Experimental Investigation on Effect of Using Dimethyl Carbonate as Additive with Jatropha Oil Methyl Ester in CI Engine

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ABSTRACT:
Out of many alternative fuels for CI engine; Jatropha oil methyl ester (Biodiesel) is good option as an alternative fuel. So for this fuel performance& emission characteristics must be tested and compared with diesel and effort should be taken to improvising it. In this paper, the work on effect of using dimethyl carbonate as additive with jatropha oil methyl ester in CI Engine is presented.
Keywords:
Compression Ignition (CI) engine, Biodiesel, Additive, Alternative Fuel Dimethyl carbonate

I. INTRODUCTION

CI Engine plays a very important role in transport sector of nation and also contributes to pollution significantly. These engines is used in heavy trucks, buses, locomotives, electric generators, farm equipment, underground mine equipment etc. [1]. Pollutants from diesel engines include carbon monoxide (CO), carbon dioxide (CO_2), sulphur oxides (SO_x), nitrogen oxides (NO_x), and particulate matter (PM). It is possible to reduce pollutant emissions in exhaust gases by using the different kind of fuels and additive, these are significant factors in the composition of exhaust gases. In diesel engines, alternative fuels are used for both reducing the consumption of petroleum-based fuels and pollutants in the exhaust gases. [2]

There are many tree species which bear seeds rich in oil. Of these some promising tree Species have been evaluated and it has been found that there are a number of them such as Jatropha curcas and PongamiaPinnata ('Karanja') which would be very suitable in our conditions. Highcetane number and calorific value that is approximately equal to diesel fuel make it possible to use Jatropha oil in diesel engines.

Oxygenated hydrocarbon fuels derived from biomass are attracting considerable attention either as replacements of, or additives to, conventional hydrocarbon fuels in internal combustion engines. They offer potential benefits as renewable fuels, with a long-term zero CO2debt, and the tendency to reduce soot formation [3-5]. Dimethyl carbonate, being non-toxic and highly miscible with diesel fuels, is one of such promising clean fuels. Carbon-carbon bonds are absent in the DMC molecular structure which contains three oxygen atoms. In a diesel engine study, Miyamoto et al. [4] found that the extent of soot reduction mainly depended on the amount of oxygen present in the fuel. Although the fuel's structure and the particular combustion conditions are of non-negligible influence on the emissions, it is worthwhile to consider the high oxygen content (53% by mass) of DMC: it suggests that DMC addition in small amounts could achieve significant soot reduction. Specifically, Rubino and Thomson [6] used a counter-flow propane/air diffusion flame to study the inhibition of soot precursor formation by adding oxygenated compounds includingDMC. They observed a remarkable reduction of soot precursors such as acetylene (C_2H_2) and benzene (C_6H_6), as well as a linear relationship between the C_2H_2concentration and the additive's oxygen and C-C bond content.. However, these benefits are achieved at the expense of increased emissions of oxygenated pollutants such as formaldehyde (CH2O) [11].

II. BIODIESEL PRODUCTION

Density, Kinematic viscosity and pour point of Jatropha oil was found higher than diesel.The direct use of vegetable oils in fuel engines is not ensuring smooth operation. Due to their high viscosity (about 11–17 times higher than diesel fuel) and low volatility, they do not burn completely and form deposits in the fuel injector of diesel engines [7]. The transesterification seems to be the best choice, as the physical characteristics of fatty acid esters (biodiesel) are very close to those of diesel fuel and the process is relatively simple. Furthermore, the methyl or ethyl esters of fatty acids can be burned directly in unmodified diesel engines, with very low deposit formation.

TRANS-ESTERIFICATION

The most common method to produce Biodiesel is using 'trans-esterification' which refers to a catalyzed chemical reaction involving vegetable oil and an alcohol to yield fatty acid alkyl esters and glycerol [7].After trans-esterification, viscosity of vegetable oil methyl esters (VOME) is reduced by 85-90% of the original oil value. VOME, also called fatty acid methyl esters (FAME), are therefore products of transesterification of vegetable oils and fats with methyl alcohol (CH3-OH) in the presence of a suitable catalyst. During the reaction, high viscosity vegetable oil reacts with methanol (or ethanol/butanol, as the case may be) in the presence of a catalyst (NaOH or KOH) to form an ester by replacing glycerol of triglycerides with a short chain alcohol.
Methanol was added in a 20% ratio in weight and 2% of the potassium hydroxide (KOH) catalyst was also dissolved in alcohol. Then, a prepared mixture was stirred at 60°C for 45 min. Thereafter, the reactant material was poured into a transparent vessel

and allowed to cool at room temperature for 6 to 8 hours for the glycerin at the bottom to settle and separate. The upper layer of the biodiesel was put into another transparent vessel for washing with an equal amount of water. The biodiesel was heated up to 110°C for 10 min to remove the moisture content. Then, the biodiesel was cooled down to room temperature before use, presenting a 94% yield.

Transesterification, also called alcoholysis consists of the substitution of the radical of one ester by the radical of one alcohol in a process similar to hydrolysis, except for the use of the radical of one alcohol instead of water. The transesterification reaction is represented by following general equation.

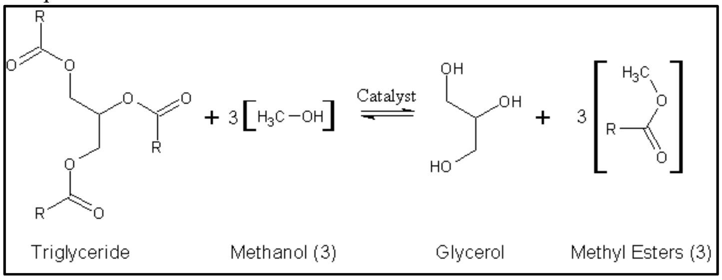

Fig. 1: Transesterification reaction

The general process is mentioned in above reaction. A fat or oil is reacted with an alcohol, like methanol, in the presence of a catalyst to produce glycerin and methyl esters (biodiesel). The methanol is charged in excess to assist in quick conversion and recovered for reuse. The catalyst is usually sodium or potassium hydroxide which has already been mixed with the methanol.

Methyl esters of Jatropha oils provide similar properties to that obtained with diesel fuels. The following are the important characteristics of good biodiesel required to substitute diesel fuel.

Table I: Physico-chemical Properties of Diesel and Jatropha oil methyl ester

SN	Description	Calorific Value (kJ/kg)	Density (kg/m3)	Kinetic Viscosity cSt (at 30°C)	Cetane Number
1	Diesel	44420	839.6	4.86	48-56
6	Jatropha methyl Ester	38480	880	5.65	51-52

III. DIMETHYL CARBONATE (DMC)

Dimethyl carbonate (DMC) has been of interest as an oxygenate additive to diesel fuel because of its high oxygen content. Diesel engines studies have shown that dimethyl carbonate addition to the fuel can significantly reduce smoke emissions [8]. However, the many simultaneous processes in an engine make it difficult to determine the mechanism responsible for this decrease.

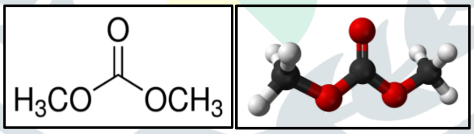

Fig. 2: Chemical Structure of Dimethyl Carbonate

Pierre A. Glaude et al. [8] studied a chemical kinetic mechanism for DMC was developed for the first time and used to understand its combustion under conditions in an opposed flow diffusion flame. It was found that the decomposition rate DMC =>H3COC(=O)O + CH3 in the flame was much slower than originally thought because resonance stabilization in the H3COC(=O)O. radical was less than expected. In the simulations of DMC in the flame, it was determined that much of the oxygen in dimethyl carbonate goes directly to CO_2. This characteristic increases the effectiveness of DMC for soot reduction in diesel engines. In an ideal oxygenate additive for diesel fuel, each oxygen atom stays bonded to one carbon atom in the products thereby preventing the formation of carbon-carbon bonds that can lead to prevention to form soot. When CO2 is formed directly, two oxygen atoms are bonded to one carbon atom thereby wasting one oxygen atom in the oxygenate additive.

G D Zhanget al. [10] did experimental study with diesel engine and found that DMC may be a promising additive for diesel fuel owing to its high oxygen content, no carbon-carbon atomic bonds, suitable boiling point, and solubility in diesel fuel. The combustion analysis indicated that the ignition delay of the engine fuelled with DMC-diesel blended fuel is longer, but combustion duration is much shorter, and the thermal efficiency is increased compared with that of a base diesel engine. Further, if injection is also delayed, NOx emissions can be reduced while PM emissions are still reduced significantly. The experimental study found that diesel engines fuelled with DMC additive had improved combustion and emission performances.

Table II.Physico-chemical Properties of Dimethyl Carbonate

Molecular formula	Boiling point, °C	Cetane number	Calorific value MJ/Kg	Density Kg/m^3	Energy density, J/mm^3	Oxygen content, wt%
$CH_3OCO_2CH_3$	90-91	35-36	15.78	1075	16.96	53.3

DMC is an oxygenate that is miscible with diesel fuel, has a high oxygen content, and can provide reductions in PM and other emissions. DMC is currently being used as an industrial chemical in many applications, including polycarbonates and as a methylating agent. Although DMC has been lightly studied for vehicle/engine applications, it is attracting some attention as a potential renewable diesel fuel. DMC differs in several key ways from diesel fuel, and it is these unique properties that can impact the performance and emissions when it is used in a diesel engine. DMC has a lower cetane number (CN) compared to the diesel, which causes an increase in the engine ignition delay. It also has a lower boiling point which favors spray atomization and mixing. The instantaneous heat release rate for DMC added to diesel fuel is also higher than that of the diesel fuel itself during the initial combustion period, making the heat release process more concentrated. The heat value of DMC, at 15.78 MJ/kg, is considerably lower than that of diesel fuel, which is around 42.5 MJ/kg, which leads to an increase in the fuel consumed per mile for the DMC blended fuel. The oxygen content also has important consequences on the difference emissions components. The most important impact is the relatively large reductions in PM that are found with the addition of DMC, which ranged up to 75% for the 20% blend in our initial studies. Along with a reduction in PM mass, a corresponding increase in particle number can be found, as particles show an increased tendency to form nucleation particles. Most studies have also shown reductions in carbon monoxide (CO) with the addition of DMC. For NOx emissions, DMC has shown mixed results, with some studies showing increases, while other studies have not. Similarly, hydrocarbons (HC) emissions have shown increases in some studies, while other studies have shown reductions. The unique characteristics of DMC must also be considered in terms of the utilization of DMC within the existing petroleum infrastructure. DMC is a flammable liquid. It has a lower flashpoint that diesel fuel, but is safer than acetone, methyl acetate and methyl ethyl ketone from a flammability point of view. In terms of diesel-DMC mixtures, one issue is that these mixtures have a high critical solubility temperature value, which is the temperature where the two components of a mixture are no longer miscible and start to separate. This could cause problems in colder climates. DMC should be stored in a tight reservoir at a cool, dry, well-ventilated location away from moist air, plastics and resins. Some additional studies of material compatibility would be useful in better understanding these potential impacts.

IV. EXPERIMENTAL SETUP

Experiments have been conducted in a computerized, single-cylinder, four-stroke, naturally aspirated, direct injection, air cooled diesel engine. The schematic representation of experimental set up is shown in Figure 2 and the specification of the engine is given in Table I. Experimental set up is computerized and all data is recorded in the computer by data acquisition system (DAS) software.

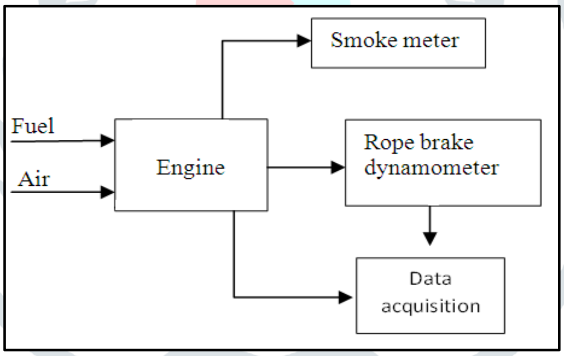

Fig. 3: Schematic representation of experimental setup.

Fuel consumption is measured with the help of weight sensor (in kg) after every minute. Air box is used to measure air flow rate. The engine is coupled with a rope brake dynamometer which is used to control the engine torque by applying tension to the rope. An OPAX 2000 II Smoke meter is used to measure the smoke intensity. Load is changed in five steps from no load to the maximum load i.e., 0 to 15 kg. The engine is operated at the rated speed 1500 rpm. The performance parameters like brake thermal efficiency and brake specific fuel consumption and Smoke intensity was measured. Finally, the test results are analyzed and compared with diesel and neat biodiesel.

Dimethyl Carbonate is added as an additive in the neat Jatropha oil methyl ester to investigate the effect on performance and emission parameters. The Dimethyl Carbonate is added in 5%, 10%, and 15% stirred and mixed in the biodiesel before actual testing. Oxygenated chemical compounds contain oxygen as a part of their chemical structure. The term usually refers to oxygenated chemical compounds added to fuels. Oxygenates are usually employed as gasoline additives to reduce carbon monoxide and soot that is created during the burning of the fuel. Compounds related to soot, such as poly-aromatic hydrocarbons (PAHs) and nitrated PAHs, are also reduced.[9]

V. RESULT AND DISCUSSION

DMC may be a promising additive for diesel fuel owing to its high oxygen content, no carbon-carbon atomic bonds, suitable boiling point, and solubility in diesel and biodiesel [10]. The aim of this research was to study the emission characteristics and performance of diesel engines operating on biodiesel fuel mixed with DMC. The results were obtained for performance and smoke emission is plotted for neat diesel, Jatropha Oil Methyl Ester (JOME) and blends of JOME and DMC.

a. Brake specific fuel consumption

Fig. 4 shows consumption of diesel, Jatropha oil methyl ester and its blend with additive DMC at different load condition. It is clear that at same load diesel consumption is lower than that of JOME, and increases as the load on the engine increases. The brake specific fuel consumption is found to be increased due slightly lower calorific value of the JOME compared to the diesel.*bsfc* increases as the amount of DMC blending increases. The highest specific fuel consumption is occurring at 15%. This is because DMC has much low Calorific value up to 15 MJ/kg and low cetane number hence fuel requirement is increased with extent of blending.

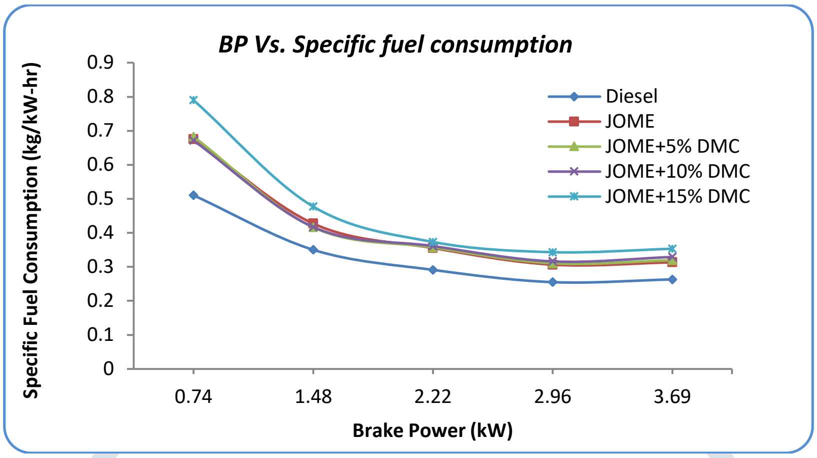

Fig. 4: Variation of BSFC Vs BP for JOME with DMC

The highest rise in BSFC is 54% (compared to diesel)& 17% (compared to neat JOME)for 20 % rated loading With JOME+15% DMC blend while least values are for diesel. Same trend is observed for all loading condition. So it is concluded that the effect of addition DMC will not help us for improving fuel economy of engine.

b. Brake thermal efficiency

DMC has high oxygen content, no carbon-carbon atomic bonds, suitable boiling point, and solubility in fuel. From Fig. 5 it has been observed that the improvement in thermal efficiency for JOME+10% DMC blends as compared with neat JOME while further DMC blending decrease the efficiency.

The highest rise in thermal efficiency is 9% for 40 % rated loading With JOME+10% DMC blends in comparison with neat JOME. This is because high ignition delay of the engine fuelled with DMC-JOME blended fuel is longer, but combustion duration is much shorter (due high inflammability), and the thermal efficiency is increased compared with that of JOME.

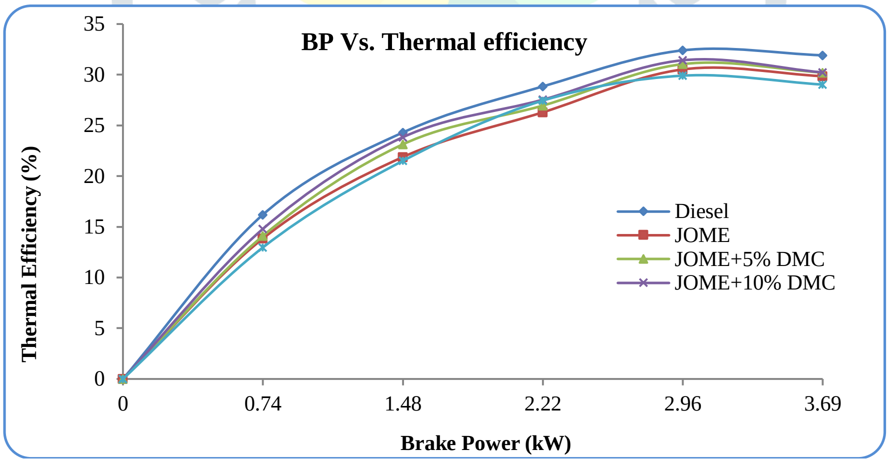

Fig. 5: Brake thermal efficiency Vs BP for JOME with DMC

C. Smoke Intensity

From Fig. 6 it is clear that smoke is reduced significantly with the addition of DMC and smoke emission reduced as amount of DMC blending is increases. This reduction is simply due to the extra oxygen present in DMC (53.3% oxygen content in DMC) as well as longer ignition delay and faster combustion is play crucial role combustion kinematics and smoke formation.

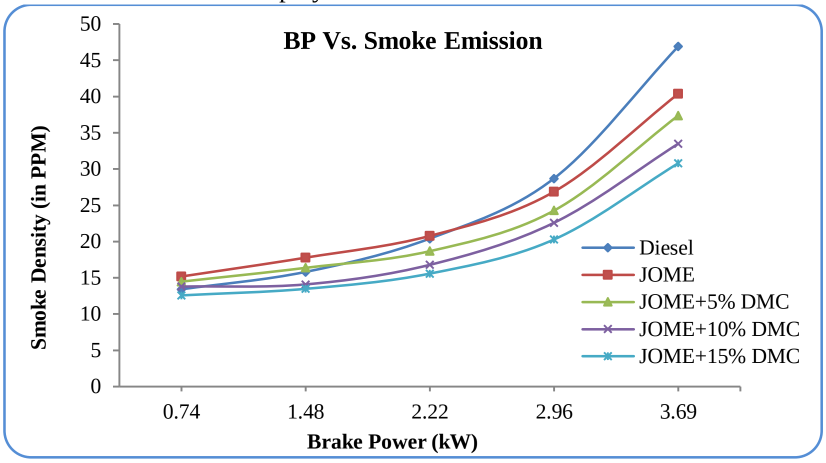

Fig. 6: Smoke density Vs. BP for JOME with DMC

Smoke emission is least with 15% DMC blending and maximum reduction smoke is observed at full load condition. The highest reduction in smoke is 34% at 100% rated loading condition in comparison with neat diesel. Hence DMC is found better for reduction of smoke emission but further NOx and CO emission are need to be investigated.

VI. Conclusions

In this experimental investigation the effect of additive on methyl ester of Jatropha with additive DMC was studied. The experimental results proved that the use of neat Jatropha in compression ignition engine is a viable alternative to Diesel.

Jatropha oil methyl ester can used without any modifications in the engine and generate a very similar brake power as compared to diesel.

The experimental study found that diesel engines fuelled with oxygenating additive such as DMC had improved combustion and emission performances and leads to smoke reduction significantly for all blends.

The specific fuel consumption is increased with DMC blending hence for same power output; more fuel has to be supplied. Also thermal efficiency is improved for low level of DMC blending. This additive is found better for reduction of smoke emission but further NOx and CO emission are need to be investigated.

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