupled to generator set of 3KW capacity. A load bank was made using three numbers of 1KW electric heaters. The emission data were recorded with the help of automotive emission analyser AIRREX HG 540 & Gas Composition was measured from NAMTECH SM054. A calibrated burette and a stop watch were used to measure the volumetric flow rate of fuel. The schematic diagram of the experimental setup along with all instrumentation is shown in figure -2

Manufacturer	Kirloskar
Engine Type	Single cylinder, four stroke, air cooled, diesel engine
Bore/ Stroke	87.5/110
Rated Speed	1500 rpm
Rated Power	5 BHP/3.5 kW
Inlet valve opens/ Inlet valve closes	4°BTDC/35.5° ABDC
Exhaust V/v opens/ Exhuast V/v closes	35.5° BBDC/4.5° ATDC

Table 1 : Engine Specifications

The emission analyser was calibrated for standard diesel engine and set to zero before each experiment. The general specification of engine is given in table 1.

The fuels used in this study are standard diesel and biodiesel is prepared in the laboratory using transesterification process, which consists of a water bath, reaction flask with condenser and a mechanical stirrer. Flask has three openings, one for temperature measurement (reaction temperature), second for stirrer and third for condenser. The blending was done on volume basis. With three blend ratio of 0%, 5%, 10% and 20% of ethanol with 100%, 95% 90% and 80% of diesel respectively. The commercial diesel fuel and anhydrous ethanol were used for the preparation of different blends. Pure diesel fuel was used as base fuel for ethanol diesel blends in this study. Different diesel – biodiesel fuel blends were kept for 24 hours and they showed no phase separation in the blends. These were designated as B0, B5, B10 & B20. The experiments were conducted under steady state for four different load (No Load, 1KW, 2KW and 3KW load) conditions and three different proportions of blends. All data were collected after the engine was stabilized. All the gaseous emissions were measured after 20 minutes of running of engine so that the stable conditions were achieved and average result could be evaluated. The steady state tests were repeated to ensure that the results are repeatable.

III. Result & Discussion

Various parameters for engine performance and emissions were recorded using various proportions of blends of biodiesel and neat diesel at four different loading condtions of engine viz. no load, 33% load, 66% load and full load. The parameters under consideration were brake thermal efficiency, brake specific fuel consumption; brake specific energy consumption and exhaust gas temperature, whereas for emissions unburned hydrocarbon, carbon monoxide, carbon dioxides and smoke capacity were identified as key parameters.

Fig 1 represents the variation of brake thermal efficiency with engine load. As the load increases the brake thermal efficiency of the engine also increases from 2.5% at no load and 5% blend to 19% for full load at 20% blend ratio. The increase in efficiency is attributed to the increase the specific gravity of the blend along with the decrease in lower heating value, as a result lesser mass of the fuel is consumed and so the relative increase in the efficiency. The early initiation of combustion leads to a significant pressure rise before TDC complete combustion and hence increase in break thermal efficiency.

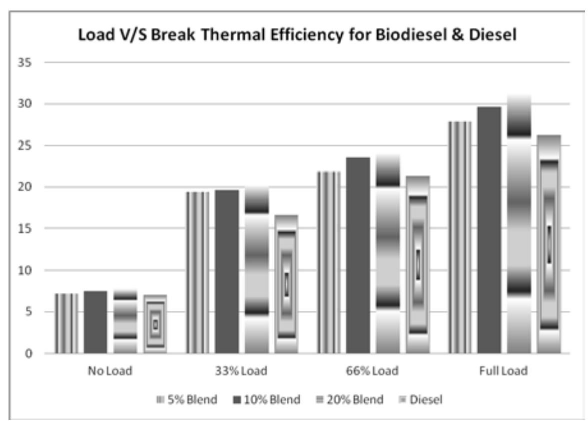

Fig.3 : BTE Vs Engine Laod

Fig 4 represents the variation of brake specific fuel consumption with engine load. The brake specific fuel consumption decreses with increse in engine load. this is evident from the Fig 3. Again the brake specific fuel consumption is reduced across the range of fuel and blend ratios. The reason for this is the increase in specific gravity of the blended fuel. The reduction is in the range of 2% to 16% from 5% blend at no load to 20% blend and full load conditions.

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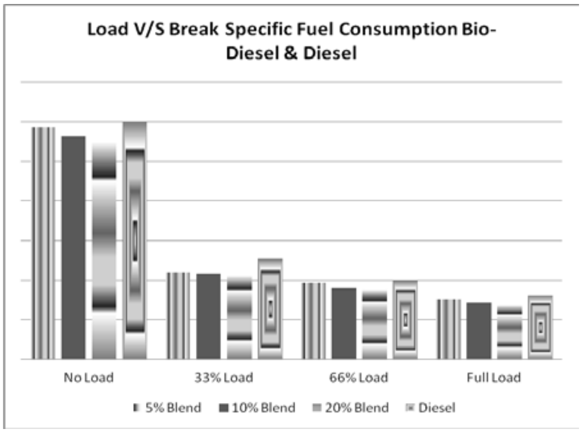

Fig. 4 : BSFC Vs Engine Load

The brake specific energy consumption of the blended fuel is reduced along the same line as the break specific fuel consumption as shown in Fig 5. This mau be due to better utilization of fuel at higher loads as compared to lower loads.

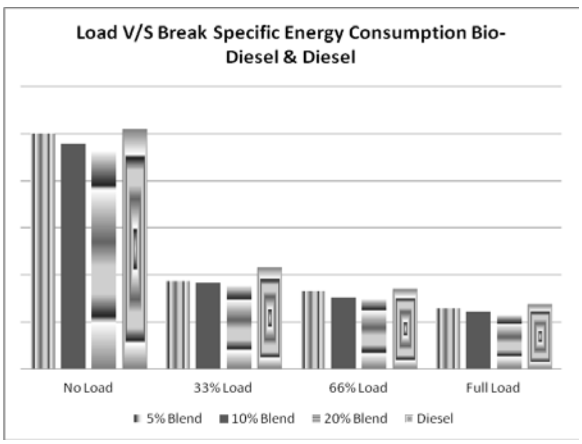

Fig 5 : BSEC Vs Engine Load

Fig 6 represnts the variation of exhaust gas temperature with engine load. The engine runs cooler as the heating value of the fuel is less than pure diesel. This is evident from the fact that the density is lower and hence mass of fuel consumed is less. The lower heating value of blend isalos found to be less so the resultant of these will have a positive effect on the engine i.e it runs at much lower tempertrure throughout the blend mixtures and load condition.

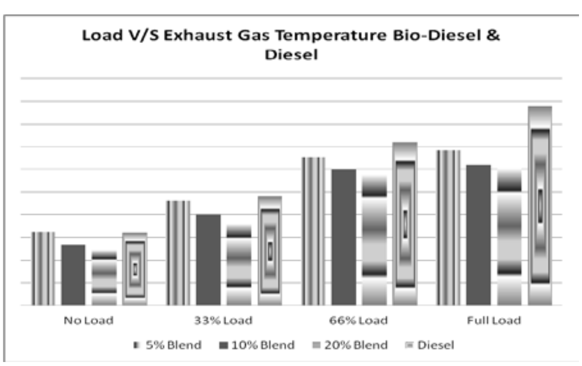

Fig 6 : EGT Vs Engine Load

Biodiesel causes significantly lower emissions compared with neat diesel and is attributed to higher oxygen content almost 10% than pure diesel and lower C/H ratio. The exhaust emission of CO and hydrocarbons (HC) is much lower than regular diesel fuel. This is because of presence of oxygen content in the RBO. As a result, burning efficiency and combustion reaction were much improved. Near absence of sulphur and aromatic content in biodiesel is another reason behind lower emissions. Emission of CO increases with increase in load as shown in fig 7. This is perhaps due to presence of fuel rich mixture at higher loads. It is also observed that CO emission is function of percentage of rice barn methyl ester in the blend.

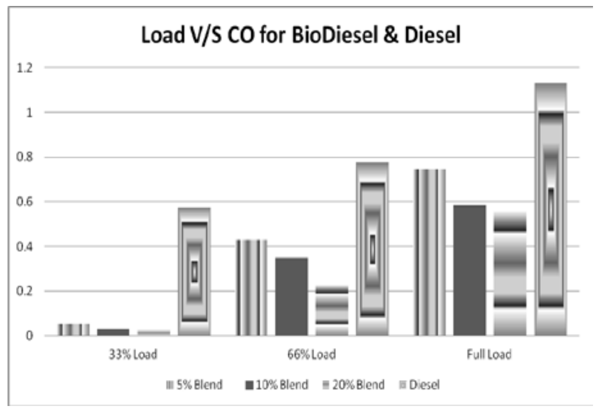

Fig. 7 : CO Emission Vs Engine Load

The variation of HC emission with engine load is shown in Fig. 8.The emission of unburned hydrocarbons in the lower heat release engine is because of the decrease in quenching distance and increase in lean flamability limits. The higher temperatures of combustion chamber walls and in cylinder gas in low heat release engine operation enables oxidation reaction to proceed closer to their completion of combustion.

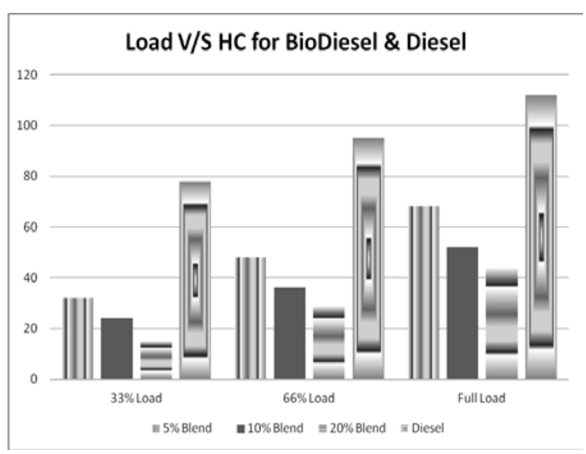

Fig. 8 : HC emission Vs Engine Load

The variation of carbon dioxide emission with load for diesel are shown in figure Fig 9. The CO_2 emission increased with load for all the blend ratios. Biodiesel is known for green house gas reduction.

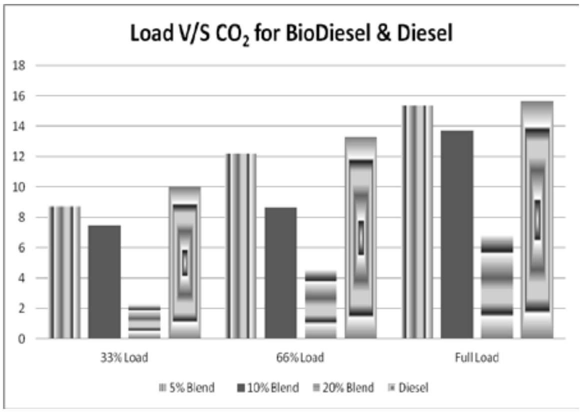

Fig. 9 : CO_2 emission Vs Engine Load

Smoke capacity increases with the increase of load as shown in Fig. 10. This is because of the amount of fuel per unit time increases as the engine load increases consequently, smoke increases. The smoke emission is reduced at all load conditions and blend ratios. Once again the reason being presence of oxygen in the lended fuel. Oxygen content of the biodiesel molecules enables more complete combustion even in regions of the combustion chamber with fuel rich diffusion flame and promotes the oxidation of already formed soot. The reduction is in the range of 10% at 33% load to 35% for full load condition.

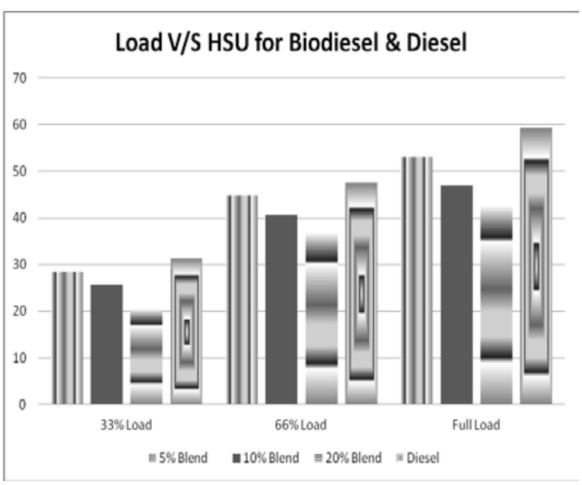

Fig. 10 : Smoke Opacity Vs Engine Load

IV. Conclusion

Based on the experimental result of this work following conclusion are drawn.

1. The high FFA level of crude rice barn can be reduced to less than 0.5% in a two step pretreatment process of transesterification using acid catalysed reaction with methanol.
2. No problem was faced at the time of starting the engine and ran smoothly over the range of rice bran oil blend ratio in the fuel. There were no sign of phase separation.
3. BSFC, and BSEC were lower than pure diesel because of lower heating value whereas the Break thermal efficiency is slightly higher. The engine is found to be running cooler across the range of fuel blend.
4. Emission of gases from the engine were less than that of pure diesel. So is the reduction of hydrocarbon, as the blend ratio increased the amount of emission also reduced.

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