PERFORMANCE OF BIODIESEL POWERED DIESEL ENGINE WITH DIFFERENT INJECTION STRATEGIES

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Abstract
The compression ignition (CI) engine is robust and deliver better performance with diesel and biodiesels. Rubber seed oil biodiesel (BRO) was tested for its feasibility as CI engine fuel. Exhaustive investigations were performedto study the effect of fuel injection timing (IT) and fuel injector opening pressure (IOP)on the performance, emission and combustion characteristics. The selected fuel showed better performance with IT of 27° bTDC (before top dead center) and injector opening pressure (IOP) of 240 bar. At the optimum operating conditions BTE 27%, HC 43 ppm, CO 0.137 vol.%, NOx 1080 ppm at 80% load. Overall the diesel engine yield higher BTE and lower emissions except NOx at IT of 27°bTDC and 240 bar IOP.
Keywords:Rubber seed oil biodiesel (BRO); Injection strategies; Performance; Emission; Combustion.

1. Introduction

Fuels to run internal combustion (IC) engines and greenhouse gas (GG) emissions are the two major challenges of the worldwide. 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 by which biodiesel could be produced which are biodegradable and renewable [1,2]. Detailed biodiesel production and its application as compression ignition (CI) fuel have been discussed [3]. The edible oils to run CI engine is not encouraged as they are consumed by people [4-6]. The vegetable oils have serious engine fouling when used as CI engine fuel due to the incomplete fuel burning and thereby carbon deposition on the injector tip and valve seats [7]. At idling condition, CI engine run on jatropha biodiesel (JOME) showed increased specific fuel consumption (SFC) and oxides of nitrogen (NO_x)with lower amount of 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]. Experimental test with biodiesel B10 and B20 at 100% load showed lower brake power (BP) and higher SFC as compared to diesel due to the increased frictional losses and increased time for heat transfer to the cylinder wall[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]. The experimental work with waste cooking oil B50 obtained from restaurants showed increased BTE, reduction in hydrocarbon (HC), carbon monoxide (CO) with higher NO_x emissions [12].Injector opening pressure (IOP) and combustion chamber (CC) shapes 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 at higher IOP [13].Uppage oil methyl ester (UOME) run diesel engine was studied and results showed that toriodal CC (TCC) was best at fuel IT of 19° bTDC to yield good performance [14]. The waste plastic oil with fuel IT of 14° bTDC resulted in lower NOx, CO and HC with higher efficiency, carbon dioxide (CO_2) and smoke levels at all the test conditions [15].Polanga biodiesel gave a maximum cylinder pressure (PP) (6.61 bars higher than that of mineral diesel) [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]. Solid waste converted fuel could be a better choice to drive CI engine at optimized IT [20]. Some authors also used Blend to operate CI engine [21].

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 BRO.Therefore, an experimental study was conducted on diesel engine to study the performance of BRO powered diesel engine with different IT and IOP.

2. Methodology

2.1. Fuels Used

In the present work, BRO was used. The properties of BRO are given 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 best BTE. The injector used had 3 holes of 0.3 mm orifice size. Figure 1 depicts 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. 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 [22, 23]. Hartridge smoke meter and five-gas analyzers (A DELTA 1600 S-non dispersive infrared analyzer) were used for gas analysis.

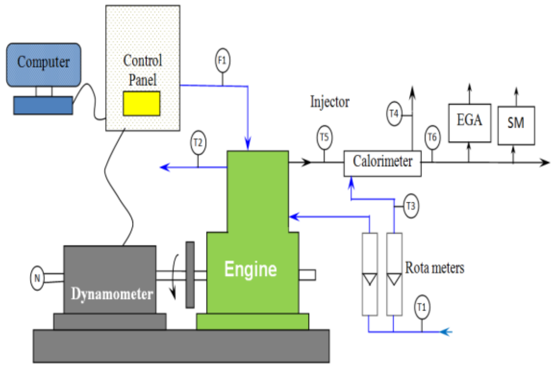

Fig. 1 CI engine test rig used for the present experimental work

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

Exhaustive investigations were performedto study the effect of IT and IOPon the performance, emission and combustion characteristics of BRO fuelled CI engine. The results of CI engine run on BRO 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 Performance Parameter

Fuel IT effect on BTE of diesel engine operation with BRO is as shown in Fig. 3.1.At 80% load, maximum BTE of 30.25%was obtained with diesel at a static IT of 23° bTDC. BRO showed higher BTE for static IT of 27° bTDC followed by static IT of 23° bTDC andstatic IT of 19° bTDC, this might be caused by lower energy content of the fuel, poor combustion quality and higher fuel utilization for the same power output. Due to higher viscosity and poor volatility, mixture formation and succeeding combustion deprived could also be a reason for lower BTE. BTE with BRO at 27° bTDC for 80% load was 25.27%.

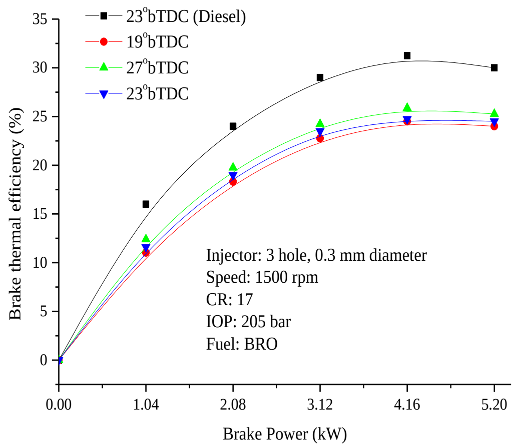

Fig.3.1 Effect of injection timing on brake thermal efficiency for BRO

3.1.2 Emission Parameters: smoke, HC, CO and NOx

Fuel IT effect on smoke emission for diesel, BRO is shown in Fig. 3.2. Formation of smoke is a process conversion of hydrocarbon fuels molecules into soot particles. BRO emitted more smoke opacity than diesel due to emission of higher HC molecules. Advance in IT to 27°bTDC decreased smoke level due to increase in BTE. The smoke opacity with BRO operation was minimum at IT of27° bTDCas compared to other two IT. Smoke emission value with BRO operation at 27° bTDC was 54 HSU,whereas for diesel smoke density was49 HSUfor 80% load.Increased HC and CO emissions trend for BRO were noticed for all IT tested as shown in Fig. 3.3 andFig. 3.4, this is caused by the decreased combustion on account of poor spray character of BRO leading to improper mixing.HC emission value with BRO operation at 27° bTDC was 46 ppm,whereas for diesel HCwas40 ppmfor 80% load.CO emission value with BRO operation at 27° bTDC was 0.16 vol. %,whereas for diesel COwas0.1 vol.%for 80% load.

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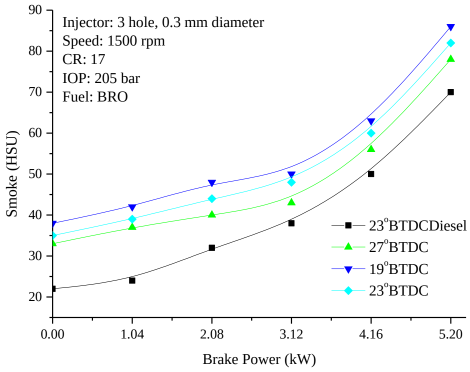

Fig. 3.2 Effect of injection timing on Smoke emissions for BRO

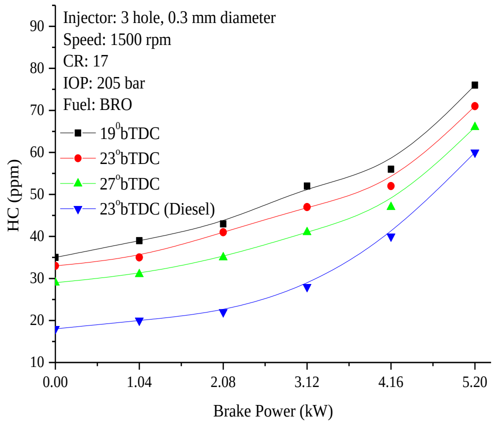

Fig. 3.3 Effect of injection timing on HC emissions for BRO

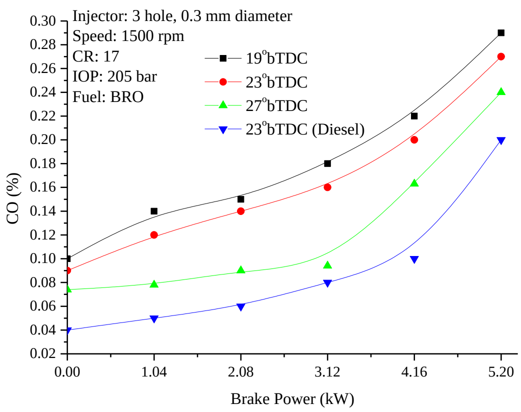

Fig. 3.4 Effect of injection timing on CO emissions for BRO

Variation in NOx is shown in Fig. 3.5. NOx was higher with diesel as compared to BROdue to lower ignition delay (ID), quick premixed heat release and higher combustion temperature.NOx value with BRO operation at 27° bTDC was 1085 ppm,whereas for diesel NOxwas1098 ppmfor 80% load.

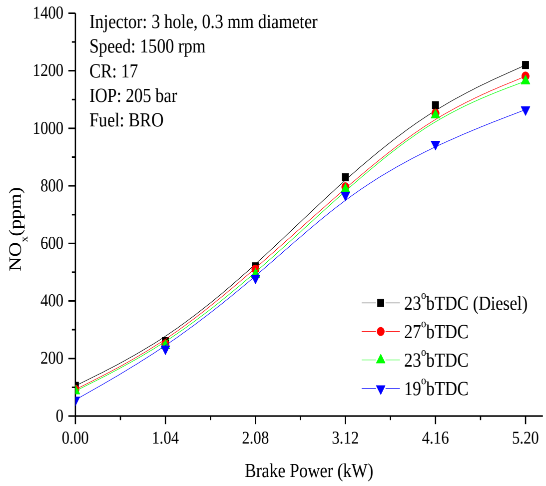

Fig. 3.5 Effect of injection timing on NO_x emissions for BRO

3.1.3 Combustion Analysis

Figure 3.6 and 3.7 shows IT effect on in cylinder pressure variation and HRRvariation with crank angle at load of 80% for BRO. Biodiesel showed lower PP and HRR as compared to diesel due to slower combustion and late mixing of air and fuel. Advanced IT showed higher PP and HRR due to more homogeneous mixing and resulting better combustion.

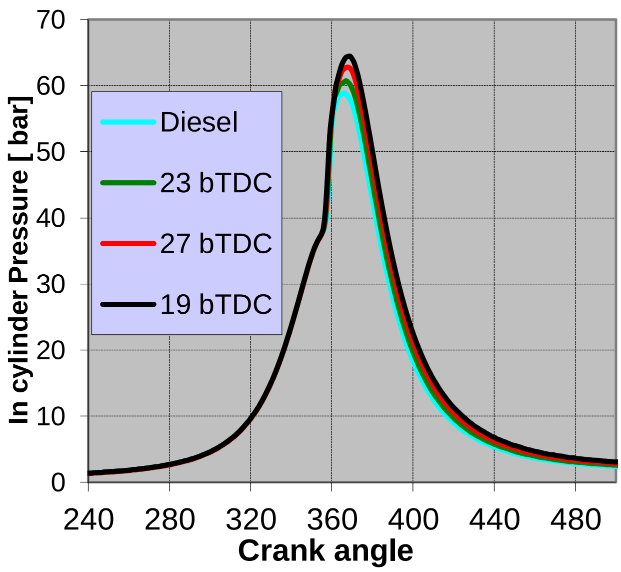

Fig. 3.6 Effect of IT on in cylinder pressure variation for BRO operation at 80% load

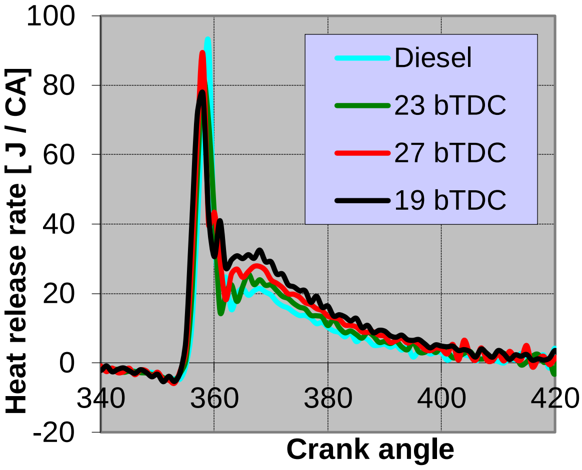

Fig. 3.7 Effect of Injection timing on heat release rate for BRO operation at 80% load

3.2 Effect of Injector Opening Pressure

IOP effect on engine performance with BRO was reported in this section. IOP varied from 220 to 250 bar. The part load (80% load) and full load test results are presented for analysis and discussions. IT was kept at 27°bTDC.

3.2.1Performance

Brake power effect on BTE for injected biodiesels at different IOPis shown in Fig. 3.8. Among all the IOP tested, the greatest BTE observed at 240 bar. This is because at this IOP, atomization, spray pattern and injected fuel mixing with air are comparatively better. Enhanced combustion improved the BTE. The maximum BTE for BRO was27% at 80% load.

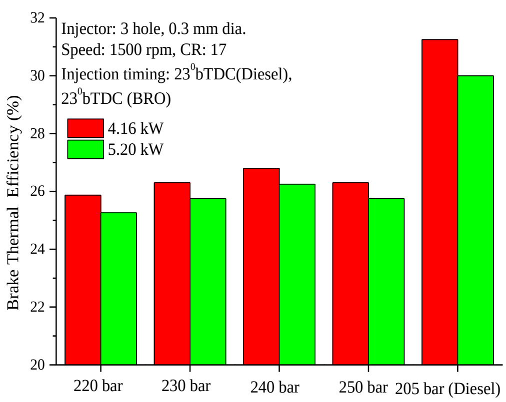

Fig. 3.8 Effect of IOP on BTE for BRO

3.2.2 Emission Parameters

In this section different emission parameters like variation in HC, CO and NO_X were studied for injected biodiesels. Figures 3.9 to 3.11 shows the effect of brake power on HC, CO, NOx emission at different IOP.A significant drop in HC and CO emission is observed at 240 bar IOP because of better combustion and enhanced atomization. At IOP 240 bar due to decreased ignition delay (ID), the performance in terms of higher efficiency and lower emissions were reported. Lower HC of 43 ppm was resulted at 80% load. CO emission of 0.137 vol. % was reported at 80% load. NOx emission increased with pressure and found maximum at 240 bar at 100% load. NOx resulted was 1080 ppm and 1148 ppm respectively at 80% and 100% loads.

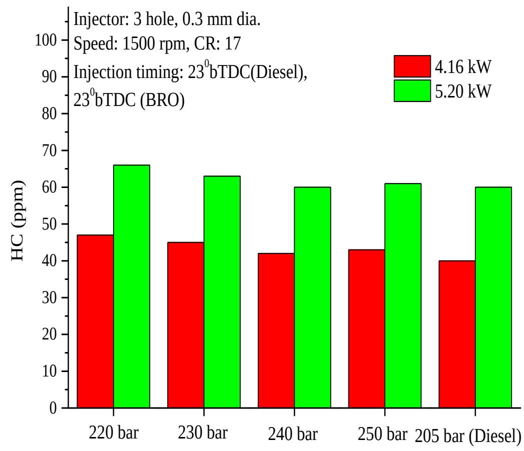

Fig. 3.9 Effect of IOPon HC emissions for BRO

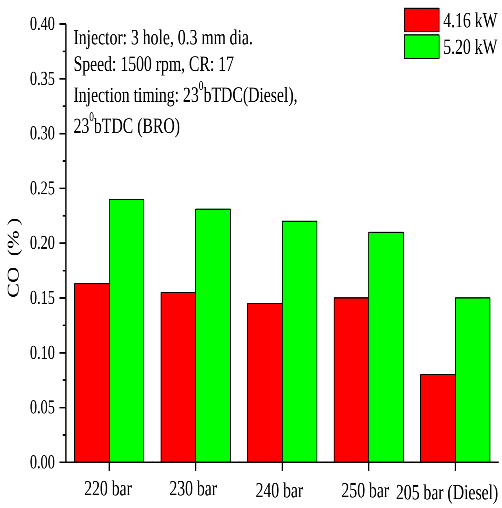

Fig. 3.10 Effect of IOP on CO emissions for BRO

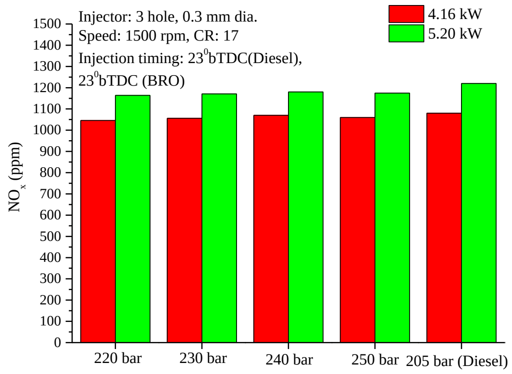

Fig. 3.11 Effect of IOP on NO_X emissions for BRO

4. Conclusions

The tests conducted on diesel engine with biodiesel concludes the following:

- The engine operation was smooth with biodiesel (BRO).
- The engine yielded better results with IT of 27obTDC and 240 bar IOP.
- Maximum BTE for BRO was 27% at 80% load.
- Lower HC of 43 ppm was resulted at 80% load. CO emission of 0.137 vol. % was reported at 80% load.
- NOx resulted was 1080 ppm and 1148 ppm respectively at 80% and 100% loads.

Overall the diesel engine yield higher BTE and lower emissions at IT of 27obTDC and 240 bar IOP.

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