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Study of Combustion Performance and Emission Characteristics of C.I Diesel Engine Fueled with Biogas and Rice Bran Oil Biodiesel in Dual Fuel Mode

Amandeep Singh*, G.S. Sidhu* and S.K. Mahla**
**L.L.R.I.E.T Moga, (PB), INDIA*
*** A.I.E.T Faridkot, (PB), INDIA*

(Corresponding author: Amandeep Singh)
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ABSTRACT: Biofuels is a good replacement of petroleum fuels. Biogas can be used in I.C engine, because of its better mixing ability with air and clean burning nature. The present study was conducted on rice bran oil methyl ester as a pilot fuel and biogas as a dual fuel used in C.I engine. The blend of rice bran methyl ester and diesel was used as a injected fuel and biogas was inducted through the intake manifold. The study conclude that the biogas induced at a flow rate of 0.9 kg per hour was found to give a better performance and lower emission than other flow rates of biogas. The cylinder peak pressure is higher by about of 11 bar in case of duel fuel than that of diesel. Rice bran oil methyl ester-biogas produced maximum brake thermal efficiency of 19.97% at 100% load. Brake thermal efficiency and mechanical efficiency was low at minor load and high at part load operations. Study shows that increase amount of pilot fuel improves thermal efficiency and reduces the CO emission at low engine conditions. The study shows that combustion performance and emission characteristics of the engine in the dual fuel operation are far better than the diesel.

I. INTRODUCTION

Today, the world having energy crisis. In India, there is acute power shortage in rural areas. So there is a need to concentrate on to solve this problem, as an environment aspect as well as petroleum oil shortage. Biofuels are the alternatives to replace the petroleum oil. Biodiesel a renewable fuel is derived from vegetable oil and animal fats. The resources of bio diesel are non-edible oil, edible oil. Biogas run dual fuel diesel engines can be a panacea to the problem of acute power shortage particularly in rural areas in India. Biogas, a renewable fuel, is produced from anaerobic fermentation of organic material. The main combustible constituent of biogas is methane. The higher Octane number of biogas makes it apposite for engines with a relatively higher Compression Ratio (CR) in order to maximize thermal efficiency [1]. Besides, the carbon content in biogas is relatively low compared to that of the conventional diesel fuel, resulting in diminution in pollutants [2]. Biogas can be used in both Compression Ignition (CI) engines and Spark Ignition (SI) engines for power generation. However, the derating of power is evident in biogas run SI engine due to its extreme sensitivity towards biogas composition leading to cycle to cycle variation [3].

A. Dual fuel diesel engine

Conventional internal combustion engines operate on a mono fuel either liquid or gaseous. However, biogas run dual fuel diesel engines operate on both liquid and gaseous fuel simultaneously. This is due to the fact that the temperature attained at the end of the compression stroke inside the combustion chamber of CI engines is around 553 K. However, the auto ignition temperature of biogas is around 1087 K [4]. Therefore, simply compressing the biogas air mixture will not ignite the charge. Hence, a small amount of liquid fuel must be supplied which initially ignites and acts as an ignition source for biogas. The liquid fuel used is called the Pilot fuel. The gaseous fuel i.e. biogas is called the primary fuel on which the engine mainly runs. It is seen that in a dual fuel engine, the combustion starts in the same fashion to that of a CI engine. However, in the later part of combustion, the flame propagates in a manner similar to that of an SI engine. It is possible to achieve a substitution of diesel up to 85% by using biogas [5].

B. Pilot fuel and its importance

The pilot fuel has a tremendous influence on the dual fuel combustion as it elicits the combustion process. The combustion process of a biogas run dual fuel diesel engine is more complex than single fuel combustion. Prior to ignition of pilot fuel, the biogas air mixture undergoes pre-ignition chemical reaction during the relatively longer compression stroke. The pre-ignition reaction results in the formation of active radicals and partial combustion products that are believed to affect the ignition of the injected pilot fuel [2]. Rice bran is the under-utilized non edible vegetable oil which is available in large quantity in rice cultivating countries and very little research has been done to utilize this oil as a replacement for mineral diesel.

The direct injection of rice bran oil cannot be done because of their high viscosity. So there is to reduce the viscosity of the rice bran oil the transesterification is to be needed. First of all FFA content is calculated to know that which type of the catalyst is used either alkali or acid. After that optimum molar ratio methanol to oil is to be calculated.

II. MATERIALS AND METHODS

A. Biogas production

Anaerobic digestion is a commonly used method for the biochemical treatment of organic waste materials, due to its stabilization and higher performance in volume reduction. It is a biochemical degradation process, in which biodegradable organic matter is decomposed by bacteria forming gaseous by-products (biogas). These gaseous by-products consist of methane, carbon dioxide, and traces of other gases. Anaerobic digestion is a complex process, which can be divided into four stages: (i) hydrolysis, (ii) acidogenesis, (iii) acetogenesis or dehydrogenation, and (iv) methanation. In the first stage, the hydrolyzing microorganisms convert the polymers and monomers into acetate, hydrogen, and some amount of VFA (volatile fatty acids), such as butyrate and propionate. Then, a complex consortium of hydrolytic microorganisms excretes the elements of the organic materials, such as cellulose, cellobiase, xylanase, lipase, protease and amylase into amino acids, and long chain fatty acids. The higher VFA that are formed by hydrolyzing microorganisms are again converted into acetate and hydrogen, by obligate hydrogen producing acetogenic bacteria. These bacteria, typically characterized as homoacetogenic are named as Acetobacterium woodii and Clostridium aceticum. The metabolism of the acetogenic bacteria is inhibited rapidly by the hydrogen accumulation. Therefore, it is essential to maintain an extremely low partial pressure of hydrogen inside the digester, for the survival of the acetogenic and hydrogen producing bacteria. The daily biogas production can also be increased by adding hydrogen producing bacteria to the digester feed slurry [9,10].

B. Extraction of rice bran biodiesel by transesterification

Rice bran oil was extracted from the germ and inner husk of rice and it contains mono-unsaturated, poly-unsaturated and saturated fat of 47%, 33% and 20% respectively. The various fatty acid composition of raw rice bran oil was found as palmitic acid, stearic acid, oleic acid, linoleic acid, linolenic acid, arachidic acid and behenic acid at 15%, 1.9%, 42.5%, 39%, 1.1%, 0.5% and 0.2% respectively. The transesterification process was used to derive biodiesel from rice bran oil using and alcohol and a base. The alcohol replaces the triglycerides into glycerol and three fatty acid esters of rice bran oil in the presence of a catalyst [6]. Due to high free fatty acid content, rice bran oil was converted into ethyl esters using ethanol in a two stage process. In the first stage, neutralization of free fatty acids from 12% to 2% was carried out by adding 2% of dilute hydrochloric acid to 1000 ml of rice bran oil at 60^0C for 2 hrs. In the second stage 490 ml of ethanol was mixed with 2.5 gms of sodium hydroxide to form sodium ethoxide. The solution was mixed to 1000 of neutralized rice bran oil for esterification. The entire mixture was transferred to a round bottomed flask and maintained at 75^0C for 1.5 hrs. The mixture was allowed to react in a rotating agitator at 150 rpm for 3 hrs and then it was kept for 24 hrs as settling period. The formation of glycerol takes place resulting in the production of rice bran ethyl ester. The glycerol was then carefully removed using a separating funnel and RBEE was washed with 5% distilled water. By this process, 84% of RBEE was obtained [7,8]. The various properties like flash point, fire point, calorific value, kinematic viscosity, density and cetane number were studied for diesel, RBEE.

C. Experiment setup

A simple diesel engine can be converted into dual fuel diesel engine by connecting a gas mixer at its inlet manifold. Further, a fuel control mechanism needs to be installed to limit the supply of liquid fuel. The power output of the engine is normally controlled by varying the flow of quantity of biogas. A four stroke, single cylinder water cooled diesel engine is employed for the present study. Five gas analyzer was used to measure the concentration of gaseous emissions such as Oxides of nitrogen, unburned hydrocarbon, carbon monoxide, carbon dioxide and oxygen level. The performance and emission tests are carried out on the C.I. engine using biogas and various blends of diesel-biodiesel blends as fuels. The tests are conducted at the constant speed of 1500rpm at various torque [11].

III. RESULTS AND DISCUSSIONS

A. Performance characteristics

It can be observed from the figure that, a higher BSFC (brake specific fuel consumption) is noticed in the dual fuel operation than that of diesel at part loads. This is due to the lower energy density of biogas, lower cylinder temperature, and the presence of CO_2 in biogas prevents faster burning [12]. The difference in BSFC between diesel and dual fuel operation are not significantly different at high operating loads. At full load the dual fuel operation has similar fuel energy conversion efficiency to that of diesel [13]. Because, less energy from the fuel is required at full load compared to no load, due to the increased cylinder temperature at full load [14,15].

At full load, the BSFC for diesel is 0.27 kg/kWh, and in dual fuel operation, with biogas flow rates of 0.3 kg/h, 0.6 kg/h, 0.9 kg/h and 1.2 kg/h, the BSFC is 0.32 kg/kWh, 0.37 kg/kWh, 0.43 kg/kWh and 0.49 kg/kWh respectively.

B. Emission characteristics

The brake specific CO emission in the dual fuel operation is considerably higher than that of diesel under all test conditions. This is due to incomplete combustion caused by dilution of charge by the CO_2 present in biogas and deficiency of oxygen. Hence, the flame formed in the ignition region of the pilot fuel is normally suppressed, and does not proceed until the biogas fuel air mixture reach a minimum limiting value for auto ignition [16,17]. The CO emission is higher by about 24% with biogas, at the flow rate of 1.2 kg/h at full load, in comparison with diesel, whereas, only 17% increment in CO emission is observed with the biogas at the flow rate of 0.9 kg/h at full load, compared with diesel. The poor mixture formation of gaseous and liquid fuel may also be another reason for the higher CO emission [18].

IV. CONCLUSIONS

The present study investigated the possibility of using rice bran oil methyl ester, as pilot fuel for a biogas run dual fuel diesel engine particularly in rural areas in developing countries like India. The results of this pilot fuel study under dual fuel mode indicated that RBME biogas produced a maximum efficiency of 19.97%. Thus, biodiesel-biogas dual fuel combustion is a promising technology that offers low NO_X and particulate matter emissions with marginal lower efficiency than diesel. The P. pinnata de-oiled cake has the potential for biogas production, and up to 73% methane is obtainable. In dual fuel operation, the biogas flow rate of 0.9 kg/h shows the optimum result in combustion, performance and emission compared to other flow rates. The diesel replacement of 0.215 kg/h is possible with biogas flow rate of 0.9 kg/h at full load. About 36% increase in the BSFC and 6.2% drop in BTE is noticed in dual fuel operation with biogas flow rate of 0.9 kg/h in comparison with diesel, at full load. At full load, 17% and 30% increase in the CO and HC emission is observed with biogas flowrate of 0.9 kg/h, in comparison with diesel. 39%, 42% and 49% reduction in NO, CO_2 and smoke emission are observed with biogas flow rate of 0.9 kg/h, in comparison with diesel, at full load respectively. On the whole, the use of biogas with diesel in a CI engine seems to be desirable to reduce emissions, saving of conventional diesel and to utilize bio energy from biomass. It is also a promising technique for the on farm electricity generation. This biogas dual fuel engine, not only consumes a wide range of gaseous fuel resources effectively, but also has the potential to avoid much of the current and future problems to the diesel engines including very significant reduction in its exhaust emissions trade-offs.

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