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EFFECT OF FUEL INJECTION PRESSURE AND INJECTION TIMING ON PERFORMANCE AND EMISSIONS OF DIESEL ENGINE USING PREHEATED BIODIESEL BLENDS

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Abstract

Biodiesel is used as an alternative to conventional diesel fuel made from renewable resources, such as animal fats, nonedible oils vegetable oil and from different seeds of plants. The oil from the seeds can be converted to fuels is called as biodiesel. In this paper we studiedand discused the effects of fuel injection pressure, timing and preheating of biofuels at different temperature. It gives an information regarding influence of the injector specifications that is noticeable at all system pressures. The data draws special attention on the complex relation of the fuel system pressure, the injector specifications and the combustion characteristics. With the help of blends the average reduction in brake power of the biodiesel fuels was reduced proportionally with the biodiesel ratio in the fuel blends. The (BSFC) and NOx emissions increased with a reduction in soot, HC and CO emissions as we increase the percentage of biodiesel. Moreover, the engine performance depend on operating conditions such as injection timing and injection pressure as also by any other means as per study. When we increase the injection timing, the BP initially increases until it reaches a peak value and then decreases slightly for all types of fuels tested. The effect of injection pressure changes depending on the pressure range and biodiesel blends.

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1. INTRODUCTION

In recent years, the energy consumption demand and the polluted environment have increased rapidly throughout the world. To solve these problems, it is necessary to find new energy sources to replace traditional energy sources. As for alternative energy sources such as biomass, wind, solar and geothermal, biodiesel is considered a potential renewable energy source since it can be supplied effectively and provides sustainable development to solve these problems . Moreover, with the abundance of raw materials (agricultural waste, animal fats, waste oil, algae), a biodiesel development plan is a good solution to motivate farmers to participate in sustainable agriculture in developing countries. The world is confronted with twin crisis of fossil fuel depletion and environmental degradation. The situation have led to the search for an alternative fuel which should be not only sustainable but also environmental friendly without sacrificing with the performance The sources of alternative fuels are the biodiesel obtained by adding non additives with diesels. The purpose is to find a suitable component in the form blends with diesel for a more suitable alternative fuel with improve performance of the engine.

2. LITERATURE SURVEY

Experimental investigations were carried out by Narsinga RL. et al [1] on a single cylinder four stroke diesel engine fuelled with biodiesel blends at different fuel injection pressures (200, 220 and 240 bar) and fuel injection timing (19°, 23° and 27° BTDC) to decide the performance, and emission characteristics.

Quadri SAP et al [2] has worked on the influence of injection opening pressure (IOP) for 20% blend (B20) of mahua oil methyl ester and 22.5liters per minute (lpm) of hydrogen dual fuel mode was investigated based on the performance, combustion and emission characteristics of a single cylinder, four stroke, direct injection (DI) diesel engine with a rated power of 3.5kW at a rated speed of 1500rpm. Experiments were carreied out at four different IOP of 200, 225, 250 and 275bar that were compared using the diesel operation at 200bar as the baseline.

Performance and emissions of a direct injection diesel engine blended with Jatropa bio-diesel prepared with methanol to get jatropa oil methyl ester (JOME) Venkatesan M et al [3] has worked and experimented with JOME single and dual fuel mode with compressed natural gas (CNG) in a single cylinder 4 stroke diesel engine.

Commercial diesel fuel blended with different concentrations of fish-oil biodiesel including B0, B10, B20, B30, B40 and B50 (corresponding to 0%, 10%, 20%, 30%, 40%, and 50% of biodiesel in blend) were used for the test engine. Kumar NK et al [4] experimented that compared to B0, the average reduction in brake power (BP) of the biodiesel fuels was reduced proportionally with the biodiesel ratio in the fuel blends. The brake specific fuel consumption (BSFC) and NOx emissions increased together with reduction in soot, HC and CO emissions as the percentage of biodiesel increases.

The discharge significant amount of pollutants such as CO, UHC, NOx, smokes, etc. which are harmful to the environment. There is a wide variety of alternative fuels available as renewable fuels to replace diesel fuel. Reddy VS et al [5] said that vegetable oils, their properties being close to diesel fuel, may be a best alternative for use in diesel engines. The high viscosity and low volatility of these vegetable oils are the major problems use in diesel engines. Such problem can be solved by the process of trans-esterification.

Alternatives like alcohols, vegetable oils and biodiesel has been done work at much depth. Increasing injection pressure and injection timing increases brake thermal efficiency, peak cylinder pressure as well as NO emissions. Chotai H et al [6] said that the optimum conditions for engine operating on diesel are 500bar/150BTDC and biodiesel is 280bar/25.50BTDC. Further increase in injection pressure and timings decreases brake thermal efficiency and cylinder peak pressure.

Kumar AA et al [7] has worked on effect of 10, 20 and 50% Karanja biodiesel blends on injection rate, atomization, engine performance, emissions and combustion characteristics of common rail direct injection (CRDI) fuel injection system were resulted in a single cylinder research engine with CRDI at 300, 500, 750 and 1000 bar fuel injection pressures at different start of injection timings and constant engine speed of 1500 rpm. The duration of fuel injection slightly decreased with increasing blend ratio of biodiesel (Karanja Oil Methyl Ester: KOME) and significantly decreases with increasing fuel injection pressure.

Prasad PV et al [8] has worked on single cylinder diesel engine using petro-diesel and palm methyl ester blend 20% as fuels under four engine loads with injection timings 170, 190, 210, 230, 280 CA BTDC. The objective of this work is to investigate the optimum injection timing for possibility of reducing the exhaust gas emissions UBHC, CO, NOx without much effect on the performance parameters BSFC, Brake Thermal Efficiency. The effect of injection timing on the biodiesel blend PME20 was investigated and the results were analyzed. With retardation of injection timing NOx emission reduced and UBHC,CO emissions increased while advanced injection timing could reverse the effect .Optimal injection timing for PME20 blend(B20) is 210 CA BTDC for slightly higher thermal efficiency and BSFC at full load operation while 190 CA BTDC could be for low NOx emission with tolerable performance parameters.

Kumar SP et al [9] has experimentally investigated using rubber seed and jatropha seed oil blended diesel fuel from 20 % (B20) to 40 % (B40) with an increment of 10% . The engine was tested at different loads from no load to full load conditions with diesel fuel at normal injection pressure of 220bar and fuel injection timing of 240CA BTDC. The experimental tests were performed at 210CA BTDC injection timings by changing the thickness of advance shim. The experimental results show that CO and UHC emissions were decreased for the blends of B20, NOx and exhaust gas temperature increased with increasing amount of biodiesel concentration in the fuel mixture.

A. Augustine et al [10] used cotton seed oil as a biodiesel in the investigation. He preheated the bio diesel at different temperature namely, 40, 60, $80, 100^{o}c$ before it was poured inside the engine.

K. K. Sureddy et al [11] mainly reviews about the quantity of preheated bio diesel added with 25% Sunflower fuel and eresults its performance for selected blend with different loads. Bio diesel was mixed with sunflower oil for rapid combustion as for the bio diesel, the cetane number is high that evaluated in shorter delay of ignition and the mixture was preheated to raise its temperature to improve the combustion process and viscocity. Analysis of the parameters required to define the combustion characteristics such as BSFC, BSEC, , Exhaust Gas Temperature, NOx, Unborn HC, and Carbon Monoxide, Smoke are the performance of engine and its emissions of preheated bio diesel.

Waste cooking oil from the university cafeteria was used as feedstock to produce biodiesel. The feedstock was then converted to biodiesel using two different methods. Eiman Ali et al [12] tested with and without preheating to study the effect of preheating on biodiesel. For each one of the two methods two types of catalysts were used that is alkali and acidic. The effect on biodiesel yield, calorific value, viscosity, and density was observed.

K.Vijayaraj et al [13] used vegetable oils for engines as an alternative fuel for diesel fuel. However, there was a limitation in using straight vegetable oils in diesel engines due to their high viscosity and low volatility. In the present work, neat mango seed oil was converted into their respective methyl ester through trans-esterification process and presents the effect of injection pressures (190, 200, 210, 220 and 230 bar) and injection timings (21o, 23o and 25o BTDC) on performance, emission and combustion characteristics of best blend (B25) of methyl ester of mango seed oil.

The aim of I.Lassoued et al [14] study was to investigate the effect of varying injection pressure on performance and emission characteristics of a four-cylinder, four-stroke, compression ignition direct injection engine fuelled with diesel fuel and 20%, 40% and 60% waste cooking oil blended with biodiesel (B20, B40 and B60). To that end, five injection pressures were tested the original 200 bar, 220 bar, 240 bar, 260 bar and 280 bar. This study results that by changing the injection pressure up to 240bar it induces significant improvement in the performance characteristics for all tested fuels to varying degrees.

Fig-1: VCR Diesel Engine

Sr No	Particulates	Description
1	Type	Kirloskar TV1
2	No of cylinders	One
3	No of strokes	Four
4	Bore	87.5mm
5	Stroke	110mm
6	Compression ratio	17.5:1
7	Rate power	5.2 kW at 1500 rpm
8	Dynamometer	Eddy current
9	Type of cooling	Water cooled
10	Type of injection	Mechanical pump-nozzle injection
11	No of nozzle hole	3
12	Fuel injection starts	23° BTDC

Table-1: Engine specifications

3. BIODIESEL

Biodiesel is an alternative fuel similar to conventional or ‘fossil’ diesel. Biodiesel can be produced from straight vegetable oil, animal oil/fats, tallow and waste cooking oil. The process used to convert these oils to biodiesel is called trans-esterification. The main benefits of biodiesel are that it can be described as ‘carbon neutral’. This means that the fuel produced no net output of carbon in the form of carbon dioxide (CO2).

3.1 Trans-esterification process

Biodiesel can be produced from straight vegetable oil, animal oil, and waste oils. There are three basic routes to biodiesel production from oil and fats. The trans-esterification process can be defined as the process of reacting that is oil with an alcohol that may be methanol or ethanol in the presence of a catalyst like potassium hydroxide or sodium hydroxide, to chemically break the molecule of the oil into esters.

Trans-esterification process is used to reduce the viscosity of vegetable oils and produce the biodiesel. In the trans-esterification process of vegetable oils, a triglyceride reacts with an alcohol in the presence of a strong acid or base, producing a mixture of fatty acid alkyl esters and glycerol. About 2 gm of catalyst (NaOH) is mixed in 100 ml methanol to prepare alkoxide, which is required to activate the alcohol. Vigorous stirring was done for 30 minutes in a closed container until the alkali is dissolved completely. The alcohol-catalyst mixture is then transferred to the reactor containing moisture free oil. Stirring of the mixture is continued for another one hour between 65 and 70o C of temperature the mixture is then taken out and poured into the separating vessel. The mixture is allowed to settle by gravity in a separating vessel.

4. METHODOLOGY

Experimental investigations were carried out by Narsinga RL. et al [1] on a single cylinder four stroke diesel engine fuelled with biodiesel-nanoparticle blends at different fuel injection pressures (200, 220 and 240 bar) and fuel injection (19°, 23° and 27° BTDC) timings to determine performance, and emission characteristics.

The combustion analysis was based on the averaged value of 100 cycles after the engine reached steady state operation. Quadri SAP et al [2] during the first test the engine was started on diesel fuel to generate baseline data. In the second test, the engine was made to run on bled B20 fuel after reaching stable conditions the results are compared to baseline data. In the third test of operation engine running on B20 fuel and inducted air is enriched with a low concentration of hydrogen (20, 22.5 and 25 lpm), the results were obtained at all loading conditions for four different IOP of 200, 225, 250 and 275 bar.

In the present investigation test Venkatesan M et al [3] were carried out to examine the performance and emissions of a direct injection diesel engine blended with Jatropa bio-diesel prepared with methanol to get jatropa oil methyl ester. Experiments are conducted with JOME single and dual fuel mode with compressed natural gas in a single cylinder 4 stroke diesel engine three injection pressures of 180, 200 and 220 bar and two injection timings 27o BTDC and 31o BTDC.

In this research, the test engine was operated at engine speeds ranging from 1200 rpm to 3000 rpm. Based on the test engine characteristics, Kumar NK et al [4] examined the brake specific fuel consumption is lowest at an engine speed of 2200 rpm and engine load of 75%.Consequently, the engine speed and engine load position were maintained for the entire experimental process at a moderate value of 2200 rpm and 75% load, respectively. Corresponding to each type of fuel, injection timing was varied from 120 before top dead center (BTDC) to 220 BTDC at an interval of 20 to evaluate the influence of its variation. In addition, the injection pressure was varied from 400 bar to 800 bar at an interval of 100.

In the present work, experiments are conducted on 3.72 kW(5 BHP) single cylinder, four stroke, water-cooled diesel engine using cotton seed oil methyl esters (CSOME) blended with diesel in various proportions to study the engine performance and emissions at different injection pressures. Reddy VS et al [5] examined effect of injection pressure on the performance and emission characteristics for various biodiesel blends of 0BD, 10BD, 20BD, 30BD and 100BD at six different test pressures of 170, 180, 190, 200, 210 and 220 bar are studied.

In the experiment injection pressure is taken as 220 and 300 and the injection timing from 230, 25.50 and 280. Chotai H et al [6] research on alternative fuels like alcohols, vegetable oils and biodiesel has been done at much depth. Along with alternate fuel, engine performance and emissions are also affected by various engine operating conditions.

Kumar AA et al [7] worked on effect of 10, 20 and 50% Karanja biodiesel blends on injection rate, atomization, engine performance, emission and combustion characteristics of common rail direct injection fuel injection system were evaluated in a single cylinder research engine with CRDI at 300, 500, 750 and 1000 bar fuel injection pressures at different start of injection timings and constant engine speed of 1500 rpm.

Experiments were conducted on single cylinder diesel engine by Prasad PV et al [8] using petro-diesel and palm methyl ester blend (PME20) as a fuel under four engine loads with injection timings 170, 190, 210, 230,280CA BTDC.

A. Augustine et al [10] reported that in diesel engine crude plant oil can be used as a working fuel directly or can be blended in certain ratios, but from more researches it was found that the viscosity of the biodiesel was more than that of the diesel. It was choking the engine and dilutation of engine oil got deposited in several parts of the engine.

5. RESULT AND DISCUSSIONS

Based on experimental results, the optimum injection strategy for the better performance and emission of the nano additive biodiesel blend for the single cylinder diesel engine was240 bar and 19° BTDC Narsinga RL.et al [1]

Quadri SAP et al [2] Maximum brake thermal efficiency, minimum brake specific fuel consumption, and lowest HC, CO and smoke emissions with increased concentration of NOx were obtained at IOP of 250bar for B20-hydrogen dual fuel mode.

Jatropa oil is used in the experiment and results were found that CNG - JOME can be used as fuel with better performance at 220 bar pressure and advanced injection timing of BTDC. In this investigation the diesel engine was set to run at advanced injection timing 31°BTDC and injector pressure 220bar to arrive at the optimum for jatropa oil methyl esters (JOME). Venkatesan M et al [3] resulted in an increase in Brake thermal efficiency of 1.28% is obtained at higher loads when compared to base line diesel operation due to the advancement in injection timing. At low loads the UBHC was high and it reduces at high load conditions. Pressure variation does not have any effect on NOx and CO emissions but higher pressure causes higher value of smoke density.

The use of fish oil was carried by Kumar NK et al [4]. The largest power deviation, 6% (between the simulation and experiment), was observed with B0, and the smallest power deviation, 2.61%, is observed with B30. Meanwhile, the largest and smallest deviation of BSFC was 5.05% with B0 and 4.77% with B30.Accordingly, with B0, B10, B20 and B30, the brake power and BSFC do not vary in the pressure range from 600 bar to 700 bar. For this range of pressure, the brake power decreases and BSFC increases. However, for the B40 and B50 fuels, brake power and BSFC are the same at low injection pressures ranging from 500 bar to 600 bar; meanwhile, the brake power decreases and BSFC increases for this pressure range.

Reddy VS et al [5] resulted the cotton seed oil 50% load and 70% load and for blends of 10BD, 20BD, 30BD, and 100BD and (0BD) diesel fuel. It was observed at 200 bar injection pressure the maximum brake thermal efficiencies of 26.3% and 25.82% (at 50% load condition) were obtained for 20BD and 30BD respectively. The lowest BSEC for 20BD blend was found to be at 200 bar injection pressure (IP) and was 12.67 MJ/kW-hr respectively. The CO emission for 20BD blend at 180 bar is 9.16% was less than that of diesel fuel at 50% load. With increasing the injection pressure to 200 bar, the CO emission was dropped by 14.7%.At 50% and 70% load operations show that the CO emission for different blends is very low compared to neat diesel fuel. Therefore, the 200 bar and 20% diesel blended fuel are the best conditions. 8.7% reduction in UHC is observed from 190 to 200 bar IP. With the increase in injection pressure from 180 to 200bar for 20BD blend at 70 % load, the smoke opacity has been reduced by 6.7%.

Chotai H et al [6] said in case of waste cooking oil 100% biodiesel, the efficiency was maximum at 280bar, BTDC. The optimum condition for engine operating on diesel was 500bar/150BTDC and biodiesel is 280bar/25.50BTDC.

Kumar AA et al [7] used Karanja Biodiesel Blends Highest achieved BTE for diesel (at 18 Mpa injection pressure) and biodiesel (at 24 Mpa injection pressure) were 32.1and 41.3% respectively.

PMEs was used as a working oil as a biodiesel. Prasad PV et al [8] said that the bsfc was decreased by 3.08% with retarded injection timing CA while it has increased by 13.88%, 14.81% for, CA respectively at full load condition. The BTE increases with an increase in engine load from 0 to 100% for all injection timings. At BTDC injection timing the brake thermal efficiency was higher compared to all injection timings while lower at crank angle. It was found that UBHC emissions reduced by about 15.69 % on advancing the injection timing to CA BTDC while increased by about 12% on retarding the fuel injection timing to CA BTDC at full load operation. Among all injection timings CA BTDC has the lesser NOx emissions. In keeping view of knocking tendency, engine behavior CA showed that optimum fuel injection timing for low NOx emissions with tolerable performance.

Rubber seed oil was used as a biodiesel in this experiment. The Kumar SP et al [9] resulted that the CO and UHC emissions were decreased for the proportion of B20, NOx and exhaust gas temperature increased with increasing amount of biodiesel concentration in the fuel mixture. The CO emission reduced from no load condition to 75% of load. Minimum UHC emission of 11 ppm was observed with biodiesel fuel at an injection timing of 21° BTDC in75% load condition.

(a) In CO emission test, the load was increased from no load to at 75% of load condition the B20 of experimental valves was deduced. It was very closer to the pure diesel fuel valves. The CO of blended fuel at B20 gives the better performance compared to the B40.

(b) Very low amount of UHC was achieved for B20 from no load to full load condition. It was varied from 16 ppm to full load 18 ppm. Another blended fuel of B40 also reduces the UHC emission as compared to the pure diesel fuel in all test conditions.
(c). The NOx and exhaust gas temperatures were increased from no load to full load condition in all test fuels. The blended fuels B20 and B40 were very closer to the pure diesel.
A. Augustine et al [10] results proved that the preheated CSOME leads to be favourable on BTE, and CO, HC emission at$80^{o}C$. But at $100^{o}C$ the BTE and BSFC were decreased due to vapour content at higher temperature.
The preheated sunflower biodiesel shows greater performance and emission results as compared to sunflower biodiesel. K. K. Sureddy et al [11] resulted the ignition delay decreases with increase in injection pressure at all injection timings. The maximum value of injection delay (12°CA) found with 21°CA BTDC of injection timing and 210 bar of injection pressure.
Eiman Ali et al [12] found that with preheating to higher temperatures, the yield was 87% with alkali catalyst and 70% with acid catalyst. On the other hand, without preheating, it was found that the yield using alkali catalyst was 98% and 75% using acidic catalyst. Further, the highest calorific value was obtained using alkali catalyst without preheating.
K.Vijayaraj et al [13] resulted that B25 could be used as an alternative fuel for diesel engine with the static injection timing of 23o BTDC with injection pressure of 200 bar without any engine modifications.
I.Lassoued et al [14] resulted at B20, under this optimized injection pressure was found to offer the best performances characteristics. Increasing injection pressure has proven its worth within a restricted limit. Indeed, for 260 bar and 280 bar, for all tested fuels, performance and smoke level characteristics were found to be dwindling.

6. CONCLUSION

From this paper we can conclude that if fuel injection pressure and fuel injection timing are varied and also by preheating biodiesel it directly affects the performance and emission of diesel engine. By analysing the different results, we can conclude that the performance of diesel engine i.e. BSFC and brake thermal efficiency is increases, also emission of the gases i.e. NO_x, CO_2, decreases.

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