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A Study on Diesel Engine Characterization Using Alternative Fuel and Its Blends

Palash Chakma[1] and HaengMuk Cho[2*]

[1,2]Division of Mechanical and Automotive Engineering, Kongju National University, 275, Budae-dong, Cheonan-si,Chungcheongnam-do 331-717, South Korea*

Abstract

Biodiesel is a renewable and oxygenated fuel which is exclusively derived from vegetable oil, animal fats, and tallow and waste product fossil oil. Many studies reported that diesel engine can be run using biodiesel without any modification in diesel engine due to similar properties to convenient fuel. So that, it’s being considered as one of the best encouraging substitutes for combustion engines although having some physical and chemical limitations. Moreover, using ethanol and methanol as additives or as blended fuels with the diesel could be improved the quality of biofuel. In this paper, different types of biodiesel blends such as BD5, BD10, BD20, BD30, BD40 and BD50 have been analyzed in four stroke diesel engine. The study found that efficiency and power decreases while increasing biodiesel blends percentage whether it may be affected by the low volatility and high density of biodiesel. Therefore, it’s also indicated that the rate of increase of biodiesel blends could lead to raising the specific fuel consumption. In general, as compared to diesel, NO_x has been increased while decreasing of CO and HC emissions is appreciated. So, based on the overall analysis, biodiesel blends BD20 is more effective than others and can be used in the diesel engine in controlling air pollution as well as the approach of acquiring energy in the long run.

Keywords: Diesel Engine, Alternative Fuel, Performance, Emission, Diesel

INTRODUCTION

In recent days, the use of alternative fuel has increased instantaneously in the mankind especially in the industrial and transport sectors due to high muscularity demand. The limitation of fossil fuel as well as global warming , time has come to find alternative fuels to meet the energy demand globally and significant impingement on the ecological scheme but alternative fuel must be readily available, eco-friendly , economically competitive and technically feasible. In near futurity, someday fossil fuels will be depleted if we do not develop advanced technologies that could utilize alternative fuels for energy supply.

Meanwhile, based on the simpleton mechanism, excellent performance, easy maintenance, low fuel oil cost, high compression ratio, high thermal efficiency and durability diesel engines are a main and widely being used in world wide. The emission causes depletion of ozone level, greenhouse effect, and acid rain productions which lead to many diseases and the degradation of the environment, that’s why; it becomes necessary to develop alternative fuel with place comparable to rock oil fuels [1]. Biofuel such as alcohol and biodiesel can be used as an alternative of fossil fuel due to reproductively, non-toxicity, and no need to modify the engine when its fueled with biodiesel or its blends and also effective to reduce toxic emissions but for long term use its requires to ensure compliance with the standards production of biodiesel fuels as per the American Society of Testing Method (ASTM D6751) biodiesel standards. In this regards, the poor quality of biodiesels and potential failure modes has been reported by the engine manufacturers which is related to engine performance and durability. Therefore, according to statements of Engine Manufacturers Association (EMA) and Diesel Fuel Injection Equipment (FIE), the biodiesels could be blended up to 7% with diesel fuel and it could be used in diesel engines without any problem. Moreover, some EMA members approved the use of biodiesel up to 20% in the blends [2-3]. However, biodiesel produces pollutants that are less detrimental to the environment when it’s burned and it has better lubricity as compared to conventional diesel fuel. At the same time, biodiesel produces less emission particles such as hydrocarbon, carbon monoxide, particulate matter and soot in the diesel engines [4]. According to the review published by Environmental Protection Agency of USA, from diesel to B20 (20% biodiesel by volume), CO, HC, and PM decreased by 13%, 20% and 20% respectively, while NO_x emissions increased by 4%. The increase in NO_x emissions serves as a major impediment to the application of biodiesel [5]. Biodiesel gives important advantages such as fairly similar or superior cetane number, flash point, non-toxic, biodegradable and better inherent lubricity characteristics than diesel fuel. On the contrary, It has some disadvantages that have to be improved are its lower volumetric energy content, unfavorable cold-flow properties, higher kinematic viscosity, poor oxidative stability and higher NO_x emissions [6]. In addition, fuel injection process (spray, evaporation, and atomization) may be affected by higher viscosity and boiling point of biodiesel fuels that causes slower burning and longer combustion duration [7]. Choosing a right feedstock is very important because the cost of feedstock for biodiesel raw materials accounts about 75-90% of the total cost of production. However, transesterification processes are seen most suitable to produce clean and eco-friendly fuel with short chain alcohols such as methanol and ethanol [8]. The European Union has estimated that air pollution is responsible for approximately350000 excess deaths/year in the member states, which is twice the number of deaths caused by traffic accidents. [9].

Thus, the purpose of this paper is to study the diesel engine characterization such as performance and emissions analysis using alternative fuel blends which is collected from the local market.

DIESEL AND BIODIESEL PROPERTIES

Table 1: Properties of diesel and biodiesel are given [2, 11]

Properties	Diesel	Biodiesel
Fuel composition	C_{10-21} HC	C_{12-22} FAME
Heating value (MJ/ kg)	42.5	37.5
Viscosity at 40℃	2.86	5.28
Density @20℃(kg/㎥)	840	871
Cetane number	52	52
Viscosity @ 40℃(mPa s)	2.95	4.57
Flash point,(℃)	70	126
Oxygen, (wt %)	0	10.8

Table 2: The technical specifications of used engine

Manufacture	Daewoo
No of cylinders	Four
No of strokes	Four
Bore & Strokes	79 & 81.5mm
Rated power	78kw@3400rpm
BHP	105hp
Displacement	1598cc
Compression ratio	9.5:1
Injection Method	Direct
Cooling system	Water
Valve	Double overhead cam

Table 3: Performance analysis of used biodiesels

Fuel used	Partial used	Engine specification	Operating system	Variation	Results	References
Cotton seed and its blend	Diesel and Biodiesel	One-Cylinder, 4 stroke, TV1 DI, 5.2KW, 17.5CR	1500rpm	Five loads	B75: NOx, CO and Smoke emissions low. B0 and B25 records lowest CO at all loads	[1]
Two waste cooking oils (5% & 10%)	Conventional	One-Cylinder, DI, 4-stroke, NA, 5.4KW, 395cc, 18CR	2200rpm	Four loads	Increased BSFC up to 4% and reduced BTE up to 2.8%, and Increased NOx and CO2.	[3]
Canola oil (5%, 10%, 15% and 20%)	Pure diesel	NA, single-cylinder, DI, 4-stroke	2200rpm	Four loads	BSFC increased by 6.56% and reduced BTE by 4.2%, and NOx increased by 8.9%.	[6]
10%,20%,30%, 50% waste cooking oil	Pure diesel	4-stroke, one Cylinder, DI, 95mm x 82 mm, and 582 cc	1000-2000rpm	CR:14, 16, 18	CO2, NOx: Increased and HC, CO, DP: Reduced	[10]
Biodiesel(Cooking oil), 15% Ethanol, 15% Methanol	Pure diesel	2-Cylinder, 4-cycle, DI,LC,KubotaGL7000	3000rpm	Five loads	HC, CO: Increased, NOx: Decreased, BSFC: Varied	[11]
100%, 15%, 7.5% palm oil	Conventional	4-Cylinder, NA, WC, IDI, 1.8 L	2000rpm	100 h	The reduction of wear with the increased content of biodiesel	[12]
100% Waste olive	No. 2 (EN-590)	3-Cylinder, WC, DI, 2.5 L	8–15kW and 1800–	50 h	CD: no visual difference; Wear: no visual	[13]

oil			2100rpm		difference	
100%, 50% soybean oil	No. 2 (EN 590)	TC, DI, 1.9 L	NEDC driving cycle	1350 km, 750km	Wear: higher except piston	[14]
20% Rice bran oil	Conventional	4-Cylinder, NA, WC, DI	Ten running cycles	100 h	CD: significantly lower; Wear: lower	[15]

DP: Delay period, CD: Carbon deposit, HC: Hydro carbon, CO: Carbon monoxide, NO_x: Nitrogen oxide, BSFC: Brake specific fuel consumption, CO_2: Carbon dioxide, NA: Naturally aspirated, WC: Water cool, DI: Direct injection, TC: Turbo charged, EGR: Exhaust Gas Recirculation, PAH: Polycyclic Aromatic Hydrocarbon, O_{xy}-PAH: Oxygenated Polycyclic Aromatic Hydrocarbon

EXPERIMENTAL SETUP

The engine used for this experiment was naturally aspirated, water-cooled, 4-cylinder, direct-injection diesel engine. The specifications of the engine are shown in Table 2. The engine was connected to an alternator and a control system was used for adjusting its speed and torque. The fuels used in this study include diesel fuel, biodiesel and biodiesel blends. The blending percentage of biodiesel with diesel was mixed to 0%, 5%, 10%, 20%, 30, 40% and 50%, and are identified as BD0, BD5, BD10, BD20, BD30, BD40 and BD50 fuels. The biodiesel was collected from local market as required. The main parameters expected from the engine were power produced by the engines, speed, fuel consumption, exhaust gas temperature; exhaust gas analysis measured using Global Diagnostic Software (GDS) system. The major properties of the diesel and biodiesel are shown in Table 1.

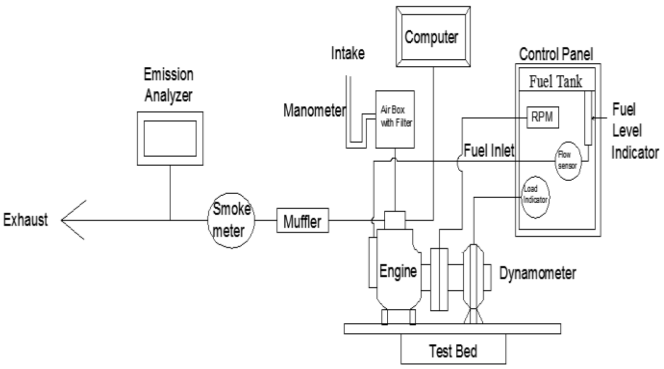

Figure 1: Schematic diagram of experiment setup.

Figure 2: Lab experimental setup.

RESULTS

Performance analysis

From the Fig. 3, it is observed that the biodiesel blending percentage increased while brake horse power decreased respectively. The output torque also decreased with increasing blend ratios and affects the brake power of the engine, since torque and power are directly proportional when the engine speed is fixed.

The Fig. 4 shows mechanical efficiency is inversely proportional to the biodiesel blend percentages. Meanwhile, the higher mechanical efficiency of biodiesel is actually responsible for high volatility and low density of ester which helps the atomization of the fuel and thus leads to better combustion. On the contrary, low volatility and high density affects the fuel atomization due to lower mechanical efficiency. Therefore, both graphs show that slight difference between brake power and mechanical efficiency for all blends but it is insignificant when compared to BD0. Also there is no percentage change in between BD10 and BD20 blends and performance is shown quietly similar. The percentage of biodiesel ratios is exactly proportional to the specific fuel consumption which is shown Fig. 5. When compared to biodiesel, biodiesel has the lower calorific value which leads to increase fuel consumption. Moreover, it’s cleared that more fuel has been consumed by BD50 while producing power with respect to BD0.Meanwhile, the lower calorific value of biodiesel is totally depending on quantity of oxygen content whether it is high or low. Note that the variation of engine power is expected the lower calorific value and energy formation of biodiesel. It is analyzed that engine speed is speed directly to the horse power. Fig. 6 shows that engine power decreased while biodiesel percentage increased. So, we can write the engine performance is greatly influenced by the biodiesel percentage.

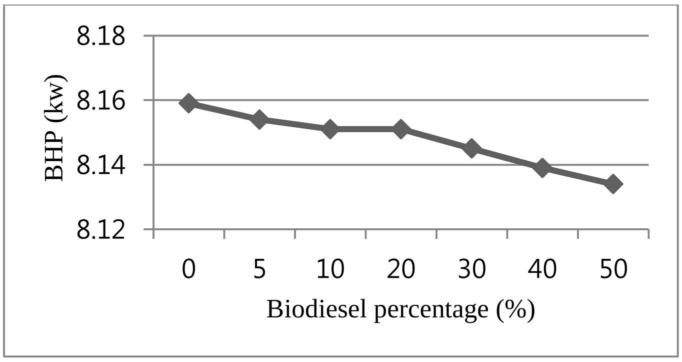

Figure 3: Comparison between horse power and biodiesel.

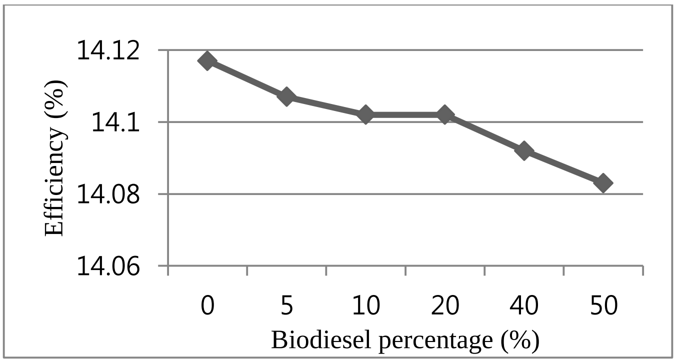

Figure 4: Comparison between efficiency and biodiesel.

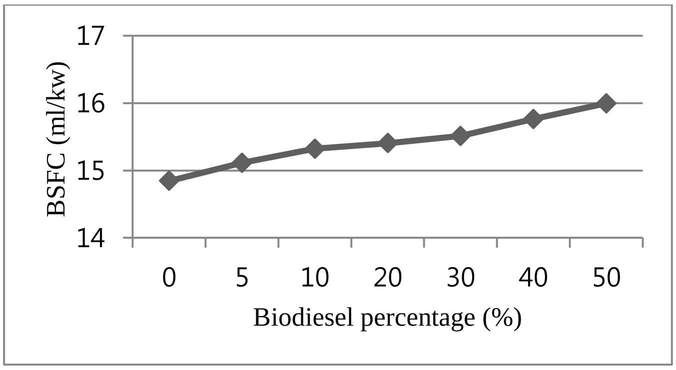

Figure 5: Comparison between specific fuel consumption and biodiesel.

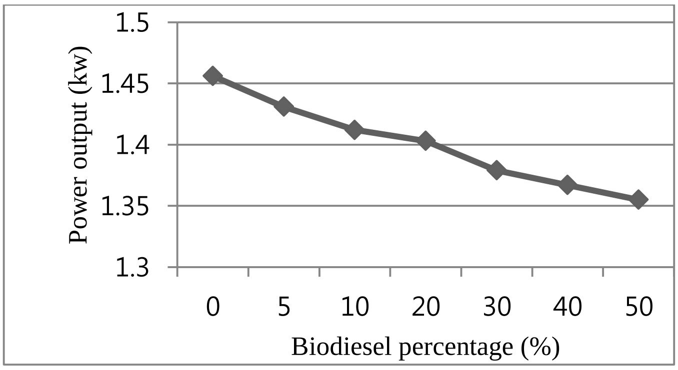

Figure 6: Comparison between engine power output and biodiesel.

Emission analysis

An extensive analysis has been carried out using various types of biodiesel blends on emissions by Environmental Protection Academy (EPA), USA which is shown in Fig. 7. The NO_x emission variation percentages for B20, B40, B60 and B80 are 2.1%, 4.2%, 6%, 8.1% and 10% respectively. The rate of NO_x increment depends on the biodiesel percentage ratios. Usually, the pressure, combustion chamber, temperature, compressibility and low oxygen contamination is mainly responsible for NO_x formation. However, when the temperature exceeds 1093℃, NO_x formation takes place because it is highly on dependent temperature. On the other hand, The percentages approximately 12%B20, 22%B40, 31%B60, 40%B80 and 47%B100 of PM and then 12%B20, 23%B40, 32%B60, 40%B80 and 47% of CO respectively. Finally, the decrement percentages of HC are 22%B20, 34%B40, 49%B60, 60%B80 and 66%B100.

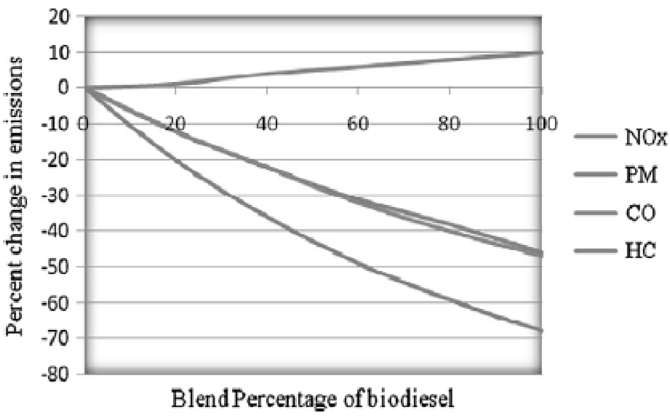

Figure 7: Illustration between emissions and biodiesel percentages for heavy duty engines [5].

Emissions from IIASA [16] and from Fig. 8 & 9, it can be seen that the release rate of NO_x emission increases all over the world. China shows that very large amount of NO_x emission as compared to other countries. However, USA causes a decrease of NO_x due to lower consumption of oil from 2015 to 2035 but the reverse is true for India. As a whole, it can be concluded that important NO_x reductions increased, especially in the developing world scenario is not quite impressive, can be acquired through energy system measures. Normally particular materials (PM) create from pave and unpaved road dust, construction dust, agricultural land preparation and harvest dust but the industry and domestic sectors are also dominating to increase PM emissions by small combustion sources.

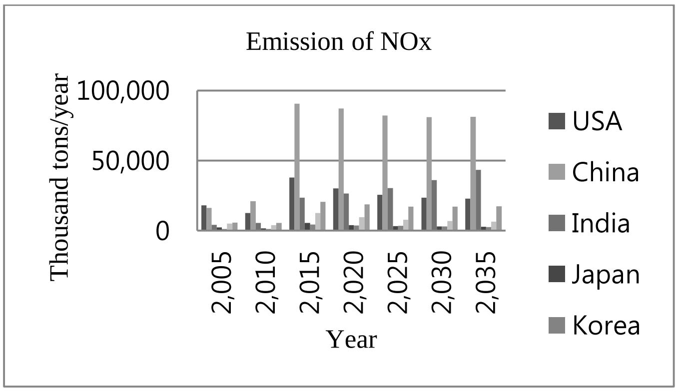

Figure 8: Total impact on NO_x by country [16].

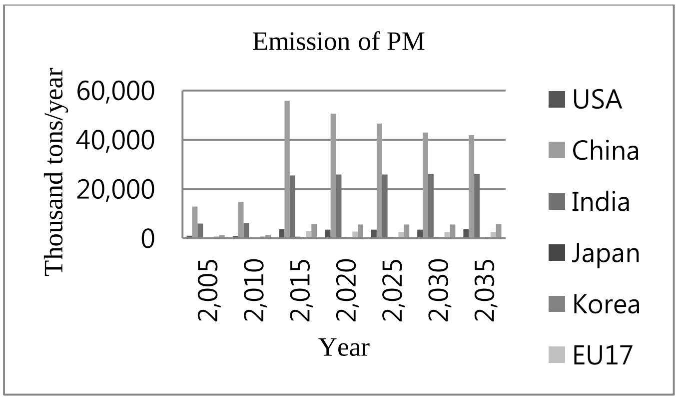

Figure 9: Total impact on PM by country [16].

CONCLUSIONS

With the emissions analysis and characteristic reference to the execution of biodiesel blends, the following conclusions can be written based on the engine performance.

1. The biodiesel (BD20) blends performance was truly consistent in the diesel engine than other blends and result almost similar to conventional fuel and then could be used as an alternative to diesel fuel to control exhaust emissions.
2. When biodiesel blends percentage was increased the specific fuel consumption of the diesel engine was also increased due to higher oxygen content and lower calorific value of biodiesel.
3. Engine power is reduced with increasing biodiesel blend ratios while efficiency is increased with increasing biodiesel blend ratios. This fluctuation may only due to viscosity, calorific values, and oxygen content.
4. Study shows that NO_x emission is increased while CO and HC emissions are reduced for all the blends as compared to that of diesel fuel.
5. It can be told that proper injection timing, pressure, and compression ratio can be boosted up engine performance when diesel fueled with biodiesels and carbon deposit, oil dilution, ring sticking, injector chocking are also reported while using biodiesel in cold weather.

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