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EXPERIMENTAL ANALYZATION AND OPTIMIZATION OF SINGLE CYLINDER DIESEL ENGINE FOR PONGAMIA BIO DIESEL BLENDS BY USING TAGUCHI METHOD

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ABSTRACT

The main aim of this project is to find the effective compression ratio of direct injection (DI) single cylinder Variable Compression Ratio (VCR) diesel engine with respect to brake power, fuel economy and emissions through experimental investigations and design of experiments (DOE) method. The experiments are carried out with Pongamia Methyl ester biodiesel with different combinations like 10%, 15%, 20% under three levels and the responses brake power, fuel economy and emissions were investigated. The optimum values of the response could be predicted using Signal - Noise ratio(S/N ratio) and optimum combination of control parameters were specified. Using Taguchi method an inverted L9 orthogonal array has been utilized to determine the engine test trials layout. In order to maximize the performance of Pongamia Methyl ester biodiesel engine the signal to noise ratio (SNR) related to higher the-better (HTB) quality characteristics has been used. It is found that, at compression ratio of 18:1 for A20 blended fuel (20%PME+80%Diesel) shows better performance which is very close to neat diesel fuel. It is also found that the increase of compression ratio increases the BTE and reduces BSFC and having lower emission without any engine in design modifications.

Keywords: Wear Diesel engine; Compression ratio; performance; methyl ester of Pongamia oil.

INTRODUCTION

Diesel engines are commonly used as prime movers in the transportation, industrial and agricultural sectors because of their high brake thermal efficiency and reliability. The increasing industrialization and motorization of the world has led to a steep rise in the demand of petroleum based fuels. Due to the depletion of the world's petroleum reserves and the increasing environmental concerns, there is a great demand for alternative sources of petroleum-based fuel, including diesel and gasoline fuels. Biodiesel, a clean renewable

fuel, has recently been considered as the best candidate for a diesel fuel substitution because it can be used in any compression ignition engine without the need of modification. Chemically, biodiesel is a mixture of methyl esters with long-chain fatty acids and is typically made from nontoxic, biological resources such as vegetable oils, animal fats, or even used cooking oils. Vegetable oils are promising feedstock for biodiesel production since they are renewable in nature, and can be produced on a large scale and environmentally friendly. Vegetable oils include

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edible and non-edible oils. More than 95% of biodiesel production feedstock comes from edible oils since they are mainly produced in many regions and the properties of biodiesel produced from these oils are much suitable to be used as diesel fuel substitute. However, it may cause some problems such as the competition with the edible oil market, which increases both the cost of edible oils and biodiesel. Moreover, it will cause deforestation in some countries because more and more forests have been felled for plantation purposes. In order to overcome these disadvantages, many researchers are interested in non-edible oils which are not suitable for human consumption because of the presence of some toxic components in the oils.

Furthermore, non edible oil crops can be grown in waste lands that are not suitable for food crops and the cost of cultivation is much lower because these crops can still sustain reasonably high yield without intensive care. However, most non-edible oils contain high free fatty acids. Thus they may require multiple chemical steps or alternate approaches to produce biodiesel, which will increase the production cost, and may lower the ester yield of biodiesel below the standards. Animal fats contain higher saturated fatty acids and normally exist in solid form at room temperature that may cause problems in the production process. Its cost is also higher than vegetable oils. UFO is not suitable for human consumption but is a feedstock for biodiesel production. Its usage significantly reduces the cost of biodiesel production. However, the quality of UFO may cause concern because its physical and chemical properties depend on the contents of fresh cooking oil and UFO may contain lots of undesired impurity, such as water, free fatty acids. Since the cost of raw materials accounts about 60–80% of the total cost of biodiesel production, choosing a right

feedstock is very important. Also, the yield and properties of biodiesel products produced from different feedstock would be quite different from each other. Although at present biodiesel cannot entirely replace petroleum-based diesel fuel, there are several distinct advantages of biodiesel over diesel fuel. Biodiesel has higher combustion efficiency, cetane number than diesel fuel. It is biodegradable and more than 90% biodiesel can be biodegraded within 21 days. Biodiesel has lower sulfur and aromatic content than diesel fuel and that means it will not emit lots of toxic gas. Moreover, it reduces most exhaust emissions except NO_x, such as monoxide, unburned hydrocarbons, and particulate matter. A number of methods are currently available and have been adopted for the production of biodiesel fuel. There are four primary ways to produce biodiesel

EXPERIMENTAL SETUP AND PROCEDURE

TESTING PROCEDURE

Engine was started and warmed up at low idle, long enough to establish the recommended oil pressure and was checked for any fuel and oil leaks. The engine was run on no-load condition and speed was varied from 1550 rpm to 1650 rpm. Engine was run to gain uniform speed, after which it was gradually loaded. Experiments were conducted at different loads such as 0 kg, 3 kg, 6 kg, 9 kg, and 12 kg. The engine was run for 10 minutes and data were collected during last 4 minutes. For different blends of PME, performance tests were carried out at three different compression ratios.

SMOKE METER

Smoke meter is used to determine the smoke density of the engine exhaust. The AVL 437 smoke meter has been designed for simple oneman operation either from alongside a vehicle for either free acceleration or steady state test procedures.

Control is via a compact and rugged handset with a digital L.C.D. display.

- **Type:** AVL 437 smoke meters
- **Make:** AVL India Pvt. Ltd
- **Measuring range:** 0 to 100 HSU.

SPECIFICATIONS OF THE APPARATUS

In the test setup there are several instruments that have been used for the purpose of the experiment. Brief specifications of the instruments are given below.

Manufacturer	: Kirloskar Oil Engines Limited
Type of Engine	: Vertical, 4-stroke single Cylinder
Compression ratio	: Variable
Maximum Power	: 8 HP
Max brake power	: 6.02 kW
Rated Speed	: 1800 rpm
Bore and stroke	: 87.5 × 110 (mm).

VARIABLE COMPRESSION ENGINE (VCR)

We using variable compression ratio engine (VCR) with respect to various load and bio diesel pongamia oil blends with combustion of fuels for effective compression ratio in single cylinder diesel engine

COMPRESSION RATIO ADJUSTMENTS:

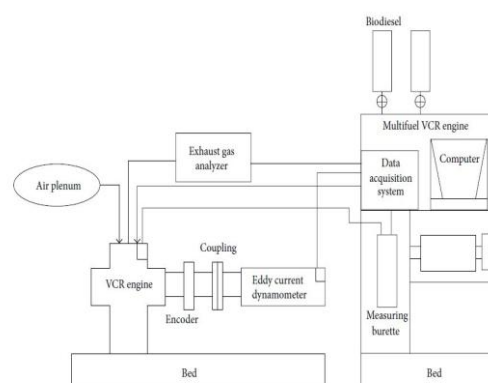
Slightly loosen 6 Allen bolts provide for clamping the tilting block. Loosen the lock nut on the adjuster and rotate the adjuster so that the compression ratio is set to "maximum". Refer the marking on the CR indicator. Lock the adjuster by the lock nut. Tighten all the 6 Allen bolts gently. You may measure and note the centre distance between two pivot pins of the CR indicator. After changing the compression ratio the difference can be used to know new CR.

Table 1: Specification Details of the engine with VCR

S.No	Parameter	Engine specifications
1	Engine type	Single cylinder four stroke diesel engine
2	Bore x stroke	87.5 mm x 110 mm
3	Maximum power output	5.2 kw at 1800 rpm
4	Compression ratio	17.5 : 1
5	Loading	Eddy current dynamometer
6	Fuel injection	23 Btdc
7	Injection	Direct injection
8	Engine speed	1800 rpm
9	Compression principle	Compression ignition
10	Valve timing	Inlet opens BTDC 4.5 Inlet closes ABDC 35.5 Exhaust opens BBDC 35.5 Exhaust closes ATDC 4.5
11	Lub. Oil pump delivery	6.50 lit/min.
12	Sump capacity	2.70 litre
13	Oil consumption	1.5% normally exceed of fuel
14	Connecting rod length	234 mm
15	Injection pressure	175 (bar)
16	Injection timing	35 ° (crank angle)

EXPERIMENTAL SETUP

Fig. 1: Schematic Diagram of the engine setup



EXHAUST GAS ANALYZER

Exhaust gas analyzer is used to determine the emissions such as HC, CO, CO₂, and NO_x.
 Manufacturer: SMS Auto line Equipments Private Limited

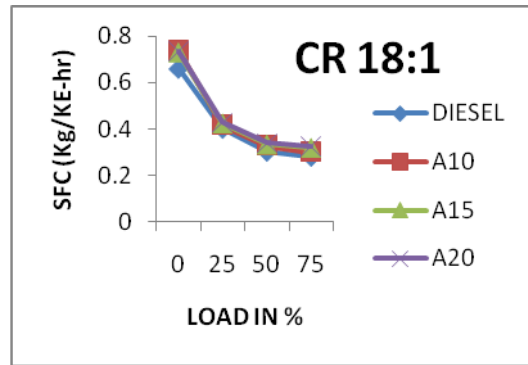
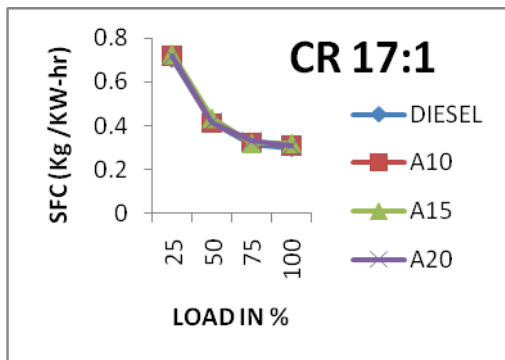
Type: Crypton 290 five gas analyzer

ENGINE PHOTO



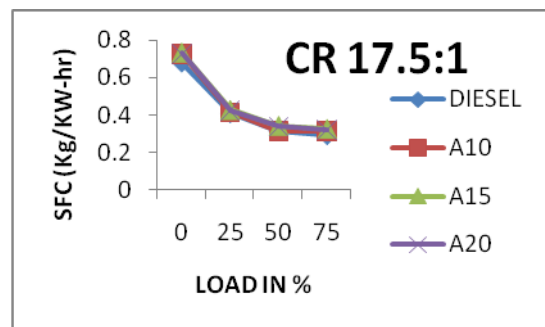
Fig 2: Engine Setup

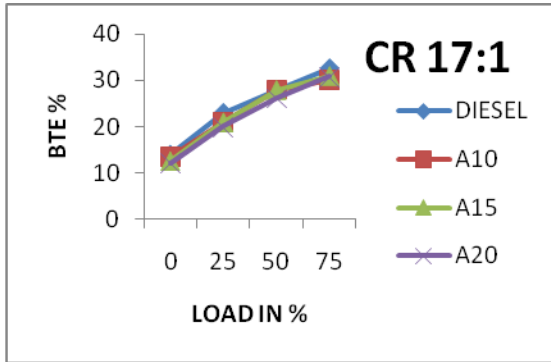
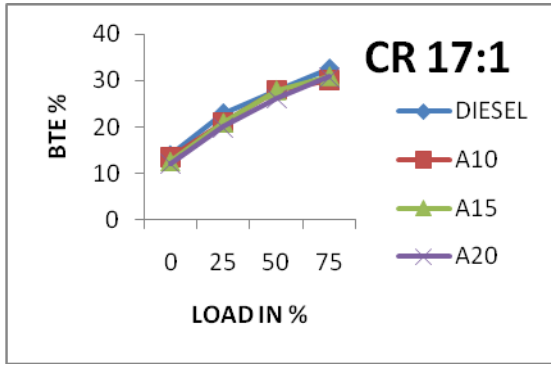
RESULTS AND DISCUSSIONS
EFFECT OF COMPRESSION RATIO ON PERFORMANCE AND EMISSION CHARACTERISTICS
SPECIFIC FUEL CONSUMPTION (SFC).



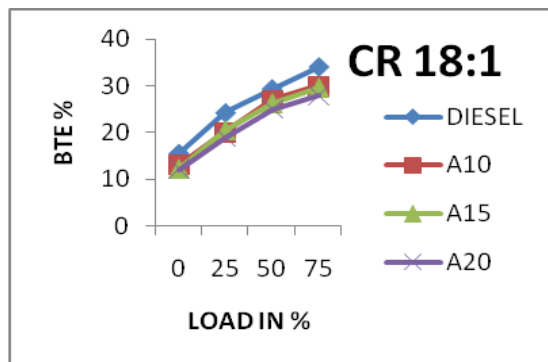
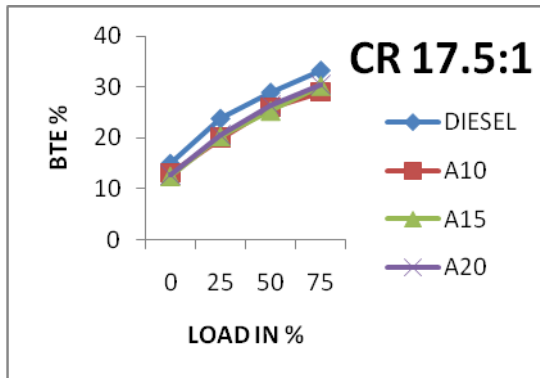
Graph shows the variation of SFC for different blends of PME and neat diesel fuel with different compression ratios. It is observed that the SFC gradually decreases with increasing compression ratio. At maximum load with the compression ratio of 17.5 the SFC for A10 is 0.318 kg/kW-hr and 2% reduction of SFC is achieved when compared with the neat diesel fuel.

This is due to increase in compression ratio which leads to reduction in dilution of charge by residual gases, which results in better BTE and lower SFC. Further, it is also due to low volatility and higher cetane number of biodiesel when compared to diesel which will result in improved combustion at high compression ratio. According to blend ratio, the SFC for A10 is lower than that of other blends under high compression ratio and full conditions. At high percentage of blends, the SFC increases. This is due to fuel density, viscosity, and heating value of the biodiesel.





BRAKE THERMAL EFFICIENCY (BTE)

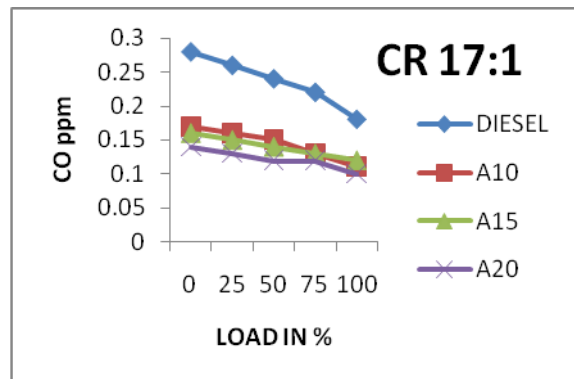


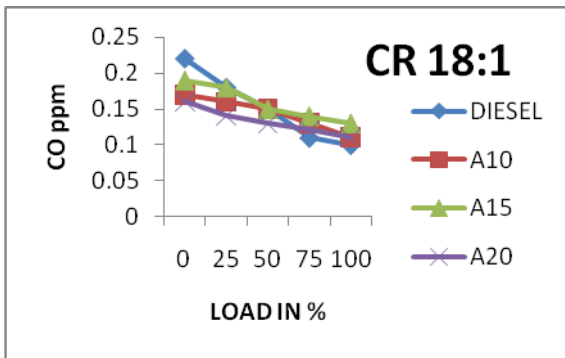
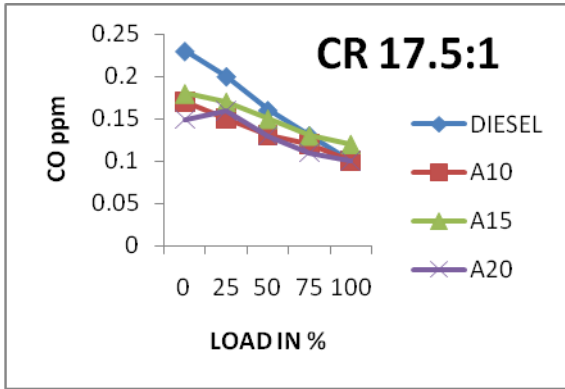
Graph shows the variation of BTE for different blends of PME and neat diesel fuel with

different compression ratios. It is observed that the BTE gradually increases with increasing compression ratio. At maximum load with the compression ratio of 18, the BTE for A10 is 30.2% and it is almost equal to the neat diesel fuel (32%). This is due to increase in compression ratio which ensures better air-fuel mixing and faster evaporation and leads to complete combustion.

Further, it is also due to biodiesel blends having low volatility when compared to diesel fuel and therefore the improvement in their combustion characteristics at high temperature resulted from higher compression ratio than the improvement in case of diesel fuel with the same compression ratio rise. According to blend ratio, the BTE is reduced with the increasing concentrations of biodiesel in the blend at all compression ratios. The BTE for A10 is higher than that of other blends under higher compression ratio and full load conditions. This is due to presence of excess amount of oxygen in A10 which resulted in improved combustion when compared to the neat diesel fuel. Whereas, reduction in compression ratio resulted in lowering the BTE due to lower compression pressure and temperature, slow combustion process, and more dilution by residual gas.

CARBON MONOXIDE (CO)



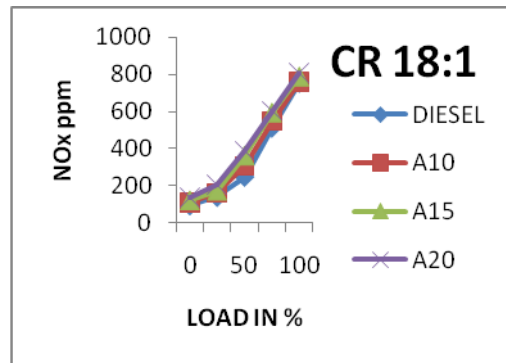
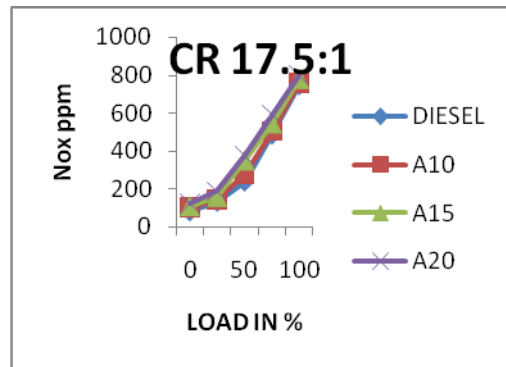
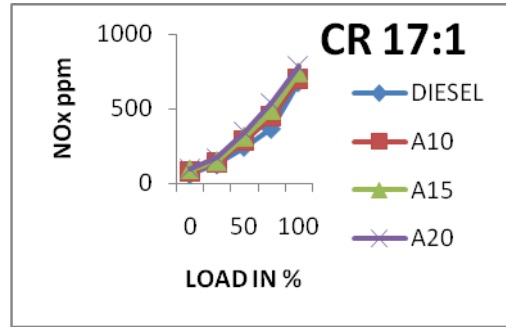


Graph shows the variation of CO for different blends of PME and neat diesel fuel with different compression ratios. It is observed that the CO gradually decreases with increasing compression ratio. At maximum load with the compression ratio of 17, the CO for A20 is 0.1 ppm and 18% reduction of CO is achieved when compared with the neat diesel fuel. This is due to complete combustion; less dilution of charge by residual gases accelerates the carbon oxidation to form carbon dioxide.

Further, it is also due to increase in compression ratio which actually increases the air temperature inside the cylinder and consequently reduction in delay period causes better and complete burning of the fuel and lowers the CO emissions. According to blend ratio, the CO emission increases with the increasing concentrations of biodiesel in the blend at all compression ratios. The CO emission for A20 is lower than that of other blends under higher compression ratio and full load conditions. This is due to presence of additional oxygen content in the biodiesel, which enhances the complete combustion and leads to reduction in CO emission. The carbon monoxide emissions are increased at lower compression ratio due to more dilution of fresh air

with residual gases, lower compression temperature, and poor mixing of fuel and air.

OXIDES OF NITROGEN (NO_x)



Temperature plays a vital role in NO_x formation. It also depends upon the compression ratio, equivalence ratio, and geometry of the combustion chamber, advanced fuel injection, and pressure and temperature of the inlet air.

Figure shows the variation of NO_x for different blends of PME and conventional diesel fuel with different compression ratios. It is observed that the NO_x gradually increase with increasing compression ratio. At maximum load with the compression ratio of 18, the NO_x for A20

is 809ppm and it is almost equal to the neat diesel fuel 752ppm. This is due to increase in compression ratio and increase in the combustion pressure and temperature which accelerates the oxidation of nitrogen to form oxides of nitrogen. Further it is also due to increase in compression ratio and increase in the combustion temperature which in turn increases the compression ratio which leads to increase in NO_x emission.

At high compression ratio, ignition delay reduces and peak pressure increases resulting in high combustion temperature and leads to an increase in NO_x emission. According to blend ratio, the NO_x emission increases with the increasing concentrations of biodiesel in the blend at all compression ratios. The NO_x emission for A20 is lower than that of other blends under higher compression ratio and full load conditions. This NO_x emission increases for all blends due to oxygen present in the biodiesel which may provide excess oxygen for NO_x formation. Further, the biodiesel contains more double bonded molecules than petroleum derived fuels.

These double bonded molecules have a higher adiabatic flame temperature and lead to higher NO_x emission. Further it is also found that decrease in NO_x emission is observed with reduction in compression ratio due to lower combustion temperature and pressure. At low compression ratio, the premixed burning is high due to longer ignition delay resulting in lower NO_x emission.

CONCLUSION

The performance and emission characteristics of different blends of PME at different compression ratios are compared with neat diesel fuel. The summary of conclusions is given below.

It is concluded that the compression ratio of 18: 1 for A10 at maximum load shows better

performance and lower emission level when compared to that of neat diesel fuel and other blends of PME. At compression ratio of 17.5: 1, the SFC for P10 is 0.318 kg/kW-hr and 2% reduction of SFC is achieved when compared with the neat diesel fuel at maximum load. The BTE for P10 is 30.2% and it is almost equal to the neat diesel fuel (32%). The EGT for P10 is 208° C and 19.6% reduction of EGT is achieved when compared with the neat diesel fuel at maximum load. The CO, HC, and smoke emission reduced to 18%, 26%, and 21.4%, respectively, for A20 blended fuel with the compression ratio of 17: 1 having been achieved when compared with the neat diesel fuel at maximum load. Further, there is a marginal increase of NO_x for all blended fuel of PME (Pongamia methyl ester).

SCOPE OF FUTURE WORK

For future make to use of the Taguchi method for the above blends and compression ratio and will find out the optimized value for VCR engine by the given bio diesel pongamia oil. This will surely reduce the time and fuel consumption for the engine. Most of the researches used this method to find the optimized value which have proved 95% reliability hence we will use DOE method (Taguchi) to find the optimized value by using MINI TAB SOFTWARE and will find the maximum efficiency with reducing emission with best compressive ratio of engine.

REFERENCES

- [1]. Bobade S.N.1 and Khyade V.B.2 Detail study on the Properties of Pongamia Pinnata (Karanja) for the Production of Biofuel Received 22nd March 2012, revised 5th April 2012, accepted 24th April 2012
- [2]. D.Balajeel, G.shankarnayanar performance and combustion characteristics of ci engine with variable compression ratio fuelled

with pongamia and jatropha and its blends with diesel

[3]. Horng-Wen Wu, Zhan-Yi Wu- Combustion characteristics and optimal factors determination with Taguchi method for diesel engines port-injecting hydrogen- Energy 47 (2012) 411e420

[4]. Horng-Wen Wu, Zhan-Yi Wu- Using Taguchi method on Combustion performance of diesel engine with Diesel/ Biodiesel blend and port inducting Hydrogen-Applied energy 104 (2013) 362-370

[5]. Karthikeyan R, Nallusamy.N, Alagamoorthi.N, Ilangoan.V, Optimization of Engine Parameters for Turpentine Mixed Diesel Fueled DI Diesel Engine Using Taguchi Method - Modern applied science Vol 4, No 12, December 2010

[6]. Sivaramakrishnan .K and P. Ravikumar - Performance Optimization Of Karanja Biodiesel Engine Using Taguchi Approach And Multiple Regressions- VOL. 7, NO. 4, APRIL 2012

[7]. M Nataraj, V P Arunachalam, N Dhandapani – Optimizing diesel engine parameters for emission reduction using Taguchi method : variation risk analysis approach – Indian journal of engineering & material sciences Vol 12, December 2005,pp. 505-514

[8]. T Ganapathy, K Murugesan, R P Gakkhar, Performance optimization of jatropha biodiesel engine using taguchi approach –Applied energy 86(2009) 2476-248.