International Journal of Ecology and Environmental Sciences
www.ecologyjournal.in
Online ISSN: 2664-7133; Print ISSN: 2664-7125; Impact Factor: RJIF 5.28
Received: 16-11-2020; Accepted: 30-11-2020; Published: 16-12-2020
Volume 2; Issue 4; 2020; Page No. 736-742

Performance and emission strategies of biodiesel with various engine operating conditions

R Sam Sukumar[1*], M Muralidhara Rao[2], A Gopala Krishna[3]
[1] Research Scholar, Department of Mechanical Engineering, JNTUK Kakinada, Andhra Pradesh, India
[2] Professor, Department of Mechanical Engineering, Visakha Institute of Engineering and technology, Visakhapatnam, Andhra Pradesh, India
[3] Professor, Department of Mechanical Engineering, JNTUK, Kakinada, Andhra Pradesh, India

Abstract
The World is confronting with twin crisis for energy demand they are rapid depletion of fossil fuels and increased emissions with the use of fossil fuels. Researchers all over the globe are finding an alternative for this problem. One best alterative have been identified is the use of biodiesels with the existing engine operating conditions. In this study Pongamia biodiesel is considered due to its availability in abundance at the southern parts of India. The properties of Pongamia biodiesel are in line with the diesel to use in the existing engine. The impact of engine operating conditions wise Compression ratio, Injection Pressure and Injection Timing are varied for the optimized blend of B20. The results are compared with standard engine configuration with base line fuel. The compression ratio 16, Injection Pressure 210 bar and Injection timing 21^0 bTDC have produced better results when compared with standard results.

Keywords: biodiesel, engine, compression ratio, injection pressure, injection timing

Introduction

Diesel engines are the main source of fuel for heavy-duty vehicles. The diesel engine output and emissions characteristics depend on various factors such as fuel injector quantity, fuel injection times, fuel injector pressure, combustion chamber design, injectors location and size hole injection nozzles, fuel spray pattern, air turbulence etc. In direct injection diesel engines, the fuel injection system is designed to achieve a high level of fuel atomization to maximise fuel penetration, to use the entire air charge and to improve the evaporation in a very short time and to achieve improved efficiency in the combustion process. Depending on the engine size and the type of combustion system used the fuel injection pressure inside a typical diesel engine is about 200-1700 atm. The chemical and physical characteristics of each fuel vary. Therefore the combustion properties differ depending on the physical and chemical properties of the fuel. Therefore it is important to adapt the operating parameters of the motor to the combustion properties of the fuel in order to achieve optimal engine efficiency. Compression ratio (CR) is a parameter of this sort that significantly affects the engine efficiency. [1]. Alternative fuels such as biodiesel are becoming widespread due to the depletion of fossilised fuels and the negative environmental effects of oil-fuelled diesel exhaust emissions [2].

The CR influence on the performance, combustion and emission of CI engines has been tried by researchers using different test fuels. Laguitton *et al*. [3] the experiment results found that soot and NOX emissions can be minimised by decreasing CR in CI engines. The effect of CR on diesel engine performance with mahua-oil and its blend with diesel has been studied by Raheman and Ghadge [4]. The study showed that the BTHE increases with the growth in CR. On average, as CR increased from 18 to 20, the BTE grew more than 33 percent. The EGT and Brake Specific Fuel Consumption (BSFC) decreases, however as the amount of CR increases. The EGT decreased by 23%, as CR rose from 18 to 20 on average. As CR rose 18 to 19, BSFC diesel and biodiesel decreased by an average of 10.7% and 19.3% respectively. Further CR rises to 20 resulted in BSFC reduction in diesel and biodiesel by 8 percent and 11.5 percent [5].

When the period of the combustion was shortened as the injection pressure increased [6], the fuel penetration distance was extended and the mixture of fuel and air was enhanced. If the fuel injection pressure is low, the diameter of the fuel particles will increase and the ignition retardation will also increase during the combustion. This state causes ineffective engine combustion and increases CO emissions from NOx. The fuel particle size can become small if the injection pressure is increased. During the ignition time, which causes low smoke and CO emission, the mixture of fuel and air is improved. But if the pressure of the injection is too high the delay is decreased. The chances of uniform mixing decrease and combustion efficiency are therefore decreased, and therefore smoke is generated at engine exhaust [7]. CI engines are important but at the same time we have to find alternative fuels due to the exhaustion of petroleum fuels and the strict emissions regulation. Efforts to use straight vegetable oils as diesel fuel have been undertaken in previous days.

However, the greater viscosity of vegetable oils specifically influences its use in diesel engines [8-9]. The method of transesterification transforms vegetable oils into biodiesel. Biodiesel is a promising alternative fuel which provides fairly good results, reduces emissions and needs no changes to the engine [10]. The delayed injection timing or including the recirculation of exhaust gases (EGR) system will decrease emissions like NOx. This, however, is followed by increased intake of smoke and fuel [11]. Therefore from the literature the impact of engine operating parameters mainly Compression ratio, Injection Timing and Injection Pressure are greatly influencing on the engine performance and emissions.

Objective

The objective of this study is to investigate the performance and emission characteristics of a single cylinder, four stroke, constant speed, water cooled diesel engine with diesel and optimized blend of B20 of Pongamia biodiesel at various Compression ratios, Injection Pressures and Injection timings.

Biodiesel Preparation

A fractional fuel replacement for this analysis was made with neat Pongamia oil. The transesterification process converted Pongamia oil into its methyl ester. Transesterification is a mechanism for triglyceride and alcohol reaction to glycerol and ester in the presence of a catalyst. Because of its low cost and physicochemical benefits, methanol is commonly used for triglycerides and alkalis. A specific (800 ml) quantity of Pongami oil, (200 ml) methanol, and (2 g) sodium hydroxide have been taken. Stirred using REMI magnetic stirrer with Hot plate the contents and the mixture heated up to 70 °C before the formation of esters started. Then cooling was allowed without stirring overnight in a conical flask. There have been two layers. The underside is glycerol and the ester's top layer. The experimentation is shown in figure1.

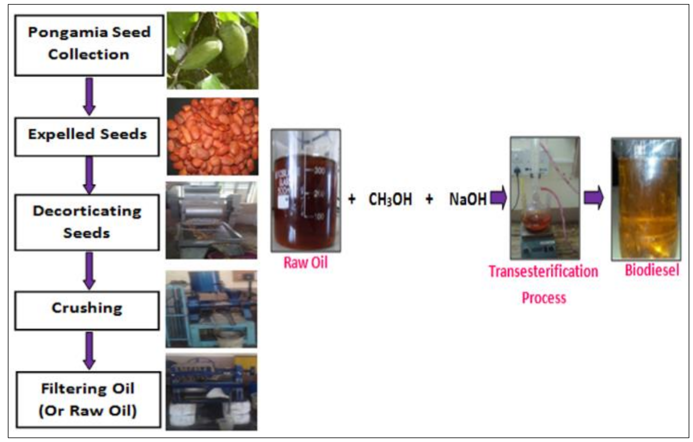

Fig 1: Pongamia Biodiesel Preparation

The properties of pongamia biodiesel after transliteration process are tested as per ASTM testing procedures in Research center of Mechanical Engineering Department, Swarnandhra College of engineering and technology. The Physiochemical properties of tested fuels are tabulated in table 1.

Table 1

S No	Property	Ref. Std. ASTM	Units	Pongamia Oil Methyl Ester (POME)	Diesel
1	Calorific Value	D6751	KJ/kg	39800	42120
2	Flash Point	D93	^{0}C	128	52-96
3	Fire Point	D2500	^{0}C	134	62-106
4	Density	D1448	gm/cc	0.880	0.830
5	Viscosity	D445	mm^2/s at 40 ^{0}C	3.5	2.5 to 3.5
6	Cetane Number	D613	-	55	47-55

Experimentation

Experiments were performed with the mixed biodiesel in a four-stroke computerised single-cylinder direct-injection diesel engine. An optical sensor was used to assess the fuel consumption. A differential pressure transducer is used to calculate the airflow rate. An eddy current dynamometer was connected for different engine loads. The emission parameters and smoke opacity have been calculated respectively by an AVL-444 digas analyzer and an AVL 437 smoke metre. Air exhaust, coolants and input temperatures are measured using thermo couplers. In a step of 0.5 kW, the load is substituted from no charge to the allowable limit. The present fuel engine (Compression ratio 1:16: 200 bar for injecting pressure and 23° for injection time) has been developed for diesel fuel. Injection at a high pressure is needed to produce better atomisation and spray properties. Mixed biodiesel viscosity is slightly higher than that of diesel. Likewise the duration of burning takes slightly longer. In order to boost engine performance using mixed biodiesel for different Compression ratios (14-18) injecting pressures (190-230 bar) and injection timing systems (19-23°bTDC), an investigation was conducted to take this into account. By adjusting the clearance volume by moving the tilting arrangement provided over the engine head for changing compression ratio, by spring tension of the needle valves in the injection nozzle, fuel injection pressure was increased. By changing the density of the shim in the fuels pump, the injection times were advanced.

By changing the shim thickness attached to the base of the pump body, the injection timing can be adjusted. The removal of shims results in a reduction in the thickness, which in turn increases fuel injection time. This is how the time of injection is progressed. The photographic view of the experimental setup is shown in Figure 2. The engine operates at a rated speed of 1500 rpm for all the tests. The engine specification is given in Table 2.

Fig 2: Pictorial view of Experimental Setup

The Specification of the Engine considered for the research studies carried out are tabulated in table 2.

Table 2: Specifications of the CI Engine considered for experimentation.

Engine parameters	Specifications
Make	Kirloskar
Model/Type	TV1/Four stroke
Number of cylinders	Single
Bore/Stroke	87.5 mm/110 mm
Rated power	3.5 kW @ 1500 rpm
Capacity (cc)	661
Type of cooling	Water cooled
Compression Ratio range	12–18
Injection timing range	0 - 25^0 BTDC
Loading	Eddy current dynamometer
Data acquisition device	NI USB-6210, 16-bit, 250 kS/s.
Temperature sensors	Type RTD, PT100 and Thermocouple, K Type
Load sensor	Load cell, type strain gauge, range 0-50 kg
Fuel flow transmitter	DP transmitter, Range 0-500 mm WC
Air flow transmitter	Pressure transmitter, Range (-) 250 mm WC
Software	"Engine soft" Engine performance analysis software
Rotameter	Engine cooling 40-400 LPH; Calorimeter 25-250 LPH

Uncertainty Analysis
The uncertainty is measured using different criteria such as instrument selection, working environment, calculation and methods of conduction. The instrument's precision depends on the study of uncertainty. In addition, the percentage of uncertainties for BP, BTHE and BSFC varies. The root-summary approach decides these parameters and has found the percentage of uncertainty is 2.05 [13].

Results and Discussions
Biodiesel (POME) at B20 was chosen for further investigation from the first stage. In this stage, optimize the compression ratio of the engine. The compression ratio (CR) was varying from 14 to 18 in steps of 2 for optimization. These results were analyzed with normal Diesel having compression ratio at 16.

Effect of Compression ratio

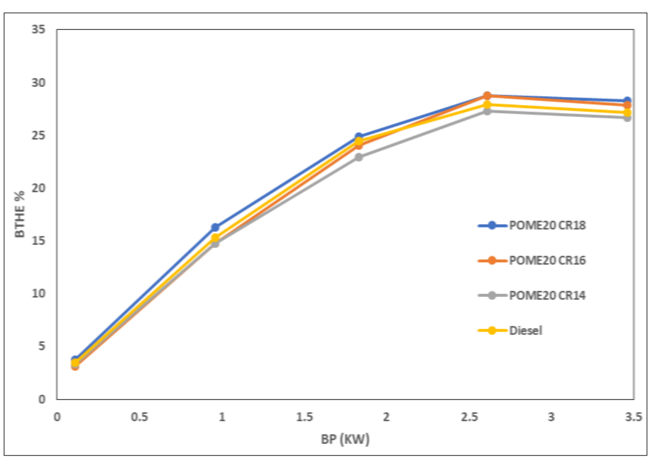

Fig 3: Impact of Compression ratio on Break Thermal Efficiency

Thermal efficiency of B20 when varying compression ratio along with Brake power is shown in fig 3. The blend B20 of POME at CR18 shows higher BTHE value at rated load than blend B20 at CR14 and CR16. The percentage decrease of BTHE for blend B20 at CR14 and CR16 were 5.2% and 1.5% than blend at CR18 but it is 1% lower than Diesel. Higher compression ratios permit the same combustion temperature to be reached with less fuel, while giving a longer expansion cycle, creating more mechanical power output and lowering the exhaust temperature.

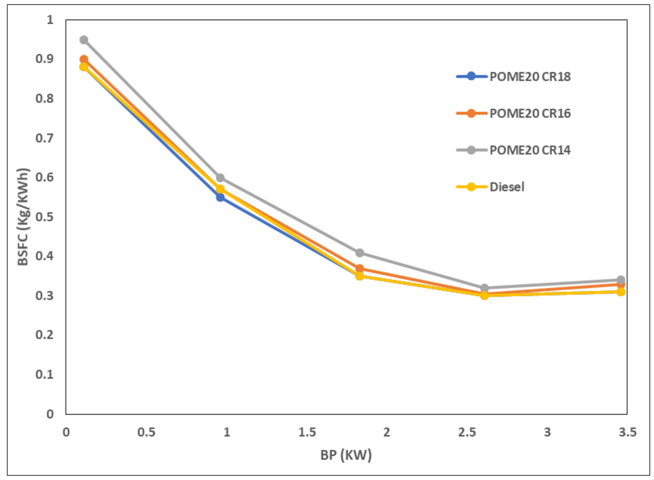

Fig 4: Impact of Compression ratio on BSFC

Brake specific fuel consumption of B20 when varying compression ratio along with Brake power is shown in fig 4. The blend B20 at CR18 shows lower BSFC value at rated load than blend B20 at CR14 and CR16. The percentage increase of BSFC for blend B20 at CR14 and CR16 were 6.25% and 1.6% than blend B20 at CR18. The possible reason for this trend could be that with an increase in CR, the maximum cylinder pressure increases due to the fuel injected in hotter combustion chamber and this leads to higher effective power. Therefore, fuel consumption per output power will decrease.

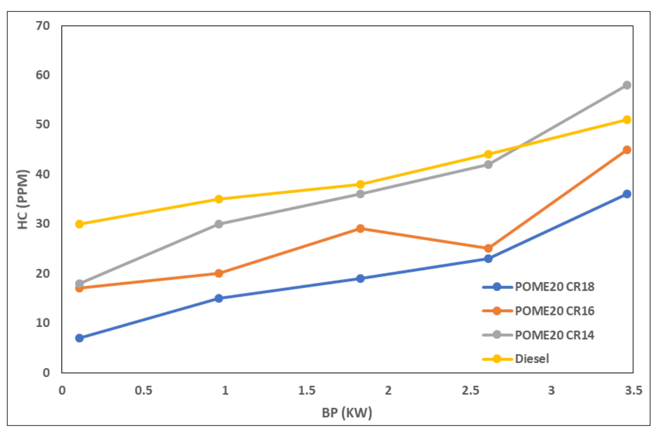

Fig 5: Impact of Compression ratio on Unburnt Hydrocarbons

Unburnt hydro carbon emissions of B20 when varying compression ratio along with Brake power is shown in fig 5. HC emission values were lower for blend B20 at CR16. The percentage increase of HC for blend B20 at CR14 and CR18 were 6% and 15% than Diesel. The reason behind HC emissions increase, the lower compression ratio engine tenders a reduced pressure at the beginning of injection and a longer penetration time due to the increased auto ignition delay and subsequent increased penetration of the fuel spray into the chamber.

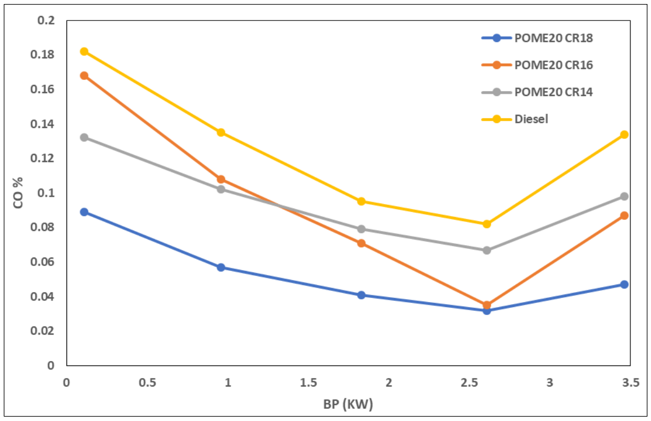

Fig 1: Impact of Compression ratio on Carbon Monoxide

Carbon monoxide emissions of B20 when varying compression ratio along with Brake power is shown in fig 6. The carbon monoxide emissions of the engine for biodiesel blend B20 at CR14, CR16, CR18 were 8 to 50% lower when compare with Diesel. At lower CR, insufficient heat of compression delays ignition and so CO emissions increase. More or less for CR16 and CR18 the results shown similar trend with minor deviation.

Effect of Injection Pressure

In this stage, best compression ratio for blend B20 of POME chosen for further study from the second stage. In this stage injection pressure was to optimize for best blend (B20 of POME) at best compression ratio CR16. The injection pressure was varying from 190 bar to 220 bar in steps of 10 bar.

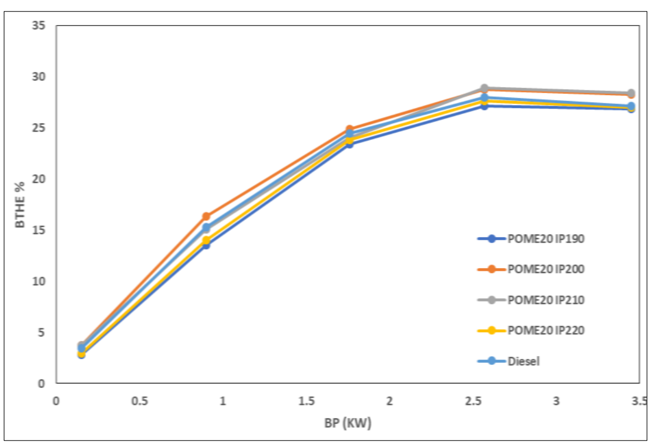

Fig 7: Impact of Injection Pressure on Break Thermal Efficiency

Brake Thermal efficiency of B20 when varying Fuel Injection pressure along with Brake power is shown in fig 7.

At injection pressure 210 bar, the biodiesel blend B20 of POME shows 3.6% higher thermal efficiency than B20 of POME at 200 bar but it was 3% higher than Diesel. The increase in brake thermal efficiency of biodiesels was due to better combustion of proper atomization resulted from increasing injection pressure upto certain pressure, but it decreases by further increasing injection pressure, may be due to over evaporation of fuel, that decreases penetration efficiency.

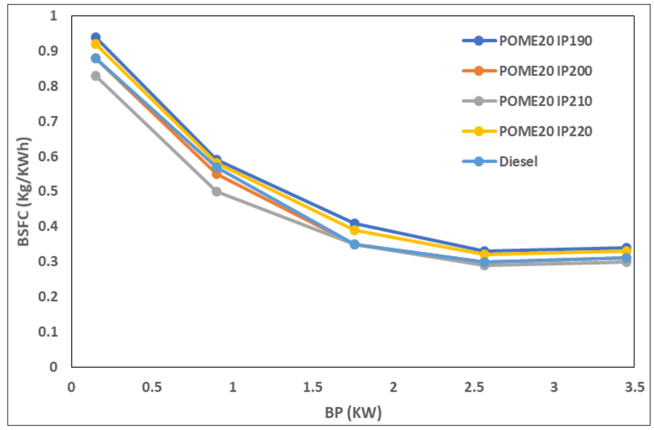

Fig 8: Impact of Injection Pressure on BSFC

BSFC of B20 when varying compression ratio along with Brake power is shown in fig 8. The brake specific fuel consumption for B20 at CR16 and 210 bar was reduced by 6.6% than blend B20 at normal conditions. This may be due to the fact that, as injection pressure increases the penetration length and spray cone angle increases, so that at optimum pressure, fuel air mixing and spray atomization was improved.

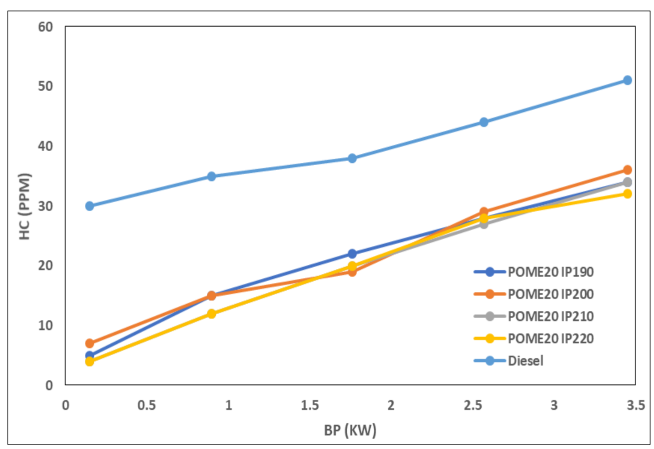

Fig 9: Impact of Injection Pressure on Unburnt Hydro carbons

Unburnt hydro carbon emissions of B20 when varying fuel injection pressure along with Brake power is shown in fig9. The HC emissions were reduced nearly 35-45% than conventional Diesel. When injection pressure increases HC emissions decreases upto 210 bar then it was increased, which may be because of finer fuel spray and results in reduced momentum and poor penetration of the droplets resulting incomplete combustion.

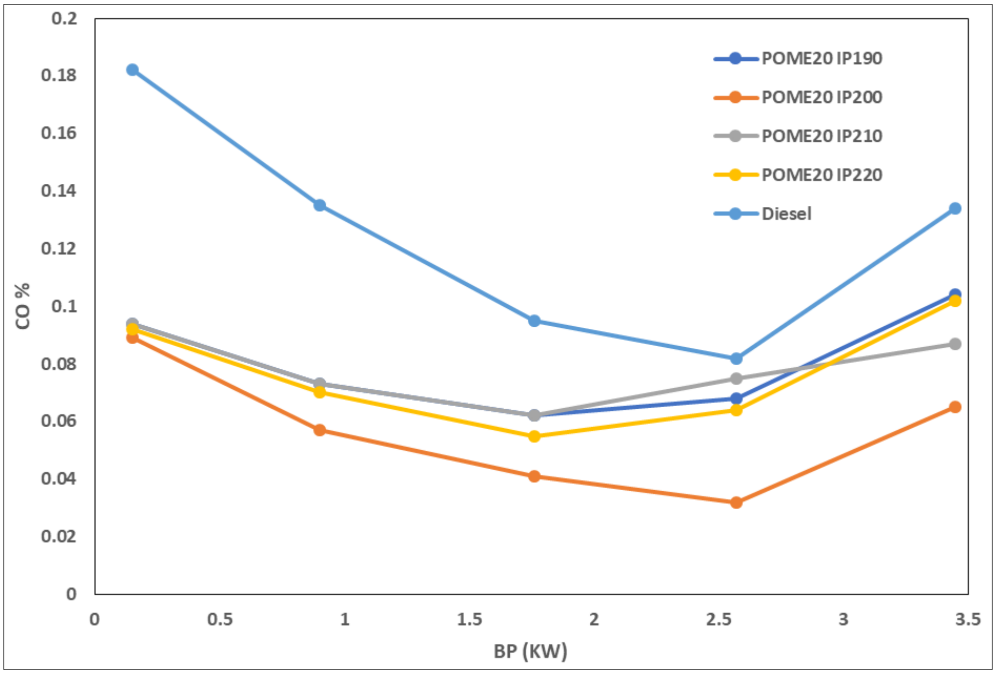

Fig 10: Impact of Injection Pressure on Carbon Monoxide emissions

Carbon monoxide emissions of B20 when varying fuel injection pressures along with Brake power is shown in fig 10. CO emissions were reduced nearly 5-20% than conventional Diesel. Carbon monoxide emissions formed due to insufficient oxygen to convert carbon dioxide in the combustion.

Effect of Injection Timing

In fourth stage, best configuration of biodiesel blend, compression ratio and injection pressure (B20 of POME at CR16 and Injection pressure 210 bar) was chosen for further investigation from the third stage. In this, the injection timing was varying from 19^0 bTDC to 23^0 bTDC in steps of 2^0 bTDC for finding the best injection timing on Diesel engine.

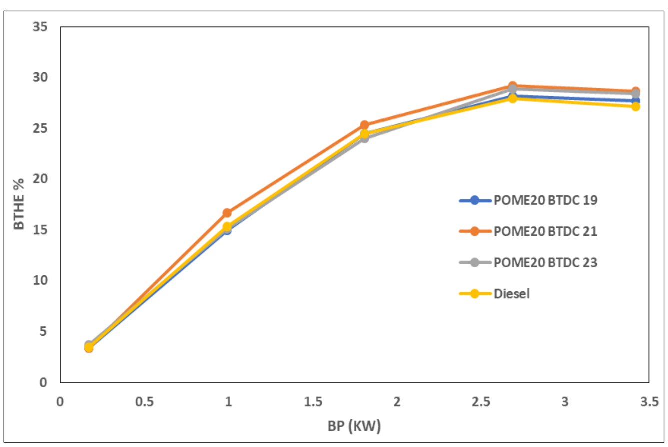

Fig 11: Impact of Fuel Injection time on Break Thermal Efficiency

BTHE of B20 when varying fuel injection timing along with Brake power is shown in fig 11. The percentage increase in brake thermal efficiency values attained for POME B20, PRE 210 at 21 bTDC was 6.5% than POME B20, PRE 210 at 23 bTDC. The percentage decrease in BTHE for POME B20, IP 210 at 23 bTDC and B20, IP 210 at 190 bTDC was 9.3% and 10.7% respectively than POME B20, IP 210 at 21 bTDC. But for POME B20, IP 210 at 21 bTDC is 9% higher than Diesel. The maximum efficiency was obtained at 21^0 bTDC injection timing, retardation of injection timing leads to fast start of combustion and combustion continues in the power stroke.

This results in smaller peak heat release rate and increases effective pressure to do work.

Consequently, the work output was high for retarded injection timing and therefore the brake thermal efficiency increases as the injection timing was retarded up to 210 bTDC but it was decreased further retarding the injection timing may be the ignition delay. More ignition delay might be because of decrease in combustion efficiency and increase of peak pressure and temperature at the end of the combustion.

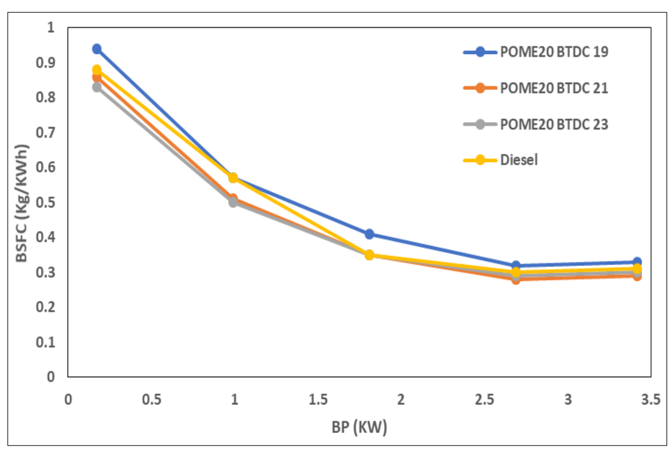

Fig 12: Impact of Fuel Injection time on BSFC

BSFC of B20 when varying fuel injection timing along with Brake power is shown in fig 12. The percentage decrease in brake specific fuel consumption values attained for POME B20, PRE 210 at 21 bTDC was 6.6% than POME B20, PRE 210 at 23 bTDC. Hence the most favorable injection timing for blend B20 was 210 bTDC. It was observed that the BSFC was decreased with retarding injection timing and subsequently increased with injection timing from standard value. It can also be observed that retarded injection timing leads with lower BSFC this was due to optimum delay period and smaller amount of fuel.

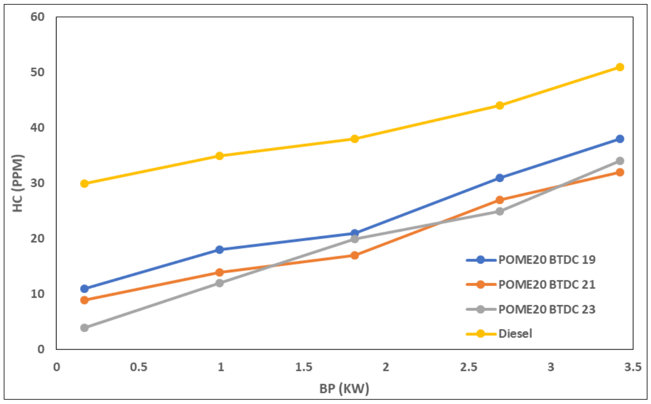

Fig 13: Impact of Fuel Injection time on Emissions of Unburnt Hydro Carbons

Unburnt hydro carbon emissions of B20 when varying fuel injection timing along with Brake power is shown in fig 13. From the results it was observed that total unburned and partially burned Hydro Carbon emission of all biodiesel blends tested in this work as fuel in conventional engine was lower than Diesel fuel. This will lead to the decreased quantity in HC emission present in the exhaust emissions. Overall POME B20 at CR18, 210 bar and 210 bTDC having lower HC emissions.

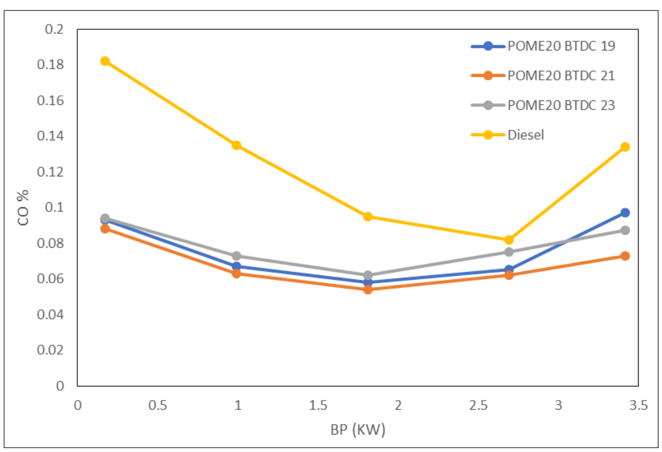

Fig 14: Impact of Fuel Injection time on Emissions of Carbon Monoxide

Carbon monoxide emissions of B20 when varying fuel injection timing along with Brake power is shown in fig 14. Under the same operating condition, the CO emission increases with the delay of the fuel injection timing. This was because the combustion occurs after TDC.

At this time, the cylinder temperature was lower. With the injection timing delayed, the ignition delay was shortened, the proportion of premixed combustion was reduced, and the CO from combustion of combustible mixture was not oxidized and frozen.

Conclusions

- The brake thermal efficiency was higher by 5.2% and 1.5 % for B20 at CR18 when compare to blend B20 at CR14 and CR16 respectively. The BSFC shows lower value for blend B20 at CR18, The percentage increase of BSFC for blend B20 at CR14 and CR16 were 6.25% and 1.6% than blend B20 at CR18. HC, CO emissions were lower for CR18 & CR16 for B20 blend. The percentage decreases of HC and CO were 48.8% and 55.5% respectively than conventional Diesel at CR16. More or less for CR16 and CR18 shown better results compared to others in terms of emissions CR16 shown best results and also due to avoid design complexities CR16 is considered for further studies.
- The effect of injection pressure on performance and emissions of biodiesel blend has marginal. At injection pressure 210 bar, the biodiesel blend B20 of POME shows 3.6% higher thermal efficiency than B20 of POME at 200 bar but it was 3% higher than Diesel. The brake specific fuel consumption for B20 at CR16 and 210 bar was reduced by 6.6% than blend B20 at normal conditions. The HC emissions were reduced nearly 35-45% than conventional Diesel. CO emissions were reduced nearly 5-20% than conventional Diesel. Better results were observed at injection pressure 210 bar for blend B20 at CR16.
- Brake thermal efficiency of POME B20 at retarded injection timing (21^0 bTDC) was increased by 6.4% than normal conditions (23^0 bTDC). The brake specific fuel consumption was decreased 6.6% while retarding injection timing from 23^0 bTDC to 21^0 bTDC. HC and CO Emissions were reduced by 7.4% and 17.3% while retarding the injection timing from 23^0 bTDC to 21^0 bTDC. Moreover, blend B20 at CR18 with injection pressure 210 bar and injection timing 21^0 bTDC shows better performance and emission results.

Scope for future investigation

Further with the optimized results the performance can be improved by adding nanoparticles or oxygenated additives. By incorporation of EGR technique and emulsifying techniques can be tested for further improvement.

Acknowledgements

The Authors are thanking the Staff and Management of Mechanical Engineering Department, Swarnandhra College of Engineering and Technology for carrying out the present research.

References

1. Heywood John B. Internal Combustion Engine Funda mentals. New Delhi, India: McGraw Hill Book Company, 1988.
2. Hirkude JB, Padalkar AS. Performance and emission analysis of a compression ignition engine operated on waste fried oil methyl esters. appl Energy. 2012; 90:68-72.
3. Laguitton O, Crua C, Cowell T, Heikal MR, Gold MR. The effect of compression ratio on exhaust emissions from a PCCI diesel engine. Energy Convers Manage. 2007; 48(11):2918-24.

4. Raheman H, Ghadge SV. Performance of diesel engine with biodiesel at varying compression ratio and ignition timing. Fuel. 2008; 87(12):2659-66.
5. Jindal S, Nandwanaa BP, Rathore NS, Vashistha V. Experimental investigation of the effect of compression ratio and injection pressure in a direct injection diesel engine running on Jatropha methyl ester. Appl Therm Eng. 2010; 30(5):442-8.
6. Lee Seang-wock, Daisuke Tanaka, Jin Kusaka, Yasuhira Daisho. "Effects of Diesel Fuel Characteristics on Spray and Combustion in a Diesel Engine." JSAE Review. 2002; 23:407-414.
7. Celikten Ismet. "An Experimental Investigation of the Effect of the Injection Pressure on Engine Performance and Exhaust Emission in Indirect Injection Diesel Engines." Applied Thermal Engineering. 2003; 23:2051-2060.
8. Yarrapathruni VHR, Voleti RS, Pereddy NR, Alluru VSRR. "Jatropha Oil Methyl Ester and Its Blends used as an Alternative Fuel in Diesel Engine." Thermal Science. 2009; 13(3):207-217.
9. Reddy Rana Pratap, Sharanappa K, Godiganur Ch, Suryanarayana Murthy. "The Effect of Karanja Oil Methyl Ester on Kirloskar HA394DI Diesel Engine Performance and Exhaust Emissions." Thermal Science. Doi: 10.2298/ TSCI1004957G. 2010; 14:957-964.
10. Lakshmanan S. "Biodiesel: An Eco-friendly Alternate Fuel for the Future: A Review." Thermal Science. 2009; 13(3):185-199.
11. Hountalas D, Mavropoulos G, Zannis T, Mamalis S. "Use of Water Emulsion and Intake Water Injection as NOx Reduction Techniques for Heavy Duty Diesel Engines." SAE Technical Paper 2006- 01-1414, SAE International, Washington, DC, 2006.
12. Satish Naidu U, Venkateswara Rao G, Sam Sukumar R, Muralidhar Rao M. "Performance and Emmision Analysis of Pongamia Biodiesel on Vcr Engine by Varing Injection Pressure" International Journal of Mechanical Engineering and Computer Applications, 2016, 4(1). ISSN 2320-6349.
13. R Sam Sukumar, Maddula Muralidhara Rao, A Gopala Krishna. "Experimental Investigations with Zinc Oxide and Silver doped Zinc Oxide Nanoparticles for Performance and Emissions Study of Biodiesel Blends in Diesel Engine", International Journal of Ambient Energy. DOI: 10. 1080/ 01430750.2020.1795717, 2020.