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Experimental Studies on the Effect of Swirl on Combustion and Emissions of Diesel Engine Fuelled With Karanja Bio-Diesel

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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 Modification Of Engine Combustion Chamber Design, For Inducing Turbulence To Improve The Combustibility Of Combustible Mixture. A Survey Of Literature Shows That Experimental Studies Have Not Been Done On A Swirl For Evaluating Influence On The Combustion And Emission Characteristics Using Diesel Blends As Well. The Objective Of This Work Is To Study The Effect Of Swirl On Combustion And Emissions Of A Bio-Diesel (Honge) Fuelled Diesel Engine. It Has Been Noticed That For The Engine Under Consideration With Swirl Gives Optimum Performance.
Objective Of This Work Is To Study The Effect Of Combustion Chamber Geometry On Combustion, Performance And Emissions Of A Bio-Diesel (Karanja) Fuelled Diesel Engine. It Has Been Noticed That For The Engine Under Consideration With Swirl Gives Optimum Performance.

NOMENCLATURE

TDC	: top dead centre
BTDC	: before top dead centre
UBHC	: unburned hydrocarbon
NO_X	: oxides of nitrogen
CO	: carbon monoxide
CI	: compression ignition
HRR	: heat release rate
SFC	: specific fuel consumption
CV	: calorific value
CR	: compression ratio
IP	: injection pressure

I. INTRODUCTION

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 re-entrant 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. 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 [12]. An increase in viscosity of bio-diesel will result in poor atomization characteristics due to decreased cone angle during fuel injection [13]. 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 [14]. 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 [15]. Also when the injection pressure is increased fuel particle diameter will be reduced. The mixing of fuel-air becomes better during ignition delay period [16].

This work relates to engine design modification to induce turbulence by enhancing swirl during combustion. The present work has been undertaken to study the effect of injection pressure on performance and emission characteristics of CI engine. The experiments have been carried out at constant speed of 1500 rpm and compression ratio of 17.5 at different injection pressure. The emission characteristics like, carbon monoxide, NOx and UBHC along with combustion characteristics like HRR and cylinder pressure have been studied.

II. EXPERIMENTAL SET UP

The experiments were conducted on a computerized CI engine test rig shown in Fig.1.

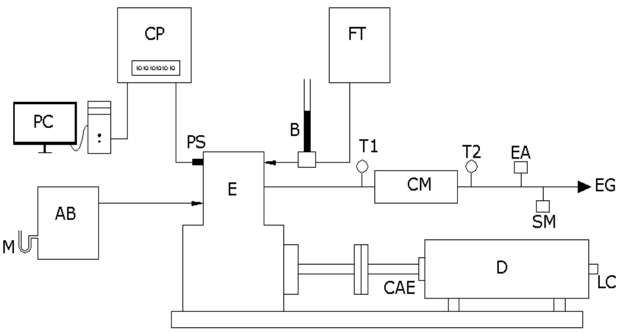


Fig.1 Experimental set up

A Kirloskar make single cylinder 4-stroke, direct injection, water cooled CI engine test rig of 5.2kW, CR=17.5, IP=200bar rated power at 1500rpm is directly coupled to the eddy current dynamometer the engine and the eddy current dynamometer are interfaced to a control unit, with built in software in a computer. This software is used for recording test parameter such as fuel flow rate, temperatures, air flow rate and speed for calculating performance parameters such as brake power (BP), brake thermal efficiency and specific fuel consumption. The calorific value and the density of particular fuel are fed to the software for calculating above performance parameters. The exhaust emissions such as CO, UBHC, and NOx were measured with PEA205-5gas analyzer. The engine specification is shown in table.1.

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	Cubic Capacity	661cc
08	Compression ratio	17.5:1

Table.1.Engine Specification

III. MODIFICATION MADE TO PISTON CROWN

Turbulence is very important in mixing and combustion of fuel with air in CI Engine. In the present work the turbulence was induced by modifying the base piston face to a threaded-piston. During the modification care was taken to maintain compression ratio of 17.5. This was done by adding a thin layer of material on the piston crown by aluminum alloy welding and performing threading operation in the piston crown in such a way that the volume of the material removed balances the volume of material added so that the compression ratio of the engine is not altered in any way. The surfaces over the piston crown were finished to close tolerances on an engraving machine. Pictorial views of original and threaded pistons are shown in Fig. 2 and Fig. 3 respectively.

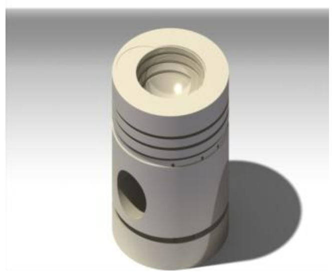


Fig.2. Standard piston Fig.3. Threaded piston

At the end of compression stroke, the fuel vapor squeezes into threaded piston spirally due to direct compression, which leads to the enhancement of turbulence for better mixing and combustion.

IV. EXPERIMENTAL PROCEDURE

A set of experiments were conducted for standard and modified piston engine at the rated engine speed of 1500rpm at compression ratio of 17.5 and at the injection pressure of 200 bar. Tests were conducted at 20% load, 40% load, 60% load and 80% load. The test was conducted at the injection timing of 21^{o} before TDC. The combustion and performance characteristics were found and emission characteristics like CO, UBHC and NOx were recorded for diesel and subsequently for blend of H20 (20% Honge+ 80% of Diesel).

V. RESULTS AND DISCUSSION

The results of the engine experimentation are presented in Figs. 4-11. All comparisons have been made at constant engine speed 1500 rpm and injection timing 21^{o} crank angle.

Cylinder pressure

Figure shows the cylinder pressure with crank angle for standard and threaded pistons at CR=17.5 and varying injection pressure for 200, 250 and 300bar for H20 blend. It is found that the threaded piston produces higher cylinder pressure compared to standard piston. This trend is attributed due larger delay period with the threaded piston in which more amount of fuel is accumulated in the combustion chamber.

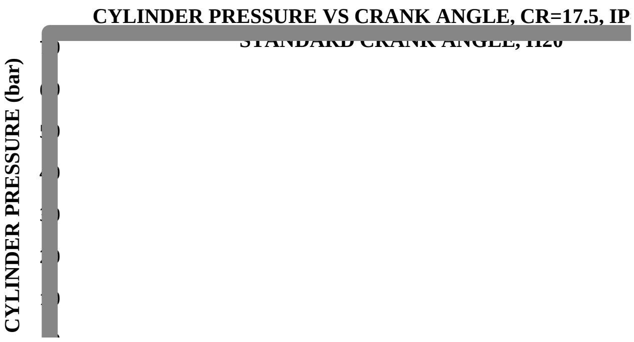


Fig.4. Cylinder pressure Vs Crank angle

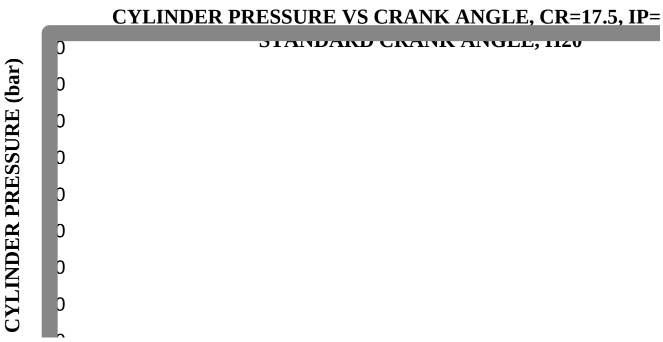


Fig.4.1. Cylinder pressure Vs Crank angle

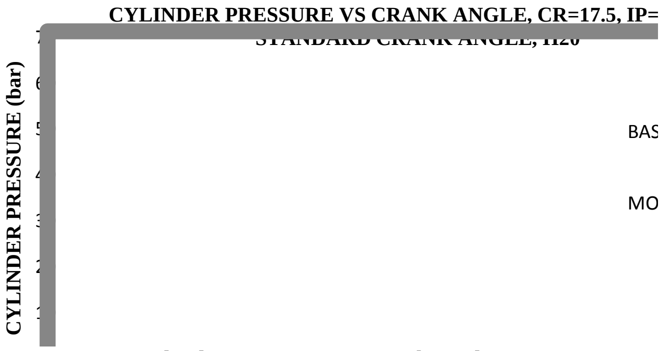


Fig.4.2. Cylinder pressure Vs Crank angle

Heat release rate

The net heat release rate is an important parameter for the analysis of combustion characteristics in the engine cylinder. The net heat release rate can be expressed as

$$dQ/d\theta = (\gamma/ \gamma-1)\, dV/d\theta + (1/ \gamma-1)\, V.\, dP/d\theta$$

Where, $dQ/d\theta$ is heat release rate (J/deg),
p is the in-cylinder pressure,
V is the in-cylinder volume and
γ is the ratio of specific heats.

In equation 1, the cylinder content is assumed to be homogenous mixture of air and combustion products. It is further assumed that γ=1.3 as an appropriate value of γ for CI engine is 1.3 to 1.35 [1].

The heat release rate varying with crank angle at 80% load condition for standard and threaded pistons is shown in figure. It is seen that the premixed combustion region is rather lower for swirl indicating that reduction of delay period due greater mixing of fuel with air because of swirl generation.

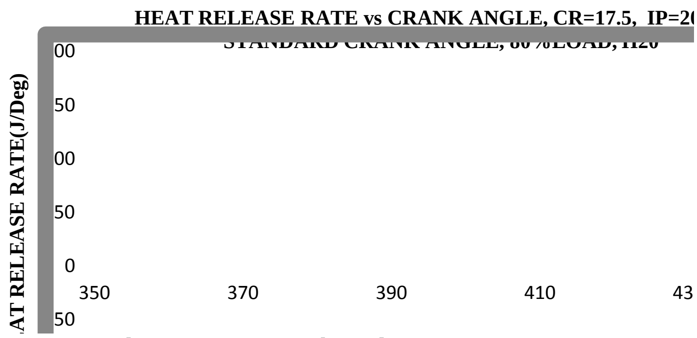


Fig.5. Heat release rate Vs Crank angle

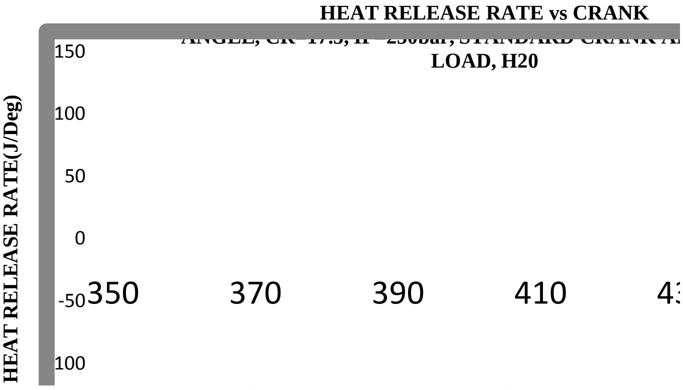


Fig.5.1. Heat release rate Vs Crank angle

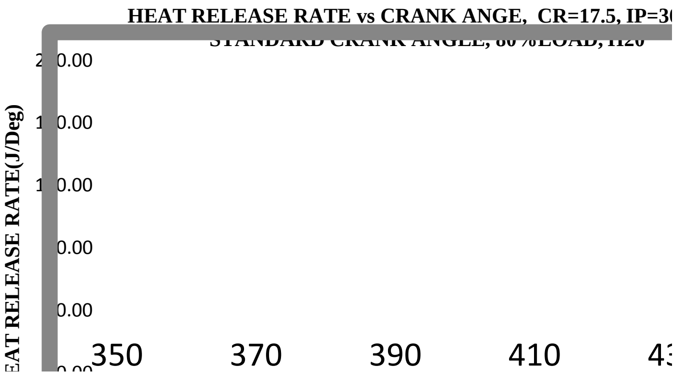


Fig.5.2. Heat release rate Vs Crank angle

HC EMISSION

Figure shows the HC emissions with standard and threaded pistons at CR=17.5 and Injection pressure for 200, 250 and 300bar for H20 blend. The HC emission is the direct result of incomplete combustion. It is apparent that the HC emission is decreasing with the increase in turbulence in threaded piston, which results in complete combustion of fuel.

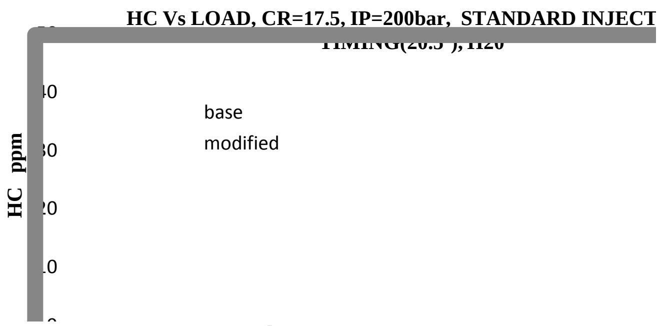


Fig.7. HC emission Vs Load

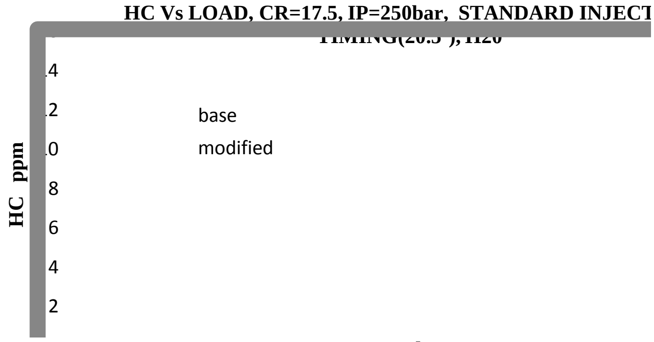
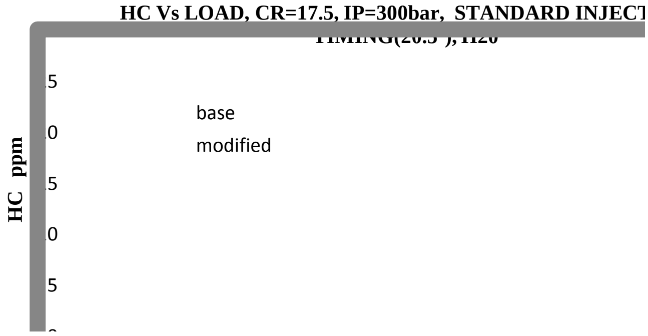


Fig.7.1. HC emission Vs Load



CO EMISSION

Generally CI engines operates with lean mixtures, hence the CO emission would be low. It is observed from all the above figures that CO emission for modified piston have been decreased due to increase in turbulence due to swirl motion in threaded piston the oxidation of carbon monoxide is improved, which results in reduction of CO emissions. The CO levels with standard piston are high at full load conditions due to combustion inefficiencies.

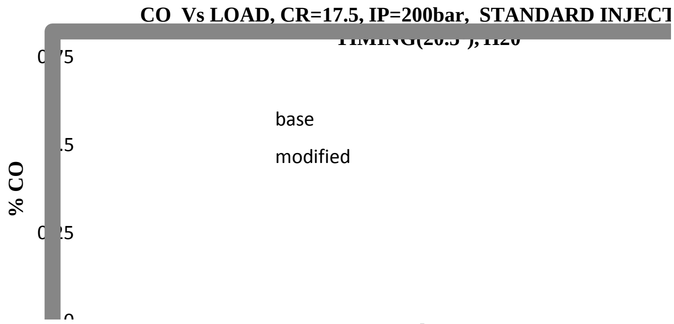


Fig.8. CO emission Vs Load

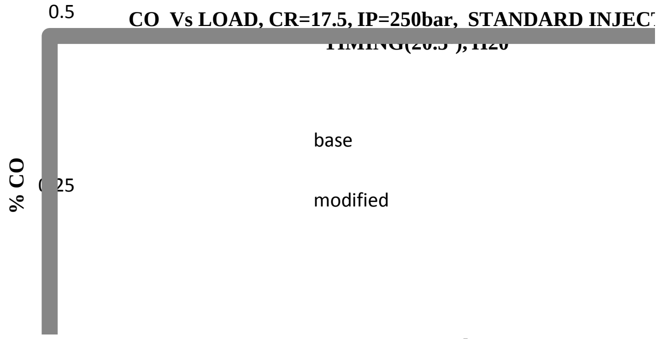


Fig.8.1. CO emission Vs Load

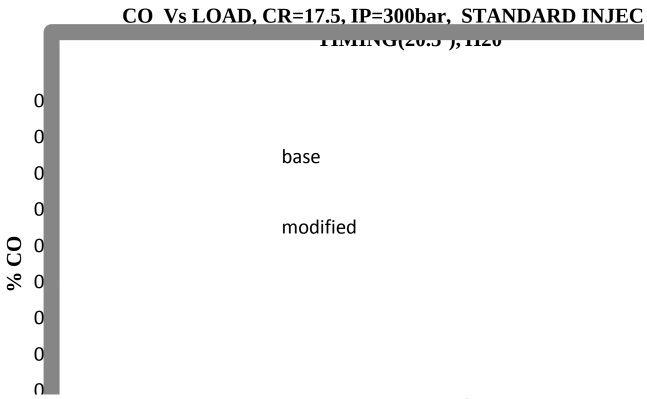


Fig.8.2. CO emission Vs Load

NO_x EMISSION

Figure shows the comparison of NO_X emission with load for threaded and standard pistons. It is observed that the NO_X emissions are slightly increased for H20 blend with modified piston in comparison with the standard piston. It is because formation of NOx is temperature dependent phenomenon. As the load increases the combustion gas temperature increases which inturn increases the formation of NOx. This due to the higher temperature in the combustion chamber because of complete combustion of fuel with swirl generated threaded piston.

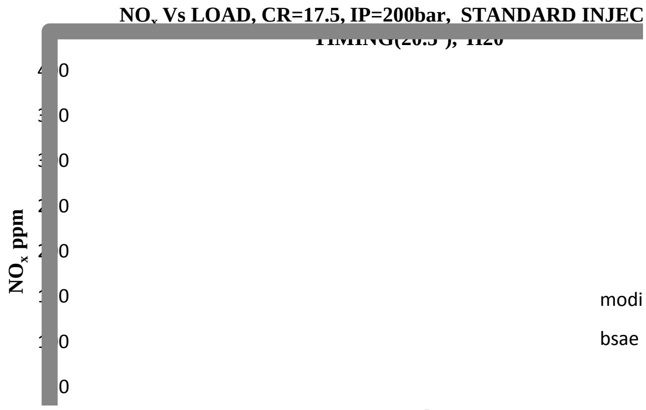


Fig.9. NO_X emission Vs Load

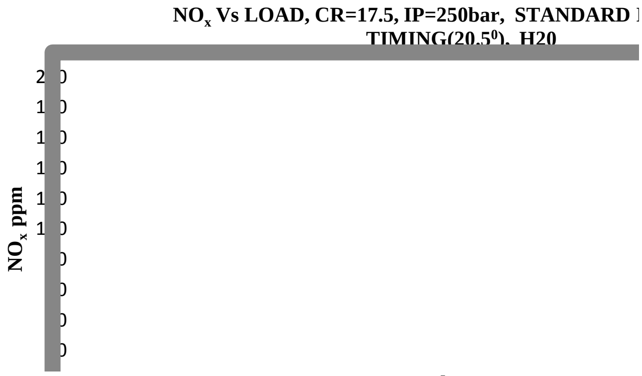


Fig.9.1. NO_X emission Vs Load

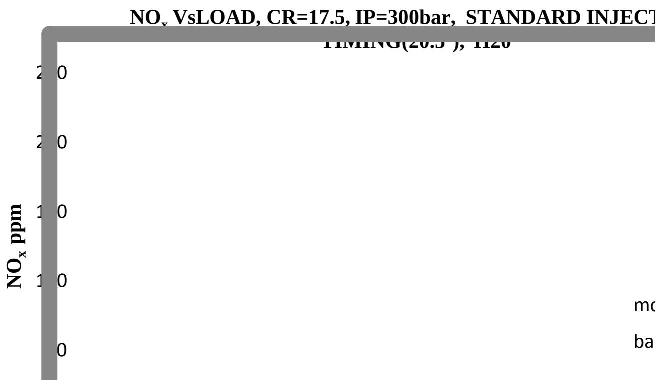


Fig.9.2. NO_X emission Vs Load

VI. CONCLUSIONS

The Experimental investigation on combustion in threaded-piston CI engine was conducted on single cylinder, 4-stroke, direct injection, constant speed diesel engine. The test was conducted at 1500 rpm, CR=17.5, injection pressure of 200, 250, 300bar and standard crank angle. The major conclusions observed from the experiments are as follows:

- A comparison of the results obtained on the standard and a modified piston engine have been made with reference to the combustion and emission characteristics and is generally observed that the modified piston gives enhanced combustion and lower emissions compared to the standard piston.

- Peak cylinder pressure and peak heat release were slightly lower in premixed combustion and slightly higher at diffused combustion in modified piston.
- CO and HC emissions are found to be lower with modified piston.
- Better mixing of fuel and better combustion due to swirl action with modified piston increases the combustion and cylinder wall temperature which results in increase of NO_X emissions compared to standard piston engine.

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