International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878 (Online), Volume-7, Issue-6, March 2019

Experimental Investigations on CI Engine using different Combustion Chambers and Biodiesel as Fuel

Shaik Hussain, A Siva Kumar, A Aruna Kumari

Abstract : The rapid utilization of crude oils in present days has been created shortage of petroleum products. The shortage of crude oil reserves has a major impact on industrial, transportation and agriculture sectors. Therefore there is a necessity to alter crude oils with alternative fuels. This paper investigates the performance and pollutant parameters of compression ignition engine with soap nut and palm stearin methyl esters as alternative to diesel fuel. Piston bowl configuration has a major effect in the preparation of air-fuel mixture. Hence in this work attempts are made to minimize the exhaust pollutants and improve the performance parameter by varying the combustion chamber geometry. The various combustion chamber designs viz., Hemispherical, Toroidal, Re-entrant and double wedge combustion chamber are employed. The results indicates that Re-entrant combustion chamber is a better choice with soap nut methyl ester as a fuel.

Index Terms: Soap nut methyl ester, palm stearin methyl ester, combustion chamber, biodiesel, compression ignition engine.

I. INTRODUCTION

Energy is treated as the most significant for development of any nation. Presently the fossil fuels are the major source of energy for transportation, industrial and agriculture sectors. With the growing demand the consumption of fossil fuels are increased rapidly. To compensate this many of the countries importing oils gulf countries. Therefore it creates burden on the economy of the nation. Further the rapid utilization of fossil fuels also leads to exhaust of crude reserves. To overcome this effect many of the researchers have investigated different types of alternative fuels like biogas, liquefied petroleum gas, vegetable oils and alcohols. From the experimental results they observed that vegetable oils are best suited alternative fuels owing to their similar fuel properties. The vegetable oils like peanut, linseed, mahua, karanja, cotton seed, jatropha palm, sunflower were investigated in diesel engines in place of diesel fuel [1-5]. The investigations on DI engine using soya bean, jatropha and rapeseed oil reveals that the performance parameters were comparatively less compared to base fuel. The results also indicated that these fuels were well suited for small run tests where as for long run tests these fuels creates certain problems like piston ring sticking and carbon deposition problems [6-10]. Further the effects of using coconut oil and blends of coconut oil in a compression ignition engine were noticed. From the results it was concluded that coconut oil and its blends may be used in compression ignition engines without any alternation of the engine. It was also observed that with the increase of blend percentage of coconut oil the specific fuel consumption was reduced [11-16]. Further The turbocharged DI diesel engine was made to run using mustard seed oil as a substitute fuel. The duration of engine run for one cycle was nearly about 150 hours. The experimental results with mustard seed oil indicated that the brake power was less compared to base diesel engine. But the torque and thermal efficiency were nearer to base engine. Further the pollutant formations like carbon monoxide and hydrocarbon pollutants were high at low load conditions. At full load condition the smoke pollutant parameters observed were lower compared to base engine [17-19]. Investigations were carried out on a compression ignition engine with Palm biodiesel and blends of palm biodiesel and the results were compared with base engine. The performance characteristics were almost equal to standard engine. But the emission parameter NOx levels for palm biodiesel and blends of palm biodiesel were high compared standard engine. Further the tests were carried out with Exhaust Gas Recirculation(EGR) and observed that the nitrogen pollutant levels were decreased [20-21].

Revised Manuscript Received on 30 March 2019.
* Correspondence Author
Dr.Shaik Hussain*, Mechanical Engineering Department, Malla Reddy Engineering, Hyderabad, Telangana, India.
Dr. A Siva Kumar, Mechanical Department, Malla Reddy Engineering College and Management Sciences, Medchal, Hyderabad, Telangana, India
Dr. A Aruna Kumari, Mechanical Engineering Department, Jawaharlal Nehru Technological University, Hyderabad, Telangana, India.

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II. MATERIALS AND METHODOLOGY

A. Engine Setup

The investigations are carried out on single cylinder, 4-stroke, direct injection (DI), compression ignition engine. The details of the test equipment are given in Table 1.

Parameter	Specification
Engine Power	5.2 kW
Cylinder Bore	87.5 mm
Stroke length	110 mm
Speed	1500 rpm
Compression ratio	17.5:1

No. of Cylinders	1
Connecting rod	234 mm
Stroke type	Four
Cooling	Water
Speed type	Constant
Loading type	Eddy current

Table 1. Test Engine Specification

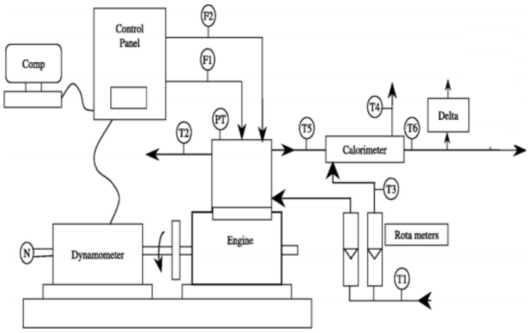

Fig.1. Experimental setup layout

Fig.2. Experimental setup

(a) TCC b) RECC c)DWCC (d) HCC

Fig.3. Types of Combustion Chambers

Parameters	Standards	Diese	PSME	SNME
Specific gravity	ASTM D 1298	0.83	0.85	0.86
Density (kg/m^3)	ASTM D 1298	830	877	871
Kinematic Viscosity @ 40 ^{o}C	ASTM D 445	3.01	5.49	4.53
Heating value (MJ/kg)	ASTM D 5865	42.5	39.09	40.02
Flash point	ASTM D 92	50	220	164
Fire point	ASTM D 92	60	280	212
Cetane number	ASTM D 613	47	42	51

Table 2: Comparision of diesel and biodiesels properties

B. Experimental Procedure

Along with the base diesel two other biodiesels are considered for running the test engine. The two biodiesel are Palm Stearin Methyl ester(PSME) and Soap Nut Methyl ester(SNME). These fuels properties are investigated as per ASTM standards and compared with base diesel fuel. The property comparison of PSME,SNME and Diesel are given in table 2. In addition to standard combustion chamber(Hemispherical) design, three more combustion chamber shapes are used to conduct the experiments. Toroidal combustion chamber(TCC), Re-entrant combustion chamber(RECC) and Double Wedge combustion chamber are the other three types. These shapes are shown in fig.3. At each load the performance and emission characteristics such as specific fuel consumption, brake thermal efficiency, mechanical efficiency and indicated thermal efficiency are evaluated. In addition to performance the pollutant parameters like carbon dioxide, carbon monoxide, hydrocarbon and oxides of nitrogen are estimated.

III. RESULTS & DISCUSSIONS

A. Performance Characteristic

The performance characteristics evaluated are mechanical efficiency, brake thermal efficiency, indicated thermal efficiency and specific fuel consumption. The experiments are carried out with diesel, PSME and RSME as fuel by varying combustion chamber designs. The experimental results are presented below. The graph drawn between brake output power and thermal efficiency is presented in fig.4. From the observations it is learnt that with the increase of load the brake thermal efficiency(BTE) linearly increases from minimum load to max load condition. Further the BTE observed for toroidal piston configuration with Palm Stearin Methyl Ester(PSME) is less compared to other piston configurations. At maximum load condition the BTE is about 30.02% for RE SNME. It is nearly 5.29% more when compared with standard diesel engine. The squish movement is high in modified combustion chamber compared to standard piston. This may be the reason to increase in thermal efficiency. Fig.5 shows the variation of indicated thermal efficiency(ITE) with Brake output power. The ITE noticed is maximum at full load condition for RE SNME and is about 42%.

The minimum indicated thermal efficiency is recorded for double wedge combustion chamber compared to all other combustion chambers and is about 32.85%. Re-entrant combustion chamber with SNME indicated thermal efficiency is 3.34% more correlated to standard diesel engine. The graph is plotted between mechanical efficiency and brake output power and is shown in fig.6. The mechanical efficiency(ME) is increased from zero load to maximum load condition. The RE SNME ME is high at full load condition. TPSME showed lower mechanical efficiency at same load condition. At full load condition RE SNME mechanical efficiency is 15.16% high compared to standard diesel operation. Correct flame propagation with air fuel mixture movement may be the reason for highest mechanical efficiency. The variation of specific fuel consumption with brake power as shown in fig.7. From the figure it is noticed that the SFC is decreasing from zero load to 50% of the full load condition rapidly and for remaining load conditions there is no much deviation. The highest SFC is recorded for Toroidal PSME. The lowest SFC is noticed for Re-Entrant combustion chamber at maximum load condition. Compared to standard diesel engine the specific fuel consumption for Re-Entrant SNME is 14.12% less at full load operation of the engine. Proper mixing of air fuel mixture may be the reason for decreased specific fuel consumption.

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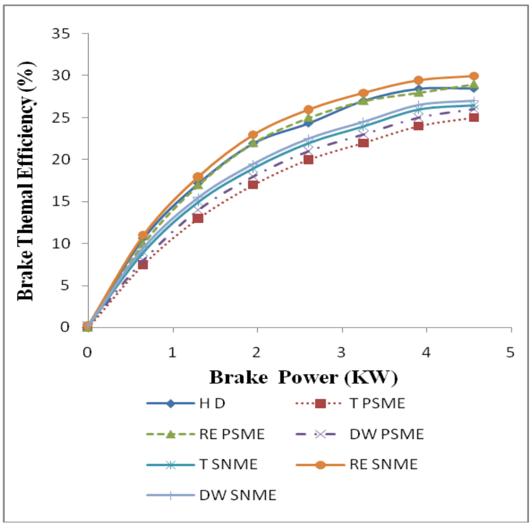

Fig.4 BP vs BTE

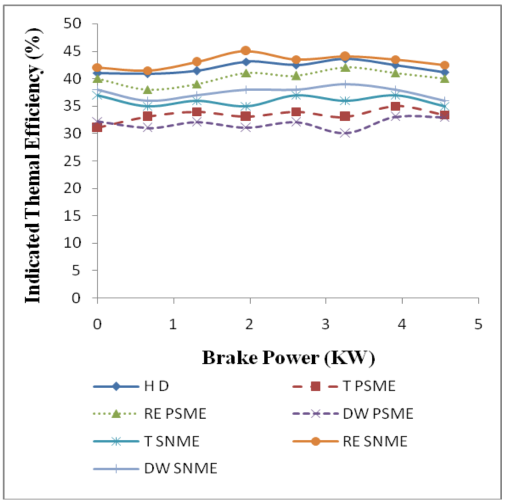

Fig.5 BP vs ITE

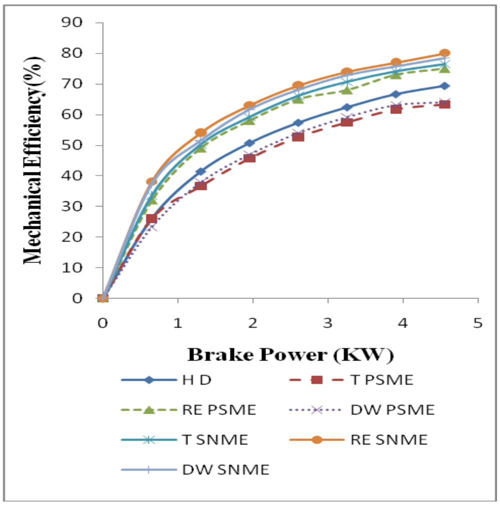

Fig.6 BP vs ME

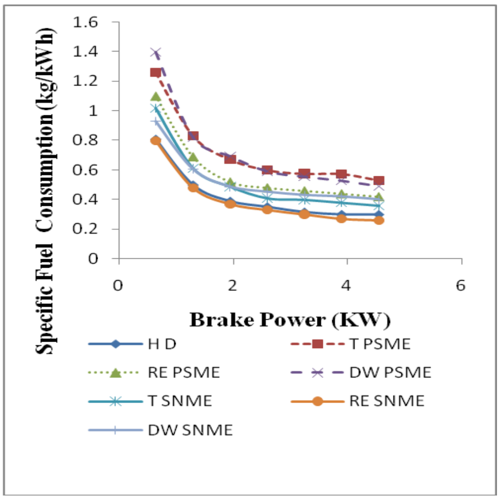

Fig.7 BP vs SFC

B. Emission Parameters

Investigations are carried out to determine the emission parameters with various piston geometry and by using two different kinds of biodiesel(SNME & PSME). The emission parameter viz., carbon dioxide, carbon monoxide, hydrocarbon and NO_x are computed.

The CO emission pollutant variations with brake out put power is indicated in fig.8. From the plot it is observed that from zero load condition to 55% of the full load condition there is no much difference in carbon monoxide pollutants. After 55% of full load condition the CO pollutants are increased drastically. The Toroidal PSME carbon monoxide pollutants are high compared to all other piston geometries. The lower CO pollutants are observed for Re-entrant SNME. At full load condition the CO pollutants are about 29.9% less for Re-entrant SNME Compared to base engine.

A graph is drawn between brake power and hydrocarbon pollutants is shown in fig.9. The HC pollutants are increased from zero load to full load condition. From the graph it is noticed that for double wedge SNME the HC emissions are high correlated to other piston geometries. The minimum hydrocarbon pollutants are recorded for Re-entrant SNME. At full load condition the HC pollutants for Re-entrant SNME are about 22.85% less correlated to base engine.

The deviation of carbon dioxide pollutants with brake output power is presented in fig.10. The CO_2 emissions are linearly increased from minimum to maximum load operation. The highest carbon dioxide pollutant levels are recorded for double wedge PSME and the lowest is observed for Re-entrant SNME. Nearly about 18% lower carbon dioxide pollutant levels are recorded for Re-entrant SNME compared to standard engine.

The fluctuations nitrogen emission levels with brake power is indicated in fig.11. From the figure it is noticed that for all configurations of pistons the oxides of nitrogen emission levels are high at full load condition. More combustion temperature is the reason for increased NO_x levels. But compared to all other piston geometries Re-entrant SNME has shown low NO_x emission levels.

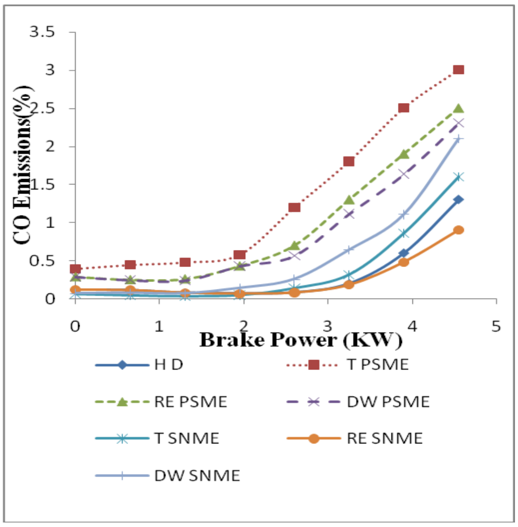

Fig.8 BP vs CO

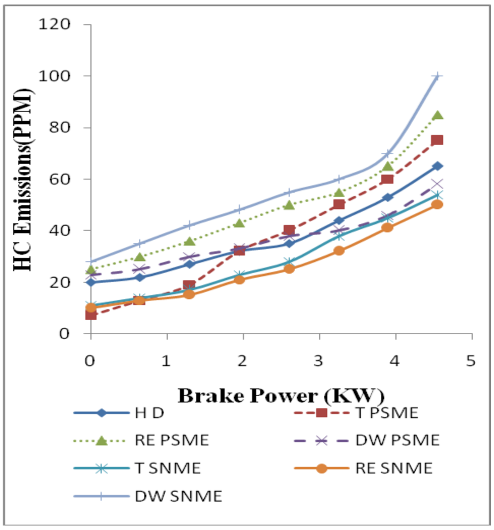

Fig.9 BP vs HC

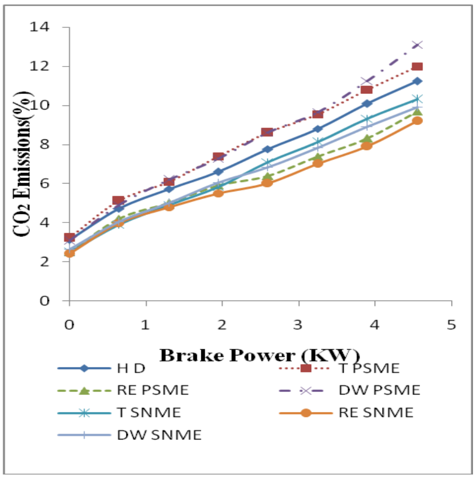

Fig.10 BP vs CO_2

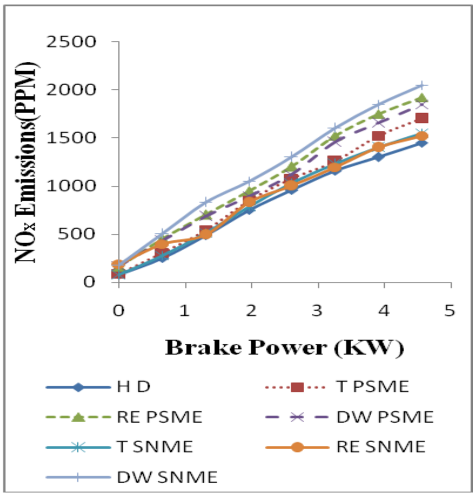

Fig.11 BP vs NO_x

IV. CONCLUSION

In this study investigations are conducted on four stroke, water cooled, single cylinder compression ignition engine. The SNME and PSME are used as fuels with different combustion chamber geometries. From the present study the following conclusions are drawn.

- The Re-entrant SNME brake thermal efficiency is 5.42% high correlated to standard engine. The reduction of air squish on the piston crown leads to mix more quantity of fuel charge.
- The Re-entrant SNME indicated thermal efficiency is 3.64% high correlated to conventional engine. The thrust produced by reaction gases is more due to variation in cross section.
- The Re-entrant SNME mechanical efficiency is 15.25% more correlated to standard engine.
- The SFC is low for Re-entrant SNME and is about 12.98% correlated to base engine. The main cause to decrease SFC is adequate air fuel mixture formation and maximum heat release rate.
- The carbon monoxide pollutant levels for Re-entrant SNME is about 29.85% less correlated to conventional engine. The reason is proper air motion in the combustion chamber.
- The Re-entrant Hydro carbon pollutant levels are about 22.35% low correlated to standard diesel engine. The reason is increased temperature in the cylinder walls.
- Compared to base engine the oxides of nitrogen pollutant levels for Re-entrant is more and is about 5.21%. This is mainly due increase combustion temperature. But compared to all other geometries Re-entrant combustion chamber with SNME has shown less NOx levels.

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