ISSN (Online) 2456-1290
International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
Vol 1, Issue 4, August 2016

Performance and Emission Characteristics of a CI Engine with Redesigned Piston Fuelled With Biodiesel and Additives

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Abstract: -- The increased attention on alternative fuels in the recent years was mainly driven by increasing oil prices, strong emission norms and the concern on clean environment. The biodiesel has emerged as a potential substitute for diesel fuel on the amount of its renewable source and lesser emissions. In order to increase the swirl in the combustion chamber, we are redesigning the piston crown with elliptical shaped grooves over it.

The present research is aimed to investigate experimentally the performance and exhaust emission characteristics of a direct injection compression ignition engine equipped with a redesigned piston crown fuelled with conventional diesel fuel, blend of diesel and rice bran oil biodiesel, and blends of diesel and rice bran oil biodiesel with varying proportions of zinc oxide nano materials as additives over the entire range of load on the engine. The piston in the diesel engine is replaced and then fuelled with the above said fuels. The performance parameters such as brake power, specific fuel consumption, thermal efficiencies are calculated based on the experimental analysis and engine emissions such as CO, HC, CO_2, and NO_x emissions are measured. The data has been analyzed and the results are presented and discussed in this project.

***Key Words:*-- Rice bran oil, Biodiesel, Zinc oxide nano particles, Trans-esterification, Performance, Emissions.**

I. INTRODUCTION

As we know that diesel engines are the primary sources of energy for transportation in India due to their advantages over gasoline engines. Longer life span, smooth running, lesser fuel consumption, reliability and consistency are few of the reasons for their extensive use. Emissions are the main problem in diesel engines. Globally there is a great concern about combustion related pollutants such as carbon monoxide(CO), unburnt hydrocarbons(HC), oxides of nitrogen (NO_x), carbon dioxide(CO_2), smoke, particulate matter, acid rains, photo chemical smog and depletion of ozone layer has led regulatory agencies to impart strict emission norms.

Biodiesel is one of the most promising alternative fuel for diesel engines. Biodiesel is defined as a fuel comprising of mono alkyl esters of long chain fatty acids derived from vegetable oil or animal fat. It contains no petroleum but it can blend at any level with diesel to create a biodiesel blend.

There are three types of oils possible for biodiesel production,

- Vegetable oil,
- Used cooking oil,
- Animal fat..

Rice bran oil is one of the most promising alternative fuel for diesel engines. RBO is a non-conventional, inexpensive, low grade vegetable oil. Rice bran oil is the oil extracted from the germ and inner husk of rice. It is the notable for its very high smoke point of 490° F (254° C) and its mild flavor, making it suitable for high temperature cooking method such as stir frying and deep frying. It is popular as cooking oil in several Asian countries including japan and china**.** Crude RBO is a source of high fatty acids and byproducts are derived from the crude rbo and the resultant is used as a feed stock for biodiesel, which is quite economical and affordable.

Table 1: Properties of Diesel and RBO bio-fuel

Property parameter	Diesel	Rice bran oil biodiesel
Viscosity at 40°C, mm^2/s	3.4	4.23
Flash Point,°C	68	116
Fire Point, °C	75	128
Density at 30°C	0.85	0.885
Calorific Value,Mj/kg	43	38.7

It is well known that in DI diesel engines swirl motion is needed for proper mixing of fuel and air. Moreover, the efficiency of diesel engines can be improved by increasing the burn rate of fuel air mixture. This can be achieved in two ways; one by designing the combustion chamber in order to reduce contact between the flame and the chamber surface, and two by providing the intake system so as to impart a swirl motion to the incoming air. The swirl ratio and resulting fluid motion can have a significant effect on air-fuel mixing, combustion, heat transfer, and emissions. When the piston moves close to the top dead center [TDC], the variation of swirl ratio depends on the shape of the combustion chamber. For combustion chamber bowl-in piston, the gases are squished in to the piston bowl when the piston moves close to TDC. The momentum of inertia of gases decreases abruptly, leading to the increase of swirl ratio. This increase in large scale flow speed contributes to the fuel spray being spread out which accelerates the processes of the fuel-air mixing and rate of combustion in diesel engines. The effect of swirl on combustion and emissions of heavy duty-diesel engines has been investigated and suggested that optimum level of air swirl that minimizes soot depends on engine running conditions.

II. MATERIALS AND METHODS

A. RICE bran oil biodiesel

Crude RBO is extracted from the rice bran husk, it is filtered and purified. The crude and purified, RBO is made to undergo trans-esterification process to convert into rice bran oil biodiesel is the oxygenated fuel which contains oxygen as a compound and imparts oxygen while burning and helps for better and complete combustion thereby reducing some emissions.

B. Nano Technology:

The study of structures between 1-100 nanometer ranges in size is defined as Nano Technology. Nano materials and particles will acts as catalyst to increase the rate of reaction so that it produce good yield as compared to other materials. From studies the increase in surface area to volume ratio of particles altering mechanical, thermal and catalytic properties of materials being used.

While accelerating the rate of combustion the Nano particles in biodiesel acts oxygen couriers by contributing and redistributing oxygen in the combustion chamber. In doing this, a faster more powerful and complete burn occurs which requires less fuel for the same work output required of the engine. Through this process Nano particles reverses the carbon build up on the cylinder wall, which simultaneously decreasing the exhaust emissions and particulate matter produced during normal operation.

C. Properties of ZnO Nano powder

Table 2: Physical properties

Appearance	White solid
Molar mass	81.38g/mol
Density	$5600 kg/m^3$

Table 3: Chemical properties

Melting point	1975 °C
Boiling point	2360 °C
Flash point	1436 °C

D. Elliptical Grooved Piston (EGP 9)

In order to enhance the air swirl intensities inside the cylinder, changes on the piston crown has been selected and nine elliptical shaped grooves are made on the piston. The selected dimensions for the elliptical groove cutting are given below,

Major axis of the ellipse = 15mm
Minor axis of the ellipse = 8mm
Number of grooves to be made = 9 No's
Angle between consecutive grooves = 40°
Depth of the groove = 2mm

Figure 1: ***Top View Of The Elliptical Groove Piston Crown***

III. EXPERIMENTAL SETUP

The experimental set up consists of a diesel engine, engine test bed, fuel and air consumption metering equipment, Exhaust gas analyzer and smoke meter. The schematic diagram of the engine test rig is shown. Single cylinder,4-stroke Water cooled vertical axis diesel engine is used in laboratory.

Figure 2: Replacing Piston in Test Rig

Figure 3: Schematic diagram of engine test rig.

Standard piston in the engine was replaced by redesigned piston having elliptical grooves on the piston crown. The engine was first operated on diesel fuel with no load for few minutes at rated speed of 1500 rpm until the cooling water and lubricating oil temperatures reaches to 85^{o}C. The same temperatures were maintained throughout the experiment with all the fuel modes.

Table 4: Specifications of the diesel engine

Engine Manufacturer	**KirloskarOil Engines Limited, India**
Engine Type	Vertical,4 stroke, Direct Injection
Ignition Type	Compression Ignition
Cooling Method	Water cooled
No of Cylinders	Single cylinder
Starting Condition	Hand Cranking
Bore(D)	80 mm
Stroke(L)	110 mm
Rated Speed	1500 rpm
Rated Power	5bhp,3.7 kW
Compression Ratio	16.5:1

The baseline parameters were obtained at 0%, 20%, 40%, 60%, 80% and 100% of load on the engine with the diesel fuel (DF). The diesel fuel was replaced with the blend of 80% diesel and 10% rice bran oil biodiesel (B20) and test was conducted by varying the loads in the same manner. After the B20, the same test was conducted with theB20+ ZnO Nano fluid in 50,100,150 ppm separately. The tests were conducted with these three fuels by varying the load on the engine. The brake power was measured by using an rope brake dynamometer. The mass of the fuel consumption was measured by using a fuel tank fitted with a burette and a stop watch. The performance parameters such as brake thermal efficiency and brake specific fuel consumption were calculated from the observed values. The exhaust gas temperature was measured by using an iron-constantan thermocouple. The exhaust emissions such as carbon monoxide, Carbon Dioxide, Nitrogen Oxides, hydrocarbons and unused Oxygen were measured by AVL Di Gas 444 exhaust analyzer and the smoke opacity by AVL smoke meter 437C for diesel fuel, a blend of diesel and biodiesel blends separately under all load conditions. The results from the engine with a blend B20 and blend of B20+50 ppm, B20+100 ppm , B20+150 ppm were compared with the baseline parameters obtained during engine fuelled with diesel fuel at rated speed.

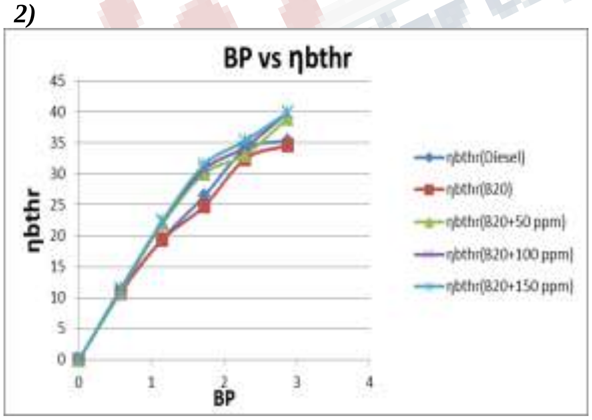
IV. RESULTS

A. *Performance Characteristics*

The results obtained regarding the performance and emissions of the engine with elliptical grooved piston are shown with the help of graphs. The variation of brake thermal efficiency with varying load for diesel, b20, b20 with zno nano fluid proportions is shown below.

1) Brake Thermal Efficiency

2)



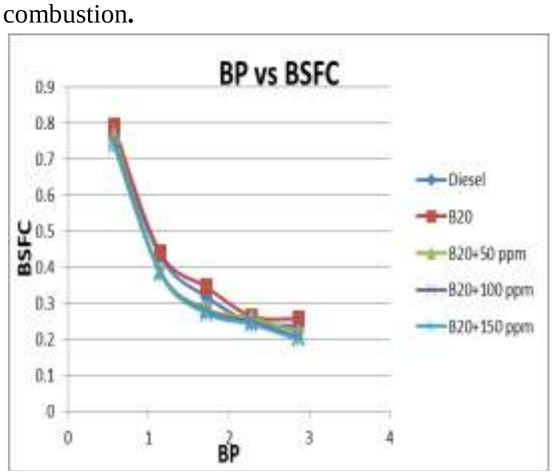
Graph 1 : Variation of η_{bth} with Load

The brake thermal efficiency increased with load for all fuel modes. The brake thermal efficiency of B20+50 ppm, blend of B20+100 ppm, blend of B20+150 ppm was higher than that of the conventional diesel fuel over the entire range of the load. The reason may be the extended ignition delay and the leaner combustion of biodiesel, resulting in a larger amount of fuel burned.

The thermal efficiency obtained for diesel and b20 are 35.37%, 33.40% respectively at full load. The decrease in thermal efficiency for b20 when compare to diesel is due to lower calorific value, higher viscosity and ineffective utilization of heat energy due to higher molecular weight of methyl ester. Whereas for b20 with zno for 50ppm, 100ppm and 150ppm are 34.8%,35.6 and 35.51%.the increase in thermal efficiency when b20 is added with additive of 50ppm and 100ppm when compare with b20 and diesel was due to sufficient oxygen content present in nano fluid. Due to this it forms homogeneous mixture and proper combustion takes place and leads to higher thermal efficiency.

2) Brake Specific Fuel Consumption

Figure shows the variation of brake specific fuel consumption with load for diesel, b20 and with b20 when added with additives. The SFC values obtained for diesel and b20 are 0.2366 kg/kwhr and 0.2556 kg/kwhr respectively, whereas for b20+50ppm, b20+100ppm and b20+150ppm.the increase in SFC for b20 is due to high density and viscosity, which leads to effect of mixture formation further leads to slow combustion.



Graph 2: Variation of Brake specific fuel consumption with load

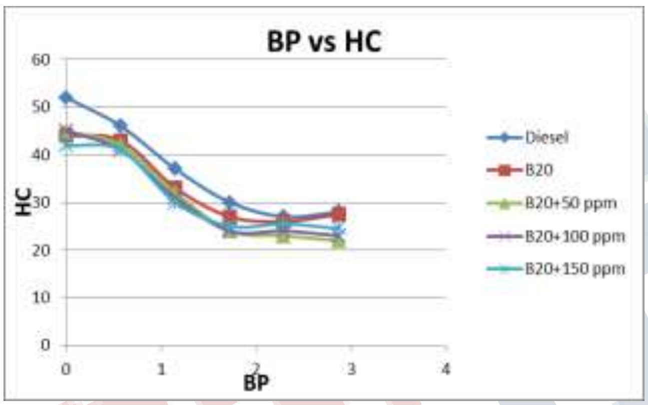
IFERP
ISSN (Online) 2456-1290
International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
Vol 1, Issue 4, August 2016

When ZnO is used as additive for 100ppm SFC is reduced than diesel at full load , this is due to catalytic chemical oxidation of fuel which leads to improves the combustion of fuel. For 150ppm SFC is increased than diesel due to lean mixture. So for B20+150ppm specific fuel consumption is more than diesel.

B. Emission Characteristics

1) HC Emissions

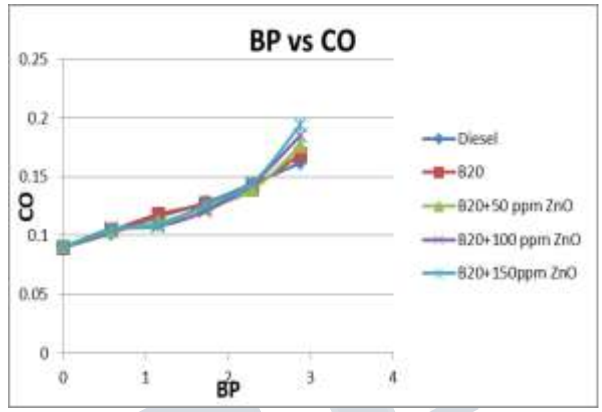
The HC emissions were minimum at medium load and maximum at full load of the engine for all the fuel modes. The HC emissions of the pure biodiesel, blend B20 and B20 with Nano fluids were higher at low and medium loads and significantly lower at higher loads than those of diesel fuel.



Graph 3:Variation of HC Emissions with Load

It is due to the better combustion achieved at a medium speed and with a medium sized load. The hydrocarbon emission with brake power for diesel, B20 and B20 with Nano fuel additive. Hydrocarbon emission was slightly increased for B20 when compare with diesel. The values obtained are 50ppm and 100ppm.the increase in emission for B20 at full load is due to enough oxygen is not present and it forms rich micture. So incomplete combustion takes place hence increase in emissions.

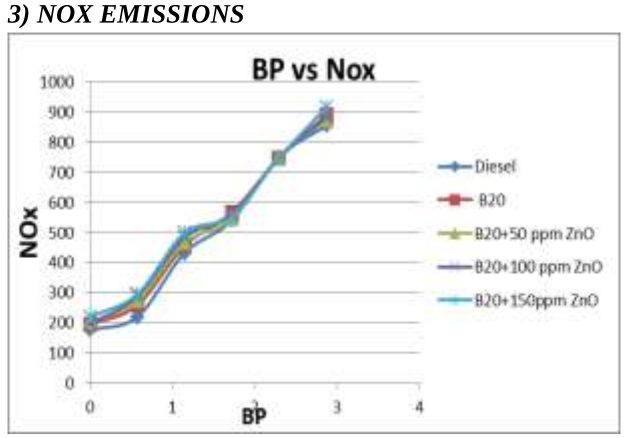
2) CO Emissions



Graph 4: Variation of CO Emissions with Load

The variations of carbon monoxide emissions with brake power. Generally co emissions occur due to fuel rich combustion and insufficient time. The emission values obtained for diesel and b20 at full load condition are 0.08% and 0.07%.the increase in co emissions for diesel are due to lack of oxygen or due to engine running in too rich condition. The decrease in emission level for b20 is due to presence of 10 to 11% of oxygen content in biodiesel. By adding additives for b20+100ppm has obtained lower emission when compared to diesel. The values obtained are 0.06%, 0.05% and 0.09% for b20+50ppm,b20+100ppm and b20+150ppm.the emissions reduced at 50ppm and 100ppm at full load due to the oxygen present in additives and forms stoichiometric mixture and complete combustion takes place with less emissions of co.

3) NOX EMISSIONS



Graph 5: Variation of NOx Emissions with Load

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ISSN (Online) 2456-1290

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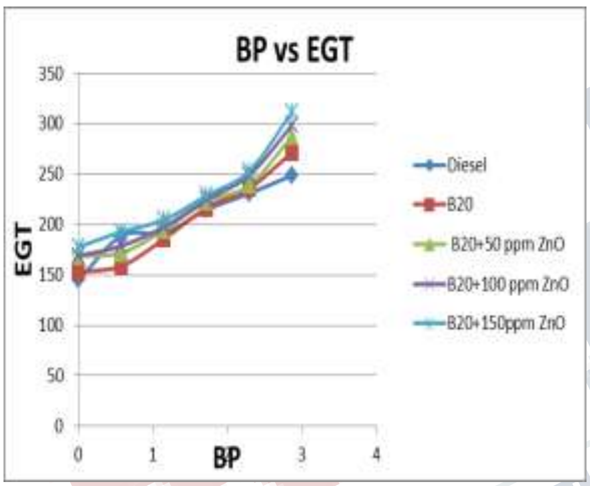
The NOx emissions of B20, B20+50 ppm, B20+100 ppm, B20+150 ppm were less at low loads and more at medium and high loads than those of diesel fuel. It is due to the higher oxygen content and combustion temperature of the biodiesel and the ethanol at medium and high loads.

4) Exhaust Gas Temperature

From the graph the variation of exhaust gas temperature with brake power for diesel, B20 and for biodiesel with Nano fuel additives are obtained as 245°C,266°C,270°C,283°C and 293°C.The temperature values increased for all B20, B20+50ppm,B20+100ppmand B20+150ppm when compare with diesel. Due to combustion rate increases at full load ,the exhaust gas temperature obtained is also higher at full load.



Graph 6 : Variation of Exhaust Gas Temperature with Load.

V. CONCLUSION

The experiments were conducted with rice bran oil biodiesel and ZNO as a nano fluid has been studied and investigated the performance and emission characteristics of a diesel engine having elliptical grooves on piston. The following conclusions based on the experiment are,

- ❖ B20 is having lower efficiency and higher energy consumption due to low calorific value of fuel and poor atomization of fuel. With the addition of nano fuel additives there is a significant increase in thermal efficiency compare to biodiesel without additives.
- ❖ The brake thermal efficiency for b20+100ppm increased by about 1.26% when compared with diesel at full load.
- ❖ The reduction in co emission by using b20+100ppm has observed when compare with diesel. The co emissions reduced by 25% when compared with diesel.
- ❖ The HC emissions are obtained minimum for b20+100ppm when compared with diesel and other biodiesel nano-fuel additives.
- ❖ Nox emissions are increased for all biodiesel nano fuel additives and for b20 when compare with diesel at full load. For b20+100ppm the emission value obtained is minimum when compare with b20,b20+50ppm and b20+150ppm and increased when compare with diesel. This is due to higher combustion temperature.

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