ENGINE PERFORMANCE OF BIODIESEL FROM FEEDSTOCK FOR CLEANER ENVIRONMENT: A REVIEW

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Key words: Biodiesel, internal combustion engine, emission, diesel engine.

Abstract. The search for renewable energy sources is being intensified globally and this includes alternative fuels for compression engine. Biodiesel from inedible oil bearing seeds has been discovered as a good replacement for diesel fuel. This paper is a review of literature of formulae for engine parameters, performance of compression ignition engines when run with biodiesel from the most common feedstocks. Research findings show that biodiesel can replace or substitute diesel fuel and its biorefinery can be set in developing countries like Nigeria. The paper also highlight its advantages of biodiesel for reduce greenhouse emission as a renewable fuel.

Introduction

An internal combustion engine is a reciprocating heat engine in which fuel mixed with correct amount of air burnt inside a cylinder. The gaseous products of combustion form the working substance which make the piston move and produce mechanical work at the engine crankshaft. The I.C. engines are classified on the basis of following systems and their variations: Number of strokes required for the completion of one cycle, thermodynamic cycle, ignition system, kind of fuel used, number and arrangement of cylinders, fuel supply system, cooling system, lubrication system, governing system, valve location and field of application (Rajput,2007).

1.Performance Parameters

The engine performance is expressed in terms of certain parameters as defined below (Kumar, 2010).

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Mechanical efficiency: The ratio of brake power to indicated power is called mechanical efficiency

Mechanical efficiency $\eta mech = B \cdot P / I \cdot P$

The mechanical efficiency is a measure of the mechanical perfection of the engine or its ability to transmit the power developed in the cylinder to the drive shaft. The mechanical efficiency essentially depends on the design of the engine, its condition and load, and its values from 75 to 90% for different types of engines.

Thermal efficiency of an engine is the indicator of conversion of heat supplied into work energy. It is based either on indicated power or on brake power. The indicated thermal efficiency of an I.C. engine is the ratio of heat converted into indicated work to the heat energy in fuel supplied to the engine.

Indicated thermal efficiency = $\eta i_{th} = \dfrac{I \cdot P}{Mf \bullet Cv}$

Where Power and mechanical Efficiency M_f = mass of fuel supplied

Cv = lower calorific value of fuel in

Cv $I.P$ = Indicated power in watt

Brake thermal efficiency is the ratio of heat converted into useful shaft work to the heat supplied to the engine in fuel.

Brake thermal efficiency = $\eta_{bth} = \dfrac{B \cdot P}{Mf \bullet Cv}$

From the expression for ηi_{th} and η_{bth} as given above, we can write

$$\frac{\eta_{bth}}{\eta_{i\,th}} = \frac{BP}{IP} = \eta_m$$

$$\eta_{bth} = \eta m \bullet \eta_{i\,th}$$

Specific fuel consumption, the fuel consumption and the evaluation of fuel cost is an important factor considered to have an indication of the relative economy of the engine under test when compared with test results on other engines. The criterion of economic power production is the specific fuel consumption (sfc) which is defined as the mass of fuels required to be supplied to an engine to develop unit KW power per hour. That is

$$S \cdot F \cdot C = \frac{\mathrm{M}f}{B \cdot P}\left(kg / kwh\right)$$

The value of SFC is approximately 1.47kg/kwh for diesel engines and 1.85kg/kwh for petrol engines.

Brake power of the engine for both fossil diesel and biodiesel fuels (Heywood, 1986) as:

$$Pb = \frac{2\Pi NT}{60}$$

Where,

$T = F * R$

Pb = brake power, Nm/s or W

T = torque, N.m

F = weight, N

N = number of revolution per second.

Air-fuel ratio: It is defined as the ratio of the mass of air to the mass of fuel in the air-fuel mixture. This ratio remains practically constant for petrol engines over a wide range of operation. However, for diesel engines the air-fuel ratio varies with load as the mass of air remains constant but the mass of fuel changes with load on the engine.

2.Engine Performance Characteristics of Oil and Biodiesel

2.1.Engine Performance of Oil. A lot of research work has been carried out to use vegetable oil both in its neat form and modified form (Agarwal et al., 2008; Georing et al., 1982; Bagby, 1987). Studies have shown that the usage of vegetable oils in neat is possible but not preferable (Alton, 1998). During World War II, Seddon (1942) experimented with using several different vegetable oils in Perkins p-6 diesel engine with great success and concluded that vegetable oils could be used to power a vehicle under normal operating conditions. However, it was noted that much work was needed before vegetables oils used as a reliable substitute for diesel fuel. Bruwer et al. (1981) reported the use of sunflower seed oil as a renewable energy source. When operating tractor with 100% sunflower oil instead of diesel fuel, an 8% power loss occurred after 1000h of operation, which was corrected by replacing the fuel injector and injector pump. Tarbrough et al. (1981) reported that raw sunflower oils were found to be unsuitable fuel, while refined sunflower oil was found to be satisfactory. Tahir et al. (1982) reported that oxidation of sunflower oil left heavy gum and wax deposit on tested tractor, which could lead to engine failure. Betts et al. (1982) and Engler et al. (1983) reported that the sunflower seed oil is acceptable only for short-term use as a fuel source but long term durability test indicated severe problems due to carbonization of combustion chamber. Bacon et al. (1981) evaluated the use of several vegetable oils as potent fuel sources and reported that use of these oils caused carbon build up in the combustion chamber. Schoedder (1981) used rapeseed oil as a diesel fuel replacement in Germany with mixed results. Short term engine tests indicated similar energy outputs in both rapeseed oil and diesel fuel. Initial long-term engine tests showed that difficulties arose in engine operation after 100h due to deposits on piston rings, valves and injectors. Auld et al. (1982) analyze rapeseed oil and showed a relationship between viscosity and fatty acid chain length. Bettis et al. (1982) reported that rapeseed oil contained 94-95%of the energy content of diesel fuel, and to be approximately 15 times viscous.

Reid et al. (1989) evaluated chemical and physical properties of 14 vegetable oils. They pointed out that the oils are very differently form petroleum-based fuel because of high viscosity. Engine test showed that carbon deposits in the engine were reduced if the oil was heated prior to combustion. It was also noticed that carbon deposit levels differed from oils with similar viscosities because of oil composition.

2.2. Need of Blending and its Effect on Performance. Engelman et al. (1978) reported that 10-50% soybean oil fuel blends with diesel minimize the carbon deposition in combustion chamber. Quick (1980) used over 30 different vegetable oils to operate compression engines and reported that the use of raw vegetable oil fuels can lead to premature engine failure. Blending vegetable oils with diesel fuel was found to be a method to reduce chocking and extend engine life. Sims et al. (1981) indicated that short-time engine tests with 50% vegetable oil fuel blend had no adverse effects. Carbon deposits on combustion chamber components was found to be approximately same as that found in engines operated by Bartholomew (1981), Barsic and Humke (1981), Wanger and Peterson (1982); Walt and Hugo (1982) working on different oils such as pea nut oil, cottonseed oil, sunflower oil, rapeseed oil and sun flower oil respectively. German et al. (1985) reported that carbon deposits on the internal engine components were greater for the tractor fueled with 50/50 sunflower oil/diesel than those fueled with a 25/75 sunflower/diesel fuel blend.

Sapaun et al. (1996) reported that power outputs were nearly the same for palm oil, blend of palm oil and diesel fuel, and 100% diesel fuel. Short-term using of palm oil fuel showed no adverse effects. Several researchers (Hofman et al. 1987; Peterson et al, 1981; Pryor et al., 1983) have indicated that vegetative oil fuel blends had encouraging results in short term testing, whereas problem occurred in long term durability tests. Pestes and Stanislao (1984) employed a one to one blend of vegetable oil and diesel fuel to study the piston rings deposits. Premature piston ring sticking and carbon built up due to the use of the one fuel blend caused engine failure. These investigators recommended that to reduce piston ring deposits a fuel additive or a fuel blend with less vegetative oil was needed. The atomization and injection characteristic of vegetative oils were significantly different from that of diesel fuel due to the higher viscosity of the vegetative oils (Ryan et al., 1984).

Engine performance tests showed that power output slightly decreased when using vegetable oil fuel blends. Nag et al. (1995) showed that performance tests using fuel blend as great as 50-50 seed oil from the Indian. Ambulate plant and diesel fuel exhibited no loss of power. Knock free performance with no observable carbon deposits on the functional parts of the combustion chamber were observed during these tests. Mc Cutechen (1981) compared engine performance of direct injection engine to indirect injection engines when fueled with 30% soybean oil 70% diesel fuel. The result indicated that indirect injection could be operated on this fuel blend while the direct injection engine could not without catastrophic engine failure occurring. The direct injection engines showed injector coking and piston ring sticking as a result of using sunflower oil.

Mc Donnell et al. (2000) reported that rapeseed oil could serve as a fuel extender at inclusion rates up to 25%. As a result of using rapeseed oil as a fuel injector life was shortened due to carbon build up.

Obodeh and Ezimokhai (2009) investigated diesel engine fuelled with diesel-kerosene blends. They reported that kerosene-doped diesel will be more receptive to modern emission control equipment due to its low sulphur content as compared to diesel fuel.

2.3. Engine Performance Characteristics of Biodiesel. Biodiesel has a low heating value, (10% lower than diesel) on weight average basis because of presence of substantial amount of oxygen in the fuel but at the same time biodiesel has biodiesel has a higher specific gravity (0.88) as compared to mineral diesel (0.85). The overall impact is approximately 5% lower energy content per unit volume.

Thermal efficiency of an engine operating on biodiesel is generally better than that operating on diesel. Brake specific energy consumption (bsec) is a more reliable criterion compared to brake- specific fuel consumption (bsfc) for comparing fuels having different calorific values and densities. Several experimental investigations have been carried out by researchers around the world to evaluate the engine performance of different biodiesel.

Clark et al. (1984) reported that the derivatives particularly the methyl esters of rapeseed, soybean and other seed oil have been shown to be similar to diesel in performance. Mittelbach et al. (1985) examined that the exhaust from combustion of vegetative oil ester is lower in carbon monoxide and particulate content but higher in nitrogen oxide than diesel fuel.

Usta (2005) showed that tobacco seed oil methyl ester can be partially substituted for the diesel fuel at most operating conditions in terms of performance parameter and emissions without any engine modifications and pre heating of the blends.

Kalligeros et al. (2003) reported that engine fueled with pure marine diesel fuel and blends containing two types of biodiesel, at proportion up to 50%, the performance was satisfactory. Monyem and Gerpen (2001) evaluated the impact of oxidized biodiesel on engine performance and emission. AJohn Deere 4376 turbocharged DI diesel engine was fueled with oxidized and unoxidized biodiesel and the performance and emission were compared with no.2 diesel fuel. The engine performance of the neat biodiesel and their blends was similar to that of no.2 diesel fuel with the same thermal efficiency, but higher fuel consumption.

Peterson et al. (1992) reported that the engine performance of a diesel engine fuelled with methyl and ethyl esters of rapeseed oil was comparable to standard diesel fuel with ester showing slightly lower power output and associated higher brake-specific fuel consumption. The methyl ester was reported to produce slightly more power than the ethyl ester. Baiju et al. (2009) investigated the suitability of methyl and ethyl ester from karanja oils as an alternative diesel fuel. They reported that methyl esters produced slightly higher power than ethyl esters and exhaust emissions of both esters were almost identical. These studies show that both esters can be used as a fuel in compression ignition engine without any engine modification.

Wang (2000) shown that the heavy trucks fueled by B35 emitted significantly lower particulate matter (PM) and moderately lower carbon monoxide (CO) and hydro-carbon (HC) than the same trucks fueled by number 2 diesel (D2). Oxides of nitrogen (NOx) emission from B35 and D2, however, were generally in the same level.

Raheman and Phadatare (2004) investigated the fuel properties of karanja methyl ester and its blend with diesel from 20 percent to 80 percent by volume and in running a diesel engine with these fuels. Their results showed a reduction In exhaust emissions together with increase in torque, brake power, brake thermal efficiency and reduction in brake-specific fuel consumption made the blends of Karaja esterified oil (B20 and B40) a suitable fuel for diesel.

Carraretto et al. (2004) checked the operation of a biodiesel fuelled boiler for some months and started that biodiesel appears to be a promising solutions for boilers with only minor adjustments and the performances are comparable with oil operation. Carbon monoxide emission is reduced but no No3 are increased.

Spataru and Romig (1995) and Schumacher and Bolgert (1996) both studied several blends of No. 2 diesel and SME or canola methyl ester (CME) to determine and compare engine emission from the Detroit Diesel corporation (DDC) 6 V92TA engine (a type of diesel engine widely used in transist buses and heavy trucks) operated on those fuels. Grabaski et al. (1996) also employed a 19991 DDC series 60 engine to determine emission of NOx, Co, HC, and PM that result from blending biodiesel 9methyl soy ester) and conventional diesel. The test showed that as the percentage of biodiesel blend in fuel increased, the NOx increased, but HC, CO, and PM decreased.

Schumacher and Peterson (1995, 1996) both conducted about 100,000miles of road test on cummins B5 9L engine running on 100% biodiesel. Both emission test results showed that CO, HC, and smoke emission from biodiesel tend to be lower.

Chang et al. (1996) studied the effects of using blends of methyl and isopropyl ester of soybean oil with no 2 diesel at several steady state operational conditions in John Deer 4276 T engine. Both methyl and isopropyl ester provided significant reductions in PM emission as compared with no 2 diesel fuels. Emission of CO, and HC were also reduced significantly but NOx increased by about 12%.

Harrington (1985) remarked that the fatty acid methyl esters of seed oil and fats have already been found suitable for use as fuel in diesel engine because trans-esterification provides a fuel viscosity that is close to that diesel fuel.

Altin et al. (2004) investigated the use of sunflower oil, cottonseed oil, soybean oil and their methyl esters on a single cylinder, four- stroke direct injection diesel engine. They reported that the maximum torque with diesel operation as 431 Nm at 1300rpm and that the vegetable oil was almost of the same value. Maximum power with diesel fuel operation was recorded as 7.45KW at 1700rpm, but the values of maximum engine power for each of the value was less than that of diesel at about 1700rpm. They attributed the results to the higher viscosity and lower heating values of vegetable oils. In addition, they reported that the specific fuel consumption of biodiesel (methyl esters) were generally less than those of raw vegetable oils. The higher specific fuel consumption values reported in the case of vegetable oil s are due to their lower energy content.

Lower CO emissions are observed for methyl esters in comparison to raw vegetable oils. This was attributed to better spraying qualities. NOx emissions from vegetable oils were observed to be lower than those from mineral diesel, and the NOx emission from methyl esters were higher than those of the raw vegetable oils (Agarwal, 2006).

2.4. Engine Emissions from Biodiesel. Since biodiesel is free from sulphur, hence less sulfate emissions and particulate reduction is reported in the exhaust. Due to near absence of sulfur in biodiesel, it helps reduce the problem of acid rain due to transport fuels. The lack of aromatic hydrocarbon (benzene, toluene etc.) in biodiesel reduces unregulated emissions as well like ketone, benzene etc. Breathing particulate has been found to be hazard for human health, especially in terms of respiratory system problem. PM consists of elemental carbon, sulfates and moisture, unburnt fuel, unburnt lubricating oil and remaining may be metal and other substances.

Biodiesel is oxygenated fuel (hence more complete combustion) and causes lesser particulate formation and emission. Smoke opacity is a direct measure of smoke and soot. Studies have shown that smoke opacity for biodiesel is generally lower (Agarwal, 1998, 2001: Scholl, 1983: Kalligeros et al., 2003).

CO is a toxic combustion product resulting from incomplete combustion of hydrocarbons. In presence of sufficient oxygenated fuel and leads to more complete combustion, hence CO emissions reduce in the exhaust. Altin et al. (2001) reported that CO emission for biodiesel is marginally higher in comparison to diesel, while Scholl et al. (1983) reported the reverse.

The NOx forms by oxidation of atmospheric nitrogen at sufficiently high temperatures. Kinetics of NOx formation is governed by Zeldorich mechanism, its formation is highly dependent on temperature and availability of oxygen. Several researchers (Agarwal, 2006 and Kalligeros, 2003) have reported that there are slightly increase in NOx emissions for biodiesel.

3. Advantages of Biodiesel

It is obtained from renewable raw materials. Biodiesel can be produced from vegetable, animal and recycled oils. Among vegetables, although there are more than three types of oil, the most common one in biodiesel production is soybean, rape, sunflower and palm. The recycled oils come from the collection of sectors such as restaurants, nourishing, domestic kitchens, etc.

During its combustion, it costs smaller amount of CO_2 than the one absorbed on their, so that the final balance of CO_2 emissions is positive.

Bio-diesel is considered as a CO_2 neutral emissary. Therefore, the combustion of biodiesel does not contribute to the greenhouse effect; it is neutral and it aids to fulfill the protocol of Kyoto.

It does contain neither benzene nor other carcinogenic aromatic substances, such as aromatic hydrocarbons.

It is easily biodegradable, and in case of spill and/ or accident, it does not put in danger neither the ground nor underground waters. Biodiesel is biodegradable in approximately 21 days. The absence of a chemical and synthetic compound makes it innocuous with our environment.

It is not dangerous merchandise, the flash point is over 110^{o}C, and it is therefore not classified as dangerous, which helps on safe storage and safe manipulation.

From the socioeconomic point of view, bio-fuel is a viable alternative for crop lands in decadence. This way, population will come back to rural areas keeping reasonable employment and wealth level, and helping new different agrarian factories to be developed.

4. Disadvantages of Biodiesel

At low temperatures, it can begin to solidify and to form crystals that can obstruct the flow of the fuel in the systems.

Due to the solvent properties of bio-diesel, it softens and degrades certain materials, such as natural rubber and polyurethane foam. It is therefore sometimes to change some hoses and gaskets of the engine fuel line, especially in old vehicles.

Production costs are still higher than the costs of diesel itself, and it is basically dependent on the oil sources which have been used.

Biodiesel performance per litre is about 10% less in terms of energy than the performance of petroleum diesel fuel.

Conclusions and recommendation

A review of literature indicated that numerous researches have been undertaken on the production of biodiesel from various feedstocks and its utilization in diesel engines. The research result reveals that biodiesel can be effectively substitute fossil diesel in diesel engine due to its lower emissions, non-toxicity, reduced greenhouse emissions, biodegradability. Owing to numerous benefits of biodiesel, concerted efforts in the area of research, development and dissemination on biodiesel and use in West Africa.

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