EFFECT OF FUEL INJECTION TIMING, INJECTION PRESSURE AND COMBUSTION CHAMBER SHAPES ON THE PERFORMANCE OF DIESEL ENGINE RUN ON BIODIESEL

VaishnaviShivkumar Hirekodi[1],JyotiMahantesh Mangasuli[2], S.V. Khandal[3*], Balaji. K[4]
[1,2] Student, Department of Aeronautical Engineering, School of Technology, Sanjay Ghodawat University, Kolhapur, Maharashtra, India.
[3,4]Faculty, Department of Aeronautical Engineering,School of Technology, Sanjay Ghodawat University, Kolhapur, Maharashtra, India.
*Corresponding author: Email ID: sanjeevvkhandal@gmail.com

Abstract
The compression ignition (CI) engine is knownfor robustness and its better performance when powered with diesel or biodiesel. In this work Rubber seed oil biodiesel (BRO) was used as CI engine fuel. Experimental tests were conducted on diesel engine to study the effect of fuel injection timing (IT), fuel injector opening pressure (IOP)and combustion chamber shapes (CCS) on the performance, emission and combustion characteristics when run on BRO. In the first phase the IT and IOP were optimized. In the second phase, the effect of combustion chamber shapes was studied. The test fuel yielded better results with 27° bTDC (before top dead center)IT,240 bar injector opening pressure (IOP) and reentrant toroidal combustion chamber (RCC). At the best operating conditions BTE 28.8%, smoke 47 HSU, HC38 ppm, CO 0.135 vol.%, NOx 1182 ppm at 80% load. Lower ignition delay (ID) and combustion duration (CD) with higher peak pressure (PP) and heat release rate (HRR). Overall, the diesel engine yielded higher BTE and lower emissions except NOx with IT of 27°bTDC, 240 bar IOP and RCC.

Keywords:Rubber seed oil biodiesel (BRO); Combustion chamber shapes (CCS); Performance; Emission; Combustion.

1. Introduction

Internal combustion (IC) have better fuel economy. Fuels to power these engines and greenhouse gas (GG) emissions produced by these engines are the two major challenges of the world. A wide range of plants on earth those yield seeds to extract oil from them can be grown in the waste forest land in India [1,2]. Biodiesel is a best alternative to replace diesel if different injection strategies are used [3]. The edible oils to power compression ignition (CI) engine is not encouraged as they are consumed by people [4-6]. The vegetable oils have serious engine fouling because of incomplete fuel burning and thereby carbon deposition on the injector tip and valve seats [7]. At idling condition, diesel engine run on jatropha biodiesel (JOME) yielded increased specific fuel consumption (SFC) and nitrogen oxides (NO_x)with lower lelel CO and HC emissions [8]. The CI engine test powered with Annona methyl ester blends showed 6.4% higher fuel efficiency at 33° before top dead center (bTDC) and 11.9% lower SFC. Higher NOx with 13.5% lower smoke emission was reported at fuel IT of 33°bTDC as compared to original fuel IT [9]. Pyrolysis oil could also be a best choice to run diesel engine with optimized engine operating parameters[10].BTE was same at 100% load with karanja and its blends and at lower loads increased biodiesel percentage in the blends gave lower BTE and higher CO emissions. Heat release rate (HRR) increased with increase in load [11]. Addition of nanoparticle enhances the engine performance due to enhanced combustion process [12].Injector opening pressure (IOP) and combustion chamber shapes (CCS) effect on performance of Pongamia oil methyl ester (POME) powered diesel engine was studied, the toriodal re-entrant combustion chamber (TRCC) resulted in higher efficiency with improved SFC [13].Uppage oil methyl ester (UOME) run diesel engine resulted good performance withtoriodal CC (TCC) at fuel IT of 19° bTDC [14]. The waste plastic oil with IT of 14° bTDCshowed lower NOx, CO and HC with higher efficiency, carbon dioxide (CO_2) and smoke levels[15].Polanga biodiesel gave a maximum cylinder pressure (PP) [16]. The tests with biodiesel blends showed higher efficiency and SFC; lower CO, HC and smoke [17, 18]. Engine consumes more biodiesel because of its lower heat energy content and operating cost increased with biodiesel[19, 20].

Through the exhaustive literature review, it was found that scarce literature is available on the study of combined effect of IT and IOP on the performance of diesel engine run on Rubber seed oil biodiesel (BRO).Therefore, an experimental study was conducted on diesel engine to study the performance of BRO powered diesel engine with different IT, IOP and CCS.

2. Engine specification and Methodology used

2.1. Fuels Used

In the present work, Rubber seed oil biodiesel (BRO)was used. The properties of diesel and BRO fuels are provided in Table 1.

2.2ExperimentalProcedure

In the first phase, experimental tests were carried out on CI engine powered with BRO at 1500 rpm engine speed to obtain best IT that yield highest BTE. The injector used had 3 holes of 0.3 mm orifice size. Figure 1 is the CI engine test rig used. IT was varied from 19° bTDC to 27°bTDC in incremental steps of 4°bTDC; injector opening pressure was varied from 220 bar to 250 bar in steps of 10 bar. The CC shapes such as Hemispherical (HCC), Cylindrical (HCC), Toroidal (TCC) and Re-entrant toroidal combustion chamber (RCC) shapes were used in the present study. A piezoelectric transducer (Make: PCB Piezotronics, Model: HSM 111A22, Resolution: 0.145 mV/kPa) recorded in cylinder gas pressure. The average of 100 cycles was taken as the gas pressure value. HRR was determined with the procedure [21, 22]. Hartridge smoke meter and five-gas analyzers (A DELTA 1600 S-non dispersive infrared analyzer) were used for gas analysis.

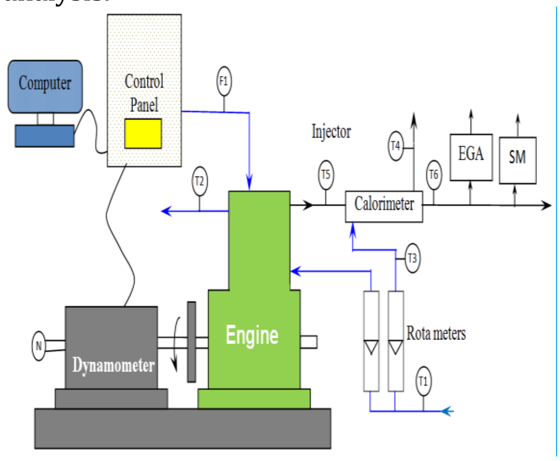

Fig. 1 CI engine test rig used for the present experimental work

Table 1: Properties of Diesel, and BRO

Sl. No.	Properties	Diesel	BRO
1	Viscosity (cSt at 40°C)	4.59	5.85
2	Flash point (°C)	65	133
3	Calorific Value (kJ/kg)	45000	36500
4	Density (kg/m³ at 15 °C)	830	874
5	Cloud Point (°C)	-10	4
6	Pour Point (°C)	-2	-8

Table 2: CI Engine Specifications

Sl. No.	Parameter	Specification
1	Type of engine	Kirloskar make Single cylinder four stroke direct injection diesel engine
2	Rated power	5.2 KW @1500 RPM
3	Cylinder diameter	87.5 mm
4	Stroke length	110 mm
5	Compression ratio	17.5 : 1
6	Software used	Engine soft
Air measurement manometer		
7	Made	MX 201
8	Type	U- Type
9	Range	100 – 0 – 100 mm
Eddy current dynamometer		
10	Model	AG – 10
11	Type	Eddy current
12	Maximum	7.5 (kW at 1500 - 3000 RPM)
13	Flow	Water must flow through Dynamometer during the use
14	Dynamometer arm length	0.180 m

Table 3: The accuracies and uncertainties

Measured variable	Accuracy (±)
Load, N Engine speed, rpm Temperature, °C Fuel consumption, g	0.1 4 1 0.1
Measured variable	**Uncertainty (%)**
HC CO NOx Smoke Temperature of BDF	±5 ±2.5 ±2.3 ±1.3 ±5
Calculated parameters	**Uncertainty (%)**
BTE , % HRR, J/°CA	±1.2 ±1.0

3. Results and Discussion

The effect of IT, IOP and combustion chamber shapes on the performance, emission and combustion characteristics of BRO fuelled CI engineis presented in this section.

3.1 Effect of Injection Timing

Study on the performance was conducted at three injection timings of 19°, 23° and 27° bTDC. The other parameters selected for the study were used as per the engine manufacturer specification. The compression ratio of 17was used during experimentation.

3.1.1 BTE

Effect of IT on BTE of diesel engine operation with BRO is given in Fig. 3.1.At 80% load, BTE of 30.25%was obtained with diesel atIT of 23° bTDC. BRO showed higher BTE for IT of 27° bTDC followed by static IT of 23° bTDC andstatic IT of 19° bTDC, this could be due to lower energy content of the fuel, poor combustion quality and higher fuel injected for the same power output. Due to higher viscosity, poor volatility andpoor mixture formation could also be a reason for lower BTE. BTE with BRO at 27° bTDC for 80% load was 25.27%.

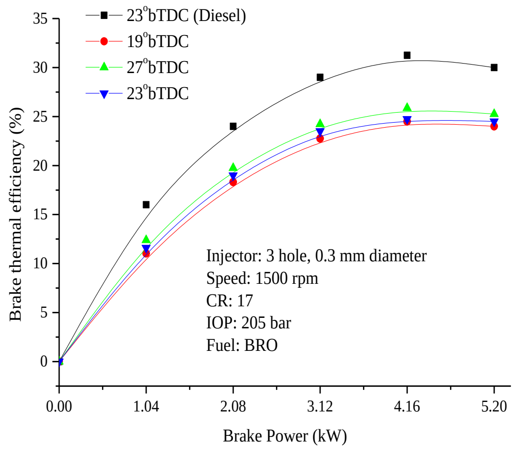

Fig.3.1 Effect of injection timing on brake thermal efficiency for BRO

3.2 Effect of Injector Opening Pressure

The effect of IOP on diesel engine performance with BRO is provided in this section. IT was kept at 27ºbTDC. IOP varied from 220 to 250 bar. Best IOP for better BTE was obtained.

3.2.1BTE

Effect of IOP on BTE for injected biodiesels at 80% and 100% loadisas shown in Fig. 3.2.

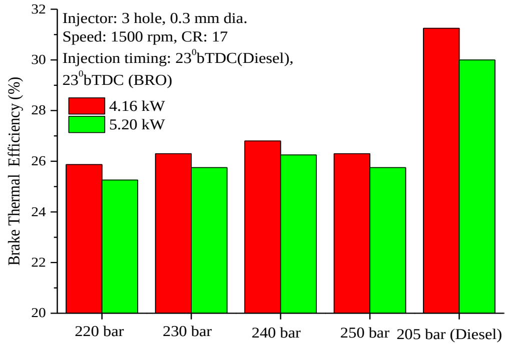

Fig. 3.2 Effect of IOP on BTE for BRO

Among all the IOP selected, BTE was highest at 240 bar. At this IOP, atomization, spray pattern and resulted more homogeneous air fuel mixture could resulted in better combustion. This enhanced combustion improved BTE and it was27% at 80% load.

3.3 Effect of combustion chamber configuration

In this section CC shape effect on performance of CI engine was reported and discussed keeping IT 27ºbTDC and 240 bar IP which were optimized in earlier sections that yield higher BTE.

3.3.1 Performance characteristics

Figure 3.3 presents various combustion chamber shapes (CCS) effect on BTE. Experimental study using various CCS showed that re-entrant combustion chamber (RCC) increased thermal efficiency than with other CCS. Proper formation of mixture of biodiesel along with air and better burning could be responsible for increased thermal efficiency when RCC. Diesel engine run on biodiesel with HCC and CCC leads to combustion before TDC thereby more compression work required. This feature decreased thermal efficiency of the engine. Biodiesel operation increased ignition delay (ID) and combustion duration (CD), these could also be responsible to reduce BTE.

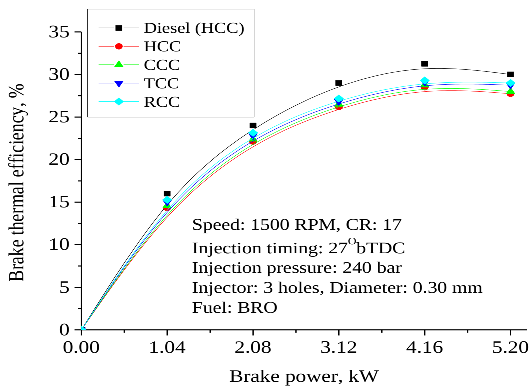

Fig. 3.3 Effect of CCS on BTE with BRO

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However, biodiesel operation with TCC was close to RCC due to more homogeneous mixture formation. BTE of BRO operation were 27, 27.6, 28.4 and 28.8% with HCC, CCC, TCC and RCC respectively against 31.25 % for diesel at 210 bar at 80% load.

3.3.2 Emission characteristics

Figure 3.4 shows smoke opacity variation with different CCS. Diesel combustion resulted in decreased smoke levels in comparison to BRO operation with all CCS. It was due to proper air-fuel mixing leading to better oxidation during combustion. For the similar operating conditions, biodiesel combustion with RCC resulted in lower smoke levels as compared with other CCS due to improved air-fuel mixing because of better turbulence. In addition it may lower the smoke levels. TCC also resulted in nearly same results as that of RCC. Smoke of BRO operation were 49, 48, 47 and 47 HSU with HCC, CCC, TCC and RCC respectively against 45 HSU for diesel at 210 bar at 80% load. HC and CO variation with different CCS is depicted in Fig. 3.5 and Fig. 3.6 respectively. Both showed increasing trend with load which is quite obvious due to more fuel injected. RCC showed lower emissions followed by TCC, CCC and HCC. The reason could be better combustion on account of homogenous mixture formation.

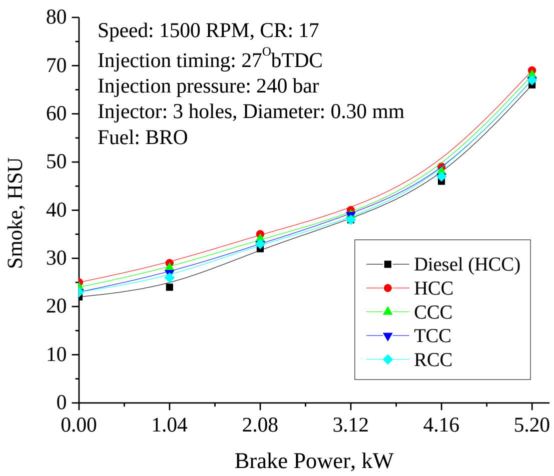

Fig. 3.4 Effect of CCS on smoke opacity with BRO

HC of BRO operation were 43, 41, 39 and 38 ppm with HCC, CCC, TCC and RCC respectively against 36 ppm for diesel at 210 bar at 80% load. CO of BRO operation were 0.145, 0.142, 0.14 and 0.135 vol. % with HCC, CCC, TCC and RCC respectively against 0.13 vol. % for diesel at 210 bar at 80% load. NOx emission also increased with load due to higher combustion temperature prevailed. NOx level was higher at 100% load as compared to 80% load. NOx of BRO operation were 1210, 1217, 1225 and 1231 ppm with HCC, CCC, TCC and RCC respectively against 1242 ppm for diesel at 210 bar at 100% load.

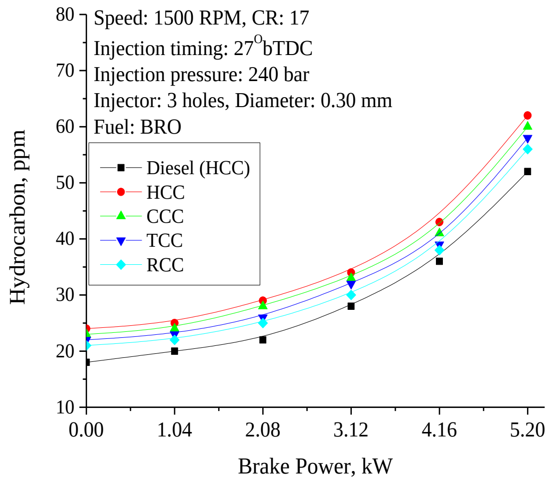

Fig. 3.5 Effect of CCS on HC with BRO

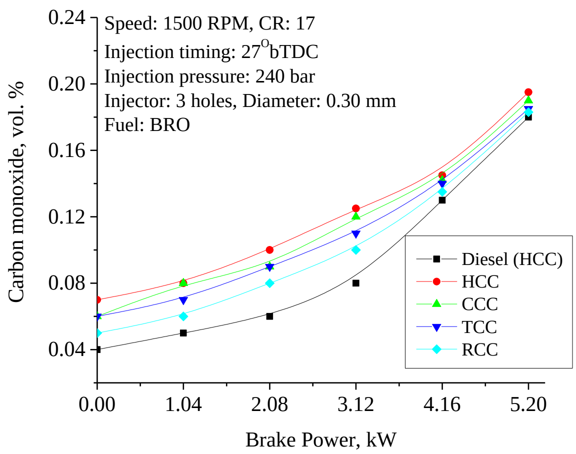

Fig. 3.6 Effect of CCS on CO with BRO

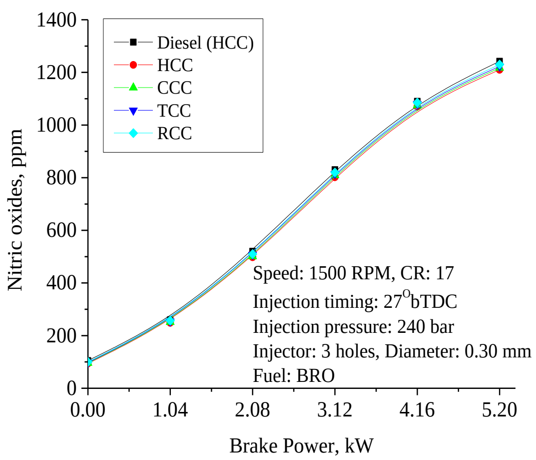

Fig. 3.7 Effect of CCS on NOx with BRO

3.3.3 Combustion characteristics

Effect of CCS on ignition delay (ID), combustion duration (CD), peak pressure (PP) and heat release rate (HRR) are provided in Fig. 3.8 to Fig. 3.11. It can be seen that both ID and CD of the BDFs were higher than the diesel. However, the ID found lower at 100% load in comparison with 80% load and on the other hand the CD was higher at 100% load as compared to 80% load. As the engine power output increased the amount of fuel supplied also increased. Subsequently it leads to increase in-cylinder gas temperature. The increase in temperature lowered ID while more quantity of fuel injected increased CD. RCC showed lower ID and CD as compared to other CCS due to better burning with higher PP and HRR.

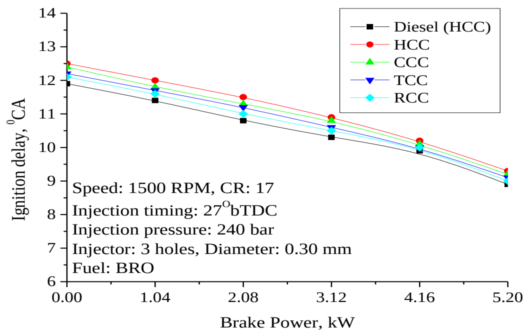

Fig. 3.8 Effect of CCS on ignition delay with BRO

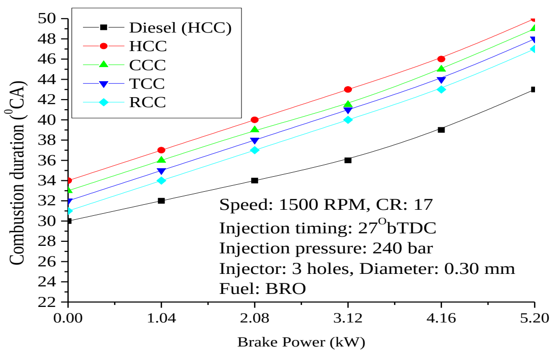

Fig. 3.9 Effect of CCS on Combustion durationwith BRO

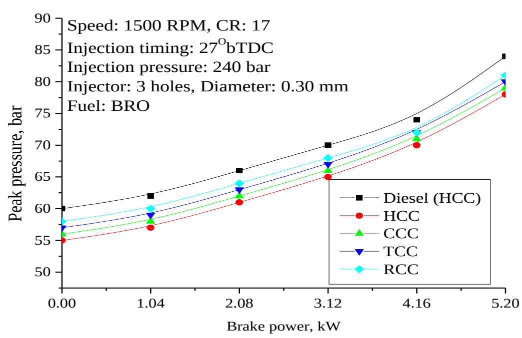

Fig. 3.10 Effect of CCS on peak pressure with BRO

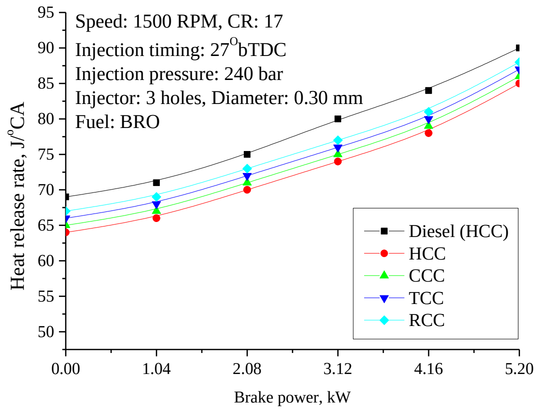

Fig. 3.11 Effect of CCS on HRR with BRO

4. Conclusions

The tests conducted on diesel engine concludes the following at IT of 27°bTDC, 240 bar IOP with RCC:

- Maximum BTE for BRO was 28.8% at 80% load.
- Smoke of BRO operation was 47 HSU with RCC against 45 HSU for diesel at 210 bar at 80% load.
- Lower HC of38 ppm was resulted at 80% load. CO emission of 0.135 vol. % was reported at 80% load.
- NOx resulted was 1182 ppm and 1231 ppm respectively at 80% and 100% loads.
- RCC showed lower ID and CD withhigher PP and HRR due to enhanced combustion.

Overall the diesel engine yield higher BTE and lower emissions at IT of 27°bTDC, 240 bar IOP and RCC.

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