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Performance and Emission Characteristics of Jatropha Biodiesel and Dimethoxy Methane Fuel Blends with EGR in A CI Engine

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ABSTRACT: In the recent years, there is multi-fold growth in vehicular population. As a result there is a marked decrease in ambient air quality because of the pollutants released by these vehicles both on and off road. It also leads to rise in Green House Gas emission because of more CO2 released to the environment. Hence researchers focus on fuel consumption and emission reduction. Due to depleting fossil fuel reserves, there is growing demand to switch over to alternative fuels. Alternative fuels like biodiesel and ethanol are renewable and relatively green, being derived from vegetable oil and sugar molasses respectively. Recently, blending of fuels to improve the combustion properties of fuel is being employed as an option.

A single cylinder, water cooled, diesel engine with a rated output of 3.7kW at 1500 rpm was used for conducting the experiments. Tests were conducted with diesel, biodiesel, biodiesel with 10%DMM blend with and without EGR and biodiesel with 20%DMM blend with and without EGR. Biodiesel with DMM blends results in lower thermal efficiency, lower smoke emissions and higher NOx emissions. By implementing EGR, NOx emission reduced and smoke emission increased.

I. INTRODUCTION

Diesel engine has been widely used as an internal combustion engine due to its reliability, durability and high fuel efficiency. However, there exist two major challenges to keep diesel engine as one of the most popular power providers. One is related to fossil fuel sustainability: the crude oil resource on earth is limited this fact is pushing the search for suitable alternative fuels. The other challenge is related with environmental concern. So far, compression-ignition engines have adapted many technical breakthroughs to meet the requirements of more and more stringent emission. These two above challenges will partially overcome by use of an alternative fuels.

II. LITERATURE REVIEW

Z.H. Huang et al. (2006) have investigated the combustion and emission characteristics of a CI engine fuelled with Diesel-dimethoxy methane blends. The volume fraction of DMM in the fuel blends are 5%, 10%, 15%, and 20%. Increasing mass fraction in fuel blends results in reduction in both exhaust CO and smoke. Even simultaneous reduction of both NOX and smoke can be realised at large DMM additions. The initial combustion duration shows a slight variation with the increase of the DMM fraction in the fuel blend, while the rapid combustion duration, the total combustion duration and the crank angle of the centre of heat release curve decrease with the increase of the DMM fraction in the fuel blend due to the improvement of the diffusive combustion phase. The maximum rate of pressure rise and the maximum rate of heat release will increase with the increase of the DMM fraction in the fuel blends. This would be due to the increase in the amount of combustible mixture for the premixed combustion phase.

A.Tsolakis et al. (2007) have experimentally investigated the combustion and emission characteristics of pure rapeseed-methyl ester or blended with ULSD AT 20% and 50% by volume. In his research, the ignition delay was reduced while

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the initial uncontrolled premixed combustion phase (uncontrolled heat release phase) was increased. This resulted increase in cylinder pressure, temperature and early fuel ignition. The emission like HC, CO and smoke will decreases while both NOX and fuel consumption will increases. The engine efficiency will not be affected by use of different fuel blends. EGR usage will reduce NOX by large extent due to increased CO_2 dilution in the intake system.

Tony E Grift et.al (2010) carried out an experimental study on engine performance and emissions by using biodiesel. The engine power will drop when using biodiesel due to lower heating value of biodiesel compared to diesel. The use of biodiesel reduces carbon deposit and wear of the key engine parts, compared with diesel. The emission like particulate matter and CO and HC are significantly reduced due to higher oxygen content, lower carbon to hydrogen ratio and lower aromatic compounds of the biodiesel. The CO_2 emission of biodiesel reduces greatly from the view of the life cycle circulation of CO_2. The blends of biodiesel with small content by volume could replace diesel in order to control air pollution and easing the pressure on scarcer sources to a great extent without significantly sacrificing engine power and economy.

Haiyan Miao et.al (2011) conducted experiments to investigate the effect of DMM and EGR on combustion and emission characteristics of a direct injection diesel engine. Results reveal that DMM results in longer ignition delay and longer premixed phase of combustion because of higher latent heat of evaporation of DMM hence the peak cylinder pressure and the premixed heat release rate increase. DMM could effectively reduces exhaust gas emission like CO, smoke and particulate matter but increases HC and NOX emissions. The increase of the EGR percentage resulted in longer ignition delay and the overall combustion shifted to a later stage while the combustion duration was reduced. Both the cylinder pressure and the amount of fuel burnt in the premixed combustion phase were reduced, thus leading to the decrease of BTE. Regarding to the effect of EGR on the exhaust gaseous emissions it reduces NOx emissions but increase other gaseous emissions. For a specific EGR ratio, DMM20 reduces smoke emission to some extent while DMM30 and DMM50 could reduce smoke emission remarkably and realise the double purpose of control in NOX and smoke emission. For a specific fuel, with the EGR ratio varies from 16% to 24%, NOx emissions could be reduced significantly, whereas the smoke emission presents a sharply increase when the EGR ratio increases from 20% to 24%.
Prasad et al analysed on jatropha curcas oil methy as an alternative fuel ester in a diesel engine. Biodiesel fuel showed reasonably good performance and the use of 100 % esterified jatropha oil gave reduction in smoke emission and increase in NOx emission while maintaining almost same BSFC in comparison with 100% diesel fuel operation. Exhaust gas recirculation is used to control the NOx emission J. Narayana Reddy et al (2005) have experimentally investigated the effect of neat Jatropha oil in a single cylinder, constant speed, direct injection diesel engine. Injection timing, injector opening pressure, injection rate and air swirl level were changed to study their influence on performance, emissions and combustion. Results have been compared with neat diesel operation. The injection timing was varied by changing the position of the fuel injection pump with respect to the cam and injection rate was varied by changing the diameter of the plunger of the fuel injection pump. A properly oriented masked inlet valve was employed to enhance the air swirl level. Advancing the injection timing from the base diesel value and increasing the injector opening pressure increase the brake thermal efficiency and reduce HC and smoke emissions significantly. Enhancing the swirl has only a small effect on emissions. The ignition delay with Jatropha oil is always higher than that of diesel under similar conditions. Improved premixed heat release rates were observed with Jatropha oil when the injector opening pressure is enhanced.

III. BIODIESEL AND DMM

3.1 BIODIESEL

Biodiesel refers to a vegetable oil or animal fat based diesel fuel consisting of long-chain alkyl esters. Biodiesel can be used alone, or blended with petro diesel in any proportions. Studies have indicated that the use of vegetable oils in diesel engines has the potential to create problems. Vegetable oils have probably elevated levels of nitrogen, this adversely affects emissions. Their high viscosity and low volatility are supposed to be at the root of all problems encountered in engines using biodiesel. The product of transesterification of vegetable oil have properties closer to petroleum fuels.

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Biodiesel consists of esters of fatty acids obtained by transesterification of vegetable oils which have properties similar to those of components of mineral diesel oil. Biodiesel production involves the use of various oil-seeds, the oil extracted from the seeds being subjected to a transesterification process that results in the conversion of the oil into the esters that constitute biodiesel.

3.1.1 ADVANTAGE OF BIODIESEL

Biodiesel fuel is a renewable energy source unlike petroleum-based diesel.
Biodiesel is free of sulphur and aromatics. In properly tuned this is expected to lead to lower particulate exhaust emissions.
The material is bio-degradable and non-toxic.
Biodiesel can be used alone or mixed in any ratio with diesel in any desired proportions.
The conditions for biodiesel storage are not significantly different from those conventional diesels.
The absence of sulphur allows more efficient use of oxidation catalysts.
The viscosity of bio-diesel is far less than that of virgin oils and closer to conventional diesel oil.
Biodiesel contains 17% oxygen by weight which leads to better combustion characteristics than diesel.
Biodiesel has higher flash point leading to greater ease in handling.
Engine exhaust emissions from biodiesel are distinctly free of polluting gases when compared with diesel
Biodiesel results in substantial reduction of hydrocarbons in exhaust emissions.

3.1.2 DISADVANTAGE OF BIODIESEL

Pure biodiesel doesn't flow well at low temperature due to lower cloud point and pour point which can cause problems of clogging fuel lines and filters in a vehicle's fuel system.
It can't be transported in pipelines due to its viscous nature. It has to be transported by truck or rail, which increases the cost.
Biodiesel has excellent solvent properties. Hence, any deposits in the filters and in the delivery systems may be dissolved by biodiesel and results in need for replacement of filter.
Biodiesel occupy more lands for cultivation results in decrease in food crop production.

3.1.3 JATROPHA OIL

It is a hardy shrub that can grow on poor soils and areas of low rainfall. Hence its being promoted for ideal plant for small farmers. It is a drought resistant, perennial plant and living upto fifty years and has a capability to grow on marginal soils. It requires very little irrigation and grows in all types of soils. It is rapidly growing tree and easily propagated. Jatropha usually grows below 1400 meters of elevation from sea level and requires a minimum rainfall of 250mm, with an optimum rainfall between 900-1200mm. The oil content of Jatropha seed ranges from 25% to 30% by weight.

3.1.4 CHARACTERISTICS OF JATROPHA OIL

Non-edible oil generally contains about 3-4 %wax and gum. De-waxing and degumming of plant oils is required not only for smooth running of the CI engine but also to prevent engine failure even if plant oils are blended with diesel. It is therefore necessary to remove wax and gum from the fresh oil before it could be used in CI engine. Analysis of Jatropha seeds revealed that the percentage of crude protein, crude fat and moisture were 24.60, 47.25 and 5.54% respectively. Jatropha methyl ester obtained from transesterification of jatropha oil using methanol or ethanol in the presence of catalyst. The toxicity of the Jatropha curcas is an advantage of producing emanates from the plant leaves that can't be eaten by animals and could act as an excellent fence.

IV. EXHAUST GAS RECIRCULATION

Exhaust Gas Recirculation is a nitrogen oxide emission reduction technique predominantly used in diesel engine. EGR works by recirculating a portion of an engine's exhaust gas back to the engine cylinder. In a diesel engine, the exhaust gas replaces some of the excess oxygen in the pre-combustion mixture. NOx forms primarily when

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a mixture of nitrogen and oxygen is subjected to high temperature. This EGR reduces the amount of NOx, the combustion generates, by lowering the combustion chamber temperature. The EGR gas is cooled with a heat exchanger to allow the introduction of a greater mass of recirculated gas.

In most studies, EGR addition resulted in increased smoke, HC, CO and reduced NOX emissions. The use of EGR was more effective only when higher reduction of NOX with lower increase of smoke is provided. Also it resulted in increased fuel consumption and reduced efficiency. The use of EGR will have the following effects inside the engine combustion chamber

V. RESULTS AND DISCUSSION

The results obtained from the present work are discussed in this chapter. The performance, combustion and emission characteristics of the engine observed during the present work are detailed. All the results are presented with a comparison between the characteristics of conventional diesel, jatropha biodiesel, jatropha biodiesel with dimethoxy methane fuel blends of 10% and 20% by volume without exhaust gas recirculation, jatropha biodiesel with dimethoxy methane fuel blends of 10% and 20% by volume with 20% exhaust gas recirculation.

VI. CONCLUSION

The combustion and emission characteristics of a compression ignition engine fuelled with biodiesel-dimethoxy methane (DMM) fuel blends with and without exhaust gas circulation(EGR) were investigated and the following are the observations

The maximum rate of pressure rise and the maximum rate of heat release increased with the increase of the DMM fraction in the fuel blends. This would be due to longer ignition delay and longer premixed phase of combustion.
Brake thermal efficiency is lower for blended fuels due to lower heating value of DMM. The increase of the EGR percentage would further reduce BTE. This would be due to fresh air is displaced by exhaust gas.Initially, NOx emissions was found to increase on increasing quantity of DMM. This is because of larger oxygen mass fraction in the DMM blended fuel. At higher loads, NOx emission was found to decrease significantly upto 40% with the help of EGR.

Smoke emissions was noted to reduce upto 30-40% on increasing DMM fraction upto 20% in the blends. CO emissions observed to decrease in biodiesel/DMM blends compared to diesel modes, however, this could be increased on increasing EGR ratio. HC emissions was found to be increase on increasing biodiesel/DMM blends due to lower boiling point of DMM fuel. This could be further increased on increasing EGR ratio.

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