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EXPERIMENTAL INVESTIGATION OF BIO-DIESEL ON ELECTRONIC DIRECT FUEL INJECTION SYSTEM

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Abstract
In the present scenario bio-diesels have received a lot of attention as an alternate vehicular fuel. But the properties of bio-diesels are not the same as diesel fuels especially their high viscosity and low volatility. Also the bio-diesels have very poor atomization characteristics due to decreased cone angle during fuel injection.

This paper relates the evaluating of EDI system at constant speed of 1500 rpm and compression ratio of 17.5 at different injection timing as well. The performance parameters such as brake thermal efficiency, carbon monoxide, NO_x and UBHC have been studied.

The objective of this work is to study the effect on combustion and emissions of a bio-diesel fuelled Electronic direct fuel diesel engine. To use acid oil, a byproduct of vegetable oil refining process for biodiesel production and study its feasibility. To suggest a suitable process for producing biodiesel from acid oil. Characterization of the biodiesel produced. To study the engine performance, emission and combustion characteristics of the biodiesel and its blends. To conceptualize, built, test and demonstrate an electronic controlled direct fuel injection (EDI) system attached to existing single cylinder engine and conduct its performance, emission and combustion characteristics of the biodiesel and its blends.

NOMENCLATURE

PME: poly methyl ester

CFD : computational fluid dynamics

SF C : specific fuel consumption

CV : calorific value

CR : compression ratio

IP : injection pressure

Bth : brake thermal efficiency

BP : brake power

TDC : top dead centre

BTDC : before top dead centre

CI : compression ignition

HRR : heat release rate

CA : crank angle

I T : injection timing

INTRODUCTION

The world is presently confronted with two crises, the fossil fuel depletion and environmental degradation. The indiscriminate extraction and lavish consumption of fossil fuels have led to reduction in underground-based carbon resources. The sky rocketing oil prices exert enormous pressure on our resources and seriously affect our economy. The fact that petroleum based fuels will neither be available in sufficient quantities nor at reasonable price in the future, has revived interest in exploring the alternative fuel resources for diesel engines.

Air motion plays a significant role in fuel - air mixing, combustion and emission processes [1]. Along with air motion, spray characteristics, spray angle, injection pressure and injection timing also have a significant role in diesel engine combustion.

Swirl, squish and tumble are the important flow pattern of air motion. These patterns not only affect the fuel-air mixing and combustion process in diesel engines, but also have significant impact on combustion quality [2].

Swirl motion of the air is adequately achieved with good intake port design [3, 4, 5, 6, 7, 8, and 9]. When there is swirl in the in-cylinder air, the swirl-squish interaction produces a complex turbulent flow field at the end of compression. This interaction is severe in reentrant combustion chamber design [10]. Intensification of turbulence is due to the highly turbulent squish of the air near TDC of compression. The intensification of turbulence leads to efficient combustion which in turn causes higher NO_x emission and less HC emissions [11]. The author however has not reported the effect of tumble. Better air mixing and combustion are possible with higher injection pressure. Higher injection pressure produces smaller fuel droplets which evaporate faster and mix rapidly with air.

Bio-diesels play an important role in the on going balance between two major societal needs, viz., fuel economy and environment friendly Emissions. Bio-diesels can be produced in a way that does not cut into food supplies as Simorouba is non edible oil. Bio-diesel production reduces the dependency on imported oil and supports the agricultural sector [12]. The properties of bio-diesel are not the same as diesel fuels especially their high viscosity and low volatility. These properties strongly affect injection pressure injection timing and spray characteristics [13].

An increase in viscosity of bio-diesel will result in poor atomization characteristics due to decreased cone angle during fuel injection [14]. The pre - heating of vegetable oil gives better performance than raw vegetable oil. It has been observed that viscosity reduces exponentially with temperature. It has also been observed that when pre - heated vegetable oil is injected into the cylinder, spray pattern and atomization character has improved. The injection pressure has an effect on the spray formation of bio-diesel blends in CI engines [15]. Also studies have shown that the combustion characteristics alter with the changes in injection pressure. With the increase in pressure, the fuel penetration distance become longer and the mixture formation of the fuel-air was improved [16]. Also when the injection pressure is increased fuel particle diameter will be reduced. The mixing of fuel-air becomes better during ignition delay period. The combined effect of increased compression ratio, injection timing and injection pressure on engine performance, combustion and emission characteristics was discussed [17]. It was observed with increased brake thermal efficiency, decreased SFC and decreased emission for PME 20. The optimum combination was observed at CR=19.1, IP = 240 bar and injection timing of 27^{o} BTDC. Studies on the effect of injection pressure on the performance and emission characteristics of bio-diesel fuelled direct injection CI engine [19, 20]. It was observed that 250bar is the optimum injection pressure with B20 and B30 blends.

CFD work on multi chambered piston has been carried out to analyze squish and tumble flow. A maximum of 13.1 m/sec squish velocity was observed at 10^{o} crank angle before TDC. The increase in squish velocity was 31% compared to a standard engine.

This work relates to engine design modification to induce turbulence by enhancing squish and tumble of charge during combustion. The present work has been undertaken to study the effect of injection pressure on performance and emission characteristics of multi - chambered piston CI engine. The experiments have been carried out at constant speed of 1500 rpm and compression ratio of 17.5 at 250 injection pressure and advance injection timing. The performance parameters such as SFC, brake thermal efficiency, carbon monoxide, NO_x and UBHC have been studied.

Biodiesel is one of the best available sources to help fulfill the energy demand of the world. More than 350 oil-bearing crops are identified, among which few only considered as potential alternative fuels for diesel engines. Direct usability of biodiesel in the existing diesel engines, comparable engine performance and reduced emission profiles of biodiesel fuels, have attracted the world and made many countries including India to initiate and adopt several biodiesel development programmes by extending many tax concessions and carbon trading benefits in their countries. Biodiesel development is extremely important under present context, as diesel engines have become the main drive of all modern economic activity.

Biodiesel is basically a mixture of fatty acid methyl ester (FAME) compounds, which can be produced from any fatty acids. Though vegetable oils are good sources of fatty acids, they are also required for human consumption, pharmaceutical, paint and lubrication purposes.

Table.1.Bio-Diesel Characteristics

Sl No	Fuel Property	Biodiesel	Diesel
1	Density at 30^{0}C (Kg/m^3)	886	843
2	Kinematic Viscosity at 40^{0}C (c.St.)	5.11	2.64
3	Cetane Number	49.6	46.8
4	Flash Point (^{0}C)	106	68
5	Pour Point (^{0}C)	-6	-20
6	Gross Heating Value (k.Cal/Kg)	9850	10860
7	Distillation Range ($T_{10\%}$ - $T_{90\%}$), (^{0}C)	306 – 342	212 – 320
8	Elemental Composition %		
	a) Carbon (C)	75.72	86.33
	b) Hydrogen (H)	13.62	13.67
	c) Oxygen (O)	10.66	-
9	Structure of Compounds		
	a) Aromatics	-	27.3%
	b) Olefins	-	3%
	c) Paraffins	-	69.7%
	d) Fatty Acid Methyl Esters	> 99.9%	-
	e) Moisture	< 0.1 %	-
10	Auto Ignition Temperature (^{0}C)	305 – 307	270 - 280

EXPERIMENTAL SET UP

The experiments were conducted on a Electronic Direct Fuel Injection (EDI) CI Engine test rig shown in Fig.1.

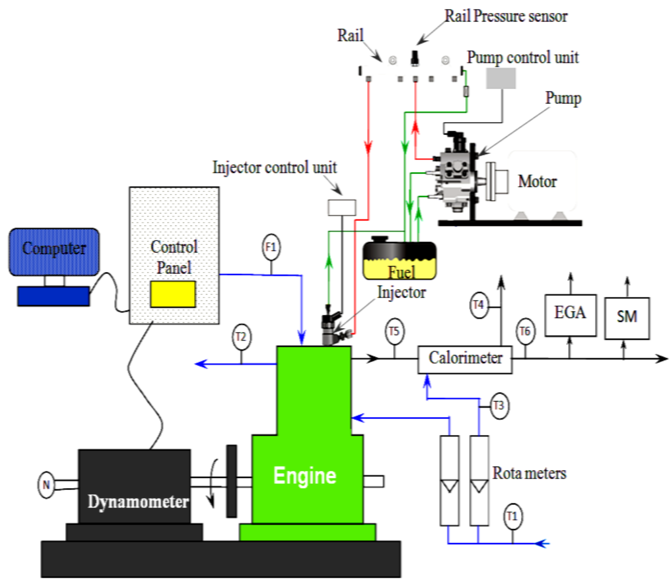

Fig.1 Experimental set up of CI engine test rig with EDI system

T1, T3 - Inlet Water Temperature. T2 - Outlet Engine Jacket Water Temperature

T4 - Outlet Calorimeter Water Temperature T5 - Exhaust Gas Temperature before Calorimeter

T6 - Exhaust Gas Temperature after Calorimeter, F1- Fuel Flow DP (Differential Pressure) unit

N - RPM encoder, EGA - Exhaust Gas Analyzer , SM - Smoke meter

Emissions and the characteristic noise of a diesel engine leads to its lower consumer acceptance of diesel engines for passenger cars. Electronic fuel injection is a technology that has the potential to change the way we perceive diesel engines. It features a high-pressure fuel rail line feeding the solenoid valve, as opposed to low-pressure fuel pump feeding unit injector or high-pressure fuel line to mechanical valves controlled by cams on the camshaft. To conduct laboratory scale experiments, on the common rail system, a single cylinder engine has to be used and also, the control for the fuel injection and the rail pressure has to be flexible. Thus, a control unit for the system was designed using which variables like injection timing, duration, rail pressure and multiple injection strategies can be easily achieved and controlled.

Table.2.Engine Specification

SL NO	ENGINE PARAMETERS	SPECIFICTION
01	Engine Type	TV1(Kirloskar)
02	Number of cylinders	Single Cylinder
03	Number of strokes	Four-Stroke
04	Rated power	5.2KW(7HP) @1500RPM
05	Bore	87.5mm
06	Stroke	110mm
07	Dynamometer	Eddy current
08	Compression ratio	17.5:1

Methodology

Biodiesel Production and Characterization. Development of an experimental setup using a single-cylinder, water-cooled, naturally aspirated, four-stroke diesel engine with all necessary instrumentation to measure performance, emission and cylinder-pressure-crank-angle data. Conduct experiments at different injection timings and optimize for both diesel and biodiesel. Conduct experiments at different injection pressures and optimize for biodiesel. Study the engine performance, emission and combustion characteristics of the biodiesel and its blends. Development of an electronic high pressure direct fuel injection system for the existing engine with complete control flexibility on the fuel injection timing, pressure, quantity and number of injections. Calibrate the injector, so as to find out what kind of pulse width should be used to deliver the required quantity of fuel for the engine to run at various conditions. Conduct experiments with the EDI system by varying injection parameters like timing, duration and pressure using both diesel and biodiesel. Study engine performance, emission and combustion characteristics and compare the results of diesel, biodiesel and its blends in the same engine. Compare the performance, emission and combustion characteristics of mechanical injection with electronic fuel injection mode operation. Study the effect of multiple injections on performance, emission and combustion for EDI system.

EXPERIMENTAL PROCEDURE

Experimental results obtained under different modes of operation of the engine have been presented. Starting with the results of the conventional fuel injection mode operation of compression ignition engine with diesel, biodiesel and their different blends are discussed and presented. Subsequently, the operation of the engine with a newly developed electronic direct fuel injection (EDI) system using diesel, biodiesel.

Results and discussion

The results of the engine experimentation on heat release rate are presented in below Figs for different injection timing.

The effect of injection timing on brake thermal efficiency for diesel and biodiesel at three injection timings is shown in Fig.2. The highest brake thermal efficiency is obtained with diesel at a static injection timing of 337^0 CA (23^0 BTDC).

Brake thermal efficiency values were found lower for biodiesel as compared to diesel for all three injection timings tested. The decrease may be attributed to the lower energy content of the fuel and higher fuel consumption for the same power output. The maximum brake thermal efficiency at 337^0 CA is 25.60% as compared to 30.7% for diesel. However, by retarding the injection timing by 4^0 CA there is an improvement in brake thermal efficiency observed for biodiesel and this may be attributed to their improved ignition qualities and that they burn more quickly and liberate heat than diesel fuel at elevated temperatures. It is about 27.2% at an injection timing of (341^0 CA) 19^0 BTDC.

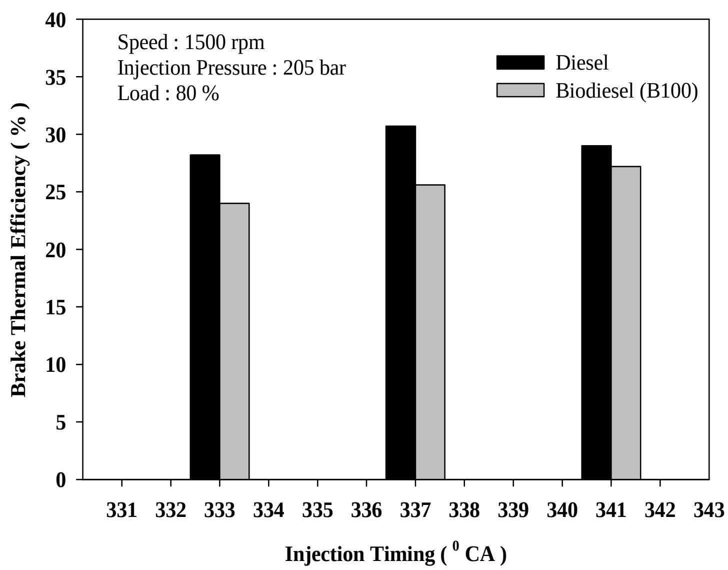

Fig.2. Effect of injection timing on brake thermal efficiency

Figure 3 shows effect of injection timing on carbon monoxide (CO) emissions for diesel and biodiesel. CO is a toxic byproduct and is a clear indication of incomplete combustion of the pre-mixed mixture. The lower CO emission for biodiesel is observed as compared to diesel for all three injection timings tested. This may be attributed to higher oxygen content and good ignition quality of biodiesel, produce much smaller amount of carbon monoxide than diesel fuel. For diesel, the amount of CO at 80 % load is 0.27%, 0.2% and 0.29% for 341^0, 337^0 and 333^0 CA (19^0, 23^0 and 27^0 BTDC) injection timings respectively. Lowest levels are found at the optimum injection timing of 337^0 CA.

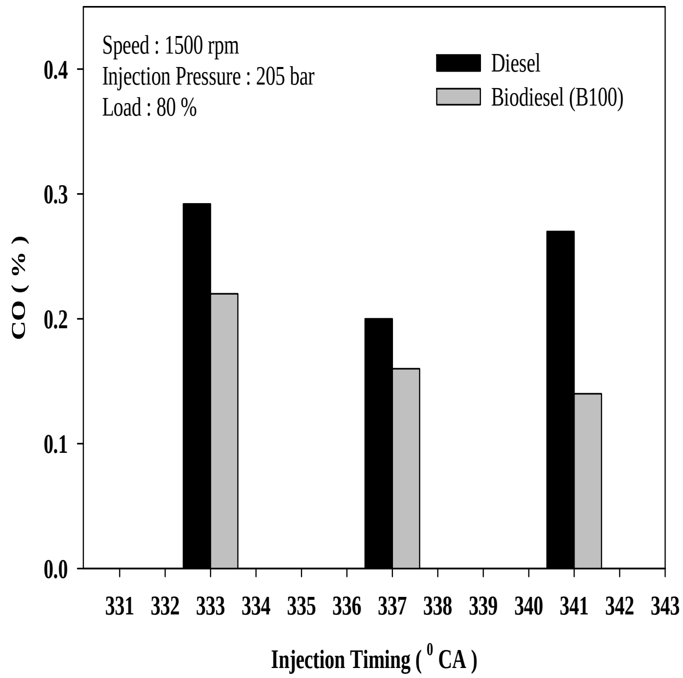

Fig.3. Effect of injection timing on CO emission

Effect of injection timing on HC emissions for diesel and biodiesel is shown in Fig.4 and they are lower at all the injection timings tested for biodiesel as compared to diesel. Biodiesel contains 11% oxygen on mass basis, which increases combustion process and thereby reduces the HC emissions. The HC emission values at 80% load are 55, 53 and 57 ppm for diesel and 49, 51 and 55 ppm for biodiesel at 341^0, 337^0 and 333^0 CA injection timings respectively. Lowest HC levels are found at the optimum injection timings of 337^0 CA for diesel and 341^0 CA for biodiesel.

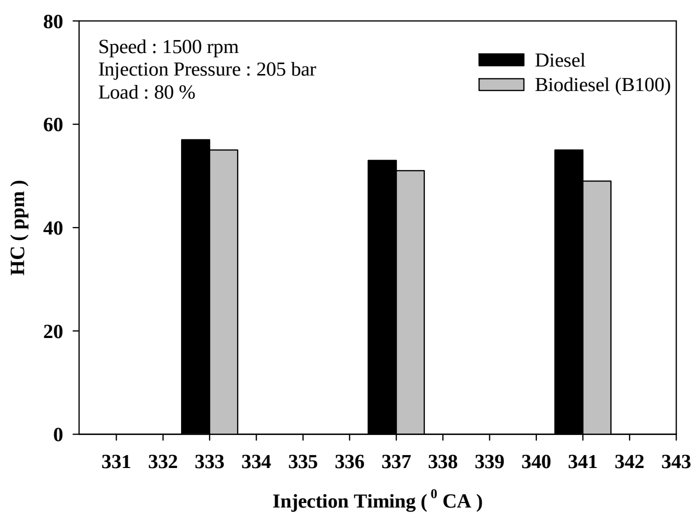

Fig.4. Effect of injection timing on HC emission

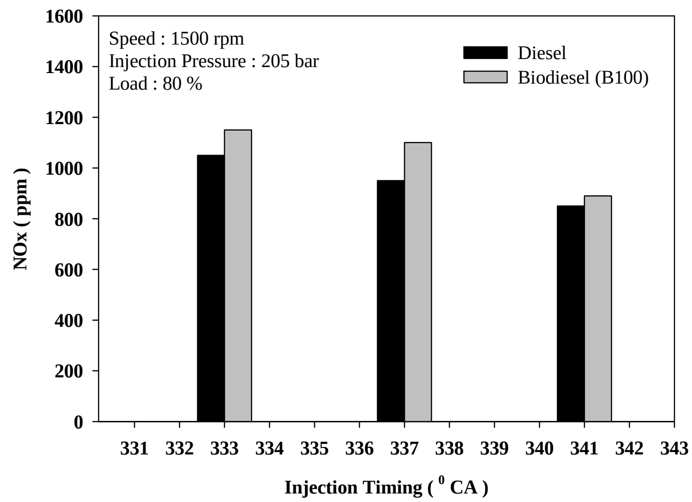

Fig.5. Effect of injection timing on NOx emission

NOx concentration levels are lower as peak temperatures are lower. Nitrogen oxide levels are higher at the injection timings of 23^0 and 27^0 BTDC as they lead to a sharp premixed heat release due to the higher ignition delay. Biodiesel produces more NOx compounds than diesel fuel due to their higher flue gas temperatures. Biodiesel contains 11% oxygen and its cetane number is higher than that of diesel fuel, which increases the peak temperature in the cylinder. With biodiesel operation, NOx emissions are slightly higher at the injection timing of 333^0 CA (27^0 BTDC) than 341^0 and 337^0 CA (19^0 and 23^0 BTDC) respectively.

Conclusions

The Experimental investigation on electronic direct fuel injection (EDI) system on single cylinder, 4-stroke, constant speed diesel engine. The test was conducted at 1500 rpm, CR=17.5, with different injection timing. The major conclusions observed from the experiments are as follows:

The effect of injection timing i.e retarding the injection timing by 4^0 CA there is an improvement in brake thermal efficiency observed for biodiesel and this may be attributed to their improved ignition qualities and that they burn more quickly and liberate heat than diesel fuel at elevated temperatures. It is about 27.2% at an injection timing of (341^0 CA) 19^0 BTDC.

The lower CO emission for biodiesel is observed as compared to diesel for all three injection timings tested. This may be attributed to higher oxygen content and good ignition quality of biodiesel, produce much smaller amount of carbon monoxide than diesel fuel. For diesel, the amount of CO at 80 % load is 0.27%, 0.2% and 0.29% for 341^0, 337^0 and 333^0 CA

HC lower at all the injection timings tested for biodiesel as compared to diesel. Biodiesel contains 11% oxygen on mass basis, which increases combustion process and thereby reduces the HC emissions. The HC emission values at 80% load are 55, 53 and 57 ppm for diesel and 49, 51 and 55 ppm for biodiesel at 341^0, 337^0 and 333^0 CA.

Nitrogen oxide levels are higher at the injection timings of 23^0 and 27^0 BTDC as they lead to a sharp premixed heat release due to the higher ignition delay. With biodiesel operation, NOx emissions are slightly higher at the injection timing of 333^0 CA (27^0 BTDC) than 341^0 and 337^0 CA (19^0 and 23^0 BTDC)

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