EXPERIMENTAL INVESTIGATION ON THE PERFORMANCE, COMBUSTION AND EMISSION CHARACTERISTICS OF A VCR DI DIESEL ENGINE WITH METHYL ESTER OF MANGO SEED OIL

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Abstract

Energy crisis and environmental degradation are the major current energy issues which need to be tackled judiciously. Supplementing energy through biodiesel is a viable, sustainable and feasible option. In the present work, biodiesel (Mango Seed oil Methyl Ester (MSME)) extracted from mango seed oil by a transesterification process. The MSME is characterized for engine performance, combustion and emission analysis at various compression ratios (CR-14, 16, and 18) and fuel blends (B9, B18, B27, B36%, and Diesel). The brake thermal efficiency (BTHE) at CR18 is higher at full load condition for all blend ratios that may be due to lower brake specific fuel consumption (BSFC) and complete combustion of mixture with excess oxygen in the biodiesel. The BSFC is decreased on increasing brake power (BP) and CR. The exhaust gas temperature is decreased (3%) on increase in CR from 14 to 18. The cylinder peak pressures and net heat release rate are lower than that of diesel because of lower heating value. The hydro carbon (HC), carbon monoxide (CO), and carbon dioxide (CO_2) emissions decreases while increasing the compression ratio, however, nitrogen oxide (NO_x) emission is increased with CR for all fuel blends and these properties were progressively lower for higher concentration of biodiesel. Overall engine performance is optimum at CR of 18 for B18 fuel blend.

Index Terms: Mango seed oil methyl ester, Variable Compression Ratio (VCR) engine, Biodiesel, Performance, Emissions

I. INTRODUCTION

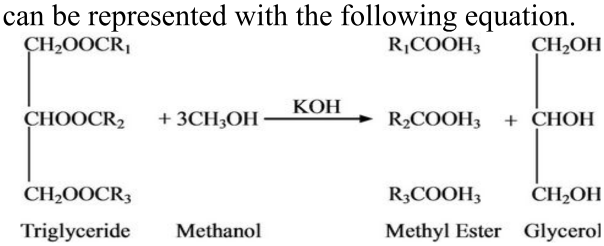
The demand on energy is increasing from day to day life due to the increase of economic activities and quality of life. All fossil fuels are hampered due to high population and non-renewability. For instance, India is heritage of many biological/environmental resources, however, importing crude petroleum products from Gulf countries. Therefore, it is necessary to develop the alternate energy sources. Extensive research is going on to find alternatives to Diesel fuel to preserve the global environments and to withstand the economic crisis. Oxygenated fuels produced from renewable sources, including alcohols and many other oxygenated compounds like biodiesel extracted from vegetable oils and kernels of different seeds. The biodiesel can be used as an alternative fuel for compression ignition (CI) engines, in which CI engines are reliable and economy. Biodiesel from karanja oil was used to investigate the performance and emission of an engine, in which emissions are reduced compared to base diesel [1]. Sanjay patil, used palm oil methyl ester on CI engine and studied the effect of compression ratio on peak pressure, net heat release rate, brake thermal efficiency and emissions, and found that at every compression ratio, increase in proportion of biodiesel decreases peak pressure and increases the BTHE [2]. Ramadhas et al. [3] used pure rubber seed oil, diesel and biodiesel blends as fuels in CI engines, in which the lower blends of biodiesel increases the brake thermal efficiency and reduce the fuel consumption. The exhaust gas emissions decrease with increasing the biodiesel concentration. Rehaman et al. [4] reported that the karanja biodiesel blends B20 and B40 reduces the exhaust emissions and increase brake power and BTHE. Sukumar Phuhan et al.[5] examined the performance and emission of Mahuva oil methyl ester in 4-stroke naturally aspirated engine, and found that thermal efficiency is nearer to diesel and emissions of CO, HC, NO_x and smoke were reduced by 58, 63,12 and 70%, respectively. Labeckas et al. [6] used rapeseed oil methyl ester (ROME) on engine and examined the effect of blends on the BSFC, in which BSFC at maximum torque (273.5 g/kW h) and rated power (281 g/kW h) for ROME are higher by 18.7%, and 23.2% relative to diesel. Similarly, different biodiesels for instance linseed oil, soybean, jatropha, cottonseed and palm oil [7-12] reported the performance and emission characteristics in Diesel engines. Barnwal et al., [13] discussed about projections of biodiesel production from natural vegetable oils in India. A maximum of 77% biodiesel is produced with 20% methanol in presence of 0.5% sodium hydroxide. Channapattana et al. [14] investigated the emission and performance of DI, CI engines for different CRs from 15-18 with biodiesel extracted from cholophyllum and inophyllum linn oil. For pure biodiesel, BTHE is 8.9% less than diesel at CR18, with major reduction of CO and HC emission. Rinu Thomas et al.[15] did experiments on VCR engine using gasoline and n-butanol blends at three CR (7:1, 8.5:1, 10:1) and observed that BTHE increases by increasing CR and improved part load efficiency and better anti knock characteristics. Hariram et al.[16] examined the influence of compression ratio on engine performance and emission of pure diesel, in which BSFC is increased with decreasing CR. Nagaraja et al. [17] investigated effect of compression ratio over the performance and emission characteristics of VCR engine fuelled with pre heated palm oil and diesel blends, in which the BP of blend O20 is 6% higher than diesel at higher CR and IMEP. The engine performance was found to be optimum when using O20 as fuel at CR 20:1 during the full load. Bhaskor J. Bora et al.[18] did their experiments using the duel fuel (diesel and raw bio gas) on VCR engine. CO and HC emissions under duel fuel mode found to be more than the diesel mode because of lower volumetric efficiency. Sivaramakrishnan studied experimental analysis on the performance of biodiesel over diesel and evaluated by response surface methodology to find out the optimized working condition [19].

The present study is aimed to investigate the effect of Mango Seed oil Methyl Ester (MSME) biodiesel on variable compression ratio (VCR) engine performance, combustion and emission. A single cylinder 4 stroke direct injection diesel engine has been used to measure the performance, combustion and emission using biodiesel and its blends with diesel.

II. MATERIALS AND METHODS

A. Biodiesel production

The process of transesterification is exchanging the organic group R″ of an ester with the organic group R′ of an alcohol. These reactions are catalyzed with the addition of catalyst (an acid or base). The above reaction accomplished with the help of enzymes. In this work, mango seed oil is transestirified [3,4,5] using different proportions of oil, methanol, and potassium hydroxide (KOH) in the ratio of 100:16:1,respectively, to have a better yield of bio-diesel. During the process, the mango seed oil molecule is chemically broken to form mango seed oil methyl ester (MSME). After transesterification, the resultant mixture was kept for 48 h thereafter separated the glycerol and MSME with help of separating funnel. The separated MSME was washed two times with distilled water get purified methyl ester of mango seed oil. The transesterification process can be represented with the following equation.



B. Biodiesel properties

The physical and thermal properties of the biodiesel blends and the Diesel fuel are summarized in Table-1. The representative values such as fire point, density, flash point, viscosity, cetane number and gross calorific value are measured for biodiesel and its blends at ETA LAB, Chennai.

Table 1: Fuel properties of diesel and biodiesel blends.

Properties	D100	B9	B18	B27	B36	Biodiesel B100
Flash point in ^{0} C	60	69	78	87	96	160
Fire point in ^{0}C	63	73	82	92	102	170
Density kg/m^3	830	839	848	857	866	929
Kinematic viscosity in cst at 40^{0}C	3.26	3.35	3.51	3.63	3.76	4.66
Calorific value in kJ/kg	42500	42225	41950	41674	41399	39442
Cetane number	51	-	-	-	-	48

A. VCR engine

Compression ratio is the key parameter in reciprocating engines. The concept of variable compression ratio promises improved engine performance and reduced emissions. The higher cylinder pressures and temperatures during the early part of combustion and small residual gas fraction owing to higher compression ratio give faster laminar flame speed. Therefore, the ignition delay period is shorter. Thus, at low loads, the greater the compression ratio, the shorter is the combustion time. Time loss is subsequently reduced. Therefore, fuel consumption rate is lower with high compression ratio at part load. The main feature of the VCR engine is to operate at different compression ratios, depending on the needs of the vehicle performance.

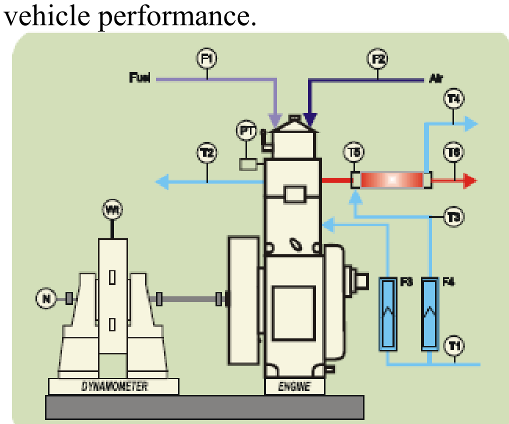


Fig.1 Experimental setup

B. Experimental Setup

In this study, a 5HP (3.5 kW) variable compression ratio 4-Stroke direct injection Diesel engine is chosen with compression ratios varying from 14 to 18 (shown in Fig.1). The air flow rate of engine is measured by mass flow sensor and the fuel consumption is measured by burette method. Loading is applied on the engine with the help of eddy current dynamometer. The experiment is carried out at different compression ratios (14,16,18) and different loads (0, 25, 50, 75% and full load). The obtained results are tabulated and presented in the form of graphs. the specifications of VCR engine are given in Table-2. Various sensors are utilized during the experiment to collect, store and analyze the data by computerized data acquisition system (IC Enginesoft). An exhaust gas analyzer (AIRREX HG-540) was employed to measure HC, CO, CO_2 and NO_X emissions.

Table 2: Specification of the variable compression ratio engine.

Product	Research Engine test setup
Engine	Single cylinder, 4 stroke, water cooled, stroke 110 mm, bore 87.5 mm, 661 cc. Diesel mode: 3.5 KW, 1500 rpm, CR range 12-18. Injection variation:0- 25^0 BTDC
Dynamometer	Type eddy current, water cooled, with loading unit
ECU	PE3 Series ECU, Model PE3-8400P, full build, potted enclosure. Includes premonitory & pe Viewer software.
Piezo sensor	Combustion: Range 350bar, Diesel line: Range 350 bar, with low noise cable
Crank angle sensor	Resolution 1 Deg, Speed 5500 RPM with TDC pulse.
Data acquisition device	NI USB-6210, 16-bit, 250kS/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	"IC Enginesoft" Engine performance analysis software
Rotameter	Engine cooling 40-400 LPH; Calorimeter 25-250 LPH

III. RESULTS AND DISCUSSION

A. Performance Characteristics

The major performance parameters such as brake power, BTHE, BSFC are evaluated for MSME, in which BSFC is an idle parameter for comparing the engine performance of fuels having different calorific values and densities.

(i) Brake power and brake thermal efficiency: Fig. 2a-c shows the variation of BTHE with BP for different compression ratios of 14, 16, and 18. BTHE is linearly increasing with increasing brake power for all the blends of MSME. It is clearly observed from Fig.3a that the BTHE is increasing [2,18,19] for blends of B9, B18, and B27, moreover, B18 and B27 shows the higher values i.e 6.77%, 4.4% than base diesel at CR18 with full load. In addition, B18 shows better BTHE than all the blends for all CR values. The possible reason for higher BTHE for biodiesel blends is due to some amount of oxygen in the molecules of biodiesel, which takes part in combustion and improves the complete combustion. It is observed that after certain limit with respect to the Diesel ester blend, the BTHE trend reversed and starts to decrease as a function of the concentration of blend.

(ii) Brake Specific Fuel Consumption: Fig. 2d-f shows the variation of BSFC with BP. BSFC as a function of load obtained during the operation on MSME-diesel blends and for all fuel is tested, in which, BSFC is higher at lower BP and load for all blends and decrease with increasing BP[3]. Fig. 3b shows the variation of BSFC with CR at full load and BSFC decrease when CR increases. For blend B18, the BSFC at full load for CR14, CR16, and CR18 are 0.32,0.31, and 0.3 kg/kWh, respectively.

(iii) Exhaust gas temperature: For a blend B18, variation of exhaust temperature with BP for different CRs is shown in Fig. 3c. EGT increases with BP for all CRs. In addition, EGT values are 3% low for CR18 compared with CR14 and CR16 [10].

A. Combustion Characteristics

(i) Cylinder pressure: The variation of cylinder pressure with crank angle for Diesel and biodiesel blends are shown in the Fig. 3d. it is observed that the peak pressure attains nearly at crank angle 20^0 after top dead centre (ATDC)[18]. The peak pressure for diesel fuel is nearly 80 bar whereas it is limited to 73 bar for all biodiesel blends, which may be higher heat content value of the Diesel than biodiesel.

(ii) Net heat release rate (NHRR): NHRR value is raised when combustion starts as shown in Fig. 3e. It is observed that the variation of combustion is not all uniform because of heterogeneous combustion in CI engines. The maximum heat release is nearly 70 J/deg at crank angle 10^0 BTDC [2].

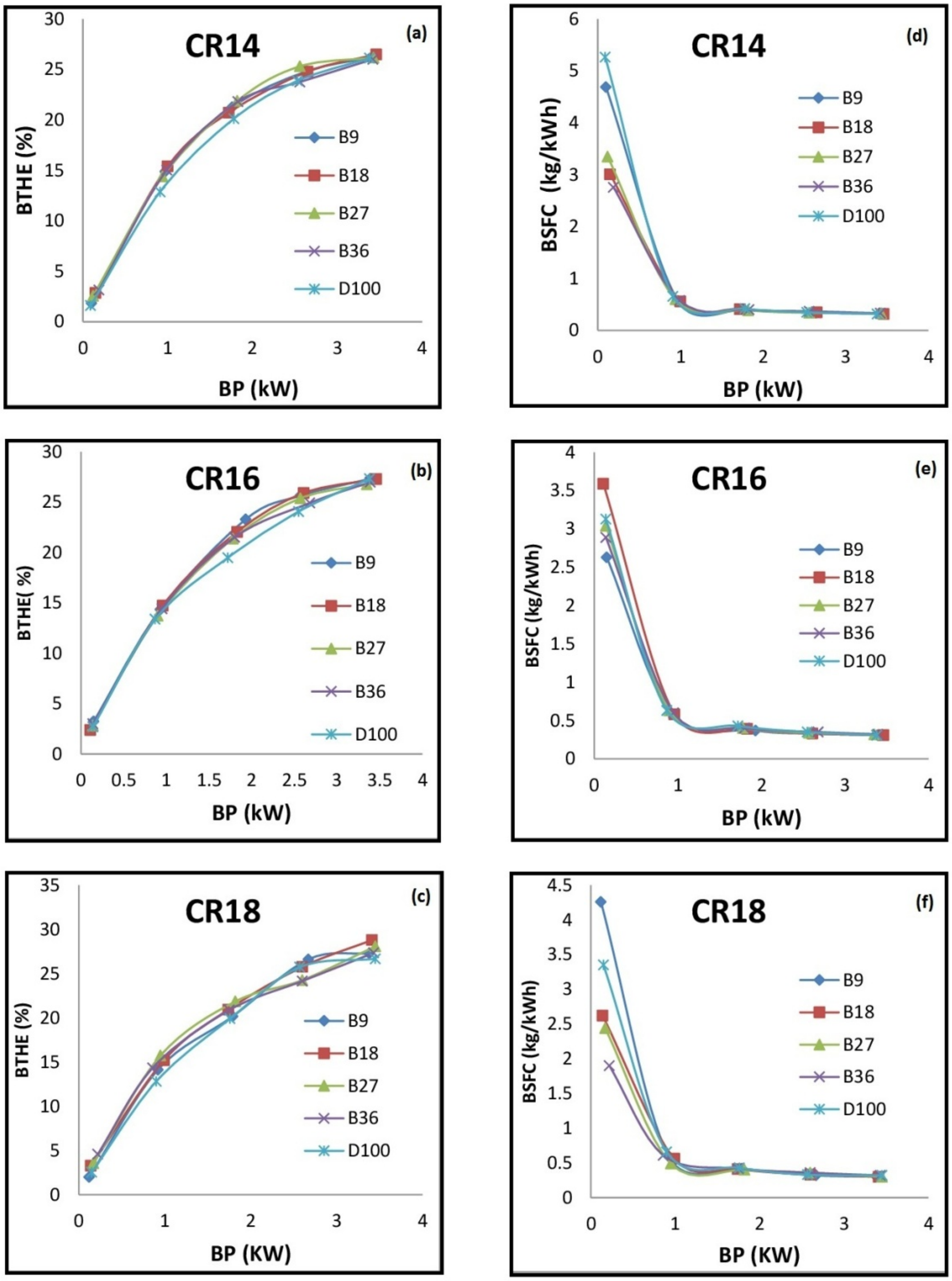


Fig.2 Variation of brake thermal efficiency with brake power for different blends (a-c) and variation of BSFC with BP for different blends (d-f)

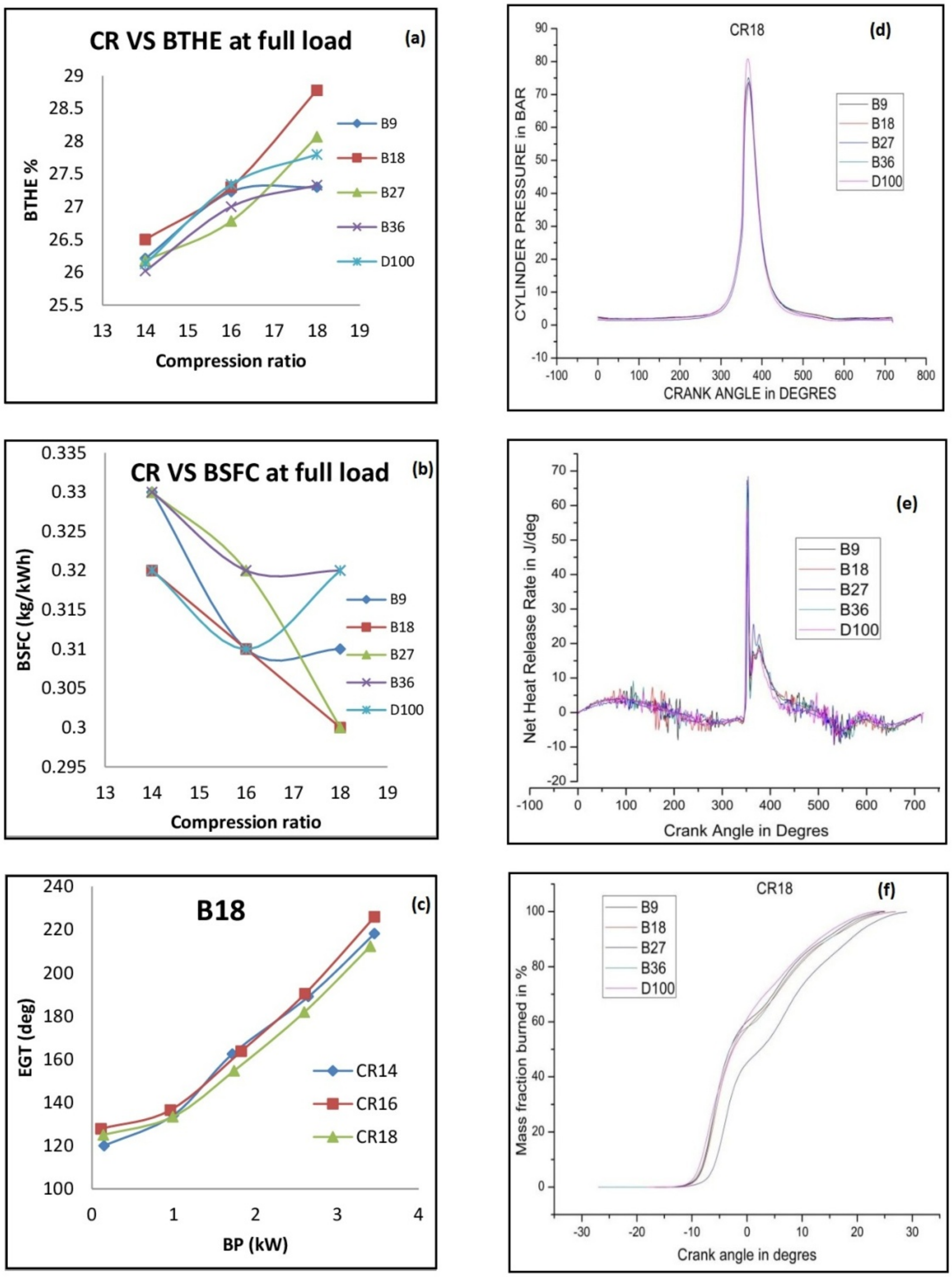


Fig.3 Variation of BTHE and BSFC with CR for different blends at full load (a-b), variation of EGT with CR for blend CR18 (c), variation of cylinder pressure, net heat release rate and mass fraction burned with crank angle for CR18 (d-f)

(iii) Mass fraction burned (MFB): The energy conversion during a combustion cycle can be described by MFB at a specific crank angle degree (CAD). In IC engine, the MFB depends on engine geometry, engine speed, air fuel ratio, ignition angle, residual mass etc. Fig. 3f shows the variation of MFB with crank angle in degrees for CR18. The complete mass of mixture burned between -10^0 and 30^0 for all blends except B27 which has different regularity in burning. For B27, it may be due to ignition delay and high concentration of biodiesel.

A. Emission Characteristics

(i) Hydro carbons (HC): Fig. 4a shows the variation of hydro carbon emission with different compression ratios of the different blends at full load. HC emissions are decreasing with increasing CR for all blends of MSME. The effect of CR is very less on HC for blend B36 and diesel. However, the HC value of B18 blend seems to be very less at CR16.75.

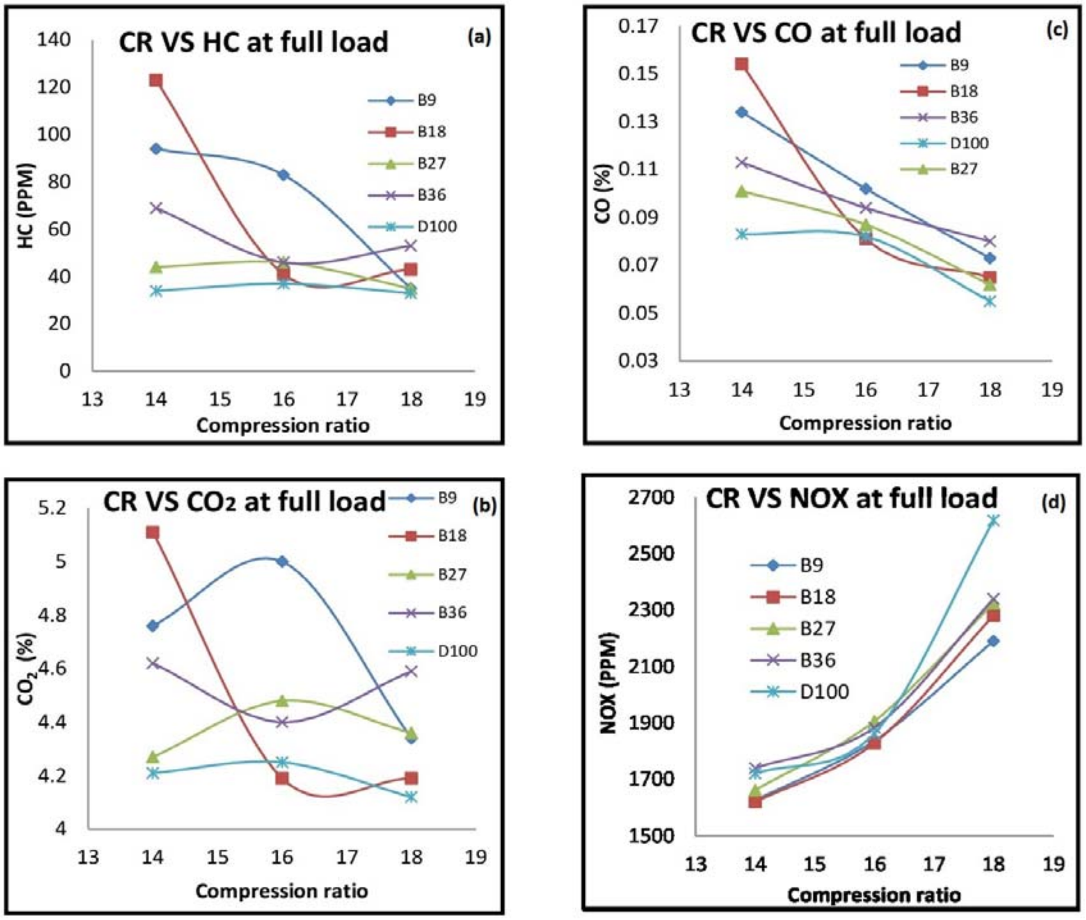


Fig. 4 Variation of HC, CO_2, CO and NO_x with compression ratio at full load

(ii) Carbon dioxide (CO_2) : Fig. 4b shows the variation of CO_2 with CR at full load. The CO_2 emission variation exhibited different manner for different blends. For instance, blend B9 and B27 first increases upto CR16 subsequently decreases, blend B18 and B36 initially decreases and then increased slightly. In addition, B18 shows lower value nearly at CR 17.

(iii) Carbon monoxide (CO): Fig. 4c shows the variation of CO emissions with CR at full load. The CO emissions are decreasing while CR increases. The blend B18 and B27 shows nearer value to Diesel at CR18. However, CO emission exhibited lower value than Diesel for B18 in between CR16 and C17.

(iv) Nitrogen oxides (NO_x): Fig. 4d shows the variation of NOx with CR at full load. NO_x emissions are increased with CR and all blends of MSME shows lower than Diesel. However, B9 and B18 blend at CR18 having low NO_x emissions.

IV. CONCLUSIONS

The fallowing conclusions are presented in VCR engine with functions of fuel blends, BP and CR. The BP, BTHE of blend B18 is higher than that of standard diesel and other biodiesel blends at higher compression ratio and full load condition. Peak pressures are attaining for diesel than MSME blends at higher CR. There is a significant reduction in CO, HC, and CO_2 for blends of MSME at CR 18. For the above observation, it has been found that the blend B18 shows better performance and emission characteristics than other blends and Diesel at compression ratio 18:1 and full load condition.

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