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Feedstock Performance Evaluation of a VCR Diesel Engine Fuelled with Hybrid

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Abstract

Alarmingsituationofworldenergystimulatedtheresearcherstolookfornewsourcesoffuelwhichmustberenewable,locallyavailableandenvironmentallybenign.Inthisregard,thesignificanceofbiodieselas technically andcommerciallyviablealternativetofossil-dieselhasledtointenseresearchin thefield.Biodieselismadefromdifferentfeedstockdependingontheavailability.Blending of different vegetable based fuels becomes a necessity and is gaining the attention of many researchers because the properties of biodiesel prepared from vegetable oils are very close to that of diesel. In this paper the research work is carried out to study performance and emission analysis of Hybrid biodiesel i.e. mixture of Cotton seed and Citrullus colocynthesis (Thumba) oil biodiesel ismixed in the proportions of CTB10, CTB20, CTB30, CTB40 and CTB50and tests are carried out on Variable compression ratio engine at various load conditions and at CR 16,17,18 respectively. The result obtained are compared with that of pure diesel (B100)at respective load and compression ratio.Comparative performance study gives the best blend for the diesel engine.The results shows that when fuelled with the biodiesel, the engine performance is comparable to that when fuelled with petroleum diesel. Considering the results, we concluded that the CTB30% is the best blend and CR 18 is the best compression ratio, where biodiesel and its blends performed well.

Keywords:*Engine performance; Emission; Cotton seed and Thumba hybrid biodiesel, biodiesel blends, VCR engine.*

1. Introduction

The world is currently facing a major energy crisis. Many countries are dependent on fossil fuels as their main source of electricity and transportation. As fossil fuels are depleting its price is increasing day by day. Thus it becomes necessary to find a solution to this growing crisis by finding a renewable, easily available and economically attainable source of renewable energy. Biodiesel can satisfy both these criteria's of sustainability and economic feasibility. Biodiesel being renewable, biodegradable fuel can reduce our dependence on conventional fossil fuels and contribute in improving environmental quality in metro cities, urban and rural sectors by reducing obnoxious automotive/vehicular emissions. Biodiesel being easily available and clean source of energy, it can replace dieselfuel in near future.

Compression ignition (C.I.) engines are the most fuel-efficient engines due to their relatively high compression ratio and few throttling losses. C.I. engines have comparativelyfeweremissions of carbon monoxide and unburned hydrocarbon than other engines. Biodiesel is made entirely from vegetable sources which does not contain any sulfur, metals,crude oil residues or aromatic hydrocarbons. Biodiesel is an oxygenated fuel. Emissions of carbon monoxide and soot particles reduces when compared to conventional diesel fuel. Use of biodiesel helps in reducing global warming as plants which are grown for vegetable oil/biodiesel production absorb emitted CO_2. Thus it maintains CO_2 balance. Biodiesel could be produced from wide variety of vegetable oils such as palm oil, sunflower oil, neem oil, coconut oil, soya bean oil, Rice bran oil, Jatropha, pongamia etc. But most of these are edible oils. The non-edible oils are Cotton seed, nilgiri oil and Citrullus colocynthesis i.e., Thumbaoil, etc.

In the present work biodiesel is produced from two different sources of non-edible vegetable oils namely Cotton seed oil and Thumba oil. These both oils are mixed with each other in equal proportion by transesterification process and different blends of hybrid biodiesel is prepared. The performance and exhaust emissions of diesel engine using blends of Cotton seed andCitrullus colocynthesis i.e., Thumbaoilbiodiesel as fuel is evaluated.

2. Literature Review

(Rakopoulos et al.2006)studied to test and compared the use of a variety of vegetables oils or biodiesels of various origins containing cottonseed as substitute to conventional diesel fuel at blend ratios of 10/90 and 20/80 in a direct injection diesel engine. Results showed that the smoke density was significantly reduced with the use of biodiesel blends as compared to that of the neat diesel fuel, the emissions were slightly decreased with the use of biodiesel blends.

(Peterson CL et al., 1992)suggested that the transesterification process has been proven worldwide as an effective means forreduction in viscosity of vegetable oil and biodiesel production. Temperatures, catalyst type, concentration ratio of alcohol to fuel and stirring speed rate have been observed to influence the transesterification process to a greater extent.

(M. Leenus et al., 2012) workedon the diesel engines to findthe feasibility of cotton seed oil as a fuel and comparedvarious methods to improve the performance of diesel engine using cotton seed oil. Brake thermal efficiency increased up to 30.4% with ethyl ester of cotton seed oil (EECSO). Smoke, HC and CO levelsminimized with EECSO compared to CSO. A blend of 60% CSO and 40% of diesel results in better brake thermal efficiency and a considerable diminution in smoke level.It wasobserved that CSO and EECSO can be used directly in diesel engines without any modification.

(VandanaKaushik et. al., 2014) concentrated their study on engine performance using Thumba methyl ester mixed with diesel in the proportion of 10, 20 and 30% by volume and compared the results with that of pure diesel. Among all thumba methyl ester diesel blends the maximum brake thermal efficiency was observed for 20% TME blend. The BSFC of engine fuelled with 20% TME diesel blend was least at maximum load among all the tested blends of TME in diesel. Compared to diesel fuel Exhaust Gas Temperature was higher for all TME blends. Among all the TME blends the lowest exhaust temperature was observed for the blend of 20%. When engine is fueled with blends of TME the volumetric efficiency obtained is highest for TME20CR19 than TME10 CR18 and TME30 CR19 and then that of pure diesel. The TME fuel has lower Mechanical Efficiency than diesel fuel. At full load the highest efficiency is achieved for TME20 CR19 than TME10 CR18 and TME30CR20. It was observed that the Engine Performance is better or optimized with TME20 and the compression ratio CR19.

(Md. Nurun et al., 2009)worked on the performance test of a diesel engine with neat diesel fuel and biodiesel mixtures. Biodiesel was prepared by transesterification process. Cottonseed oil (CSO) was preferred for biodiesel production. Cottonseed is non-edible oil, thus food versus fuel difference will not come up if this is used for biodiesel production. A maximum of 77% biodiesel was formed with 20% methanol in attendance of 0.5% sodium hydroxide. The engine investigational results showed that exhaust emissions counting particulate matter (PM), carbon monoxide (CO), and smoke emissions were reduced for all biodiesel mixtures. However, a slight enlarge in oxides of nitrogen (NOx) emission was practiced for biodiesel mixtures.

(Sunilkumar R. Kumbhar, and H. M. Dange2014) used a four stroke water cooled single cylinder 3.5kw VCR Diesel (CI) engine with Compression ratio varying from 12 to 18. The blends of Thumba with Diesel B10, B20, B30, B40, B50, and B100 were investigated. At CR 18 BTE of Thumba B10 (36.31%) showed better performance than all other blends of Thumba biodiesel and pure diesel fuel (33.27%). At CR 18 BSFC of Thumba B10, B20 (0.23kg/kwhr) showed better performance than all other blends of Thumba biodiesel and pure diesel fuel (0.25 kg/kwhr).At CR18 BP of Thumba B40 (5.15 kw) showed better performance than all other blends of Thumba biodiesel and the pure diesel (5.07 kw).Thumba B50 showed better emission performance of HC at all compression ratios. Thumba B40 showed better emission performance of CO at CR 14 and for other compression ratios Thumba B100 Showed better CO and CO_2 emission performance. For all the compression ratios ppm of NO_X coming from pure diesel was less than all other blends of Thumba biodiesel.

(R. Senthil Kumar et al., 2013) carried out performance test on horizontal single cylinder changeable speed Greaves engine with different blends of cottonseed oil (B5, B10, B15, B20, B40 & B100) and compare the presentation of cottonseed oil with diesel. Blending usual Diesel Fuel (DF) with esters (usually methyl esters) of vegetable oils is currently the most common form of biodiesel. Most commonly 80% diesel fuel is blended with 20% vegetable oil ester indicating 20% biodiesel and represented as B20. The TFC and SFC of B20 residue were very stable on different loading conditions and B15 and B20 blends has a moderate $NO_X$and CO emission. The overall evaluation shows that B20 diesel with blend 20% yields the best possible value, with less fuel consumption.

(Beena Mishra et. al.,2015) compared the performance of pure diesel and thumba oil blends B20 and B40 in a single cylinder 4 stroke 3.5 k watt VCR Kirloskar Diesel Engine computerized test setup. It was observed that blend B40 have higher BTH (29.87%) compared to that of diesel (29.49%) at CR18. At CR 15 the BSFC of the pure diesel is 0.37 kg/kw-hr while the blends B20 and B40 having 0.38 and 0.39 kg/kw hr. All the thumba biodiesel blends showed higher BSFC than that of diesel but among them B20 has lower values of BSFC. For B20 BSEC is high for all load conditions. The value of BSEC of B20 and B40 is 12.79 and 12.08 respectively and that of the diesel fuel is 12.28 MJ/kE-h. The value of exhaust gas temperature is low for diesel than small blends like B20 and B40 at both the compression ratios. But when concentration of biodiesel increased, the exhaust gas temperature also increased. Biodiesel and its blends with diesel produce less smoke as compared to pure diesel.

(Deepak S. Sanap and Prof. N. C. Ghuge2016) evaluated the performance of diesel engine using Hybrid biodiesel i.e. mixture of Cotton seed and Eucalyptus i.e. Nilgiri oil biodiesel in equal proportion as fuel. Different blends of both oils were prepared and performance and emission characteristics of C.I. engine were observed. The results showed that B37 is the best blend as it has highest Brake power and volumetric efficiency as well as higher brake thermal efficiency, compared to diesel and other blends. Emissions of HC, CO_2 and NO_X is also reduced as compared to pure diesel. The results shows that engine performance when fuelled with the biodiesel are comparable to that when fuelled with petroleum diesel. B37 is found to be the best blend as it has highest Brake power and volumetric efficiency as well as higher brake thermal efficiency and less emissions as compared to the other blends.

From the review of literatures, numerous work is done on the use of biodiesel as well as its blends in engines. Many of the literatures focused on single biodiesel and its blends. From above studies, it is clear that single biodiesel offers acceptable engine performance and emissions for diesel engine operation. The engine performance using the biodiesel and vegetable oil blends of various origins was found to be similar to that of neat diesel fuel.

The performance and emission indicators such as brake power, BTE, BSEC, CO, CO_2, HC and smoke density are evaluated and compared with pure diesel by many researchers. The results of these studies showed that different sources of biodiesel feedstock give different results to engine performance and emissions. Surprisingly some of the research yielded favorable results towards the biodiesel as compared to pure diesel. A number of the studies reported that biodiesel can improve the combustion in the engine. Most of the studies reported that the brake power for biodiesel blends is slightly lower than pure diesel. The cottonseed oil showed favorable results for the engine performance at lower blends while higher blends reduced the emission. Thumba blends showed mixed results for various researches. The lower blends showed better engine performance while higher blends resulted in lower emission characteristics.

Very few experiments have been conducted with the combination of dual biodiesel i.e. Hybrid biodiesel and diesel as a fuel. Most of the literatures suggested that Citrullus colocynthesis i.e., Thumba oil and Cotton seed is a suitable substitute to the diesel. So, the combination of Thumba oil and Cotton seed oilwhich is easily and locally available is selected for this current study.

3. Biodiesel blends

Transesterification reaction:

The main components of animal fats and vegetable oils are Triglycerides. The vegetable oil or animal fat is subjected to a chemical reaction called Transesterification to produce biodiesel. The fatty acid triglycerides are esters of fatty acids and the chemical divides up of the heavy molecules and forming simpler esters is termed as Transesterification. Thealcohol (Methyl, Ethyl, or others) is reacted withtriglycerides in the presence of a catalyst at a specified temperature for a specified time. The final products are Alkyl esters and Glycerin. The Alkyl esters are having positive properties as fuels for use in CI engines, are the main product and the Glycerin, is a by-product

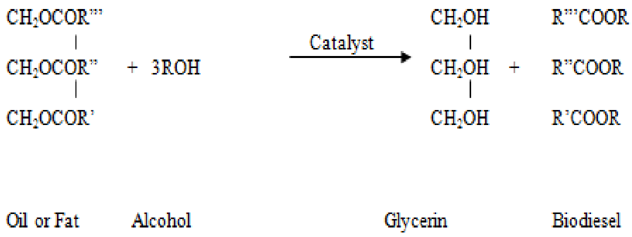

Fig.1 Transesterification reaction

1) Filtering: The vegetable oil is first filtered to remove solid particles from it. It is to be warmed up a bit first to get it to run freely; 35°C should be enough. A Cartridge filter is used for the same.
2) Removing the Water: First the oil is heated to remove the water content. Vegetable oil may contain water, which can slow down the reaction and causes saponification (soap formation). Then the temperature is raised to 100°C, holding it and allow water contents to boil off. Run the agitator to avoid steam pockets forming below the oil and exploding, splashing hot oil puddles out from the bottom. When boiling slows, the temperature is raised to 130°C for 10 minutes and allow cool to it.

With the help of transesterification process various blends of biodiesel are prepared. The biodiesel blended with diesel by volume as CTB10 (10% Hybrid biodiesel i.e. 5% Cotton seed and 5% Thumba biodiesel and 90% diesel fuel), CTB20 (20% Hybrid biodiesel i.e. 10% Cotton seed and 10% Thumba biodiesel and 80% diesel fuel), CTB30 (30% Hybrid biodiesel i.e. 15% Cotton seed and 15% Thumba biodiesel and 70% diesel fuel), CTB40 (40% Hybrid biodiesel i.e. 20% Cotton seed and 20% Thumba biodieseland 60% diesel fuel) and CTB50 (50% Hybrid biodiesel i.e. 25% Cotton seed and 25% Thumba biodieseland 50% diesel fuel). Then the samples were proceeded for their property testing.

Fig.2 Transesterification set up

Fig.3 Blends of Hybrid biodiesel

The physico-chemical properties of Hybrid biodiesel i.e. equal mixture of cotton-seed and Thumba oil biodiesel is given in the Table 1. The density, Calorific value, Cetane no., Viscosity, Flash point, carbon residue and moisture content are comparable with that of diesel fuel.

Table 1 Tested Properties of Hybrid Biodiesel

Bio-diesel blends	Density (gm/cc)	Calorific Value (MJ/Kg)	Cetane no.	Viscosity (mm^2/sec)	Moisture residue (%)
B00 Pure Diesel	0.83	42.5	49.5	2.7	NA
CTB10	0.834	42.36	49.4	2.72	NA
CTB20	0.838	42.09	49.44	2.79	NA
CTB30	0.845	42	49.5	3.1	NA
CTB40	0.85	41.5	49.65	3.33	NA
CTB50	0.853	40.5	50.2	3.6	NA

4. Experimental Set up

Table 2 Test Engine specifications

Sr.No	Description	Specifications
1	Make	Kirloskar TV1 Engine
2	No. of Cylinders	1
3	No. of strokes	4
4	Cylinder diameter	87.5 mm
5	Stroke length	110 mm
6	Connecting rod length	234 mm
7	Orifice diameter	20 mm
8	Dynamometer arm length	185 mm
9	Fuel	Diesel
10	Power	3.5 kW
11	Speed	1500 rpm
12	CR range	12:1 To 18:1
13	Injection point	0 to 25 C
14	Software	IC Engine soft

Fig.4 Experimental Set up

The engine was started and allowed to run for 15-20 minutes to get stabilized using pure diesel fuel and baseline data for B00 was generated. Compression ratio was set at 16:1, 17:1 and 18:1. Performance parameters were noted using I.C. engine software. The exhaust gas emission parameters like HC, CO_2, CO were recorded by pelting the probe of gas analyser in the exhaust pipe.

Then the load on the engine was further increased from 3 kg to 6 kg, 9 kg and 12 kg. The engine was run for sufficient time duration to ensure that the diesel fuel phase is over and the engine has started running with mixture of cottonseed, thumba biodiesels and diesel fuel as a hybrid fuel. The entire process was repeated while engine running with different blends of hybrid biodiesel i.e. CTB10, CTB20, CTB30, CTB40 and CTB50 as a fuel and various performance and emission parameters were noted.

5. Equations

Torque (T) = Load*9.81*Dynamo. arm length (Nm)

Brake power (B.P) = $\frac{2\pi NT}{60000}$(Kw)

Brake specific fuel consumption (BSFC) = $\frac{\text{mf}}{\text{B.P}}$(Kg/Kwhr)

Brake specific energy consumption (BSEC) = BSFC $\times CV$(MJ/Kwhr)

6. Results and discussion

6.1 Engine performance Analysis

The engine performance parameters such as Brake Thermal Efficiency, SFC, Brake Power and Mechanical Efficiency obtained with CTB00, CTB10, CTB20, CTB30, CTB40 and CTB50 are discussed in the following sections.

6.1.1 Brake power

It indicates the available power at the output of engine to do work.Fig.05 shows variation of brake power with load for blends CTB00, CTB10, CTB20, CTB30, CTB40 and CTB50 at CR 16 and it is observed that brake power for the blend CTB30 is more compared to pure diesel (B00).

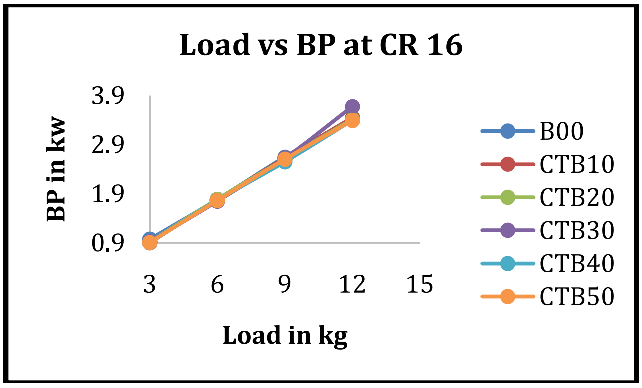

Fig.5 Load vs Brake Power at CR 16

It can be said from above graph, the Brake Power of CTB30 is increased by 7.28% as compared to pure diesel (B00).

Fig.06 and Fig.07 shows variation of brake power with load for all blends at CR 17 and 18 respectively.It is observed that there is no drastic change in brake power for all the blends when compared with pure diesel(D100) at same load and compression ratio.

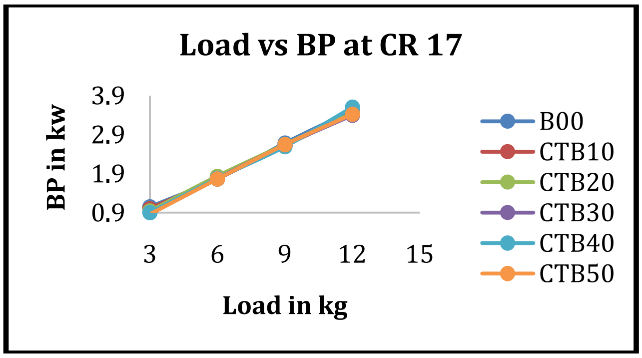

Fig.6 Load vs Brake Power at CR 17

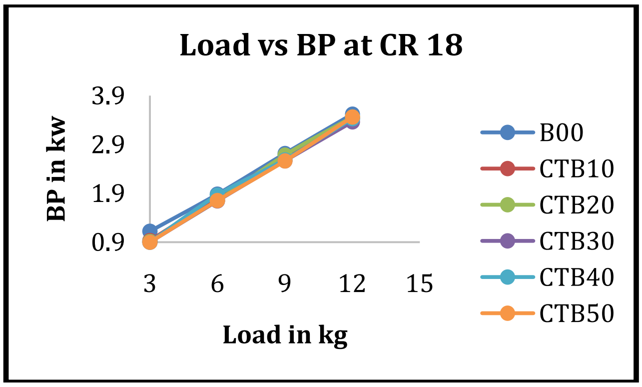

Fig.07 Load vs Brake Power at CR 18

6.1.2 Brake Specific Energy Consumption

The variation of brake specific energy consumption with respect to loads was plotted in Fig. 08, 09 and 10 for CR 16, 17 &18, respectively. The BSEC decreases with increase in load as well as CR. This is because of, at higher CR, the power generated is more with respect to fuel consumption rate. The BSEC for CTB hybrid biodiesel and all its blends are higher than diesel fuel. The blend CTB50 has consumed highest energy, 10.9, 4.8 and 6.2% more than B00 while the CTB10 consumed lowest, 2.5% more,1.8% less, and 2.7% moreat CR 16, 17 and 18, respectively. This is due to the lower calorific value of biodiesel that lowers the power generation than that of diesel fuel. CTB30 showed BSEC almost equal to that of B00 at CR17.

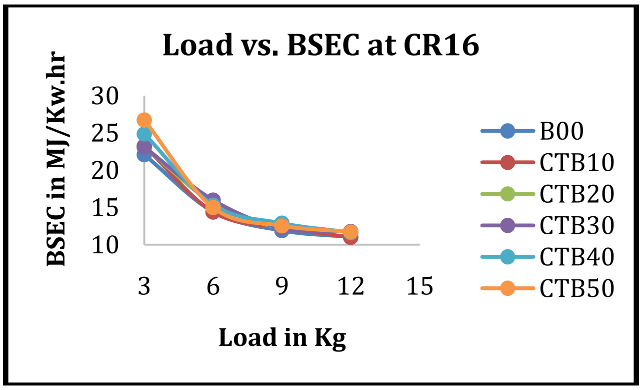

Fig.8 Load vs BSEC at CR 16

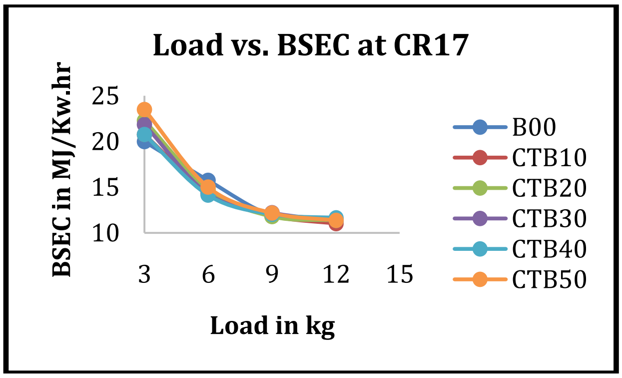

Fig.9 Load vs BSEC at CR 17

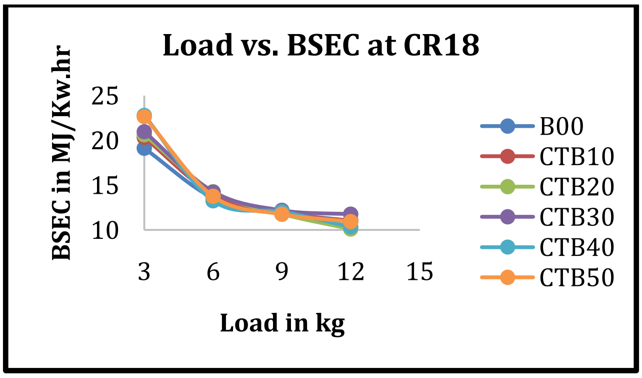

Fig.10 Load vs BSEC at CR 18

6.1.3 Brake Thermal Efficiency

The variation of brake thermal efficiency with respect to loads was plotted in Fig.11, 12 and 13 for CR 16, 17 &18. The BTE of all fuel samples increases with load as well as with CR. In comparison with diesel fuel the BTE of hybrid biodiesel blends was lower than that of diesel fuel. The blend CTB50 has lowest, 10.94, 6.12 & 8.83% lower at CR 16,17 and 18, respectively while CTB10% has constantly close i.e. about 0.74 to 3.71% lower than that of diesel fuel at respective compression ratios. This may be due to presence of extra oxygen atom in biodiesel that enhances combustion but biodiesel has lower volatility and poor atomization & fuel spray characteristics, which may affect the air fuel mixture at the time of combustion.

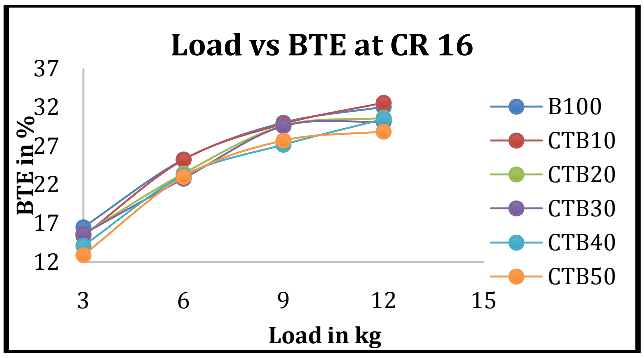

Fig.11 Load vs BTE at CR 16

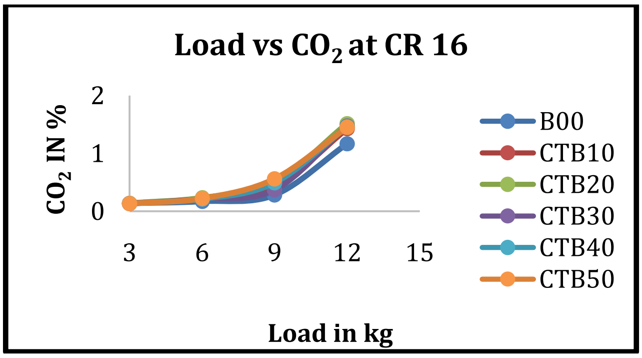

Fig.14 Load vs CO_2 at CR 16

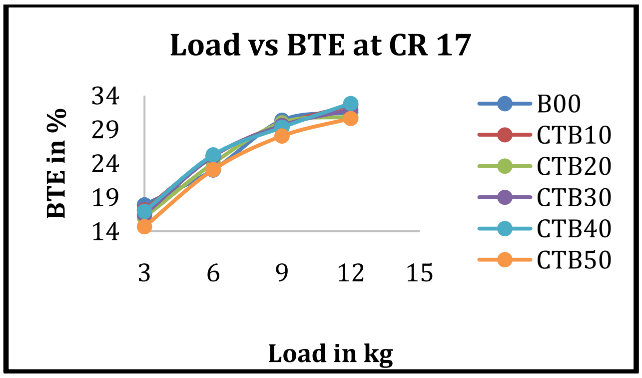

Fig.12 Load vs BTE at CR 17

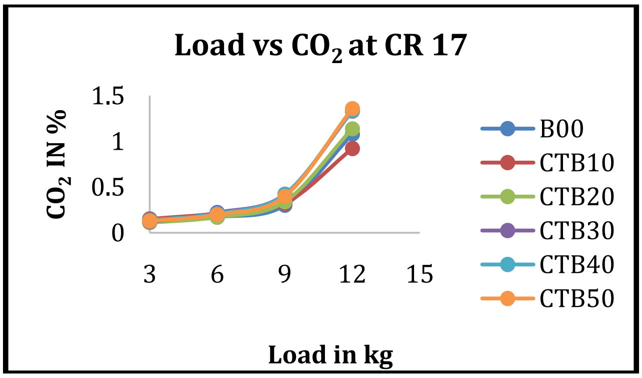

Fig.15 Load vs CO_2 at CR 17

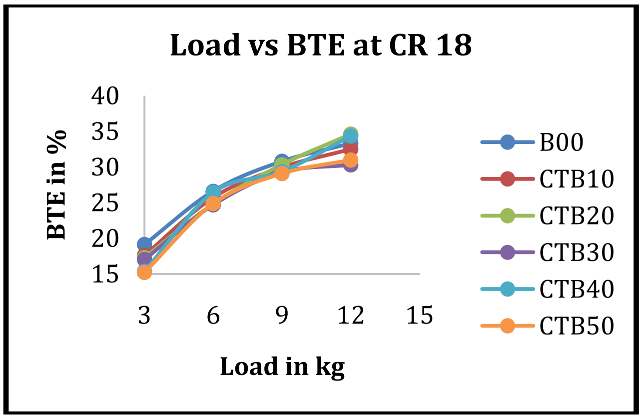

Fig.13 Load vs BTE at CR 18

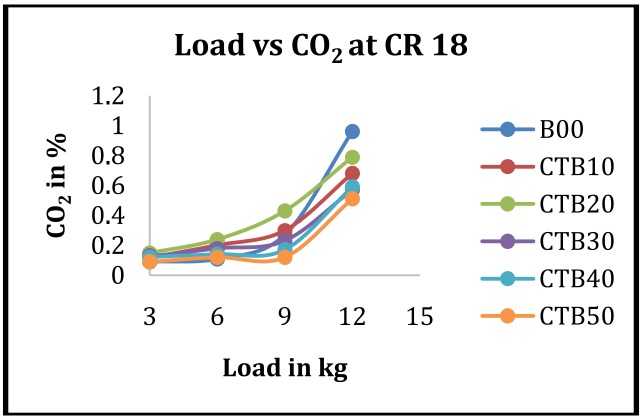

Fig.16 Load vs CO_2 at CR 18

6.2 Emission characteristics

6.2.1 Carbon Dioxide

The emissions of carbon dioxide with respect to loads were plotted in Figure 14, 15, 16 for CR 16, 17 &18. The Figure shows that at lower CR there is increase in CO_2 gas emissions by 5.00% to 39.14% for all blended fuels at all loads compared to diesel fuel while only exception is CTB10%. It has given lower CO_2 emissions by 3.44% and 8.10% at CR 17 & 18 respectively. At higher CR i.e. at 18, The CO_2 emissions of blend CTB30, CTB40, CTB50 were lower by 15.54, 26.36 & 39.18% than that of diesel fuel. Hence, we can say that at higher CR, the CO_2 emissions reduces as the amount of biodiesel in the blend increases. The CO_2 emissions depends on engine temperature & calorific value of fuels. The hybrid biodiesel fuel enhances the engine temperatures with simultaneously rise in CO_2 gas emissions.

6.2.2 Hydrocarbon

The emissions of unburnt hydrocarbon at various compression ratios and with respect to loads were plotted in Figure17, 18, 19. The figure indicates that the HC emissions decreases with increasingCR and blend proportion. Compared to diesel fuel emissions, CTB30% blend emitted 16.36, 20.40, 21.93% less HC emissions at CR 16, 17 & 18, respectively.

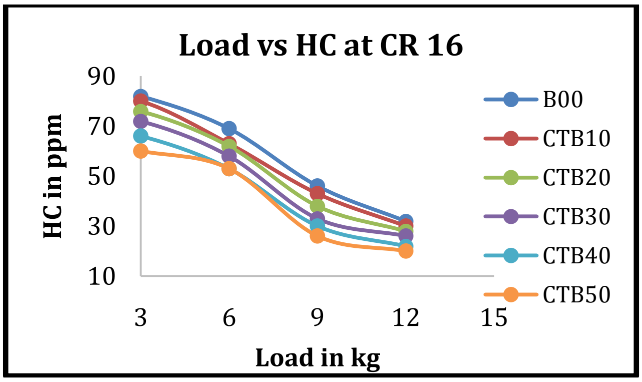

Fig.17 Load vs HC at CR 16

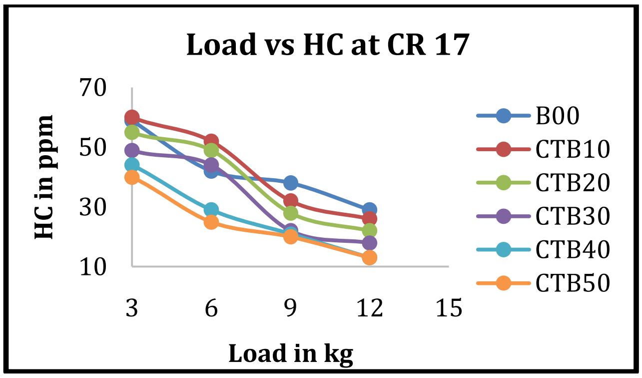

Fig.18 Load vs HC at CR 17

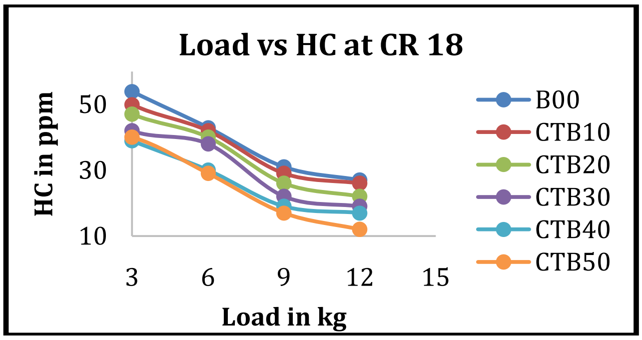

Fig.19 Load vs HC at CR 18

Conclusions

The experimental study is conducted on single cylinder, four strokes, variable compression ratio diesel engine using Cottonseed and Thumba biodiesel blends with diesel. The performance and emission analysis is evaluated by running the engine at different combination of preset CRs and varying load. The performance parameters measured are BP, BSEC, BTE and emission parameter measured are CO_2 and HC. Based on the experimental studies, following are the conclusions.

1) At CR 16 brake power for the blend CTB30 is 7.28% more compared to pure diesel (B00). There is no drastic change in brake power for all the blends at CR 17 and 18.
2) The BSEC of all blended fuels decreases with increasing load and CR but BSEC for all the blends was higher than diesel fuel. Among all blends CTB10 has lowest BSEC. i.e., 2.5% more, 1.8% less, and 2.7% more at CR 16, 17 and 18, respectively. CTB30 showed BSEC almost equal to that of B00 at CR17.
3) In comparison with diesel fuel the BTE of hybrid biodiesel blends were found lower. The brake thermal efficiency increased with load as well as with CR by all fuel samples. At CR16, CR17 and CR18 the blend CTB50 has 10.94, 6.12 & 8.83% lower BTE than that of diesel, respectively. CTB10% has constantly close i.e. about 0.74 to 3.71% lower than respective diesel fuel for the entire CR range. Among all, the blend CTB30% has performed about 97% as that of diesel fuel.
4) At lower CR there is increase in CO_2 gas emissions by 5.00% to 39.14% for all blended fuels at all loads, only exception is CTB10%. It has given lower CO_2 emissions by 3.44% and 8.10% at CR 17 & 18 respectively. At higher CR i.e. at 18, The CO_2 emissions of blend CTB30, CTB40, CTB50 were lower by 15.54, 26.36 & 39.18% than that of diesel fuel.
5) The unburnt hydrocarbon emissions reduced with increasing load and CR. The blend CTB30 has emitted lowest HC among all fuel samples.

From the results it can be concluded that CTB30 is the best blend as it has highest Brake power and brake thermal efficiency as well as lower BSEC as compared to diesel and other blends. Emissions of HC and CO_2 is also reduced as compared to pure diesel.

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