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INFLUENCE OF FIP ON CRUDE RICE BRAN BIODIESEL FUELLED DICI ENGINE

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ABSTRACT

Methyl ester of crude rice bran oil (CRME) is an underutilized non-edible biodiesel which is abundantly produced in the form of crude rice bran oil in India and most of the Asian countries. This study evaluates the performance, emission, and combustion characteristics of a naturally aspirated direct injection compression ignition (DICI) engine which is fuelled with, high speed-diesel (HD), B20R (20% CRME blended with 80% diesel fuel) operated under 80% load and full load for fuel injection pressures (FIP) from 200bar to 240bar with increment in a step of 10bar at standard injection timing (SIT) 23^o before top dead centre (bTDC), at rated speed of 1500 rpm. Finally at the end, the test results showed improved results for B20R in terms of brake thermal efficiency and emissions such as smoke opacity, hydro carbons (HC), carbon monoxide (CO), and nitrogen oxides (NOx) at 230bar FIP.

Keywords: DICI, CRME, HD, FIP, SIT, smoke opacity.

1. INTRODUCTION

The energy is essential for human beings to develop economically, socially to improve the quality of life. With modernization and industrialization the world's energy demand is growing at a rapid rate and which changes its attention to focus on alternative fuels even though the cost is higher than conventional petroleum fuels. Moreover, there is a need to curb the air pollution effectively by means of study on conventional diesel engine with the use of alternative fuels. Since, from the last three decades a lot of efforts taken by some researchers to commercialize various alternative bio fuels such as soya bean, rapeseed oil, palm oil, sunflower oil, karanja, jatropha, polanga, rice bran, moringa oleifera, uppage etc., and animal fat, methanol, ethanol, compressed natural gas, biogas, liquid petroleum gas, hydrogen.

Vegetable oils are edible or non- edible type. In 1900 at the World Exhibition the inventor of diesel engine 'Rudolf Diesel' demonstrated the use of straight vegetable oils. In those days an abundant supply of petro-diesel was available hence the research activities on vegetable oil were not seriously pursued. However, recently it received more attention when it is found that conventional petroleum fuels are depletion speedily. Therefore, it is necessary to identify environment-friendly renewable substitutes to meet the demand [8]. Biodiesel fuel is the most promising alternate fuel to petro-diesel because of its comparable physico-chemical properties. In addition, it is biodegradable, nonflammable, non toxic green fuel. Biodiesel offers as a renewable feed stock and as for as environmental concern it is clean burning free sulphur less pollutant fuel. Subramanian *et al*. [1] showed that some of the non-edible oil sources and their potential in India are given in Table-1. The neat biodiesel and its blends fuelled diesel engine showed carbon monoxide decreased by around 3-15% [2-4], unburnt hydrocarbons by around 6-40% [5-7] and smoke emissions is about to 45% [8,9] compared to ULSD (ultra low sulphur diesel). However, NOx emission levels raised by 26% [10-12], brake specific fuel consumption increased by about 6-15% [13, 14], and decreased in brake thermal efficiency by up to 9% [15, 16]. Usually biodiesels produce less HC and CO than diesel fuel [17]. Sahoo *et al*. [18] reported that Polanga biodiesel B100 has improved thermal efficiency of the engine by about 0.1%, and Smoke, NOx emissions reduced by 35% for B60, 4% for B100 respectively as compared to neat petro-diesel. Sahoo *et al*. [19] showed that maximum power obtained for 50% jatropha biodiesel blend and reduced smoke levels for all biodiesels and their blends when compared to diesel fuel. Agarwal *et al*. [20] reported that CO, HC, and PM emissions are lesser for rice bran biodiesel but NOx are higher compared to mineral diesel. Palash *et al.* [21] concluded that the biodiesel blends have beneficial in terms of HC, CO and PM emissions but adverse results on NOx emissions. Similar trends were reported by other researchers [22, 23]. Jindal *et al*. [24] investigated the effect of varying injection pressure running on jatropha methyl ester fuelled DI engine and found to be BTE increased and BSFC decreased with increase in injection pressure. Subhan Kumar Mohanty *et al*. [25] run the DI diesel engine with neat rice bran oil methyl ester and found that the power was 4% lower , higher brake specific energy consumption ,lower BTE while lesser Smoke capacity as compared to diesel. Narasimha *et al*. [26] reported the DI diesel engine which operated with rice bran biodiesel-ethanol and ethyl hexyl nitrate (EHN) blends as fuel, exhibited higher BTE while the CO, HC and NOx emissions were lower when compared to neat diesel. Venkata Subbaiah *et al*. [27] found that the highest brake thermal efficiency was 22% for diesel- rice bran biodiesel-ethanol blends. The CO and smoke emissions reduced significantly while hydrocarbons, oxides of nitrogen and carbon dioxide emissions increased with higher percentage of ethanol in diesel-biodiesel-ethanol blends. Shailendra Sinha *et al*.

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[28] found that rice bran oil methyl ester–diesel blends operated DI diesel engine exhibited superior thermal efficiency about 1.5% to 3% and emits lower CO, Smoke opacity emissions while HC, NOx emissions were higher when compared to baseline data of mineral diesel fuelled engine. Saravanan *et al*. [29] found that the 20% crude rice bran methyl ester-diesel blend operated DI diesel engine exhibited 2% higher brake specific fuel consumption, 35% lower smoke intensity and18% higher NOx emission by an average than diesel. Saravanan *et al*. [30] found that the crude rice bran methyl ester-diesel blends operated DI diesel engine (4.4kW) exhibited lower peak heat release rates and slightly higher peak pressures than that of diesel. And also 25 % RBO shows better results than other blends of RBO. Qi *et al*. [31] demonstrated on soy been biodiesel fuelledV6 diesel engine that the BSFC was increased slightly while NOx emissions decreased with retarded injection timing. Kannan *et al*. [32] examined the effect of injection timing and injection pressure on WCO biodiesel fuelled DI diesel engine. The combined effect of advanced injection timing and higher injection pressure improved the brake thermal efficiency while nitric oxide (NO) and smoke emissions were decreased. Gumus *et al*. [33] conducted experiments on canola oil methyl ester-diesel fuel blends fuelled DI diesel engine and found that the peak cylinder pressure, heat release rate, combustion performance, and NOx, CO_2 emissions decreased while HC, CO and smoke number emissions increased with retarded injection timing. However, it is evident from the literature review, a very few research work has been carried out on raw rice bran oil methyl ester particularly the effects of fuel injection pressure on the performance, emission and, combustion characteristics of DICI engine. In the present study, hence, experimental analysis is carried out on the influence of injection pressure on the performance, combustion and emission characteristics of DICI engine operated with B20R and HD as test fuels extracted from the germ and inner husk of fresh rice bran, which is a by-product obtained during the grinding of paddy. The estimated potential yield of raw rice bran oil is about 8 million metric tons if all rice bran produced in the world were to be harnessed for oil extraction. The high FFA rice bran oil is an underutilized non-edible vegetableoil, which is available in large quantities in rice cultivating countries such as India, China and Japan. Crude rice bran biodiesel has been derived from crude rice bran oil through transesterification (alkaline-catalytic) process. Some of the important properties of neat crude rice bran oil methyl ester and high speed diesel fuels were given in Table-2. Most of the properties of CRME are comparable to high speed petro-diesel fuel.

2. EXPERIMENTAL TEST SETUP AND METHOD

The test fuel samples in the present study were B20R and HD. Experimental set up is shown in Figure- 1. It consists of naturally aspirated single cylinder, 4-stroke diesel engine equipped with eddy current type dynamometer for loading. The setup contains all necessary arrangements to measure for in cylinder pressure and crank-angle etc. and the specification of engine shown in table 3.The performance parameters BP, BTE were evaluated by measuring the observations viz. speed, load, and rate of fuel consumption with instruments provided on the engine setup. Each test was conducted after attaining steady state condition of engine. The performance parameters were calculated from the fundamental relations between

Table-1. Potential of non-edible oil sources in India.

Oil source	Botanical name	Potential quantity*(T/Y)	Current utilization (T/Y)	% of utilization
Rice bran	Oryza sativa	474000	101000	21
Sal	Shorea robusta	720000	23000	3
Neem	Melia azadirachata	400000	20000	5
Karanja	Pongamia-pinnatta	135000	81000	6

*T/Y: Tons/Year

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Table-2. Properties of fuels.

Property	HD	CRME
Density@15° C - kg/m^3	840	875
Lower Heating Value - kJ/kg	43000	38400
Kinematic Viscosity@40°C – cSt	2.5	4.9
Flash point (°C)	50	168
Stoichiometric Air/Fuel ratio	14.7	13
Cetane Number	48	56

Table-3. Specifications of test engine.

Item	Details
Make	Kirloskar TV1, Single cylinder, four stroke DI diesel engine(naturally aspirated)
Injector opening pressure	200 bar
Rated power	5.2 kW (7 HP) @1500 RPM
Cylinder Bore	87.5 mm
Stroke length	110 mm
Compression ratio	17.5 : 1
Standard Injection Timing(SIT)	23° bTDC

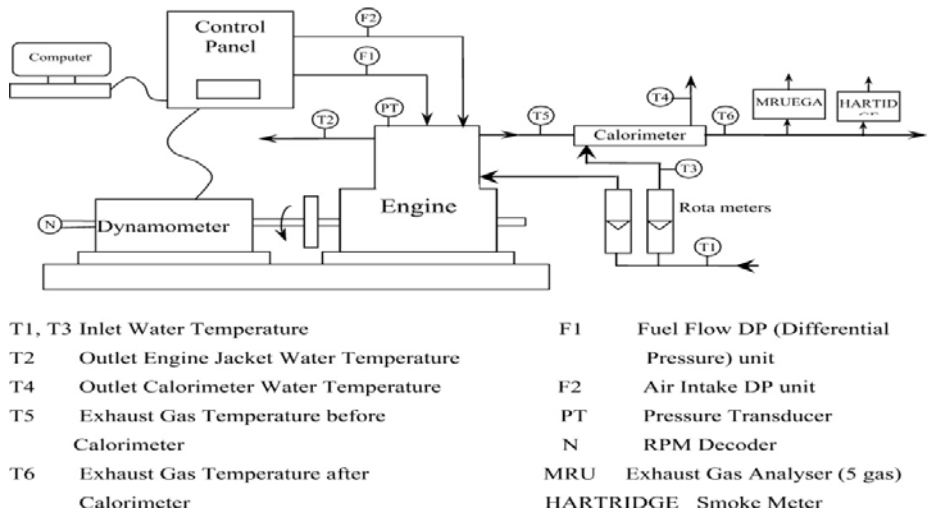

Figure-1. Schematic view of engine test setup.

these measurements. The HC, CO, NOx and Smoke emissions are directly measured from and Exhaust Gas analyser and Smoke Meter, respectively.

3. RESULTS AND DISCUSSIONS

The engine tests were carried out with test fuels B20R and HD in order to study their effect on engine performance, combustion and emission parameters at varying FIP from 200bar to 240bar in a step of 10bar gradual increment. The diesel engine performance parameter such as BTE and combustion characteristics for B20R represented graphically in Figures 2(a-b) and 7(a-b). The exhaust emissions like CO, unburnt HC, NOx and smoke opacity were measured directly which represented graphically in Figures 3(a-b) to 6(a-b).

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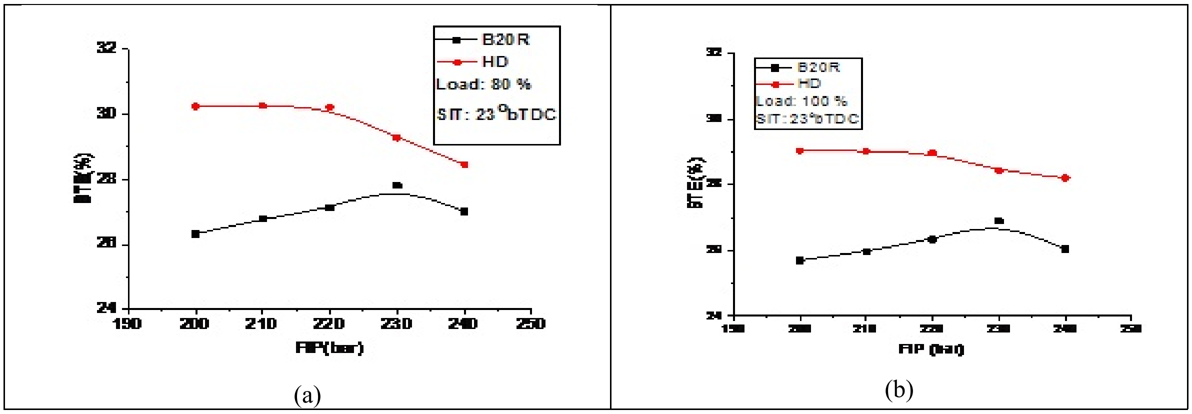

Figure-2. BTE vs. FIPs for B20R vis-à-vis HD at load (a) 80% (b) Full.

3.1 Brake thermal efficiency (BTE)

Figure-2 demonstrates that the BTE of B20R lower than HD for all the FIPs (200-240 bar). The maximum brake thermal efficiency obtained at 230bar FIP for B20R. The BTE for B20R was increased by 1.48%, 1.19 % at 80% load and full load, when compared to HD, respectively. It is noted that the increment in injection pressure does not affect significantly on improvement of BTE.

3.2 Carbon monoxide (CO)

The carbon monoxide is appeared in the exhaust indicated as lost of chemical energy [34, 35]. Air-fuel mixing is improved with the increasing FIP which caused to better combustion of the fuel thereby reduction in CO emissions [36]. Figure-3(a-b) shows, the lowest CO emissions for B20R, HD fuel at 230bar, and 220 bar FIP as 0.074 %(v), 0.084 %(v) at 80% load while it was 0.098% (v), 0.127 % (v) at full load, respectively. However, CO emissions decreased with increasing FIP up to 230bar and then increased. These CO results are in similar with literature published [37].

3.3 Hydro carbons (HC)

Figure-4a-b demonstrates that the variation of unburnt hydrocarbon (HC) emission for B20R, HD fuel at 80% and full load conditions. The figure 4b shows the HC emissions were lower for B20R relatively to HD for the entire range FIP. It may be due to better fuel-air mixing with the increasing FIP which leads to better combustion thus lower HC emissions. The HC emissions decreased with FIP up to 230bar and then increased. These variations are comparable and in agreement with literature published [37].

3.4 Nitrogen oxides (NOx)

Figure-5 a-b shows the variation of NOx emission for two emissions for different loads with different FIPs. With increasing of fuel injection pressure which improves the spray pattern to vaporize quickly thereby more complete combustion thus higher the gas cylinder temperature thereby increasing NOx emissions. The NOx emissions are higher for B20R than HD fuel for the entire range of FIP except at 230bar for 80% load. The results are in line with literature published [37].

3.5 Smoke emissions

Figure-6 (a-b) represents the smoke emissions variation with FIPs for B20R, HD fuels at 80% and full load, respectively. The Smoke opacity of B20R, HD was decreased with FIP increased. The lowest smoke opacity for B20R, HD observed to be 33HSU, 31HSU and 47HSU, 54HSU at 80% load, full load, respectively. This may be attributed to reduction of fuel drop let size of the injected fuel with increasing fuel injection pressure thus better air- fuel mixture formation during injection period thereby less smoke. This trend is in agreement with published work [37].

3.6 Combustion characteristics

The combustion analysis of B20R fuel, with respect to different FIPs (200-240bar) compared to base line data of HD (200bar), at full load can be seen from the Fig.7a-b. Figure-7(a) shows the heat release rate in the premixed phase lower for B20R for all FIPs relatively to HD and the lowest heat release rate can be seen at 240bar. Figure-7(b) shows the variations of cylinder pressure with crank angle. The highest peak cylinder pressure observed at 230bar for B20R.

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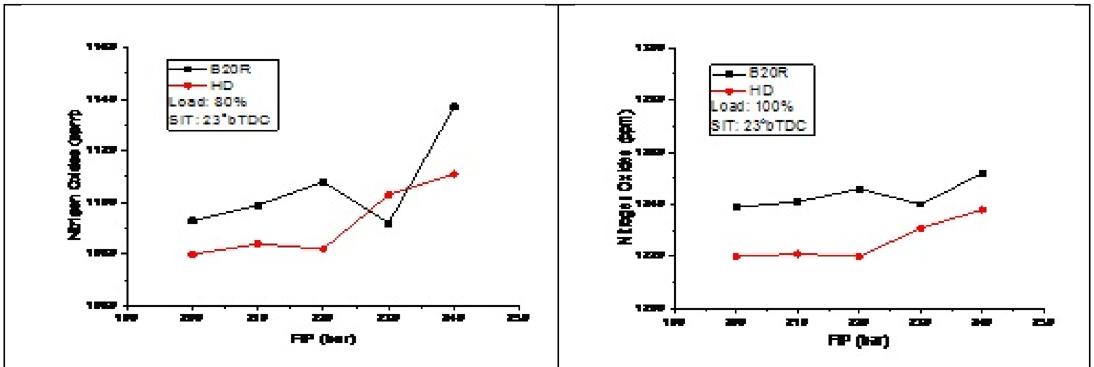
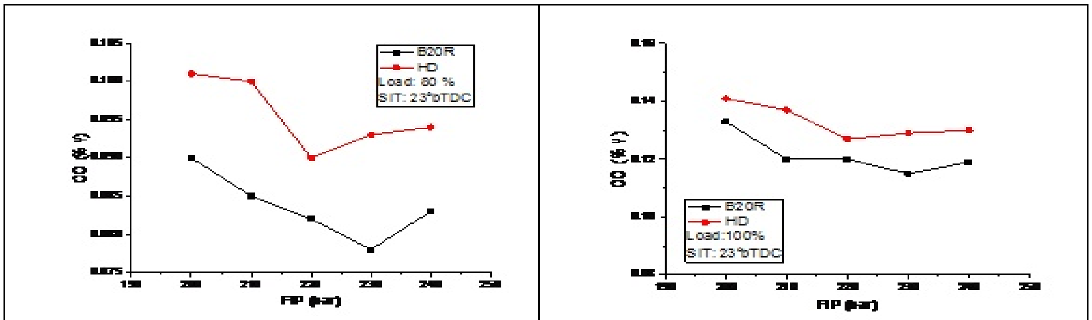


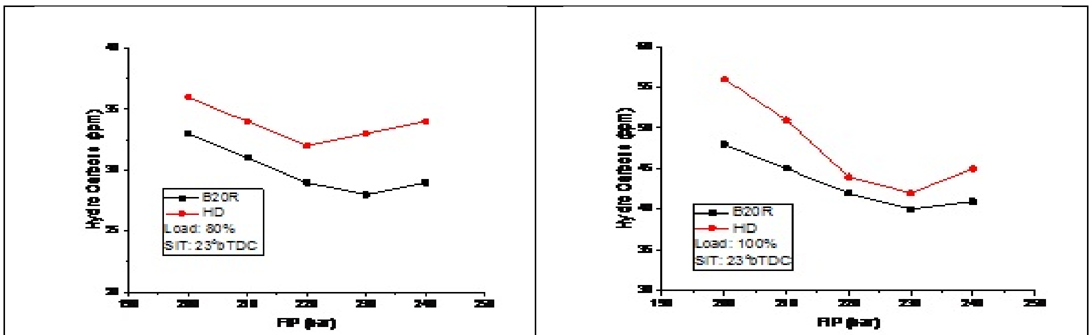
(a) (b)

Figure-3. NOx vs. FIPs for B20R vis-à-vis HD at load (a) 80% (b) Full.



(a) **(b)**

Figure-4. CO vs. FIPs for B20R vis-à-vis HD at load (a) 80% (b) Full.



(a) **(b)**

Figure-5. HC vs. FIPs for B20R vis-à-vis HD at load (a) 80% (b) Full.

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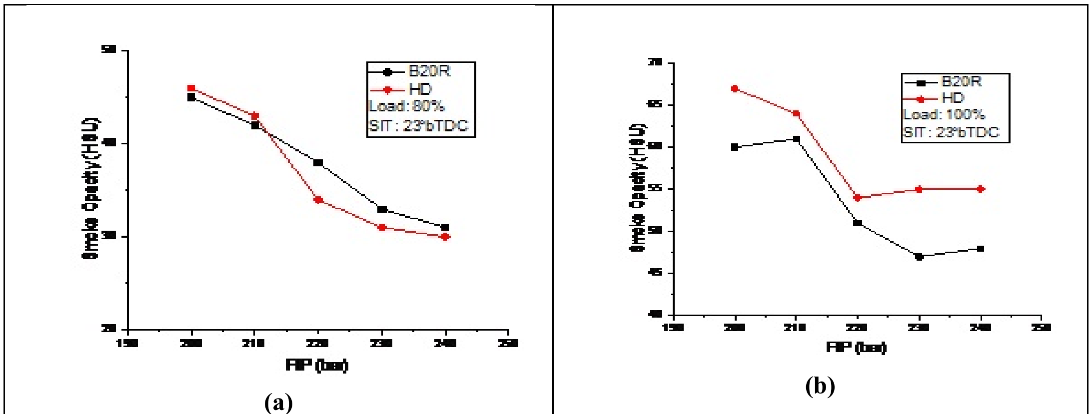

Figure-6. Smoke vs. FIPs for B20R vis-à-vis HD at load (a) 80% l(b) Full.

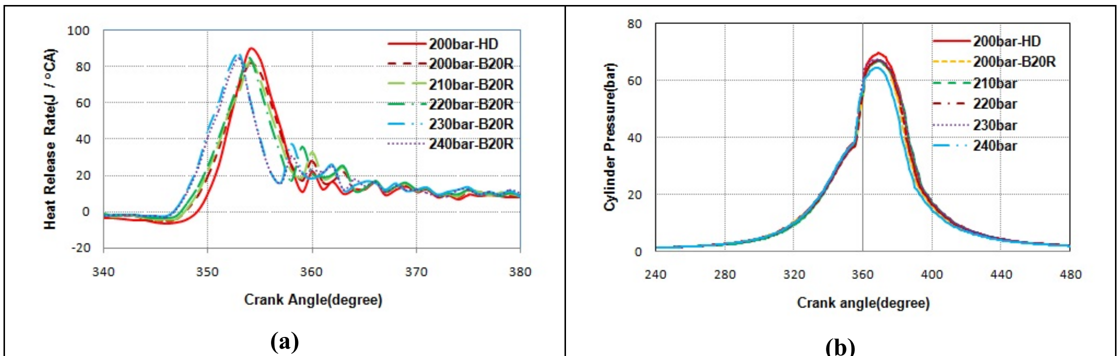

Figure-7. Combustion characteristics for B20R vis-à-vis HD at Full load for different FIPs (a) HRR vs. Crank Angle (b) Cylinder Pressure vs. Crank Angle

4. CONCLUSIONS

In the present study, DICI engine was successfully operated with crude rice bran oil methyl ester (CRME) blend B20R and HD at two different loads (80%, Full load) for different FIPs (200-240bar). The following conclusions were drawn from the analysis of experimental result.

- BTE for B20R blend was comparable to high speed - diesel and the maximum
  BTE was found at 80% load; however BTE increased with FIPs for both test fuels.
- The lowest peak HRR was observed at 240bar while the highest peak cylinder pressure was at the230bar pressure for B20R fuel but lower than HD.
- B20R has lower CO emissions in comparison to high speed-diesel. However the
  CO emissions were low at 230bar FIP.
- HC emissions of B20R blend lower than HD. The lowest HC emissions noted at 230bar.
- NOx emissions relatively higher for all FIPs except at 230 bar for B20R fuel.
- Smoke opacity of B20R blend was lower than diesel

It is suggested that up to 20% blend of crude rice bran biodiesel can be utilized CI engine without any evident issues in terms of performance, combustion and emission. On the whole, at 230bar FIP, B20R blend fuel has showed better results in terms of BTE, and emissions.

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