Experimental studies on stationary single cylinder CI engine operated on Jatropha-Diesel blended fuel with Antioxidant to minimize NOx emissions

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***Abstract** - Straight vegetable oil (SVO) has cleaner combustion properties as compared to diesel fuel. If we go for SVO it reduced PM, CO and HC emissions but NOx emission slightly increases with SVO as compared with diesel fuel. Use of antioxidant is one of the best methods to reduce formation of NOx. Objective of this paper is experimental study on stationary single cylinder CI engine of 3.5kW rated power, operated on Jatropha-Diesel blended fuel with antioxidant p-phenylenediamine to minimize NOx emission. With different concentration of antioxidant (0.005%, 0.015%, 0.025%, 0.035% and 0.05%) by weight NOx emission reduces for different loading condition and but emissions of HC and CO were found slightly increased. Maximum NOx reduction was found with 10% blend and with the concentration of 0.025% w/w of antioxidant.*

Keywords: SVO (Straight Vegetable Oil), BD (Blend), Jatropha, Antioxidant, Engine emissions

1. Introduction

Biodiesel- diesel fuel made from animal or vegetable materials. Vehicle using biodiesel emit fewer pollutants as compared to diesel fuel. Biodiesel it is a renewable fuel, composed by fatty acid methyl (or ethyl) esters, produced by Transesterification reaction between vegetable oil or animal fats and methanol (or ethanol)[1,2].

Vegetable oil can be used as alternative fuel in diesel engine. When vegetable is directly used as a fuel it is referred to as straight vegetable oil. While using SVO emissions from diesel engine reduces but NOx emission increased it is because of oxygenated nature of Jatropha (SVO) fuel [3].

Nitrogen and oxygen reacts at relatively high temperature. NOx formation in an engine depends on reaction temperature, oxygen availability and duration of availability of oxygen. With increasing load NOx emission increases because of more supply of fuel due to which availability of oxygen increases. With increase in oxygen content in fuel proper combustion of fuel takes place [4].

NOx is a major cause of acid rain, smog and ground level ozone. As the use of SVO has increased tremendously, the NOx emission could become a barrier. The reduction of NOx has great importance for the global environment [5, 6].

Temperature of the engine is very high during combustion that breaks the triple bond of nitrogen molecules and form highly reactive molecule of nitrogen that reacts with oxygen and form NOx. The flame front of hydrocarbon flame in this formation of free radical is also the cause of formation of NOx [8].

According to NREL (national renewable energy laboratory) of USA increase in NOx mainly by pre combustion chemistry of hydrocarbon free radicals. In biodiesel mainly acetylene production is main cause of increase in NOx [3]. For prompt NOx CH radical is responsible which is formed by acetylene. According to other authors, in biodiesel emission of NOx affected by combustion temperature. High amount of oxygen content in SVO leads to complete combustion but also raise the temperature of combustion and high NOx formation [15,16].

Injection of water into combustion and water emulsion is the methods to reduce NOx from vegetable oil. Ignition time retardation is the best method to reduce flame temperature and NOx. In water emulsion the volumetric energy content decreases and due to which reduction in fuel economy. EGR technique is also helpful in reduction of NOx [4,5].

Use of antioxidant for the reduction of NOx is one of best technique. When antioxidant is used it donate an electron or hydrogen atom to free radical to inhibits oxidative process that is the main cause of prompt NOx formation [21] . Antioxidant works by reducing the concentration of reactive radicals, chelating the transition metal catalyst, scavenging the initiating radicals and chain braking reaction [22]. This paper contains study of the effect of antioxidant of various concentrations on emission of engine which works on various load range.

2. Experimental details

Experiments were carried out on single cylinder, 4 strokes, water cooled, direct injection CI engine of 3.5 kW power rated coupled to a dynamo (generator) which converts mechanical shaft work of engine into electrical output with the help of alternator. Specification of engine is given below in table 1.

Flow of fuel measured with the help of burette. Time noted down for every 10 ml of fuel consumption with the help of stop watch and with this we find out fuel consumption rate. The air-box is connected to air-filter of engine through a 2.5'' pipe; this enables us to measure mass of air being utilized for combustion.

Table 1 engine specification

Parameter	Unit/type	Specification
Rated output	Hp	4.7
No of cylinder		1
Bore x stroke	Mm	102x116
Compression ratio		17
Type of engine		Compression ignition
Fuel		High speed diesel
Injection type		Direct injection
Speed	Constant speed	1500 rpm
Governor	Mechanical	Class B-1
Lubrication	Wet sump	SAE 40
SFC	gms/kWhr	338

Pressure of air entering the box is measure in terms of water column which is then converted into air-head and subsequently into air velocity which in turn helps determine mass flow rate of air. Exhaust gas temperature was measured with the help of a thermocouple. K type thermocouples was placed in the exhaust manifold to measure the temperature of exhaust gases The K type thermocouple is cheaper and a wide variety of probes are available in its −200 °C to +1350 °C range [4]. 35 bulbs of rating 100 W each were installed on the load bank. Arrangement was made to vary the load from zero to full at 3500 W. To make cooling more efficient, the engine is modified to water cooling system. The flow rate of cooling water is fix to 6 litre per minute with the help of control valve. The gas analyzer is used to find out the exhaust gas emissions. In the experimental work the gas analyzer used, was supplied by AVL India private limited. It uses Non-Dispersive Infra-Red (NDIR) detector. Carbon monoxide (CO), Carbon dioxide, Oxygen, NO_x and Unburned Hydrocarbon are measured with the help of Gas Analyser. CO is measure in vol %, HC in ppm vol. Hex., CO_2 in vol %, O_2 in vol %, NO_x in ppm.

Diesel and various blends of Diesel and Jatropha(SVO) with different percentage of p-phenylenediamine were used and study was done to measure the performance of engine. The rated power output (full load) of the engine was 3.5kW. The different loads applied to the engine for all fuels (Neat Diesel, BD5, BD10, BD15) with 0.005%,0.015%.0.025%,0.035% and 0.05% of p-phenylenediamine were 0.5 kW, 1.0 kW, 1.5 kW, 2.0 kW, 2.5 kW, 3.0 kW and 3.5kW. . The fuels for experiments were Diesel, BD5, BD10 and BD15.

Table 2 Range of investigation

Sr. No.	Parameters	Range
1.	Fuel	Diesel, BD5, BD10 and BD15
2.	P-phenylenediamine percentage	0.005%.0.015%,0.025%,0.035% and 0.05%
3.	Load	0-3.5 kW
4.	Engine Speed	1500 rpm

As p-phenylenediamine is in solid state and it is to be mix with liquid Jatropha (SVO) and Diesel blend. For homogenous mixing different methods tried i.e.

direct mixing, magnetic stir, less RPM stir and mixer grinder of 20000 RPM. Only mixer grinder of 20000 RPM mixed antioxidant with fuel blend.

Chemical structure of p-phenylenediamine

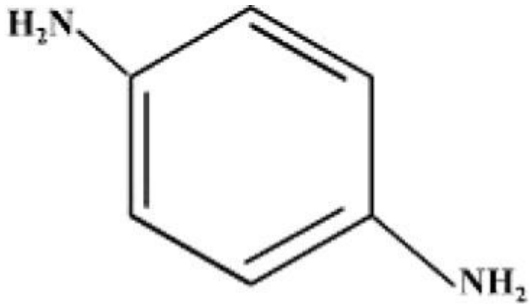

Figure 1 Chemical structure of p-phenylenediamine

Table 3 Specification of p-phenylenediamine

Property	specification
CAS number	106-50-3
Minimum assay	97%
Molecular weight	108.14
Melting point	141'C
Sulphated ash	.05%

3. Results and discussions

Engine was operated with neat diesel and various blends that were composed of Jatropha and diesel. In this paper engine performance parameters i.e. brake thermal efficiency, NOx, CO and HC emissions are calculated and their variations with respect to load are plotted.

a) **Brake thermal efficiency (BTE)-** Brake thermal efficiency is indicate the amount of power that is available at output shaft .BTE increases with increasing load up to 2.5kW and then slightly dropped at full load.

Below figure shows the variation in BTE with load using different blends of fuel (diesel, BD5,BD10 and BD15). For BD5, BD10and BD15 with different percentage of p-phenylenediamine slight drop in efficiency is observed that is because of reduction in availability of oxygen for complete combustion. By these experimental results we can further move towards emission reduction process because there is no major effect on efficiency by adding different percentage of antioxidant.

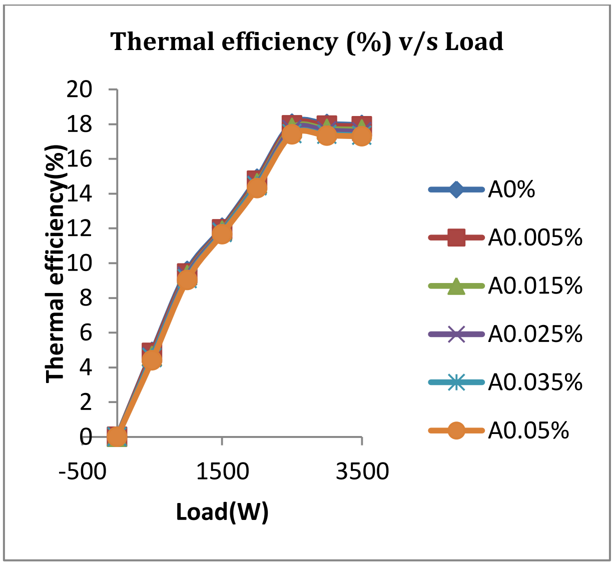

Figure 2 Variation of thermal efficiency with loads for BD10 with different percentage of p-phenylenediamine

b) NOx

Use of antioxidant reduces NOx emission. Below figure shows NOx emission with variation of load and operating with different fuel. The main cause of reduction in NOx is due to reduction in formation free radicals by antioxidants. Optimum concentration of antioxidant is 0.025%-m . If we use 0.025%-m antioxidant (p phenylenediamine) with biodiesel reduction in NOx is 24.58% observed. So concentration of antioxidant 0.025%-m level gives best result.

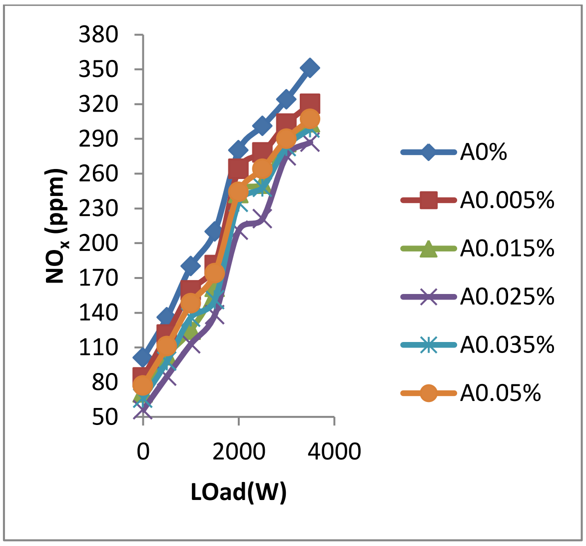

Figure 3 NO_X emissions for BD10 using different percentage of p-phenylenediamine

c) CO

Incomplete combustion of fuel is the basic cause of CO emission. The reason of incomplete combustion is insufficient amount of air, inadequate time in cycle for combustion of fuel. Too rich fuel is also cause of CO emission. If emission of CO from engine is higher that means loss of power from engine. Using antioxidant CO emission increases this is due to incomplete combustion (less availability of oxygen resulting from antioxidant addition).

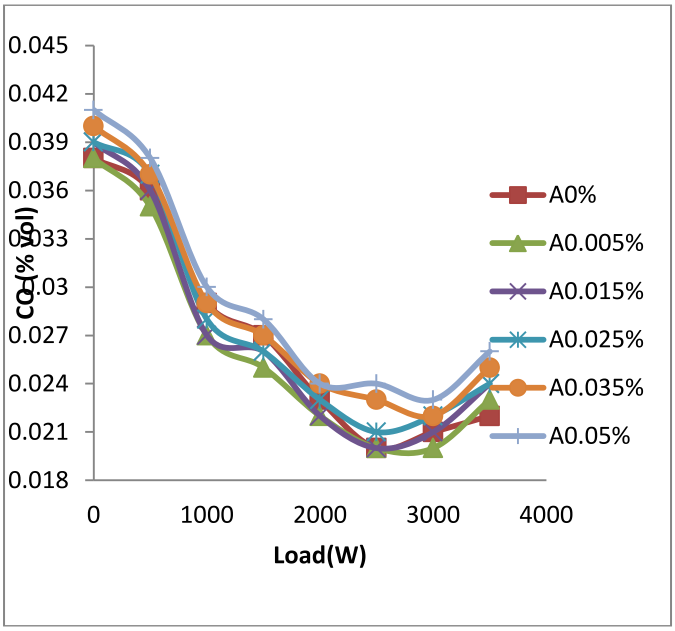

Figure 4 CO emissions for BD10 using different percentage of p-phenylenediamine

d) HC

Hydrocarbon in exhaust is direct indication of incomplete combustion. In below figure HC emission for different loads are shown using different fuel. It was found that at low load higher emission as compared to higher load conditions. Improper mixing of fuel will cause of higher HC emission. HC emission under varying load condition for different fuel shown in figure. Use of antioxidants increases the HC emission this is due to reduction in availability of oxygen.

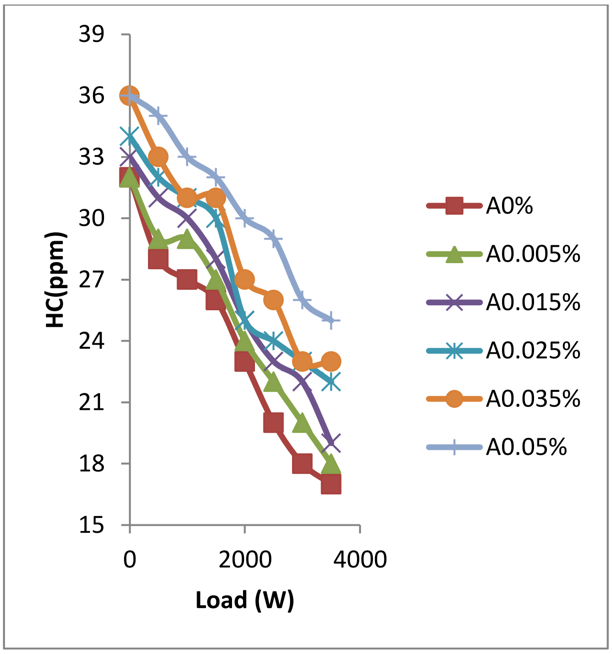

Figure 5 HC emissions for BD10 using different percentage of p-phenylenediamine

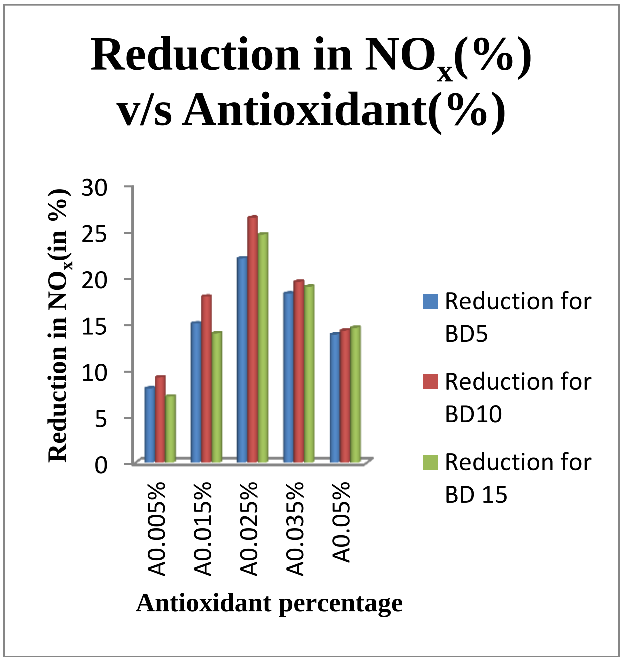

Figure 6 percentage reduction in NO_X with different percentage of p-phenylenediamine

4. Conclusion

The effects of antioxidant addition on NOx, CO and HC emissions in a Jatropha (SVO) and Diesel fuelled CI diesel engine at different loads have been studied in this work. Results show the potential benefit of antioxidant additives for NOx reduction in biodiesel fuelled diesel engines. The main conclusions of this study can be summarized as follows.

1. The presently studied antioxidants are quite effective in controlling NOx formations. They do however; have significantly more CO and HC emissions.
2. Among all the tested antioxidant p-phenylenediamine showed the best emission performance compared to Jatropha(SVO) Diesel blends. It has shown optimum NOx reduction at a level of 0.025%-m. The NOx reduction efficiency of antioxidants was observed for p-phenylenediamine mean NOx reduction percent relative to neat blends are 22%, 23.69 and 24.58% respectively at 0.025%-m concentration.
3. There is no major change in thermal efficiency is observed with the use of different percentage of antioxidant.
4. Slight decrease in BSFC was observed with p-phenylenediamine signifies a slight reduction in specific fuel consumption compared to neat Jatropha (SVO) blend.

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