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Emission Characteristics of Jatropha Biofuel Operated Passenger Bus

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ABSTRACT

Numerous laboratory studies report carbon monoxide, hydrocarbon, and engines operating with biodiesel and biodiesel blends. This paper presents a field study of multicylinder passenger bus (Ashok Leyland make) operated between Villupuram and Salem, Tamilnadu (170 Km), India using Jatropha methyl ester (JME) with different blend proportions as fuel. The total emissions of air pollutants such as carbon monoxide (CO), nitrogen oxides (NOx), particulate matter (PM) and hydrocarbon (HC) are evaluated during the operation of bus with constant speed (60 Km ±5km). Among these different proportion of blends, Jatropha methyl ester (JME20) as an alternative to the conventional fuel in the public transport considerably reduced exhaust emission.

1.Introduction

The amount of energy required to produce biodiesel from its feedstock is a fraction of the combustion energy produced by the final product. Peterson and Hustrulid (1998) estimated that substituting ~50% of the entire U.S.A. transportation petroleum diesel (PD) fuel stock with Rapeseed methyl ester (RME) or Rapeseed ethyl ester (REE) biodiesel would result in a reduction of 113–136 billion kg of CO_2 per year released in the atmosphere. This could account for ~2–3% of fossil fuel CO_2 emissions in the U.S.A. (Marland et al., 2006). The effective CO_2 emission reduction depend on the fuel production process, raw material production, and transport which may vary between different industries, process methods, providers, and locations. DeWulf et al. (2005) calculated that the renewable fraction of RME, soybean methyl ester (SME) and corn-based ethanol (EtOH) biofuels are 67.6%, 65.8% and 75.7%, respectively. Diesel engines emit substantial amounts of nitrogen oxides (NOx) and particulate matter (PM) that are harmful to human health, reduce visibility, and affect the earth's atmosphere (Jacobson, 2002; Pope et al., 2002). Recent studies demonstrated how vehicle self-pollution may be a serious health concern for passengers (Behrentz et al., 2005; Marshall et al., 2005).

Biodiesel usage with respect to clean diesel usage, generally reduces the soot fraction of PM. McCormick et al. (2001) studied the emissions from a heavy duty truck engine using biodiesel produced from various feed stocks and compared them with emissions from the same engine using a certified clean diesel fuel. During this study PM emissions were found to be substantially lower for using biodiesel than for using clean diesel, with the exception for methyl linoleate which produced significantly higher emissions (McCormick et al., 2001). The lower soot fraction and the PM emission reductions have been related to the oxygen content in the biodiesel fuel (Graboski and McCormick, 1998; Sharp et al., 2000). Generally, emissions are found to decrease more with higher biodiesel blend fractions (Peterson and Reece, 1996; Graboski and McCormick, 1998).

The direct use of laboratory-measured emission factors (even with complex driving cycles to emulate real driving conditions) in computational models has failed to accurately predict pollutant concentrations in highly impacted areas (National Research Council (U.S.A.). Committee on Vehicle Emission Inspection and Maintenance Programs, 2000). Starting in the 70s, new approaches to measure vehicle emissions in real-world conditions were introduced; including tunnel studies, remote sensing systems, C. Mazzoleni et al. / Science of the Total Environment 385 (2007) 146–159 147 road-side inspections, on-board measurement systems, chase studies etc. (e.g., Pierson and

Brachazek, 1983; Bishop et al., 1989; Sagebiel et al., 1997; Frey et al., 2003; Walsh et al., 1996; Gertler and Pierson, 1996; Stedman, 1989)

In the present field study results from an experimental approach designed to measure real-world changes in on road gaseous and PM emissions for an in-use fleet of passenger buses clean diesel fuel blend to a blend of 10% biodiesel (B10) to 40% biodiesel (B40). The real-world conditions in this study were documented including odometer readings of the buses, bus models, bus engine loads, maintenance records and environmental conditions (i.e. Atmospheric conditions).

2. Transesterfication

Transesterification is the process of using alcohol (e.g. methanol or ethanol) in the presence of catalyst such as Sodium Hydroxide (NaOH) or Potassium Hydroxide (KOH), which chemically breaks the molecule of the raw oil into methyl or ethyl esters with glycerol as a by-product.

3. Experimental Setup and Procedure

The main purpose of blending the Jatropha biodiesel with clean diesel is to decrease the viscosity of the Jatropha biodiesel and improve volatility of biodiesel without changing the molecular structure. Properties of blends of Jatropha methyl ester B10, B20, B30, B40 and diesel fuel are shown in the Table 1.

The exhaust gas analyzer measuring HC, CO, NO_x, Smoke and PM were fitted on the bus. A separate 5 litre fuel tank was used for JME blended fuel proportions for fuel supply. The bus was operated with a distance of 10 to 20Km with constant speed for each proportion of JME.

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Table 1. Fuel properties of Diesel and blends of Jatropha biodiesel.

Fuel property	D	B10	B20	B30	B40
Flash point (deg C)	54	57	60	64	66
Specific gravity	0.815	0.825	0.83	0.835	0.837
Density (kg/m3)	815	825	830	835.3	837
Viscosity at 40 deg C	2.54	3.04	3.66	3.92	4.18
Calorific value (MJ/kg)	42.14	38.66	38	37.66	35.77

"B" stands for Biodiesel & "D" stands for Diesel

The investigation was carried out for all four proportions of JME and clean diesel fuel.The various pollutant levels were measured whenever it is reaching the steady state condition. The steady-state test was repeated thrice.

4. Results and Discussion

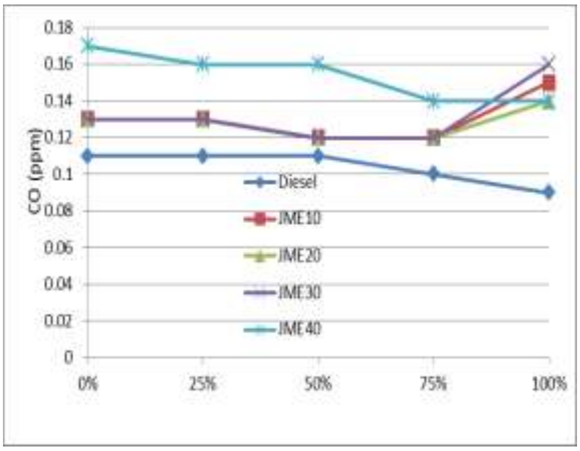

Fig 1. Load vs CO

Fig 1 shows that among all the four biodiesels blends, JME 20 has lower CO emissions when compared to diesel. This is due to more oxygen molecules present in the biodiesel, leads to complete combustion which in turn helps in reduction of CO. Further, CO emissions reduce when using biodiesel due to lower carbon to hydrogen ratio in biodiesel compared to clean diesel.

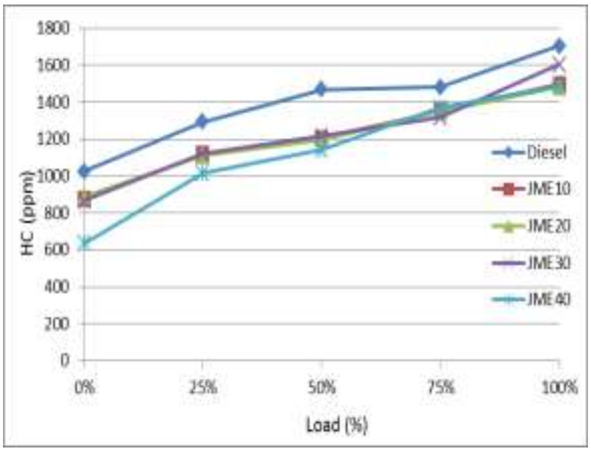

Fig 2. Load vs HC

Fig 2 shows that HC emission and it is minimum compared with other biodiesel blends at all loads. Among the four blends, JME 20 showed minimum HC emission than the others. This may be due to biodiesel contain more oxygen, which leads to better combustion when compared with diesel.

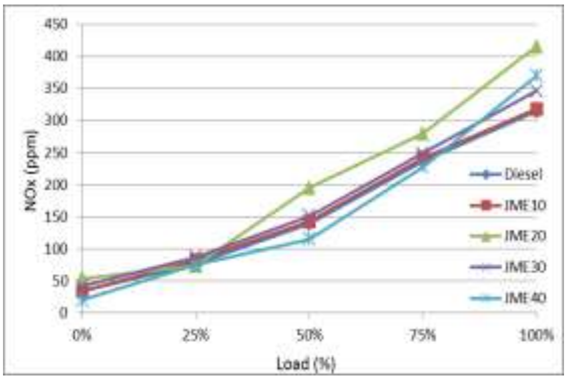

Fig 3. Load vs NO_x

Fig 3 shows that NO_x emission of diesel is minimum when compared with other blends at all loads. Among different blends, JME 20 showed maximum NO_x emissions than other blends. This may be due to the presence of oxygen in biodiesel, which leads to complete combustion of biodiesel than diesel. As a result, maximum temperature inside cylinder is more in case of biodiesel. This induces reactions for oxidation of nitrogen and hence NO_x emission is more for biodiesel. Further the NO_x emission increases with load for all the cases.

PM emission for JME 20 is lower than other biodiesel blends. It is dominating argument that PM emissions of biodiesel are significantly reduced compared to diesel. The trend which PM emissions of biodiesel will be reduced is due to lower aromatic and sulphur compounds and higher cetane number for biodiesel, but the more important factor is the higher oxygen content. It should be noted that, the advantage of no sulphur characteristics for biodiesel will disappear as the sulphur content in diesel is becoming fewer and fewer. It can be accepted by the majority of researchers that, the larger engine load is, the greater PM emissions of biodiesel will be.

The current work differs from previous laboratory studies since this has been done with passenger bus. Our result shows that the use of JME20 fuel reduces the emission when compared to conventional fuel. It is concluded that the biodiesel shows better performance at all proportions of bio fuel blended. Among the different proportions of biodiesel blends, Jatropha shows the best performance at 20% blend. The emission of HC, CO, particulate and smoke is considerably lower than the complete diesel fuel and on the other hand NOx emission is high. Interestingly, the particulate emission was reduced approximately 10 to 20% at maximum load. Therefore, it is concluded that the significant reduction in PM emissions would help in improving the environmental conditions.

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