

EMISSION CHARACTERISTICS OF A DI DIESEL ENGINE WITH BIO-FUEL

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ABSTRACT

Rapid increase in the level of carbon dioxide and other poisonous gases are leading to global warming. An exhaust from automotive vehicles is one of the most important constituents of the total environmental pollutions. At the same, the increasing energy consumption and fast diminishing energy reserves have led to an intensified search for viable renewable alternative sources of energy globally. In this paper, exhaust emission of a four-stroke direct injection naturally aspirated diesel engine operated with a number of bio-fuels was investigated. The tested bio-fuels were the blends of linseed oil (LO) and mustard oil (MO) of various percentages with conventional diesel fuel. The engine was also performed with blends of linseed oil methyl ester (LOME) and of mustard oil methyl ester (MOME) with conventional diesel fuel. The exhaust emissions including oxides of nitrogen (NO_x), carbon monoxide (CO) and smoke were investigated. Comparison of results with conventional neat diesel (ND) fuel showed that the NO_x emissions of diesel-biofuel blends were little bit higher than that of conventional diesel fuel due to oxygen content in the biofuel but the CO and smoke emissions were lower than that of conventional diesel fuel. Significant improvement in diesel exhaust emissions was achieved with esterified biofuel. The exhaust gas emissions provided indication of the potential to meet future exhaust emission standards.

Keywords: Emission, Diesel Engine, Biofuel

1. INTRODUCTION

The non-renewable nature and limited resources of petroleum fuels has become a matter of great concern. The economic and political factors are greatly associated with their procurement. The combustion of these fuels in I.C. engines causes environmental pollution. All these aspects have drawn the attention to conserve and stretch the oil reserves by way of alternate fuel research [1]. Bio-fuel may be defined as an alternative fuel that is derived from the vegetable oils and fats of plants. The auto ignition properties of vegetable oils are almost the same as those of diesel fuels and hence can be used in diesel engines with little or no engine modification [2].

Although short term tests of diesel engine using neat vegetable oil showed promising results, longer tests led to injector coking, more engine deposits, ring sticking and thickening of the engine lubricant. These experiences led to the use of modified vegetable oil as a fuel. Among liquid bio-fuels, bio-diesel derived from vegetable oils is gaining acceptance and market share as diesel fuel in Europe and the United States [3]. Technical aspects of biodiesel are approached; such as the physical and chemical characteristics of methyl ester related to its performance in compression ignition engines. Biodiesel has become more attractive recently because of its

environmental benefits and the fact that it is made from renewable sources [4].

In present days of fuel crisis and rising of price of fuels, it becomes extremely important to search for an alternative one. As days are passing away, the demand is increasing enormously. But the exhaust emission of a diesel engine is a burning question for today's. Another important thing is that burning of fossil fuels for centuries has polluted our environment considerably. CO_2 (carbon-di-oxide), CO, NO_x , SO_2 (sulfur-di-oxide) percentage in atmosphere has crossed safety limits. Limited energy resources and increasing emission regulations have motivated an intense search for alternative transportation fuels over the last three decades. A major obstacle to commercialization of these alternative fuels is the lack of widespread fuel availability. Alternative fuels that can be blended with existing petroleum-based fuels have a distinct advantage because they can be used when available but the vehicle can also be fueled with conventional fuels when the alternative is unavailable [5].

Biodiesel is an environmentally friendly alternative diesel fuel consisting of alkyl monoesters of fatty acids from vegetable oils and animal fats. Recent developments in the relative price of vegetable oils and

petroleum have produced conditions where biodiesel is close to being cost competitive. Depending on the trade-off between cost and its environmental benefits, biodiesel will probably be used blended with no.2 or no.1 diesel fuels [4]. One drawback of biodiesel is that there is an inverse relationship between biodiesel's oxidative stability and its cold flow properties [6]. Similar to alcohol fuels, biodiesel has lower energy content and different physical properties than diesel fuels and this may require engine-setting adjustments to improve engine performance and emissions.

In Bangladesh diesel is primarily used for transportation, agriculture and electric power generation. Diesel is becoming scarce and costlier, hence there is a need to preserve diesel for only automotive, and agriculture uses. For power generation alternative fuels should be used wherever possible so that diesel is conserved and made available for its primary uses [7]. Transportation of goods and people in Bangladesh is dominated by road transport, which accounts for 80% of all 1,50,000 motor vehicles and 49% of freight. Beside, Bangladesh is rapidly growing industrially. As energy and economy are closely linked it is realized that a growing economy should demand a much higher level of energy consumption. Thus there is urgent need to take all necessary steps for energy management and conservation.

There are several possible alternative sources of fuels. These are vegetable oils, alcohol such methanol and ethanol; hydrocarbon gases such as compressed natural gas (CNG), liquid petroleum gas (LPG), hydrogen producer gas etc [8]. Among them, vegetable oil presents a very promising alternative to diesel oil since they are renewable and is easily available in rural areas where there is an acute need for modern forms of energy [9]. The choice of the vegetable oil for diesel engine fuel naturally depends upon the local conditions and the production of vegetable is very simple and in agricultural country, it can be made quite economical. A number of oils are being considered world wide for use in engines. This include karanji oils, cotton seed oil, rice bran oil, rapeseed oil, sunflower oil, cesium oil, linseed oil, palm oil, Soya bin oil, Neem oil, Sesame oil etc [10]. In context of Bangladesh LO and MO are considered for this experiment. This study investigated the exhaust emissions such as, CO, NO_x, and smoke of diesel-biofuel blends of various percentages of the diesel engine. The experiment was also conducted by the blends of diesel-esterified biofuel of several percentages.

2. APPARATUS AND METHODS

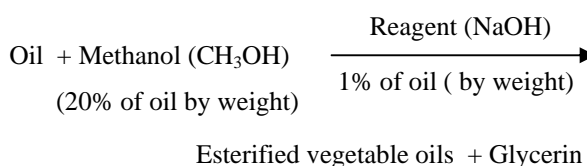
2.1 Experimental Setup

The engine used in these experiments was a single cylinder, water-cooled, direct injection diesel engine described in Table 2.1. The rpm was measured directly from the tachometer attached with the dynamometer. The outlet temperature of cooling water and exhaust gas temperature were measured directly from the thermometer attached to the engine. The fuel consumption was measured using the burret attached with the engine by the stopwatch. Air consumption was

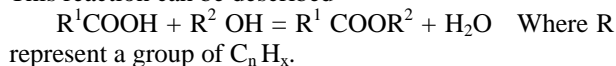
measured using the air flow meter, which consists of sharp edged-machined brass orifice carried in the side of the steel air box, which is supported on a stand and connected by flexible hosepipe to the air inlet of the engine. An inclined manometer mounted on the side of the air box measured the pressure drop across the orifice by which actual mass flow of air was measured. Digital exhaust gas analyzer whose specification is demonstrated in Table 2.2 was used to measure exhaust gas emissions.

2.2 Making of Biodiesel

Esterified vegetable oil or biodiesel is referred to as the mono alkyl esters of long chain fatty acids derived from renewable liquid sources. Biodiesel is the name for a ester-based oxygenated fuels from renewable biological sources. It can be used in CI engine with little or no modifications. Pure biodiesel is biodegradable, nontoxic and essentially free for sulfur and aromatics. Biodiesel is a methyl or ethyl ester of mainly vegetable oils. Methyl or ethyl esters can be produced from vegetable and tree oils, animal fats, etc. by esterification. Esterification is a chemical reaction in which a mixture of anhydrous alcohol (CH₃OH) and reagent (NaOH) in proper proportions is combined with moisture free vegetable oil. The materials are maintained at 60°C to 65°C and allowed to settle by gravity for 24 hours.



This reaction can be described



The ester of fatty acids has lower viscosity than the derivatives of fatty acids from which they are formed.

2.3 Test Procedure

The engine was assembled and coupled with the hydraulic dynamometer. Then a thorough check up was made which was followed by a trial run of some times with diesel fuel. The engine was first run at 1000 rpm for some time with diesel fuel for allowing it to reach steady state condition. The stopwatch was started when the fuel level passes the top spacer and stops it when it passes second. Each time corresponding values of inlet cooling water temperature, outlet water temperature, exhaust gas temperature; fuel consumption and manometers reading were taken. Exhaust gas was analyzed to determine the emission parameters CO, NO_x, smoke number etc. The engine was then run at 1200, 1400, and 1600 rpm and same procedure was continued. Engine tests were performed at injection timing 17° btdc under 134.5 kgf/cm² at constant load 4.55 kg (10 lb) and engine tests were conducted with 10%, 15%, 20%, 25% blends of LO and MO with diesel fuel

Diesel was then changed and 10%, 15% and 20% blends of LOME and MOME with conventional diesel fuel were used to run the engine. The same process was

used to run the engine. All data were taken following the same procedure as taken during the diesel fuel. Data of only 15% and 20% blend of esterified vegetable oils are presented here for discussions.

3. RESULTS AND DISCUSSION

Exhaust gas was analyzed by a digital gas analyzer and, CO and NO_x and smoke emissions were measured at various engine speeds at fixed load. Data of 10%, 15% and 20% blends of LO, MO, LOME and MOME with conventional diesel fuel were investigated but because of better results data of 15% and 20% blends are presented here for discussions.

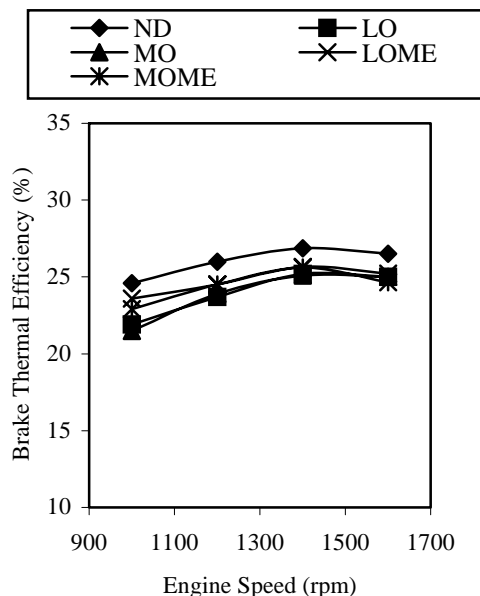


Fig 1. Engine Efficiency vs Speed curve (15% Blends, load = 4.55 kg)

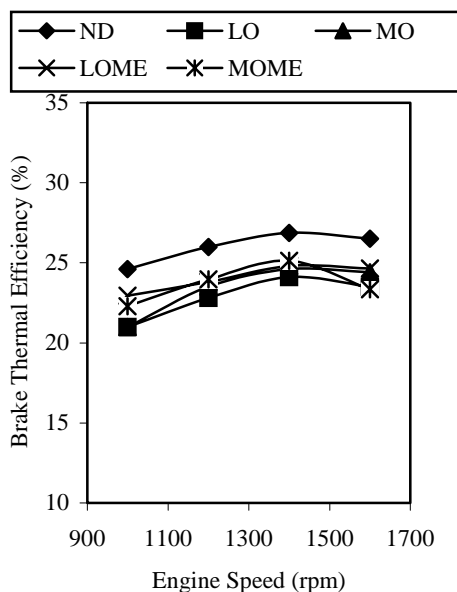


Fig 2. Engine Efficiency vs Speed curve (20% Blends, load = 4.55 kg)

Figure 1 and figure 2 show the relationship between brake thermal efficiency and engine speed. It is seen from these figures that the brake thermal efficiency of LO and MO are lower than diesel fuel but blends of LOME and MOME with diesel fuel show comparatively higher brake thermal efficiency than LO and MO due to lower calorific value and higher oxygen content. Brake thermal efficiency depends on brake power (BP), fuel flow rate (m_f) and calorific value (CV) of fuel.

Figure 3 and figure 4 show the relationship between the engine speed and CO emission. It is seen that, the CO emission of LO, MO, LOME and MOME blends with diesel is lower than that of diesel fuel. The CO decrease in the emissions may be associated with the oxygen

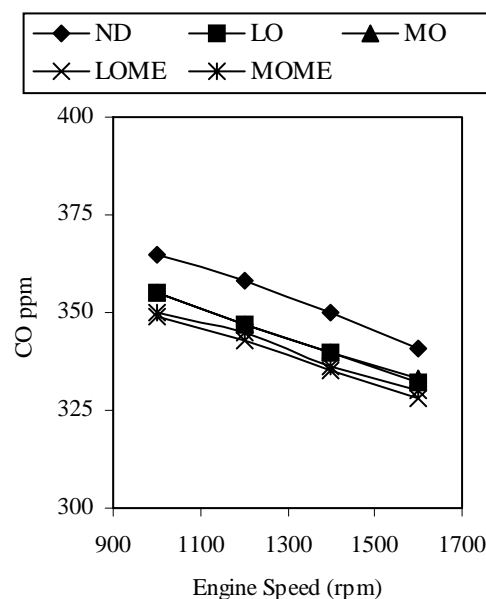


Fig 3. Variation of CO emission with Engine Speed (15% Blends, load = 4.55 kg)

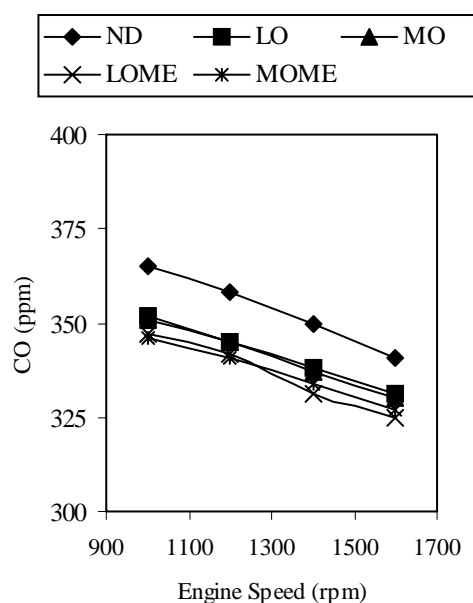


Fig 4. Variation of CO emission with Engine Speed (20% Blends, load = 4.55 kg)

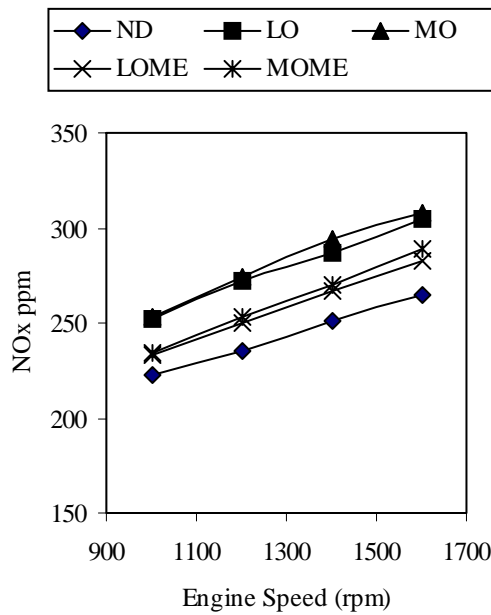


Fig 5. Variation of NOx emission with Engine Speed (15% Blends, load = 4.55 kg)

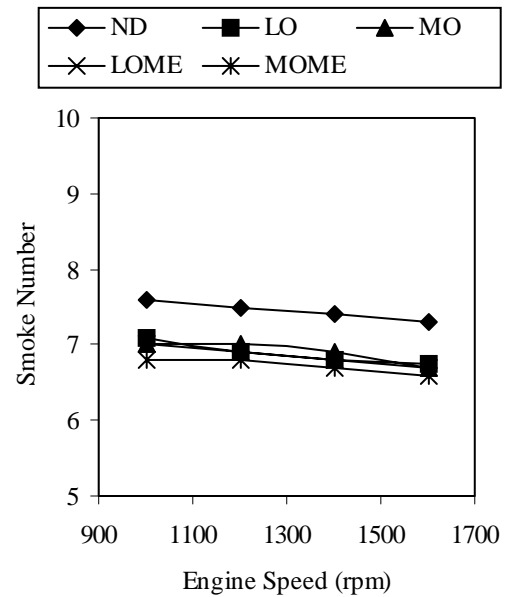


Fig 7. Variation of Smoke emission with Engine Speed (15% Blends, load = 4.55 kg)

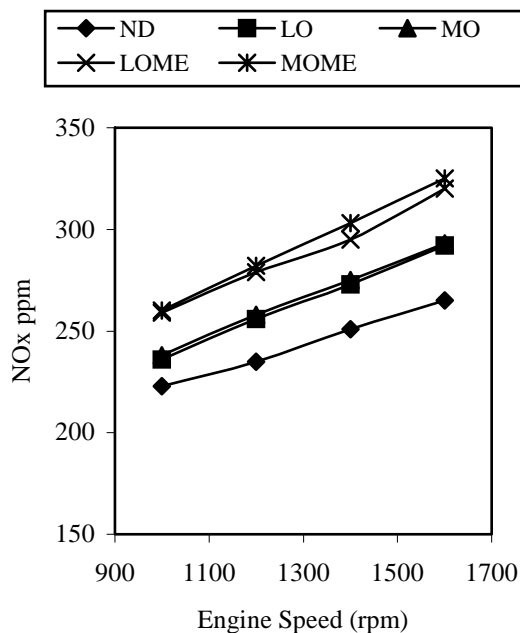


Fig 6. Variation of NOx emission with Engine Speed (20 % Blends, load = 4.55 kg)

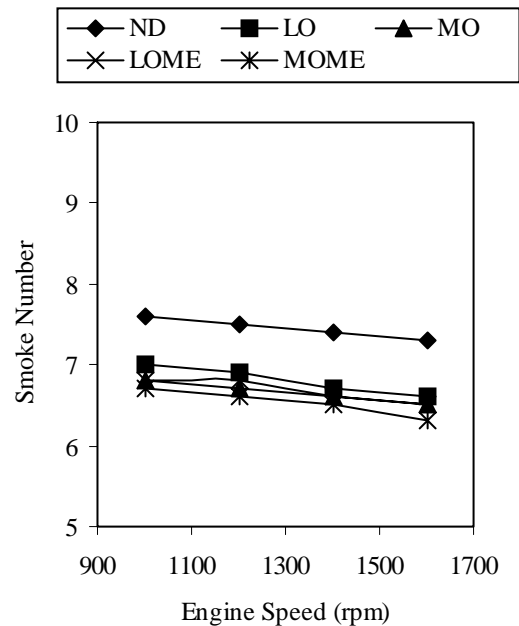


Fig 8. Variation of Smoke emission with Engine Speed (20 % Blends, load = 4.55 kg)

content in the LO, MO, LOME and MOME molecules.

Figure 5 and figure 6 show the relationship between the engine speed and NOx emission of esterified vegetable oils at fixed load. The NOx emission of blends of LO, MO, LOME and MOME with diesel increases with the increases of engine speed and higher than that of diesel fuel. Because of increasing rate of exhaust gas temperature and oxygen content in the biofuel and biodiesel, NOx emission increases.

Figure 7 and figure 8 shows the relationship between the engine speed and smoke emission of blends of LO, MO, LOME and MOME with diesel. The smoke emission of blends of LO, MO, LOME and MOME,

decreases with the increasing of engine speed and lower than that of diesel fuel. With increasing speed comparatively complete burning is occurred due to more oxygen content in the air-fuel mixture. Beside this, biofuel and biodiesel contains more oxygen than conventional diesel fuel. Complete combustion decreases smoke emission in the exhaust gases.

4. CONCLUSIONS

From this investigation it is observed that exhaust gas emissions using blends LO, MO, LOME and MOME with conventional diesel fuel in DI diesel engines are comparable with those of conventional diesel fuel. These

are summarized as follows:

1. The exhaust emissions of diesel engine with biofuel i.e. LO and MO are quite comparable with diesel fuel.
2. LO and MO show the considerable reduction in CO emission as compared to conventional diesel fuel.
3. NO_x emission of LO blends and MO blends with diesel fuel is higher than that of diesel fuel because of oxygen content in their molecules but comparable to that of diesel fuel.
4. LO and MO show lower smoke emission as compared to diesel fuel.
5. Blends of LOME and MOME with diesel fuel show comparatively better results than LO and MO.
6. Vegetable oils are environmentally friendly, do not affect engine and bearing components seriously, does not degrade lubricating oil and produces comparable amounts of carbon deposits.

Thus the above investigation suggests that esterified vegetable oils and their blends with diesel fuel can be effectively employed as suitable alternative fuels in existing diesel engine. Current economic prospects for these fuels are not yet promising. However, if research to reduce the production cost is intensified, energy produced by engines using vegetable oil fuel is likely to be economically competitive with virtually all other forms of energy. This hopefully will reduce the world's dependence on mineral oil for transportation and industrial sector use.

5. REFERENCES

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APPENDIX

Table 2.1: Specification of tested diesel engine

Items	Specification
Model	S 195
Type	Single-cylinder, four-stroke, horizontal type
Cylinder bore	95 mm
Piston stroke	115 mm
1- hr. rated output	13.2 PS/2000 rpm
Specific fuel consumption at 12 hour rated output	Not greater than 185 gm/Ps.hr
Compression ratio	20:1
Rated output	13.2 hp (maximum)
Type of cooling	Water evaporative type
Type of starting	Hand cranking
Injection pressure	135±5 kgf/cm ²
Engine number	3702

Table 2.2: Specification of Tested Gas Analyzer

Items	Title
Power supply	Line 230 V/50-60 Hz accu powered with integrated 6V-Accu
Charging time	Full charge 625h. Operating time 8h state of charge is displayed
Calibration	Automatic zero point calibration after switch on calibration time 1 minute
Fuels	Oil light, natural gas, town gas, coal gas, liquid gas, coal and wood dry
Screen	LCD with 4 rows each 20 characters, backlit.
Gas probe	Heated probe with PTC resistor temperature 65 °c (only operates with AC) cone Thermocouple NiCrNi Standard length 270 mm.
Gas hose	3-way- hose, Length 3.5 m
Air probe	Integrated current sensor
Dust filter	Cellpor-filter, 4 micron
Operating temperature	-10 °c bis +40 °c