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PERFORMANCE AND EMISSIONS OF A DUAL FUEL OPERATED AGRICULTURAL DIESEL ENGINE

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ABSTRACT:
Among Biofuels, vegetable oil and its esters (biodiesel) are the renewable alternative fuels that can be used in diesel engines with little or no modification. In the present work, an attempt has been made to use biodiesel derived from inedible and under utilized mahua oil (MO) as liquid or pilot fuel and liquefied petroleum gas (LPG) as gaseous fuel in dual fuel mode. A four stroke single cylinder diesel engine was modified to work in dual fuel mode. From the engine tests it is observed that the fumigation of LPG improves the performance of MO fuelled agricultural diesel engine.
KEYWORDS:
Alternative fuel, Mahua oil, dual fuel mode, engine performance

1. INTRODUCTION

There is a renewed interest in biofuels as fuels for internal combustion engines due to increases in petroleum price and uncertainties concerning petroleum availability. Hence vegetable oils have become more attractive as a substitute for diesel due to their environmental benefits and the fact that they are made from renewable resources. In the year 2004 – 2005, India imported 75 % of crude oil from other countries, to meet the energy requirement. It has been estimated that the demand for diesel will be 66.90 million metric ton for the year 2011-2012 (Subramanian, 2005). Hence, government of India has taken necessary steps to fulfill future diesel and gasoline demand. Biodiesel and alcohol are being considered to be supplementary fuels to the petroleum fuels. These biofuels are being looked to provide employment generation to rural people through plantation of vegetable oils and can be beneficial to sugarcane farmers through the ethanol program.

The technical advantages of using biodiesel, as fuels in diesel engine are longer engine life, safe to handle, less toxic, biodegradable, higher flash point and lower exhaust emissions. But the cost of biodiesel is higher than diesel fuel (Mustafa, 2006). Many researchers in the field of biofuels, carried out experimental work on the production and characterization of biodiesel (Ayhan, 2007).

India is producing a host of inedible oils such as linseed, castor, mahua, rice bran, karanji, neem, palash etc. Some of these oils produced even now are not being properly utilized (Agarwal, 1998). Mahua name for a medium to larger tree. As a plantation tree, mahua is an important plant having vital socio-economic value. This species can be planted on roadside, canal banks etc on commercial scale and in social forestry programmes, particularly in tribal areas. The mahua oil is an underutilized and inedible vegetable oil available in large quantities in Asian countries. The seed and oil potential of mahua tree in India is 0.5 and 0.18 million metric tons respectively (5). Several researchers (Sukumar, 2005, Raheman, 2007) carried out experimental investigations, to use biodiesel derived from MO as fuel in the diesel engine. They reported that the engine performance with mahua oil biodiesel is close to diesel and the emissions such as CO, HC and smoke emissions are lower than the diesel.

In India, biodiesel is expensive than the diesel and is not available in the market. Hence in recent years, efforts have been made by several researchers (Ramadhas, 2005, Hebbal, 2006), to use vegetable oils as alternate fuel for diesel. They reported that the use of vegetable oil as fuel in diesel engine results in lower efficiency and higher smoke emission. But the performance of the vegetable oil operated diesel engine can be improved by fumigating a gaseous fuel in the intake manifold along with air (Edwin, 2008, Banapurmath, 2009). In dual fuel engine, the liquid or pilot fuel provides ignition source for the combustion of gaseous fuel. In India, liquefied petroleum gas is one of the cheapest gaseous fuels easily available in the market. Hence in the present work, MO and LPG were used as liquid fuel gaseous fuel respectively in the dual fuel mode.

2. METHODOLOGY

In the present work, a single cylinder diesel engine was modified to wok in dual fuel mode by introducing LPG fuel tank, control valve, rotameter, flame trap and gas carburetor into the intake manifold. In dual fuel mode, MO was injected in conventional way and the LPG flowrate was controlled using the control valve.

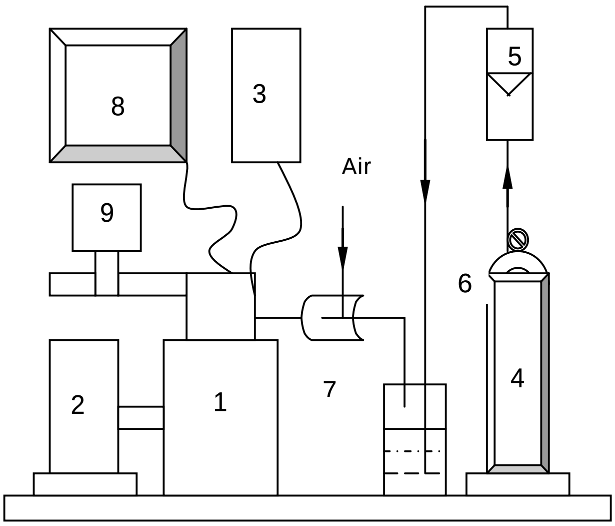
2.1 Instrumentation & experimental procedure

A single cylinder, naturally aspirated, agricultural diesel used was used in the present work. The engine details are given in Table 1. An eddy current dynamometer was used for loading the engine. The engine speed was sensed and indicated by an inductive pick up sensor in conjunction with a digital rpm indicator, which is a part of eddy current dynamometer. The diesel fuel flow rate was measured on the volumetric basis using a burette and a stopwatch. A chromel alumel thermocouple in conjunction with a digital temperature indicator was used for measuring the exhaust gas temperature. The gas flow rate was measured using a rotameter with duralumin float. A AVL make smoke meter was used to measure the smoke emission and MRU make exhaust gas analyzer was used for the measurement of emissions in exhaust gases.

Table 1. Engine Details

Engine	4 – S, Single cylinder, water cooled engine
Make / Model	Kirloskar AπV 1
BHP	3.7kW @ 1500 RPM
Bore X Stroke	80 X 110 mm
Compression Ratio	16.5 :1
Injection Timing	27° b TDC

The dual fuel engine was started by hand cranking with MO as fuel and load on the engine was increased to 75% of full load. Then slowly LPG was introduced into the cylinder through the air intake manifold and LPG flowrate was maintained constant using the control valve. At steady state condition, important observations such as gas flow rate, air flow rate, exhaust gas temperature and exhaust emissions were recorded. Then the LPG flowrate was increased to next higher values. The engine tests were conducted upto the maximum LPG flowrate such that the engine does not knock. Figure 1 shows the engine test setup.



1. Engine 2. Dynamometer 3. Fuel Tank 4. LPG Tank 5. Rotameter 6. Flame Trap Arrestor 7. Gas Carburetor 8. Data Acquisition System 9. Emission Analyser

Figure 1. Engine test setup

4. RESULTS AND DISCUSSION

The dual fuel engine runs without knocking with MO and LPG, up to the LPG energy share of 62.69%. The performance and emissions of the dual fuel engine are analyzed and given below.

Brake thermal efficiency (BTE) is defined as the ratio of brake power to the heat supplied. Figure 2 shows the variation of BTE with different LPG energy share. From the figure, it is observed that, as the LPG energy share increases the BTE of the MO fuelled diesel engine increases. The BTE of the dual fuel mode operation is close to diesel sole fuel operation (zero LPG energy share) at higher LPG energy share. This is fumigation of LPG which results in better combustion and higher BTE. When MO was used as sole fuel, the engine results in lower BTE. This is due to lower and higher viscosity of the MO, which results in poor fuel utilization and increased fuel consumption. This leads to poor BTE. Hence fumigation of LPG is one of the ways of improving the BTE of straight vegetable operated diesel engine.

The variation of carbon monoxide (CO) emission with LPG energy share is shown in Figure 3. The diesel engine results in higher CO emission When MO was used as sole fuel (zero LPG energy share). This is due to the poor combustion of the MO which results in higher products of incomplete combustion. But when LPG was fumigated, the CO emission gradually decreases upto certain LPG energy share and then increases. At lower LPG share, due to better combustion CO emission is low. But at higher LPG energy share, late combustion of large quantity of LPG results in higher CO emission. Because in dual fuel mode, combustion of liquid fuel takes place first and followed by gaseous fuel. At higher LPG energy share, the quantity of LPG supplied is high and small quantity of

MO provides weak ignition source for the combustion of LPG. This results in late combustion and higher CO emission.

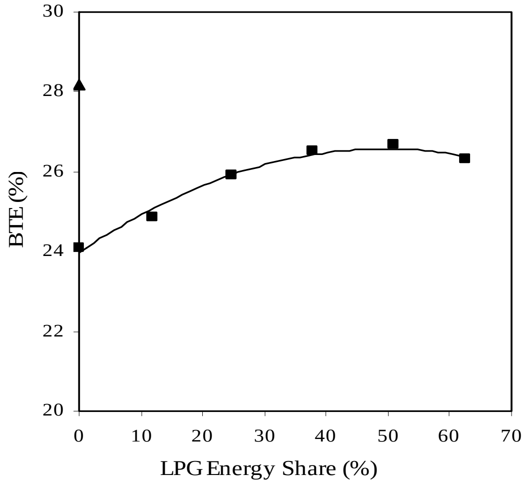


Figure2. BTE VS LPG Energy Share

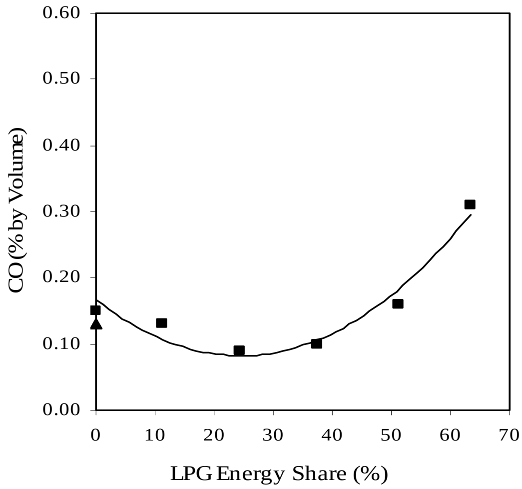


Figure3.CO Vs LPG Energy Share

Figure 4 shows the variation of unburnt hydro carbon (UBHC) emission with different LPG energy share when MO was used as liquid fuel. From the figure, it is observed that the diesel engine results in higher UBHC emission in dual fuel mode. At higher LPG energy share, the UBHC emission is high. Also the diesel results in higher UBHC emission when MO was used as sole fuel.

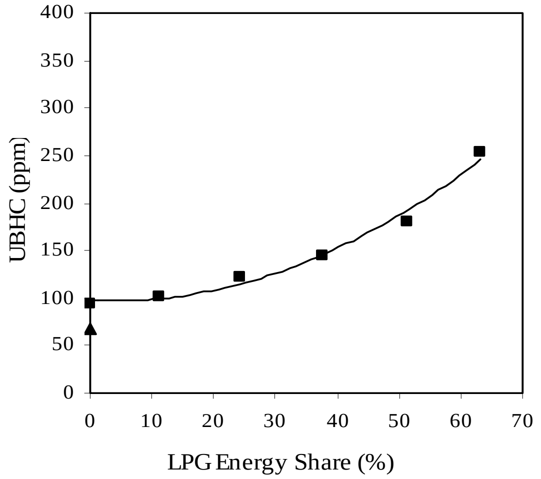


Figure 4. UBHC Vs LPG Energy Share

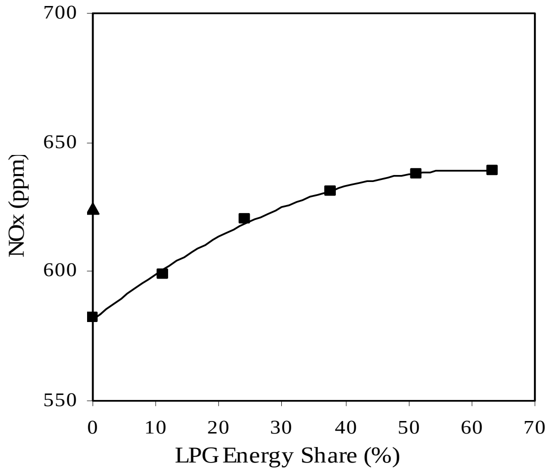


Figure 5. NOx Vs LPG Energy Share

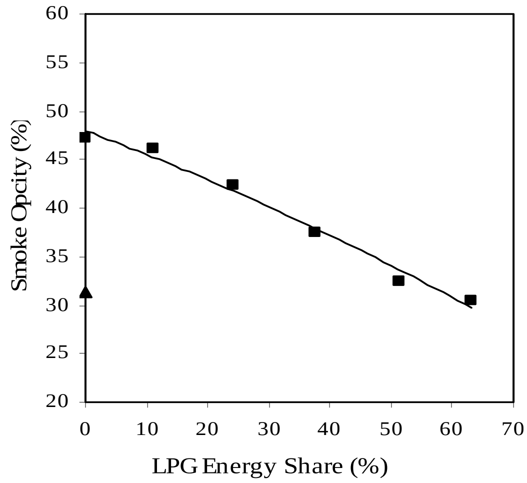


Figure 6. Smoke Vs LPG Energy Share

The variation of NOx emission with LPG energy share is shown in Figure 5. The formation of NOx is favored by high oxygen concentration and high charge temperature. The concentration of NOx emission of diesel engine is low when MO was used as sole fuel. This is due to poor combustion of MO which results in lower combustion temperature and correspondingly lower NOx emission. But in dual fuel mode, the NOx emission of the diesel engine increases. This is due to the better combustion of fuel. At higher LPG energy share, the diesel engine results in lower NOx emission due to weak ignition source provided by MO for the combustion of LPG. This reduces the combustion temperature and hence lower NOx emission.

The variation of smoke emission with LPG energy share is shown in Figure 6. From the figure it is observed that the diesel engine results in higher smoke emission when MO was used as sole fuel. But the fumigation of LPG reduces the formation of smoke due to better combustion. Hence LPG fumigation is one of the ways of reducing the smoke emission of straight vegetable oil fuelled diesel engine. The LPG structure is simple as compared to diesel and MO. This reduces the formation of smoke.

5. CONCLUSION

The engine tests show that the fumigation of LPG results in higher thermal efficiency of the MO fuelled diesel engine. Also, the fumigation of LPG reduces the smoke emission drastically and CO and NOx emissions marginally. We are carrying out further research work, to reduce the UBHC emission of the dual fuel engine. From the engine tests we conclude that MO can be used as a substitute for diesel along with LPG. Use of underutilized and inedible oil as a substitute for diesel will improve the rural economy and increase the energy security of India.

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