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Original Research Paper

Investigation on the Effects of Conventional Fossil Fuel to the Environment and Research on Renewable Fuels with Reduced Emission Using Biodiesel, Diethyl Ether and Hydrogen

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ABSTRACT

The present world inevitably depends on conventional fossil fuel for a range of utilities like industrial production, electricity generation, transportation and domestic purposes. Regardless of its increased demand, the non renewable fuel resources are diminishing at an alarming rate. The environmental pollution effect of conventional diesel is frightening. The pollution effect of diesel begins from its production and lasts till its exhausts after combustion. The research work is carried on to find a suitable renewable fuel with reduced emissions as a substitute for downsized fossil fuels. The combination of *Pongamia pinnata* biodiesel and hydrogen is tested in experimental set up of CI engine with AVL gas analyser. The emission parameters like NO_x, HC, CO and CO_2 are measured. The experimental study analysis is made for various fuel combinations of hydrogen, *Pongamia pinnata* biodiesel and DEE comparing with conventional diesel. The emission reduction technique EGR (exhaust gas recirculation) is implemented and results are compared.

INTRODUCTION

The conventional fossil fuels contribute 80% of energy demand worldwide. The major fossil fuel is crude petroleum oil, and nearly 2500 refined products are obtained from crude oil. The crude oil is on the verge of its extinction. The traditional process of oil production is the extraction of crude oil under high pressure by building oil rigs. The oil rigs are marine based or land based structures; they are mostly semi-permanent structures that will be left after the completion of oil extraction. The accident in these oil rigs result in oil spills. The consequence of these oil spills is highly damaging. The ecosystem is affected by these oil spills. A large number of deaths of aquatic plants, fishes and birds have been reported every year. The 15% of overall water pollution is due to petroleum source input to aquatic systems (Ghosh et al. 2006). In spite of heavy precautionary measures the oil spills due to accidents in oil rigs are unavoidable. The oil spills also affect humans through food chain by feeding on fishes from spill affected areas. The recent technological developments created a new trend for clear and renewable energy sources for the future (Demirbas 2012). Several researchers are experimenting to find a suitable alternative for conventional diesel. Diesel oil is natural petroleum made of complex mixture of hydrocarbons. The major composition constitute of 85% carbon and 15% hydrogen; it is oilier and heavier than petrol. The diesel generates higher energy efficiently and economically profitable, but it is more hazardous to human health. In water pollution, diesel oil directly pollutes water and aquatic life, causing effects to all living organisms in food chain including humans.

The combustion of diesel oil produces several harmful emissions like NO_x, HC, CO, CO_2 (Saravanan et al. 2008). The major contributors to greenhouse gas effect in atmosphere are CO_2 and NO_x. The diesel combustion in uncontrolled manner emits harmful particulate matter, increased NO_x and various carcinogenic substances. A real time case study of uncontrolled diesel combustion effects is found in Kolkata, where the air pollution has increased to a very higher level causing health issues to several residents and making government to impose ban on vehicles that are older than 15 years (Ayan Chandra et al. 2011). The ban is mainly imposed on trucks, taxis, mini buses and buses that are fuelled by diesel. The increased NO_x even after the ban is an evidence of threat to air pollution because of diesel vehicles. The diesel powered locomotives also lead to the same effects of health issues to workers and commuters in railways (Khairnar et al. 2011).

It is evident that diesel combustion in uncontrolled manner leads to global warming and production of diesel from crude oil using oil rigs leads to water pollution due to oil spills. The viable solution for the combined problem of energy demand and environmental pollution is replacing fossil fuels with renewable alternative fuel with reduced emissions (Suresh Kumar et al. 2007). The biodiesel obtained

from seeds of *Pongamia pinnata* is a promising fuel to replace conventional diesel (Michael Ball et al. 2009). The challenging scenario is that the biodiesel solely cannot meet the required demand, however, the dual fuel of hydrogen with biodiesel can satisfy the demand. Hydrogen is an attractive clean fuel with near zero emission. The production of hydrogen can be done by various processes like electrolysis, biomass, solar and many more (Zidanšek et al. 2009). Hydrogen is highly energy efficient fuel. The addition of hydrogen to biodiesel increases engine performance and reduces carbon emission to a significant level (Bika et al. 2008).

Exhaust gas recirculation (EGR) technique is a well know method used in Euro Emission Standard for NO_x reduction. The engine fitted with EGR set up reduces NO_x and the reduction of NO_x level is directly proportional to the increase in the EGR rate (Antonio Marques et al. 2007). The CO_2 emission reduces with EGR and biodiesel fuel combination (Kawano et at. 2007). The biodiesel engine operated with EGR is the best method to reduce NO_x with little sacrifice in engine performance (Puli et al. 2011).

MATERIALS AND METHODS

***Pongamia pinnata* biodiesel**: *Pongamia pinnata* biodiesel is a highly suitable renewable fuel for India. *Pongamia pinnata* is also called as Karanj in Hindi and Pungai in Tamil. The tree is naturally spread all over Asia. The tree can grow all over India regardless of climatic variations. The trees can be found at sea-level along the coastal areas to the foot hills of Himalayas. A group of 10 full grown trees can produce up to 400 litres of oil every year with green manure and oil cakes (Muralidharan et al. 2004). The trees of Pongamia pinnata do not require much care. The Pongamia pinnata is traditionally used as a natural insecticide. The cattle do not feed on its leaves, but the oil cakes of Pongamia pinnata contains high protein and is used as cattle feed. The tree can reach its full growth in a span of 4-6 years, has a life span of 100 years, and can normally yield for 60 years continuously.

Hydrogen: Hydrogen is a clean fuel, its emission is near zero (White et al. 2006). The energy efficiency of hydrogen is much higher than conventional fuels available today. The use of hydrogen as direct fuel has problem because of hydrogen transportation and storage. The researchers believe that hydrogen cannot be a direct fuel, but it can be a good secondary energy carrier with other fuels (Michael Ball et al. 2009).

The mass production hydrogen at economically beneficial methods is possible in near future. The clean energy will save the environment from further effect of pollution. The hydrogen is an efficient renewable fuel used in fuel cell based green cars, even in CI engines with little modification. Hydrogen has a higher flame length and has lower emissions because of its complete combustion. The hydrogen will be an essential fuel in future because of its abundant availability.

Diethyl ether: Diethyl ether (DEE) is used in engine as ignition improver and NO_x reducing agent. DEE can reduce NO_x to very significant level. DEE is produced with ethanol obtained from biomass. DEE is an alternative compression ignition fuel with higher energy density. The addition of DEE with diesel and biodiesel delays the ignition (Brent Bailey et al. 1997). The problem in engine fuelled with dual fuel of hydrogen and biodiesel is knocking. Knocking is a phenomenon that involves abnormal engine sound and vibration. The knocking will reduce the engine durability and performance. The knocking caused by the pre-ignition of the fuel, can be reduced by the injection of DEE, which will delay the ignition timing and eliminate knocking.

Experimental setup: The experiment was carried out on a stationary engine equipped with an inbuilt data acquisition (DAQ) system (Fig. 1). The AVL gas analyser and AVL Combustion Emission Bench II were used to check the emissions. The pressure sensor was used to measure the cylinder pressure. The data like engine speed and crank angle were measured using sensors in DAQ (Table 1). The entire DAQ system is connected to a computer. The data were collected from the DAQ using software know as "Engine Soft". The Eddy current dynamometer was used to apply the load to the engine. The engine set-up was modified for the induction of hydrogen. The flow of hydrogen was controlled by using a hydrogen flow meter. The flame arrester and flame trapper were used to eliminate the backfiring of hydrogen into the cylinder. The DEE is injected into the combustion chamber using an electronic circuit based control.

The EGR set up was installed, which consisted mainly of an EGR cooler and EGR control valve. The EGR setup recirculates the exhaust gas back into the air-intake manifold. The EGR cooler is water based cooling system which

Table 1: Engine specifications.

Components	Specifications
Engine	Single cylinder, Four stroke, Water cooled, Diesel, Kirloskar make, Rated power 5.2 kW, Speed 1500 rpm, Bore 87.5 mm, Stroke 110 mm, Compression ratio 17.5, Capacity 661 cc
Dynamometer	Eddy current dynamometer
Piezosensor	Range 200 bar
Water cooled adapter	For Piezosensor
Crank angle sensor	Resolution 1°, Speed 5000 rpm, with TDC marker pulse
Biodiesel injection timing	23° before TDC

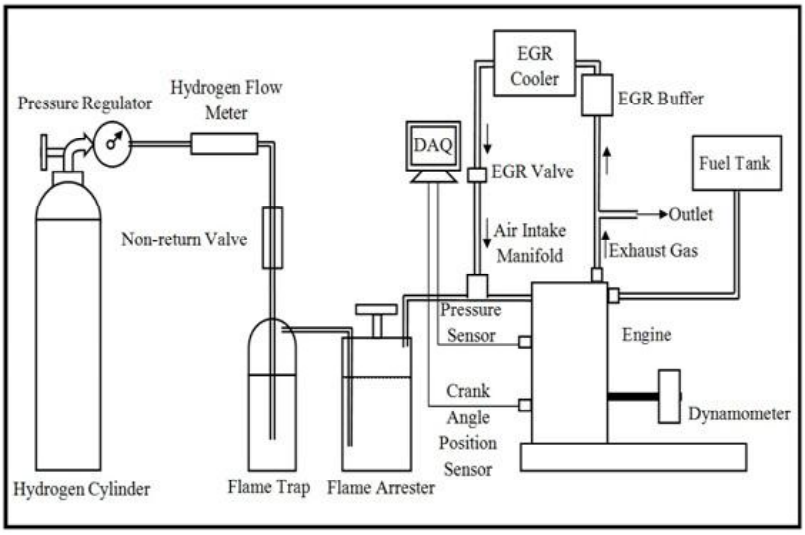

Fig. 1: Block diagram of experimental set up.

can reduce the exhaust temperature from 500°C to 30°C. The control valve can vary the EGR percentage from 0-30%.

Experimental procedure: The experiment was conducted for six different conditions. The first experiment was conducted by fuelling the engine with pure diesel. The second experiment was conducted for pure biodiesel fuelled engine. The third experiment was conducted for biodiesel with 16 LPM hydrogen induction. The fourth experiment was conducted for biodiesel with 16 LPM hydrogen induction and DEE injection flow rate was maintained at a flow rate of 2.5 g/min. The fifth experiment was conducted after fabricating EGR, using biodiesel as primary fuel and 20% EGR condition. The sixth experiment was conducted by using biodiesel and inducting hydrogen at 16 LPM with 20% EGR conditions.

Every experiment was conducted by starting the engine initially with diesel and changing to biodiesel mode. The engine was allowed to run at 1500 rpm for 15 minutes to reach the steady state condition. In case of hydrogen induction the flow meter was set to 16 LPM after reaching the steady state condition and inducted to air intake manifold. The DEE injection was done by injecting directly into the combustion chamber at 23° TDC. The sensor was used to measure the crank angle. The emissions were noted with 100% loading for each experiment. The exhaust gas was directly connected to the AVL gas analyser. The emission parameters like CO (%Vol), CO_2 (%Vol), NO_x (ppm), HC (ppm) were noted down.

RESULTS AND DISCUSSION

NO_x emission: The NO_x emission obtained for pure diesel is 450 ppm and the same for pure biodiesel of *Pongamia pinnata* is 629 ppm (Fig. 2). This increase is due to the increase in exhaust temperature for pure biodiesel. The mechanism for NO_x formation is directly proportional to the exhaust temperature. The temperature increase will lead to increased NO_x. In case of engine fuelled by pure biodiesel the efficiency of the engine will decrease to a significant level. Apparently, to increase the thermal efficiency, hydrogen induction is done. The hydrogen induction increased the thermal efficiency greater than pure diesel but the trend of NO_x increased to 820 ppm due to higher combustion properties of hydrogen. The effective way to decrease NO_x is by injecting the DEE. The effective result was obtained, and the NO_x was reduced to 124 ppm with slight reduction in performance comparing with the same for pure biodiesel and 16 LPM hydrogen.

The EGR at 20% reduces the NO_x of pure biodiesel to 552 ppm. The 20% EGR reduces the NO_x of biodiesel with 16 LPM hydrogen induction. The NO_x emission is very lower for the combination of biodiesel with hydrogen and DEE injection. Though, the NO_x emission is little higher for pure biodiesel, the valid point is that the biodiesel production does not create any harmful effects to land and water resources. Instead, the growth of *Pongamia pinnata* tree will enhance the air quality and soil quality, which is not possible in fossil fuel production.

HC emission: The hydrocarbons are the unburnt carbon compounds that are produced during the combustion. The proper combustion will reduce the HC content in the emission. The HC emission acquired for diesel is 32 ppm and biodiesel is 33 ppm, which is comparatively similar (Fig. 3).

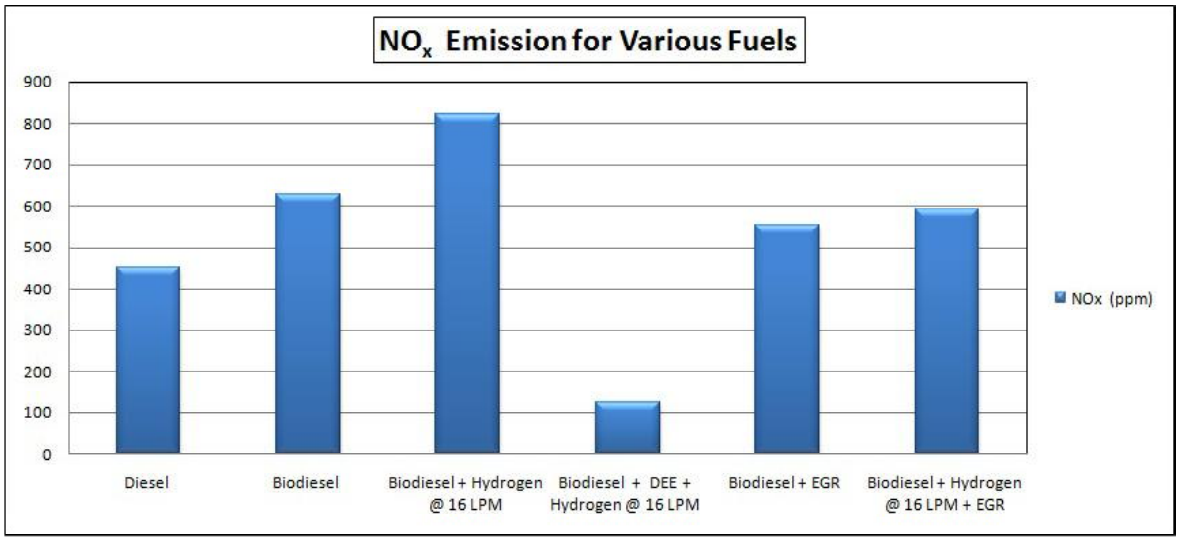

Fig. 2: Graph showing emission of oxide of nitrogen in (ppm) for various testing conditions.

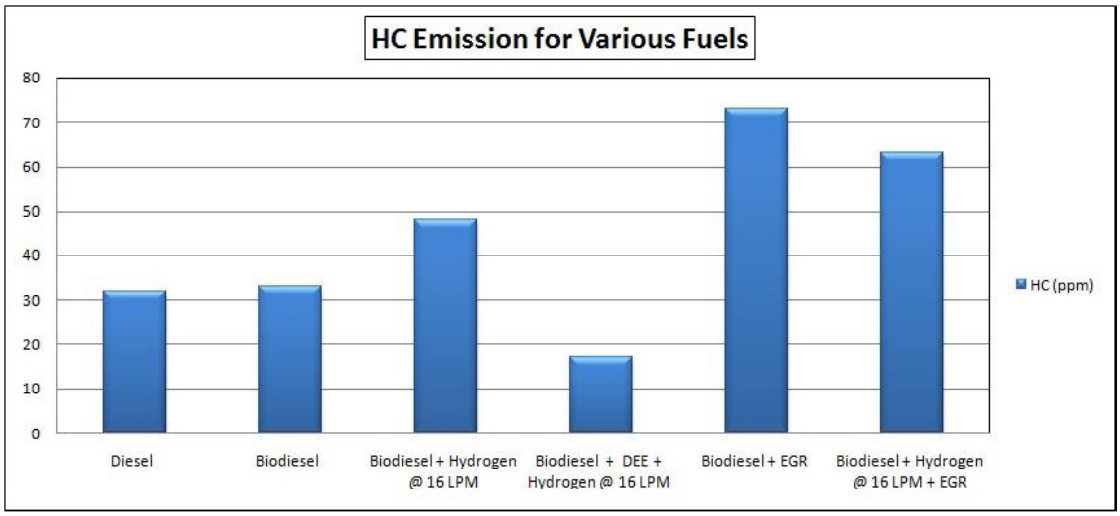

Fig. 3: Graph showing emission of hydrocarbons in (ppm) for various testing conditions.

In case of hydrogen induction, the hydrocarbon value rises to 48 ppm, which is due to the presence of excess hydrogen in the fuel. The HC emission for biodiesel with EGR increases to a maximum of 73 ppm. The result shows that combustion is not proper, obliviously exhaust gas is already burnt inert gas which will reduce the effect of combustion.

The HC emission of EGR with biodiesel and hydrogen combination is 63 ppm which is lower than latter; hydrogen addition improved the combustion.

CO emission: The CO emission for diesel is 0.05 (%Vol) and for biodiesel is 0.1 (%Vol) which is increased by 50% comparing the diesel (Fig. 4). The hydrogen induction reduced the CO to a minimal level at all conditions, 0.03 (%Vol) for hydrogen induction with biodiesel, 0.04(%Vol) for DEE injection with biodiesel and hydrogen induction, 0.02(%Vol) for biodiesel with hydrogen induction in EGR technique. The reduction is mainly due to the absence of carbon content in hydrogen fuel.

The EGR technique reduced the CO emission of biodiesel to 0.08 (%Vol), which is slightly lower comparing with pure biodiesel. The addition of hydrogen provides a better emission result in case of CO reduction.

CO_2 emission: The CO_2 emission plays a major role in global warming. The results from experiments provided a significant reduction in CO_2 with combination of renewable sources. The CO_2 emission for diesel is 6.8(%Vol), and for

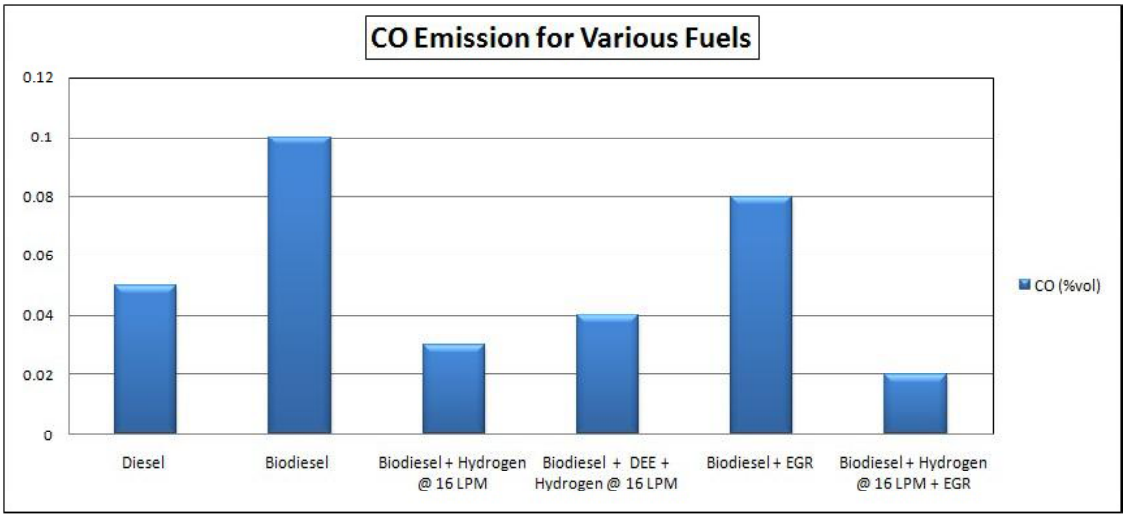

Fig. 4: Graph showing emission of carbon monoxide in (%Vol) for various testing conditions.

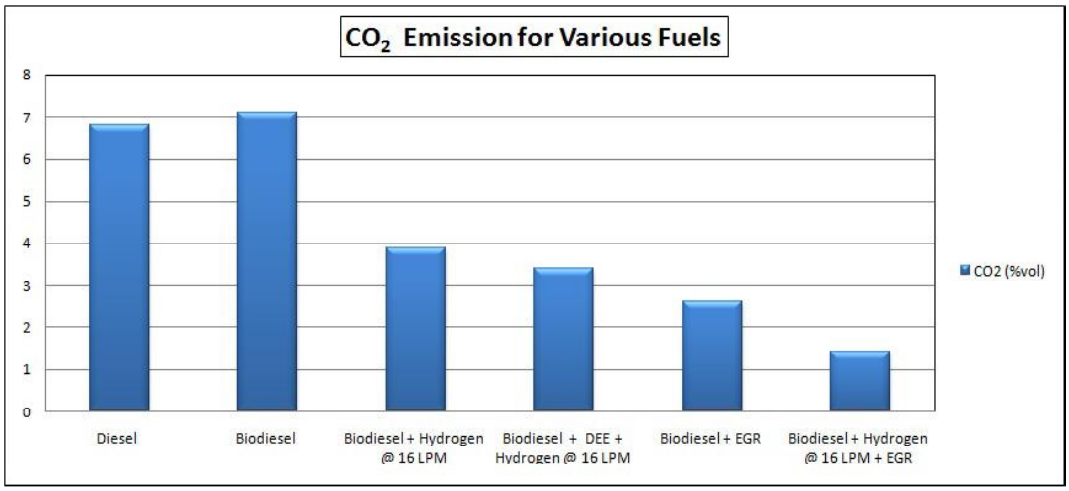

Fig. 5: Graph showing emission of carbon dioxide (ppm) for various testing conditions.

biodiesel is 7.1(%Vol) (Fig. 5). The CO_2 emission of biodiesel with hydrogen induction is 3.9(%Vol); the emission is very low comparing to conventional diesel. Further, the emission content reduced to 3.4(%Vol) for biodiesel and hydrogen induction with DEE injection.

The CO_2 emission for biodiesel with EGR is 2.6(%Vol), and for biodiesel with hydrogen induction equipped with EGR is 1.4(%Vol). The CO_2 emission is reduced in case of renewable fuel, but the carbon content present in natural fossil fuel increases CO_2 content in conventional diesel. The biodiesel, hydrogen and DEE have very less carbon content comparing the latter. The CO_2 reduction possibility is evident with the use of renewable fuel.

CONCLUSION

The research for the replacement of conventional diesel oil, which has been used for decades, is the most challenging task. The various factors of emission are related with one another. The reduction of NO_x will result in increase of HC. The emissions are directly related to combustion and exhaust temperature, which stress the sacrifice of engine efficiency to reduce emissions. The possibility of 100% satisfactory renewable fuel needs continuous optimization. The use of renewable fuels will protect the environment from the hazardous effects created by the production and combustion of conventional diesel. The results concluded that CI engine fuelled by *Pongamia pinnata* biodiesel with hydrogen induction and DEE injection provided a better emission reduction. The CI engine fuelled by *Pongamia pinnata* biodiesel and hydrogen induction with EGR technique provides acceptable emission reduction with higher engine efficiency comparing conventional diesel. The renewable fuel of *Pongamia pinnata*

biodiesel and hydrogen will be a vital energy source for a future with emission free green environment.

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ANNEXURE

CI	-	Compression Ignition
CO	-	Carbon-monoxide
CO_2	-	Carbon-di-oxide
DAQ	-	Data Acquisition System
DEE	-	Diethyl Ether
EGR	-	Exhaust Gas Recirculation
EURO	-	European Emission Standard
HC	-	Hydrocarbons
LPM	-	Litres per Minute
NO_x	-	Oxides of **Nitrogen**
PPM	-	Parts per Million
RPM	-	Revolution per Minute
TDC	-	Top Dead Center