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Performance and Combustion Characteristics of 4-Stroke Diesel Engine Using Rice Bran Methyl Esters with varied piston configurations

Subbarao B.[1*], Dr. Ramjee E.[2]

[1]Dept. of Mechanical engineering, Geethanjali College of engg. and Tech., Telangana, India
Telangana, India bsrao.hod@gmail.com;+91-8125299169
[2]Dept. of Mechanical engineering, JNTU Hyderabad, Telangana, India

ABSTRACT

Non edible crops are being grown exclusively for biodiesel production. An alternative approach is to grow a food crop and use the waste material for biodiesel. Crude rice bran oil (RBO) is unrefined non-edible vegetable oil, which is available in huge quantities in rice enlightening countries the research in this area to utilize as a replacement for mineral Diesel in not much. Crude rice bran was obtained from solvent extraction process by using n-hexane. The transesterification process for production of rice bran methyl ester oil (RBMEO) has been investigated. The production of high quality rice bran methyl esters obtained from the transestification with methanol and KOH catalyst convertor. The most commonly used single cylinder four stroke water cooled direct injection diesel engine is selected for the purpose of experimentation. The experiments have been carried out on three piston geometry by varying engine loads. In the present work, the engine performance and combustion characteristics are determinate by using Rice bran methyl ester oil as the main fuel and diesel has the pilot fuel of the engine and the results are compared from the experimental investigation.

KEYWORDS: Rice bran oil (RBO), transesterification, and properties of RBMEO.

***Corresponding author**

B. Subbarao

Associate Professor,

Dept. of Mechanical engineering,

Geethanjali College of engg. and Tech., Telangana, India

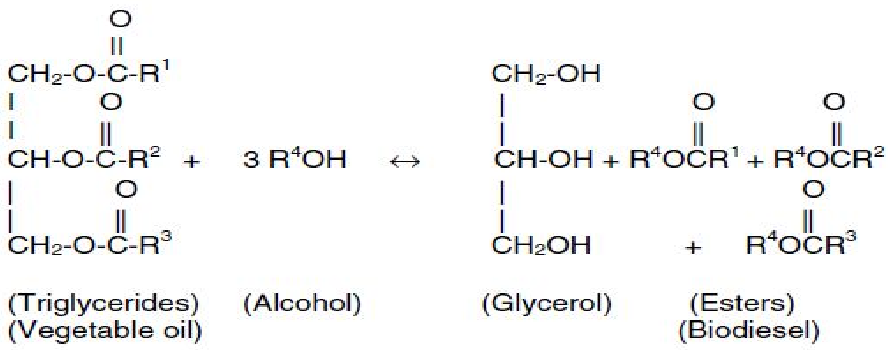
Email: bsrao.hod@gmail.com; Mob. No. +91-8125299169

INTRODUCTION

Diesel fuels have an important role in the industrial economy of any country. The high energy demand in the industrialized world and widespread use of fossil fuels is leading to fast depletion of fossil fuel resources as well as environmental degradation. The world petroleum reserves are so unevenly distributed that many regions have to depend on others for their fuel requirements. The degrading air quality due to emissions is the main adverse effect of petroleum based fuels. All these factors necessitate continued search and sustainable development of renewable energy sources that are environmentally friendly. Biomass sources, particularly vegetable oils, have attracted much attention as an alternative energy source. They are renewable, non-toxic and can be produced locally from agriculture and plant resources.

In comparison to mineral Diesel, biodiesel has a more favorable combustion and emission profile. Emissions of CO and particulate matter decrease by 45%, hydrocarbon (HC) emissions decrease by nearly 70% but NOx emissions increase by 10% with 100% biodiesel (B100) as a fuel[5]. The carbon cycle time for fixation of CO_2 from biodiesel is quite small compared to mineral Diesel. It means that biodiesel usage reduces greenhouse gas emissions compared to mineral Diesel[6, 7]. Biodiesel has a relatively high flash point, which makes it safer to handle. Agarwal et al. [8, 9]found that biodiesel provides good lubricating properties that can reduce component wear and enhance engine life.

Several researches have shown the experiment results of fuel properties of vegetable oils can be improved by transesterification, and this is the method of choice in the current study. Transesterification is a chemical reaction in which alcohol reacts with the triglycerides of fatty acids (vegetable oil) in presence of a catalyst. The alcohol combines with the triglycerides to form glycerol and esters. The rice bran oil transesterification reaction can be catalyzed by both homogeneous and heterogeneous catalysts. Homogeneous catalysts include alkalis and acids. The most commonly used alkali catalysts are NaOH, KOH, carbonates and the corresponding sodium and potassium alkoxides such as sodium methoxide, sodium ethoxide, sodium propoxide and sodium butoxide[1-3], [10–15]. Freedman et al. [11] investigated the effect of various parameters on the purity of biodiesel produced. Sulfuric acid, sulfonic acid and hydrochloric acid are usually used as catalysts in the acid catalyzed reaction. Vicente et al. [10] found more conversion with methoxide catalyst, but these catalysts are very expensive and hygroscopic. Up to about 5% FFA, the reaction can be catalyzed using an alkali catalyst. Acid catalysts (HCL, H_2SO_4) are advantageous for oil having high FFA content, as acids catalyze the FFA esterification to produce fatty acid methyl ester, increasing the biodiesel yield, but the reaction time and alcohol requirement is very high[4, 16]. The primary concerns with this method are the additional complexity of recovering and recycling the co-solvent and the hazard level associated with the proposed co-solvents.



Transesterification Reaction

RBMEO ANALYSIS FOR DIFFERENT PROPERTIES

The crude RBO and biodiesel of RBO or RBMEO were studied for different properties like Viscosity, density and calorific value for selecting the transesterification of RBO to used in the engine as a fuel. As viscosity is the root of nearly all of the operational problems, it severely affects the fuel delivery characteristics of the engine.

Equipments used:

1. Electronic Balance - To find Density.
2. Redwood Viscometer - To find Viscosity.
3. Pensky Marten apparatus – To find Flash and fire point.
4. Bomb calorimeter – To find Calorific Value.

Table 1 Properties of crude RBO and RBMEO were compared with Diesel properties

Fuel	Density (Kg/m^3)	Viscosity (Cst)	Flash point (^oC)	Fire point (^oC)	Calorific value (MJ/Kg)
Diesel	860	4-5	55	60	45.5
Crude RBO	1447	18.27	223	235	37.88
RBMEO	893	12.54	55	65	42.42

EXPERIMENTAL SETUP

Experiments were conducted on a Kirloskar TV1 type, four stroke, single cylinder, water-cooled diesel engine test rig. Fig. 1 shows the line diagram of the test rig used. Eddy current dynamometer was used for loading the engine. The fuel flow rate was measured on the volumetric basis using a burette and stopwatch. Experiments were conducted by using biodiesels selected for the study with different combustion chamber shapes like Hemispherical Combustion Chamber (HCC), Toroidal Combustion chamber (TCC) and Shallow Depth Combustion chamber (SDCC) shapes as shown in Fig.2. Finally the results obtained with biodiesel operation were compared with Diesel.

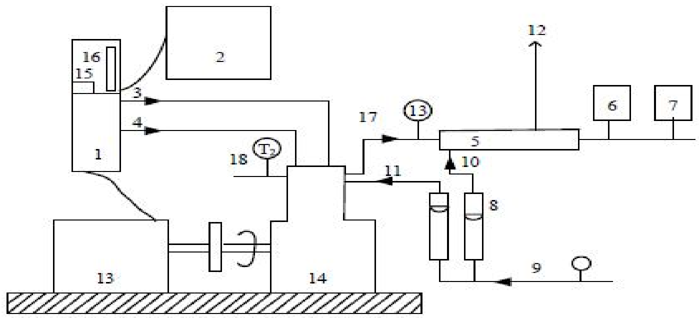


Figure 1 Experimental set up arrangement to test biodiesel

1-Control Panel, 2-Computer system, 3-Diesel flow line, 4-Air flow line, 5-Calorimeter, 6-Exhaust gas analyzer, 7-Smoke meter, 8-Rota meter, 9,11-Inlet water temperature, 10-Calorimeter inlet water temperature,12- Calorimeter outlet water temperature, 13-Dynamometer, 14-CI Engine, 15-Speed measurement,16-Burette for fuel measurement, 17-Exhaust gas outlet, 18-Outlet water temperature, T1- Inlet water temperature, T2-Outlet water temperature, T3-Exhaust gas temperature.

Figure 2 Different types of pistons shown in the above figure, like Hemispherical, Toroidal and shallow depth shapes to test biodiesel

The experiments are conducted at different loads at constant rated speed of 1500rpm. The ignition lag phase. In order to get proper air fuel mixing, a systematic air movement also called swirl is essential, which produce higher relative velocity between fuel droplets and air. Hemispherical combustion chamber is the baseline geometry considered. Table 2, shows the specifications of the engine.

Table 2 Specifications of the engine

S. No	Parameters	Specification
1	Type of engine	Kirloskar make Single cylinder four stroke direct injection diesel engine
2	No. of cylinders	01
3	No. of Strokes	04
4	Fuel	Diesel
5	Rated Power	5.2 KW/7 hp @ 1500 RPM
6	Bore & Stroke	87.5 & 110 mm
7	C R	17.5:1
8	Dynamometer arm length	185 mm

RESULTS AND DISCUSSIONS

1.1. Brake thermal efficiency (BTE) of Diesel.

The variations of brake thermal efficiency with brake power of diesel for different induced loads with different combustion chambers at 180bar injection pressure are shown in Fig 3. It is observed that the BTE for diesel fuel with Hemispherical Combustion Chamber (HSCC) mode of operation was higher than Toroidal combustion chamber (TCC) and Shallow Depth combustion chamber (SDCC). This is mainly due to good swirling force in the base combustion chamber than other two combustion chambers. The study with different combustion chamber shapes showed that for diesel operation with HSCC resulted in better performance compared to TCC and SDCC. Therefore substantial differences in the mixing process may not be present. It is observed that, maximum increase in efficiency is found at full load for the entire pistons.

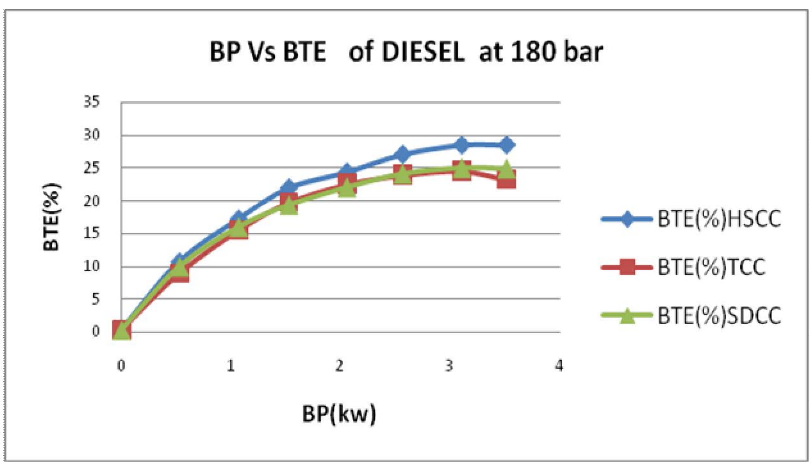


Figure 3 Variation BTE with BP of Diesel at 180 bar

1.2. Brake thermal efficiency (BTE) of RBMEO.

The variations of brake thermal efficiency with brake power of RBMEO for different induced loads with different combustion chambers at 180bar injection pressure are shown in Fig 4. The figure shows that the BTE of RBMEO fuel with Toroidal combustion chamber (TCC) and Shallow Depth combustion chamber (SDCC) gives better results than Hemispherical Combustion Chamber (HSCC). At higher loads TCC gives good results than SDCC. This is mainly due to geometry of TCC and SDCC than HSCC. The study with different combustion chamber shapes showed that for RBMEO operation with TCC resulted in better performance compared to SDCC and HSCC. It is observed that, maximum increase in efficiency is found at full load for the TCC and SDCC.

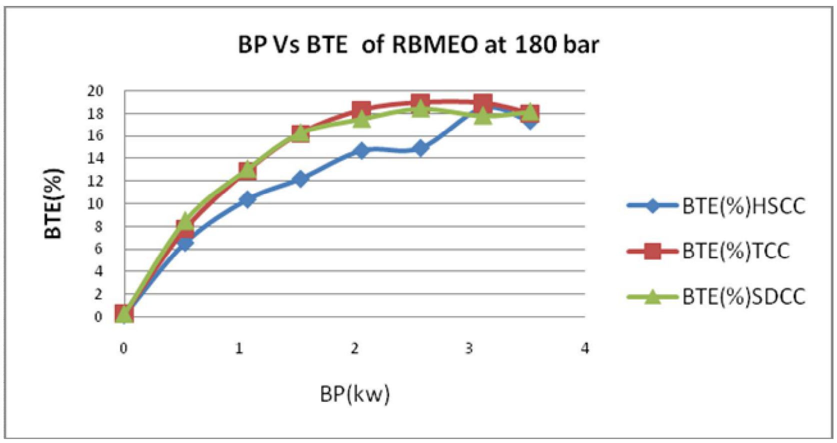


Figure 4 Variation BTE with BP of RBMEO at 180 bar

1.3. Variation of BTE with BP for both Diesel and RBMEO at 180bar.

From Figure 5, It is observed that the BTE increases in diesel fuel with base piston i.e. HSCC at all loads compared to other pistons including biodiesel RBMEO also.

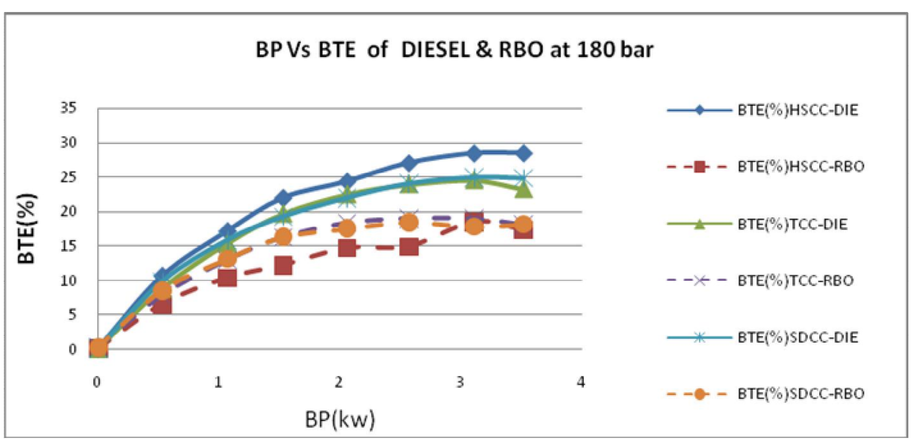


Figure 5 Variation BTE with BP of Diesel and RBMEO at 180 bar

1.4. Brake specific fuel consumption (BSFC)

The brake specific fuel consumption variations with brake power for different induced load rates of diesel are shown in Fig 6. It is observed that the maximum reduction in BSFC is found at full load conditions with 180bar injecting pressure. Further observed the BSFC is further reduced by changing the piston bowl geometry for different flow rates of diesel at 180bar injected pressure. This is because the inducement of enhanced air swirl in the shallow depth combustion chamber leads to the complete combustion of charge in the combustion chamber with liberation of maximum energy.

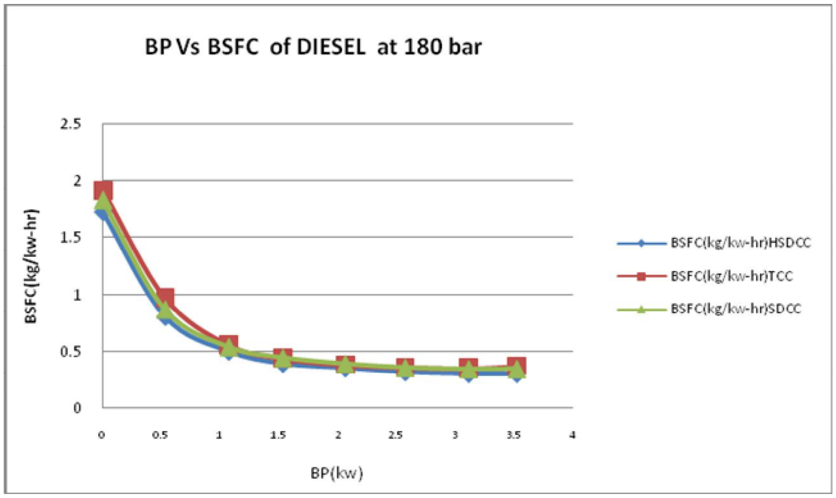


Figure 6 Variation BSFC with BP of Diesel at180bar

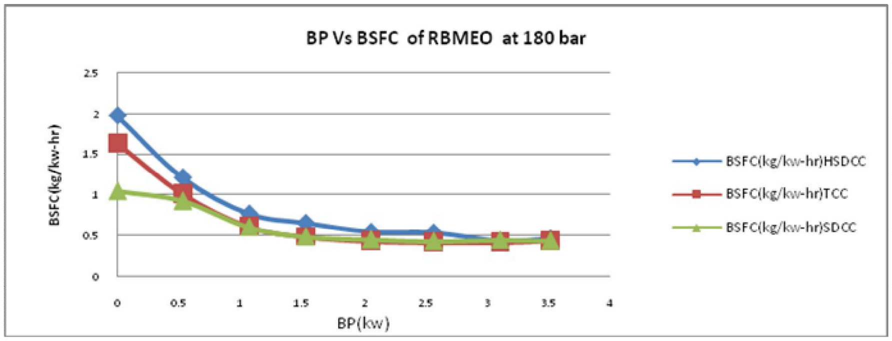


Figure 7 Variation BSFC with BP of RBMEO at180bar

Figure 7, shows the variation of BSFC at 180bar with BP of RBMEO. It is observed that the maximum reduction in BSFC is found at full load conditions. Further observed the BSFC is further reduced by changing the piston bowl geometry mainly SDCC for different flow rates of RBMEO at 180bar injected pressure.

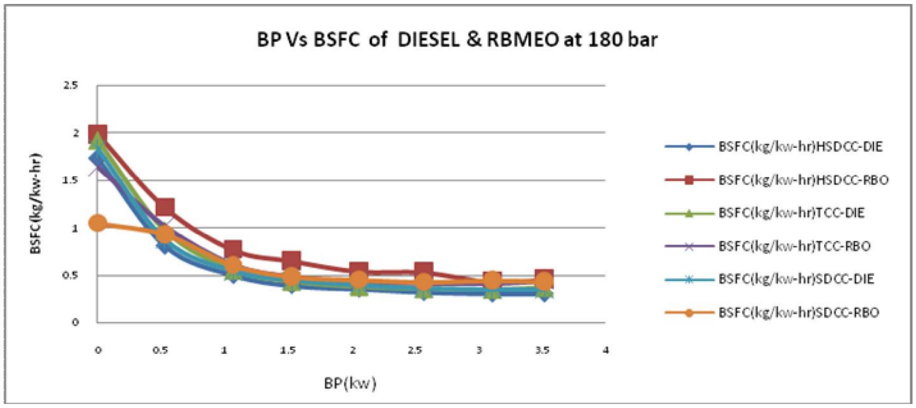


Figure 8 Variation BSFC with BP of Diesel & RBMEO at180bar

Figure 8: shows BSFC variation of Diesel and Biodiesel RBMEO with BP at 180bar injection pressure. It is observed that at higher loads maximum reduction of BSFC with respective BP by varying piston geometry. Further observed that diesel has maximum reduction of BSFC with SDCC than biodiesel and other combustion chambers.

CONCLUSIONS

Paddy (Rice) crop is most useful food crop in India, and during this investigation, trans esterification as well as catalyst removal from biodiesel has been studied in detail. Trans esterification reaction parameters control the yield of the ester, whilst catalyst removal is required for purification of the ester to make it suitable fuel for Diesel engines.

In this experimental study, effect of different piston bowl geometry was investigated on direct injection single cylinder diesel engine at variable injection pressures and timings was investigated. The following conclusions were drawn from results.

- Break Thermal efficiency of diesel with HSCC was increased 3.95% than TCC and 3.46% than SDCC at full load condition engine operating with 180bar injection pressure.
- Break Thermal efficiency of RBMEO with TCC was increased 4.02% than HSCC and 0.51% than SDCC at full load condition engine operating with 180bar injection pressure.
- Break specific fuel consumption of diesel with HSCC decreased by 0.068 kg/Kwh with TCC and 0.44 kg/Kwh with SDCC at full load condition operating with 180bar injection pressure.
- Break specific fuel consumption of RBMEO with SDCC decreased by 0.004 kg/Kwh with TCC and 0.0016 kg/Kwh with HSCC at full load condition operating with 180bar injection pressure.

From the above discussed properties of RBMEO, it can be concluded that, the oil has most of the properties similar to the diesel fuel, and it is well suited as an alternative fuel in the compression ignition engine.

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