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FULL LENGTH ARTICLE

Impact of ternary blends of biodiesel on diesel engine performance

Prem Kumar *, Mahendra Pal Sharma, Gaurav Dwivedi

Biofuel Research Laboratory, Alternate Hydro Energy Centre, Indian Institute of Technology Roorkee, Roorkee, Uttarakhand 247667, India

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Abstract The Pongamia and waste cooking oils are the main non edible oils for biodiesel production in India. The aim of the present work is to evaluate the fuel properties and investigate the impact on engine performance using Pongamia and waste cooking biodiesel and their ternary blend with diesel. The investigation of the fuel properties shows that Pongamia biodiesel and waste cooking biodiesel have poor cold flow property. This will lead to starting problem in the engine operation. To overcome this problem the ternary blends of diesel, waste cooking biodiesel and Pongamia biodiesel are prepared. The cloud and pour point for ternary blend, (WCB_{20}:PB_{20}:D_{60}) were found to be 7 °C and 6.5 °C which are comparable to cloud and pour point of diesel 6 °C and 5 °C, respectively. The result of the test showed that brake specific fuel consumption for Pongamia biodiesel and waste cooking biodiesel is higher than ternary blend, (WCB_{20}:PB_{20}:D_{60}) due to their lower energy content. The brake thermal efficiency of ternary blend and diesel is comparable while the Pongamia and waste cooking biodiesel have low efficiency. The result of investigation showed that ternary blend can be developed as alternate fuel.

1. Introduction

Biodiesel is an alternative diesel fuel consisting of the alkyl monoesters of fatty acids derived from vegetable oils or animal fats and non-edible oil. The recent research shows that biodiesel is renewable in nature, and it also reduces the emission of harmful gases. The vegetable oil can be used as a source for biodiesel production. Numerous non edible oils like Jatropha, Pongamia, Mahua, Neem and waste vegetable oil (WVO) have been examined including soybean oil, sunflower oil, cotton seed oil, rapeseed oil, in addition to waste (used or fryer) vegetable oil. The vegetable oils can be safely burned for short periods of time in a diesel engine. However, using raw vegetable oil in a diesel engine for extended periods of time may result in severe engine deposits, piston ring sticking, injector coking, and thickening of the lubricating oil [1–3]. The high viscosity of raw oil reduces fuel atomization and increases fuel spray penetration. Higher spray penetration is thought to be partly responsible for the difficulties experienced with engine deposits and thickening of the lubricating oil. However, these effects can be reduced or eliminated through transesterification

* Corresponding author.
E-mail address: premchaudhary653@gmail.com (P. Kumar).

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of the oil to form biodiesel [4–7]. Many researchers reported that the biodiesel even surpassed the petroleum based diesel in several aspects of engine operation including brake thermal efficiency (BTE) and exhaust emissions [8–11].

Experiments on the diesel engine are performed and it was found out that by using various blends of biodiesel from Pongamia and WCB, brake specific fuel consumption (BSFC) is increased. The finding indicates that there is an increase in the BSFC when using biodiesel as compared to diesel for the same power output. This is because the heating value of biodiesel is less as compared to diesel [12–18]. It was found that there is no significant change in the thermal efficiency while using Pongamia biodiesel (PB) up to PB_{20} but there is a slight decrease in thermal efficiency when PB_{100} was used which is due to the lower energy content of biodiesel. Pongamia biodiesel emits lower gaseous emission than diesel fuel while expected NOx increases to 2% with PB_{20} and 10% with PB_{100} [19]. Dwivedi et al. [20] reported that PB scores very well as an alternate fuel of choice as it helps in decreasing dependency on fossil fuels and also as it has almost no sulfur. Higher cetane of PB as compared to petro diesel implies its much improved combustion profile in an internal combustion engine. The pollutant components from exhaust are also decreased by using PB.

Suresh kumar et al. [21] reported that the blends of PB with diesel up to 40% by volume (PB_{40}) could replace the diesel for diesel engine applications for getting less emissions and better performance and will thus help in achieving energy economy, environmental protection and rural economic development. The investigation shows that BSFC for PB_{20} and PB_{40} is equal to or less than diesel. BSEC is less than diesel. CO and HC emission reduced in case of all blends of PB as compared to diesel while CO_2 and NOx emission are increased for all blends of PB as compared to diesel. Baiju et al. [22] investigated the impact of PB and its blends on diesel engine and found out that PB_{20} has lowest BSFC. NOx emission is higher by 10–25% for PB. CO, HC and Smoke emissions are reduced using PB. Engine Performance is similar in case of PB and diesel. Chauhan et al. [23] and Sahoo et al. [24] found out that BTE of diesel is higher as compared to biodiesel by 3–5%. CO_2 and NOx emissions are lower in case of diesel. CO and Unburnt hydrocarbon emissions are lower in case of PB. Raheman and Phadatare [25] state that PB and its blends reduce CO emission by 73–94% in case of PB. Smoke emission is reduced by 20–80%. NOx emission is reduced by 26%. For PB_{20} and PB_{40} BSFC is reduced by 0.8–7.4%. For PB_{60} and PB_{100} BSFC is increased by 11–48%. PB_{20} and PB_{40} have higher BTE than diesel while PB_{60} and PB_{100} have lower BTE than diesel. These characteristics of biodiesel reduce the noxious emissions in the exhaust gas compared to petrodiesel; carbon monoxide (CO) by 46.7%, unburned hydrocarbons (UHC) by 45.2% and particulate matter (PM) by 66.7% while, NOx emissions have been reported to increase due to the high oxygen content of biodiesel [26]. The brake thermal efficiency of PB with different compositions at 5%, 10%, 20%, 30% and 100% with diesel was about 3–5% lower with PB and its blends with respect to diesel. Unburnt hydrocarbon, CO, CO_2 and Smoke were lower with PB fuel. However, NOx emissions of Pongamia biodiesel and its blends were higher than diesel [23]. Xiangmei et al. [27] used WCO for biodiesel production and investigated the engine performance without any modification to diesel engine, the WCB_{20} significantly reduces CO, HC and particles emission by 18.6%, 26.7% and 20.58%, respectively. Murat [28] used turbocharger to evaluate the performance of diesel engine and the result showed that the BTE of WCB was slightly higher than that of diesel fuel in both naturally aspirated and turbocharged conditions, while WCB yielded slightly lower brake power and torque along with higher fuel consumption values. It was also observed that emissions of CO in the operations with WCB were lower than those in the operations with diesel fuel, whereas NOx emission in WCB operation was higher. This study reveals that the use of WCB improves the performance parameters and decreases CO emissions of the turbocharged engine compared to diesel fuel. Jain et al. [29] used WCB to evaluate the performance of diesel engine biodiesel up to WCB_{100} and it is found that brake specific fuel consumption for WCB_{100} (411 g/kWh) is about 17.8% higher than diesel (349 g/kWh) at full load while the brake thermal efficiency of waste fried oil methyl ester (24.2%) is almost similar to diesel (24.5%) at full load without any modification in the engine design. The results from the review suggest that PB and WCB could be a potential fuel for diesel engine and play a vital role in the near future. But the main problem associated with it is its poor cold flow property. The poor CFP of PB and WCB leads to crystallization of fuel particles and it leads to starting problem in engine during cold climatic condition. It is due to high CP and PP of PB and WCB. To overcome this problem various methods have been suggested by the researchers which include blending of biodiesel. The objective of this work is to investigate the cold flow behavior of PB, WCB and their ternary blends with diesel. The paper also describes the impact of these fuels on engine performance and emission.

2. Measurement methodology

The PB and WCB samples were analyzed for (methyl esters) ME formation at a predetermined interval of time by Gas Chromatograph (metal make) equipped with a flame ionization detector and a capillary column for injecting the sample [30]. The GC oven was kept at 230 °C (5 °C/min). Nitrogen was used as carrier gas. Quantitative analysis of % ME was done using European standard EN 14,103:2003 (DIN EN, 1410). The % ME yield was calculated using Eq. (1).

$$\%\text{ of ME} = \frac{\sum A - A_{EI}}{A_{EI}} \times \frac{C_{EI} - V_{EI}}{m} \times 100 \quad (1)$$

$\sum A$ = total peak area from the methyl ester in C14 to that in C24:1;
A_{EI} = peak area corresponding to methyl heptadecanoate;
C_{EI} = concentration of the methyl heptadecanoate solution (mg/ml);
V_{EI} = volume of the methyl heptadecanoate solution (ml);
m = mass of the sample (mg).

For the purpose of error analysis, 3 tests were conducted for single sample and then the average of the 3 readings was taken for further investigation purpose.