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Performance and Emission Characteristics of Hybrid Biofuels in DI Diesel Engine

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ABSTRACT

Rubber seed oil (RSO), derived from the seeds of Hevea brasiliensis, is an exciting alternative with great potential for use in biodiesel production. Furthermore, it can be injected directly into an internal combustion engine, blended with diesel derived from fossil fuels. The present work deals with the potential estimation of waste cooking oil (WCO) bio diesel and RSO biodiesel, characterization of biodiesel, performance and exhaust analysis of biodiesel blends in DI diesel engine. The best results in terms of performance and emission are obtained for B10 blend which resulted in highest brake thermal efficiency of 19.2 % at 80% loading. The NO_x emissions are maximum for B20 blend.

KEYWORDS:

Transesterification; Hybrid biofuels; Rubber seed oil; Engine performance; Emissions

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1. Introduction

It is known that global energy demands are mainly fulfilled by fossil fuels. However, global energy demands seem to increase at slower pace in recent years due to unprecedented efficiencies created by novel renewable energy technologies as well as enforcement of stringent energy policies and environmental legislations. There is a dramatic shift in energy pattern where the demand for energy harvesting from fossil fuels has declined since year 2014. Azcan et al [7] concluded that Methyl ester content of biodiesel was increased from 90.04% to 97.74% by molecular distillation at 170 - 200°C, 10 mbar and 0.12 - 0.24 mL/min feed flow rate. The current state of global energy is called 'The Grand Transition'. In this state, there is a strong demand for renewable energy due to the emergence of new technologies, greater environmental challenges. It is well-known that the burning of fossil fuels such as coal and oil leads to environmental problems and decarbonisation of energy systems (increasing the utilization of low carbon energy sources such as renewable energy) to address environmental issues such as climate change, it's one of the toughest challenges that require full commitment from all relevant parties.

Suresha et al [2] concluded that castor and sunflower biodiesels can be used as alternative fuel for the CI engines. Arunkumar et al [1], summarized with technology advance, the microwave assisted transesterification method is a promising method that enhances the quality and quantity of oils produced and also decreases the time required for the same.

Biodiesels play an important role to fulfil the demand for alternative fuels, which will help reduce carbon emissions. Wang et al [10] studied that microwave-assisted extraction is a new separation technology, which has a short extraction time, high efficiency and low energy consumption. Besides the prices of raw materials, the technology used for biodiesel production is equally important in order to produce biodiesel with competitive prices as those for diesel. Taghvaei et al [12] confirmed that through microwave assisted extraction of edible oils from cotton seed, there is no need to apply heat treatment (cooking process) in order to destruct oil cells and coagulate proteins. Biodiesels produced from conventional alkaline-catalysed transesterification requires long reaction times (typically more than 60 min) due to heat transfer from heating surface to oil by conduction, convection and radiation. The mode of heat transfer between the surface and interior of the material is thermal conduction. The chemical reaction is dependent on the convectional heating that results in long reaction time in order to achieve a high conversion of crude oil into biodiesel.

Purandaradas et al [3] concluded that biodiesel has become alternative fuel due to its environmental benefits and easily available as renewable resources. In South East Asian countries, where 77 % of the world's total natural rubber is produced, rubber tree seeds (Hevea brasiliensis) are presently disposed as waste biomass resulting from latex production. Chen et al [8] presented a novel and efficient procedure to obtain trans-resveratrol from tree peony seed oil-extracted residues by imidazolium-basedionic liquid based microwave ultrasonic synergistic simultaneous extraction and hydrolysis (IMUSEH) method. Because the seed kernels contain 40-50% oil, rubber seed oil (RSO) is a potential feedstock for the production of biodiesel fuel as sustainable and environmentally friendly replacement for petroleum diesel fuel.

Duz et al [4] concluded that the conversion of C. Tinctorius oil to methyl ester was over 98.4% at 6 min. The utilization of RSO as a feedstock for biodiesel fuel production could also lower the price of biodiesel fuel due to reduced cost of the raw material, which accounts for more than 80% of the total manufacturing costs. However, the high content of free fatty acids (FFAs) in RSO must be reduced to less than 2.5 wt % prior to the production processing in order to obtain a high-quality biodiesel fuel. There is a two-step procedure for the production of biodiesel fuel from RSO containing 17% FFA. Adewale et al [5] infirmed that low cost RSO can mitigate the environmental damage and increase the quality of the resultant biodiesel fuel (low NO_x emissions, high cetane number and oxidative stability). The FFA was firstly esterified using sulphuric acid (H_2SO_4) as a catalyst followed by transesterification of the triglycerides. A three-step process can be used for producing fatty acid methyl esters from RSO containing 45% FFA. The triglycerides and FFAs in RSO were initially converted into sodium salts of FFAs (soap) by saponification. The soap was acidified and then esterifies to biodiesel. However, both approaches using a conventional mechanical stirring method required large amounts of reagents, a catalyst, a long reaction time and a high reaction temperature. Zhang et al [9] optimized the extraction of polyphenols of lotus seeds by Microwave Assisted Extraction (MAE).

Zumar et al [6] summarized that the principles underlying microwave irradiation were initially described followed by the several benefits of microwave over conventional heating and the different effects of microwave irradiation on pre-treatment of lignocellulosic biomass. Ghosh et al [13] studied two photon microwave transition with pulse in Rydberg atom gas in the phase transition with dynamic rotation of field ion has to be formulated the bonding rotation of Rydberg gas mole. Mgudu et al [14], concluded that the results were a highest yield of 44.34% when beans were treated at 280W for 120 seconds resulting in refractive index values ranging from 1.4712 – 1.4718 and a free acid value of 0.336. Escaray et al [15] concluded that the enormous ecological and agronomic importance of several Lotus species is unquestionable. Many of these species constitute perhaps the best alternative to alleviate serious threats imposed to formerly cultivated areas. In this work, the performance and emission characteristics of biodiesel are experimentally assessed and discussed.

2. Materials and methods

Waste cooking oil (WCO) and RSO were collected from School of Mech., REVA University. The WCO and RSO are converted to biodiesel using transesterification. MAE is used to obtain crude oil from Jatropha curcas seeds [11]. Filtration is done to separate solid waste present in the oil. First the larger particle is separated by sieving through the micron size holes. After removing visible dust particles, FFA in the oil is estimated to be 16.46, which is too acidic. Hence two stage esterification is carried out. To test the FFA content, first weigh 1gm of WCO and then mix it with 2 drops of phenolphthalein and 10 ml of propan-2-ol. Then slowly open the valve and mix the distilled water and potassium hydroxide (KOH), then the colour will change after mixing. Transesterification process is achieved by adding 150ml methanol and 5gm of KOH pellets and then heating the biofuel by maintaining 60°C temperature for complete 3 hrs. Fig. 1 shows the photograph of the batch reactor used. After this, the oil is shifted to a settling flask and left for 3 to 4 hrs. The glycerine, excess catalyst, dirt, grime, flour particles and soap contents in biodiesel are removed by washing the biodiesel 6 to 8 times using water at 60°C. After washing, the biodiesel is heated for 30 minutes at 100°C-125°C to remove the water content in the biodiesel. To indicate sufficient vaporisation took place, the flash point and fire point of oil are determined for a change in their composition. Fig. 2 and Fig. 3 show the respective test apparatus. The flash point of oil is found to be 190°C. The fire point of oil is found to be 195°C using Pensky Martin equipment. The specifications of test engine are given in Table 1.

Fig. 1: Batch reactor for transesterification

Fig. 2: Flash point test

Fig. 3: Fire point test

Table 1: Kirloskar 553 cc water cooled engine specifications

Specification	Value
Capacity	3.7 kW
Compression ratio	16.5:1
Bore diameter	80mm
Stroke length	110mm

3. Results and discussion

Figs. 4 and 5 show the comparison of BTE vs. Load for WCO biodiesel and hybrid biodiesel (RSO) respectively. The BTE of WCO blend B10 is the highest when compared to the hybrid biodiesel. Figs. 6-9 show that WCO biodiesel B80 blend and hybrid biodiesel B10 blend have resulted in the lowest efficiency. WCO biodiesel B10 blend and hybrid biodiesel B20 blend have produced lowest NOx emissions. In terms of CO_2 emissions, WCO blend B40 and hybrid biodiesel blend B10 have produced the lowest emissions. Whilst WCO blend B80 and hybrid biodiesel blend B20 have produced highest CO_2 emissions.

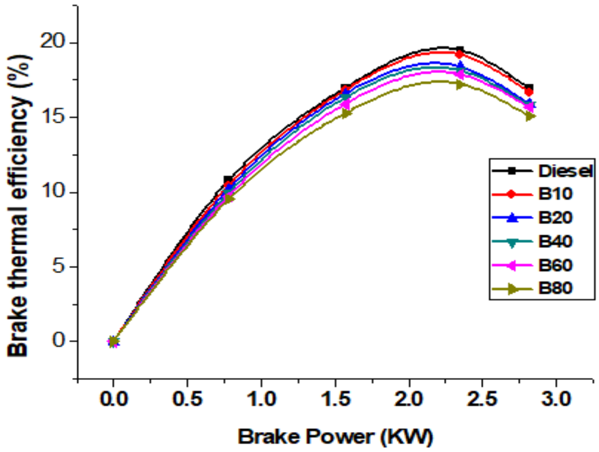

Fig. 4: BTE (WCO) vs. BP

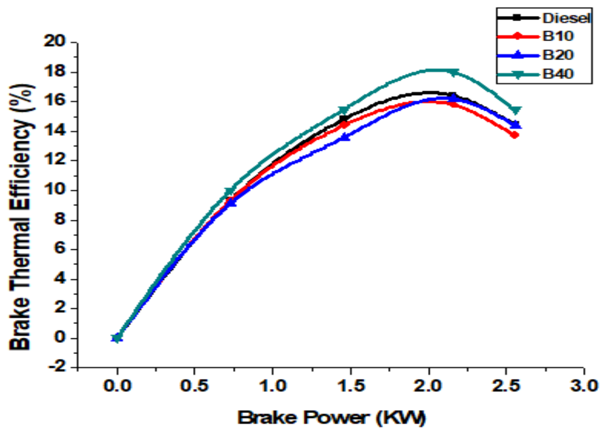

Fig. 5: BTE (hybrid biodiesel) vs. BP

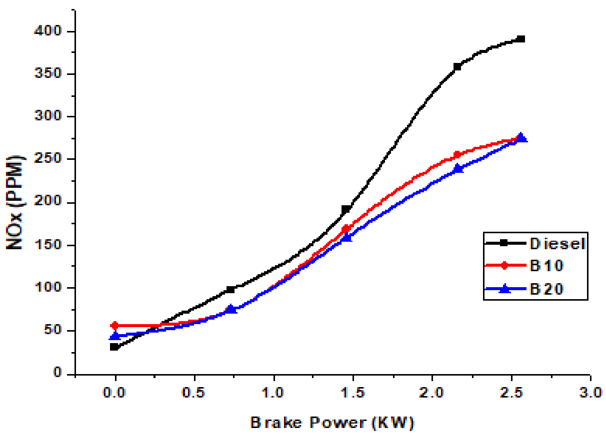

Fig. 6: NO_x (WCO) vs. BP

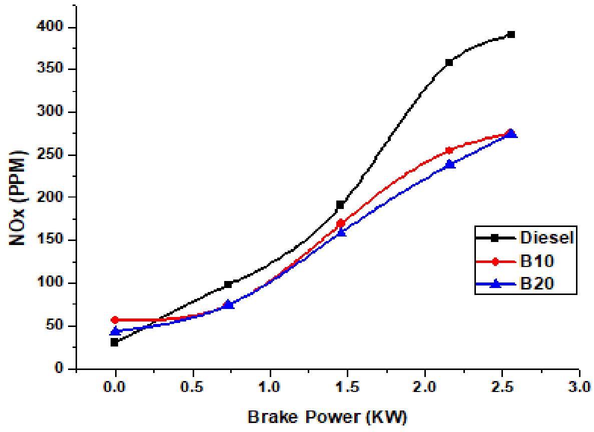

Fig. 7: NO_x (hybrid biodiesel) vs. BP

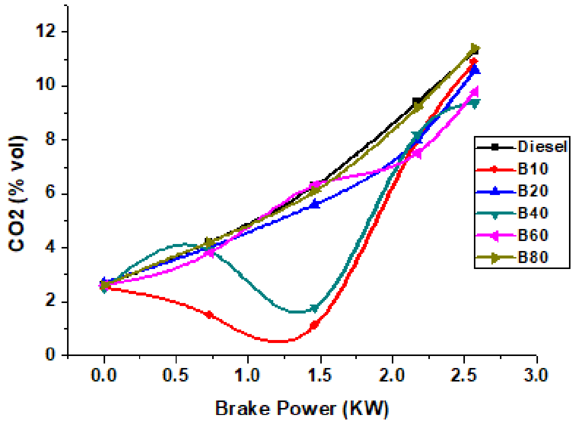

Fig. 8: CO_2 (WCO) vs. BP

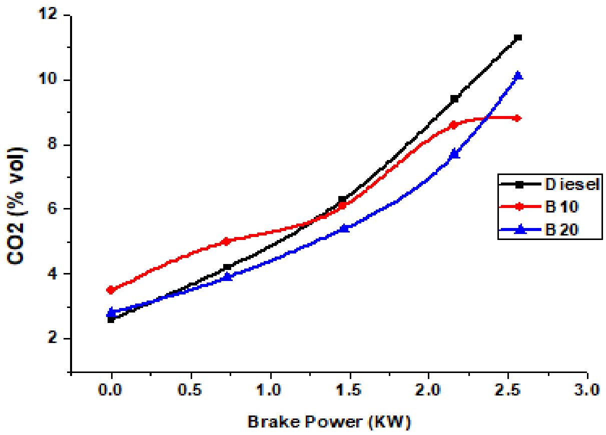

Fig. 9: CO_2 (hybrid biodiesel) vs. BP

4. Conclusion

The biodiesel blend B10 produced from WCO exhibits similar properties in comparison with diesel. The highest brake power of 1.75 kW is obtained for B10 blend at 80% load. It is also observed that BTE increases with increase in load up to 80% as a result of better combustion. B10 blend hybrid RSO biodiesel has resulted in less emission of CO, CO_2 and un-burnt HC but resulted in higher NO_x emission due to higher heat release rate.

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