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Effect of injector nozzle on the performance, emission and combustion characteristics of single cylinder four stroke diesel engine

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Abstract

The design and the manufacture of Internal Combustion (IC) Engines are under significant pressure for improvement. This research work focuses on improving the performance and reducing the emissions for the bio diesel blend by incorporating minor modifications in the engine. It is known that piston-bowl diameter influences the in-cylinder mixing of fuel with air and the pollutant formation processes. The bowl geometry and its dimensions such as the pip region, the bowl lip area and the torus radius are all known to have an effect on the in-cylinder mixing and combustion process. The experimental work was carried out in single cylinder, four stroke, compression ignition engine for diesel, J20, J40 & J50 (Jatropha methyl ester) with three different nozzle holes (3,4 & 5). Conclusions were drawn to utilize and improve the percentage of biodiesel blend with minor modifications on the engine.

Introduction

Daming Huang et al (2012) confirmed that biodiesel as one promising alternative to fossil fuel for diesel engines and has become increasingly important due to environmental consequences of petroleum-fuelled diesel engines and the decreasing petroleum resources. Jinlin Xue et al (2011) reports about biodiesel engine performances and emissions. The use of biodiesel leads to the substantial reduction in PM, HC and CO emissions accompanying with the imperceptible power loss, increase in fuel consumption and increase in NOx emission on conventional diesel engines with no or fewer modification. Ghosh et al (2007) concluded after studying the prospects of jatropha methyl ester (biodiesel) in India that the fuel could be safer as a result of the high flash point, the mileage obtained was comparable to that of fossil diesel, and emission was greatly reduced. Sahoo & Das (2009) investigated the performance and emission characteristics of non-edible Jatropha (JB), Karanja (KB), and Polanga (PB) oil based methyl esters blended with conventional diesel in proportions of 20%, 50%, and 100% on a water –cooled three-cylinder tractor engine. Jinou song et al (2008) did investigation on flow field in simplified piston bowls and concluded that squish flow played an important role in the turbulence generation process near the TDC during compression. The coupling among the swirl, squish, bowl shape and turbulence are much more pronounced for the flow fields in the combustion chambers and the piston bowl configurations should be designed to coincide with the contour lines of the turbulence. Jaichander & Annamalai (2012) showed that the performance, emission and combustion characteristics of biodiesel from pongamia oil could be improved by suitably designing the combustion chamber. POME resulted in increased combustion chamber temperature that produced higher oxides of nitrogen in TCC than HCC and SCC.

Materials and Methods

Biodiesel, which is a relatively clean-burning, renewable fuel produced from fresh and used vegetable oil, can be used to replace at least a portion of the diesel fuel consumed in this country. Ghoshet al (2007) cleared that JOME has been shown to be an outstanding biodiesel that is fit for use in neat or blend form in unmodified engines. The following types of fuels were used for the engine testing work in this research work.

- Diesel 100% (D100)
- Jatropha 20% + diesel 80% (J20)
- Jatropha 40% + diesel 60% (J40)
- Jatropha 50% + diesel 50% (J50)

Diesel J20 J40 J50

Fig.1 Photographic views of tested fuels

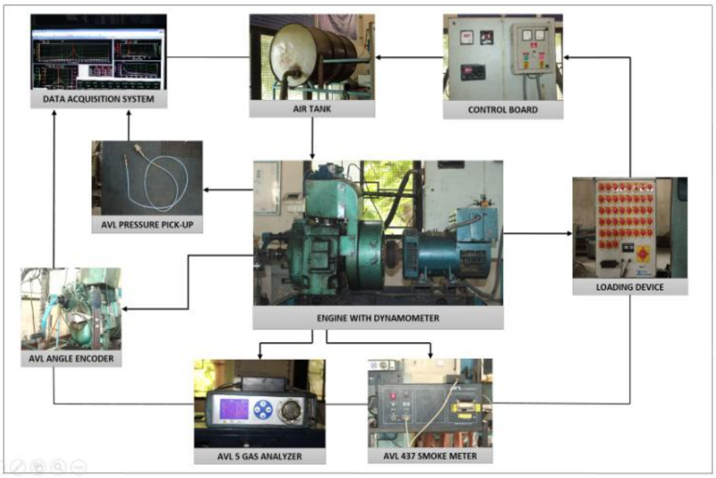
Methyl esters of jatropha oil are one of the best alternative fuels used in diesel engines for research purposes. The cetane number of Jatropha oil is marginally close to that of the diesel fuel. The flash point of Jatrophamethyl ester (JOME) is 140ºC, compared to 50ºC for diesel. Jatropha oil has certain

Better combustion and presence of oxygen content in the

advantages over petroleum crude, like greater safety during storage, handling and transport.

Engine set up

The diesel engine is a constant speed, four stroke, vertical air-cooled type, coupled with an electrical swinging field dynamometer with rheostat loading. The fuel tank is placed on the weighing machine to measure the quantity of fuel consumed in unit time. A calibrated orifice meter with a U - tube manometer is provided along with an air tank on the suction line, for measuring the air consumption. An AVL pressure transducer (piezo electrical type) is used to measure the pressure developed in the engine cylinder. AVL angle



encoder is used to indicate the position of the crank shaft with time. The output of the pressure transducer and the angle encoder is processed in the AVL data acquisition system, and various combustion parameters are obtained.

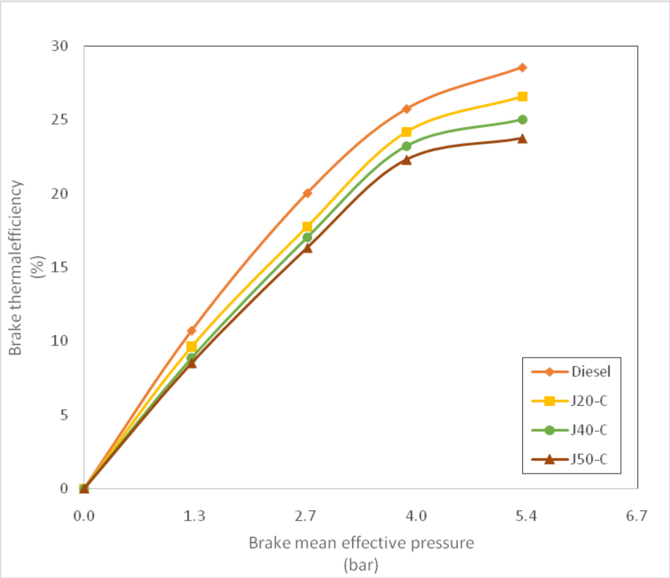
Fig. 2 Photographic view of the set-up

Table I. Engine Specifications

Results and discussions

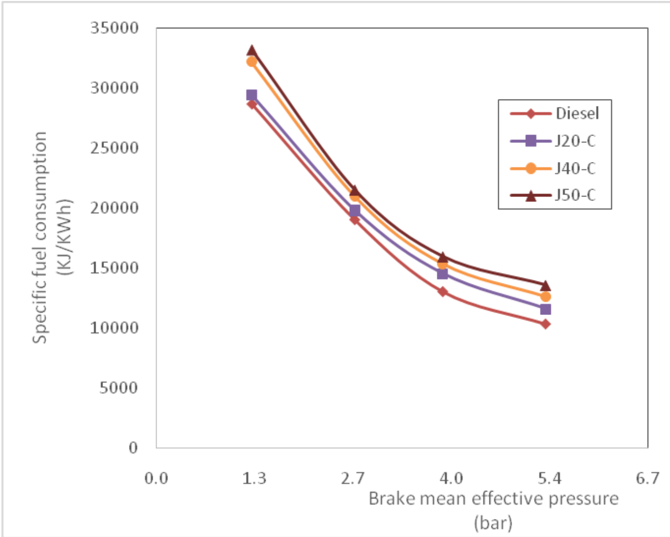
This section discusses the initial experimental work done in a single cylinder diesel engine. The experimental work was carried out in a single cylinder direct injection four stroke diesel engine coupled to an electrical dynamometer with all the necessary accessories. The experiments were conducted from no load to full load in the conventional operating conditions (standard injection timing of 23º TDC, and the standard fuel injection pressure of 200 bar) in the engine. The various biodiesel blends such as J20, J40, & J50 were tested along with the conventional diesel fuel. The performance, emission and the combustion characteristic curves are presented with necessary explanation.

1. Brake thermal efficiency



It can be observed from the Figure that the brake thermal efficiency of diesel fuel is marginally higher for all the power outputs than the biodiesel blends such as J20, J40 and J50. The reason for the reduction in efficiency for the biodiesel blends is due to the significant increase in the viscosity levels. The values of the viscosity (cst at 40^{0}C) are 4.33, 4.66, and 4.825 for J20, J40 and J50 respectively. The viscosity leads to poor atomization of fuel, which has an effect on mixing with air. These in turn reduces the level of effective combustion and efficiency. The figure also clears that the efficiency gradually decreases when the percentage of blend increases with diesel fuel.

2. Specific Energy Consumption



The Specific energy consumption for diesel fuel is always lower than that of biodiesel blends J20, J40 & J50 for all the power outputs. This is due to the marginal reduction in calorific value for the biodiesel blend, the calorific values

Model	TAF1
Type	Vertical, Four stroke cycle, Diesel engine.
No Of Cylinder	1
Cooling Type	Air-cooled engine.
Cubic Capacity	0.662
Rated Speed	1500 rpm
Governing	Class “B1”
Stroke Length	110 mm
Cylinder Bore	87.5 mm
Engine Power	4.4 KW
Compression ratio	17.5:1
Inlet Valve open	4.5 degree before TDC
Inlet Valve Closed	35.5 degree after TDC
Exhaust Valve Open	35.5 degree before TDC
Exhaust Valve Closed	4.5 degree after TDC
Fuel injection timing	23 degree before TDC
Injector opening	200 bar

(kJ/kg) of the biodiesel blend are 42890, 41780 and 41225 for J20, J40 and J50 respectively. Since the density of biodiesel is marginally higher than that of diesel, the engine needs more amount of biodiesel to compensate the lower calorific value of bio diesel. The figure also clears that the specific energy consumption gradually increases when the percentage of blend increases because of its significant reduction in the calorific value at all the tested conditions.

Experimental work with different types of nozzles

Since the research work is focussed on higher percentage of biodiesel blend, optimization work is done for J40. The JOME blend J40 is tested by fitting or changing the injector nozzle holes without changing any other parameters.

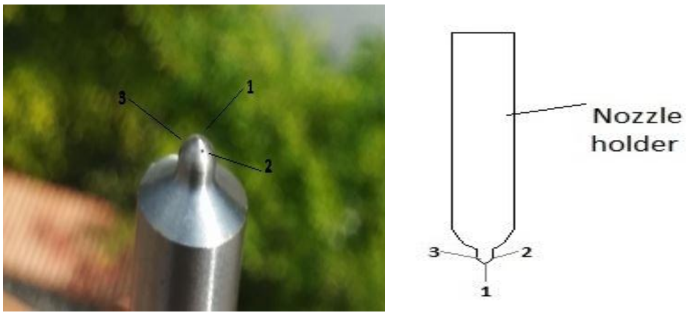


Fig. 3.Three holed nozzle

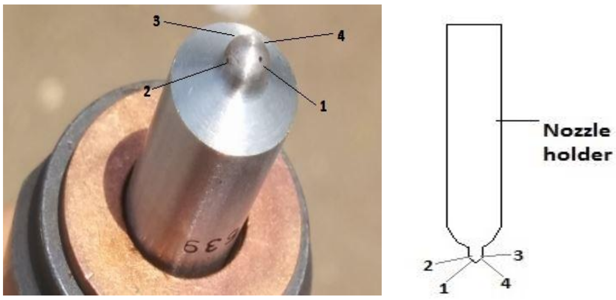
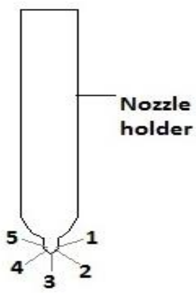


Fig. 4.Four holed nozzle



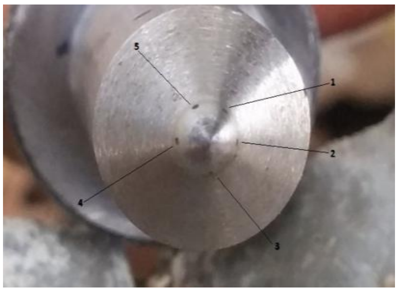
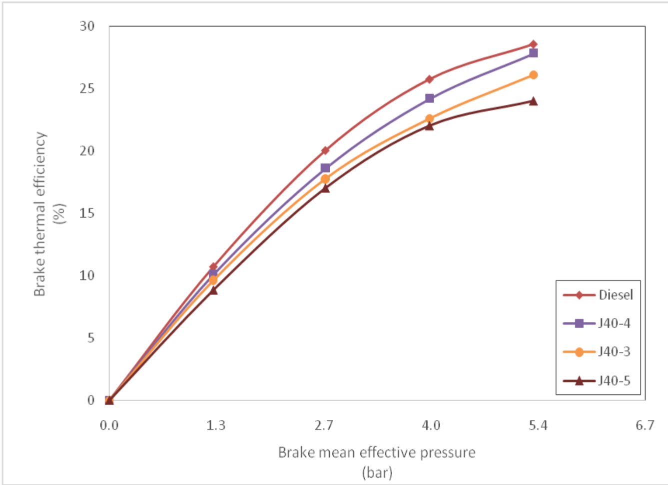


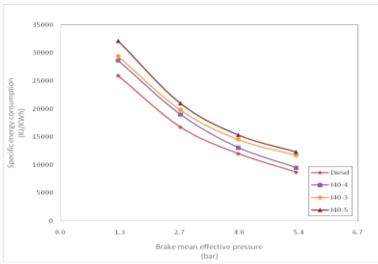
Fig. 5.Five holed nozzle

3. Brake thermal efficiency



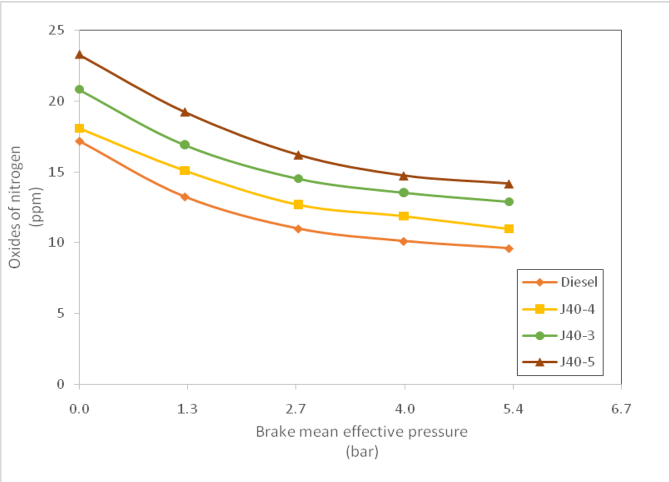
The brake thermal efficiency increases as the brake mean effective pressure increases. From the fig, it is evident that the four hole nozzle produces more brake thermal efficiency overall. This is because the four hole nozzle produces better mixing of air and fuel thereby resulting in better combustion and hence the brake thermal efficiency is increased.

4. Specific Energy Consumption



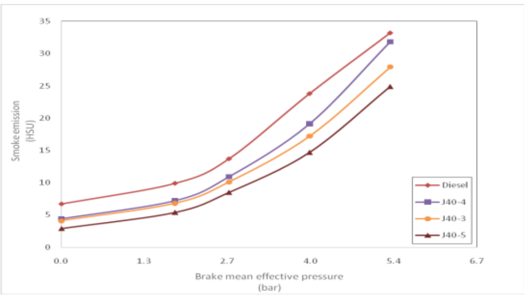
Specific energy consumption refers to the amount of fuel consumed. Fig shows that the four hole nozzle has the least specific energy consumption than the three hole and 5 hole nozzles.

5. Oxides of nitrogen



NO_x emission is lower for 4 hole nozzle when compared with 3 hole nozzle. Five hole nozzle has high rate of smoke and very less NOx due to incomplete combustion. Four hole nozzle injects more atomized fuel and hence utilizes more oxygen inside the combustion chamber compared to three hole nozzle and hence has lower NOx emissions than three hole nozzle.

6. Smoke emission



It is observed that Smoke emissions are marginally lower in biodiesel blend when compared with the diesel fuel. This occurs because of the presence of internal oxygen content, which causes more amount of combustion. Thus the increase in oxidizing effect is also reduced the soot emissions.

Combustion characteristics

It is seen that the biodiesel blend shows higher peak pressure when compared with the diesel fuel. This is due to the increase in the cylinder temperature because of the presence of internal oxygen content for the biodiesel blend. The same trend is observed for all the power output.

It is clear that the amount of fuel burning in the expansion phase is more for the biodiesel blend because of the presence of fatty acid content. The late burning of long chain fatty acid fractions in the expansion stroke increases the temperature of exhaust gasses (**Nagaraju et al 2008**)

The diesel fuel always shows the maximum heat release when compared to the biodiesel blend because of its lower calorific value. It is also observed that Bio diesel blend shows earlier heat releasing characteristics because of the shorter delay period when compared with the diesel fuel. The increase in the amount of biodiesel blend does not show any improvement in heat release rate.

Conclusion

On analyzing, the test results shows better performance in the conventional piston in terms of brake thermal efficiency and specific energy consumption when bio-diesel blends of jatropha were used. The change of injector nozzles gave better results especially with the four hole nozzle. The performance characteristics are found to be better when the tests were carried out using J40 blend as fuel fitted with the four hole nozzle.

Acknowledgement

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Nomenclature

aTDC	- After top dead centre
bTDC	-Before top dead centre
B.T.E	-Brake thermal efficiency
CI	-Compression ignition
DI	- Direct injection
JOME	-Jatropha methyl esters
J20	-Jatropha 20% + Diesel 80%
J30	-Jatropha 30% + Diesel 70%
mm	-Millimeters
NO_x	-Oxides of Nitrogen

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