

Experimentally Optimization of a Variable Compression Ratio Engine Performance Using Different Blends of Cotton Seed with Diesel Fuel at Different Compression Ratio

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Abstract— The scarcity of world's petroleum reserves and the sources are at the extreme of getting abolished. Due to the increase in the price of petroleum, environmental concern and availability of fuels are greatly affecting the trends of fuels for transportation vehicles. To fulfill the rising energy demand renewable fuel like biodiesel is in forefront of other technologies. Biodiesel oil one of the option as alternative transport fuel. In the present study, experimental investigations were carried out on a small size, variable compression ratio diesel engine with cotton seed - diesel blends (10–25% by volume) as fuel to determine the optimum blending ratio for the engine performance. Cotton seed oil is non edible vegetable oil, high viscosity, low volatility and widely available in India. It has been observed that B-20 blend (20% cotton seed +80% diesel fuel) gives highest brake thermal efficiency & lowest brake specific fuel consumption as compared to all other blending combinations at different compression ratios. Optimized B20 blend gives very close thermal efficiency, 2.46% lesser to diesel fuel at compression ratio 17 at 75% of maximum load i.e. 12 kg. Among all diesel blend maximum break power was found 3.295 kW by B20 blend at compression ratio 17.

Index Terms— brake thermal efficiency, brake specific fuel consumption, biodiesel, compression ratio

I. INTRODUCTION

The present generation is heavily biased towards the conventional energy sources such as petroleum products, coal, atomic energy etc., which are finite in nature besides causing environmental pollution. The fast depleting petroleum reserves have already waved a warning signal all around the globe to look for alternate

means to cater to the ever increasing needs of energy. [1] Our society relies heavily on internal combustion (IC) engines for different purposes, viz. transportation, agriculture and power generation. Therefore, research in both gasoline and diesel engines is required for improvement in fuel efficiency and emission reduction. Even a small improvement in fuel efficiency can have a major impact on economy and pollution [2].

Biodiesel oil one of the option as alternative transport fuel. Diesel fuel can be replaced by biodiesel made from vegetable oils. There are different types of vegetable oil available such as peanut, sunflower, rape, soybean, coconut, cottonseed, linseed, castor and mustard, has been tested worldwide [3]. In developed countries, there is growing trend toward using modern and efficient bioenergy using a range of biofuels, which are becoming cost wise competitive with fossil fuels. It has almost no Sulphur, no aromatics and more oxygen content which helps it to burn fully. It has higher cetane number which improves combustion. Since straight vegetable oils cannot be used directly without bringing its properties closer to petroleum fuel as diesel. Mainly viscosity reduction is sufficient to improve its flow and atomization properties. Four important techniques are available to reduce viscosity of these oils such as heating, transesterification, emulsification and blending [3,4]. Transesterification (conversion of vegetable oil into biodiesel) is the best technique to bring the properties of vegetable oil closer to mineral diesel [4,5,6].

The main objective of the present research was to explore the possibility of running an IC engine on cotton seed oil in direct injection variable compression ratio engine without any substantial modifications in the engine design. Performance characteristics like brake

power, brake specific fuel consumption, brake thermal efficiency, exhaust gas temperature of biodiesel blended fuelled C.I. engine were evaluated and compared with that by fuelling diesel while the engine running at no, part and full load condition. A stationary CI engine with variable compression ratio (VCR) was used to compare the performance of dual-fuel (cotton seed oil + diesel) mode with that of neat diesel mode.

II. MATERIALS AND METHOD

A. Materials

The cotton seed oil used in this study was purchased from local supplier of Bikaner, Rajasthan, India, Methanol & KOH were purchased from Savita scientific supplier, Jaipur, India and petroleum diesel was supplied by the local filling station in Jaipur. Biodiesel was prepared from used cotton seed oil by alkali catalysed transesterification. KOH was used as the catalyst amounting 1.0% on mass basis and 20% methanol was treated with the used cottonseed oil. The water bath shaker was used for the base catalysed transesterification process.

B. Properties of Biodiesel

The properties of the diesel and cotton seed biodiesel (B100) are tabulated in the table 1. These properties are compared with ASTM standards. The properties were tested at Mechanical Engineering laboratory Manipal University, Jaipur, India.

TABLE I. COMPARATIVE PROPERTIES OF THE DIESEL AND BIODIESEL

Properties	ASTM standard	Diesel	B100
Kinematic Viscosity, at 40°C, cSt	<5	2.570	5.800
Density, at 15°C, kg/m ³		828.100	895.700
Flash Point, °C	>130	78.000	162.000
Fire Point, °C	>53	85.000	173.000
Cloud point, °C	-3 to 12	<10	-3
Calorific value (MJ/kg)	>35.00	44.680	40.610
Cetane number	40 to 55	51.000	52.300

III. EXPERIMENTAL SETUP

A single cylinder, direct injection, four-stroke, vertical, water-cooled, naturally aspirated variable compression ratio multi-fuel engine, with a bore of 80 mm and a stroke of 110 mm was selected for this experimental study. The engine has a provision of loading by eddy current dynamometer. The compression ratio of the engine can be varied by rising and lowering the bore and the head of the engine with the help of handle mounted at the head of the engine. As the bore and the head of the engine are raised and lowered, the clearance volume is changed resulting in the change in the compression ratio. The water jacket is provided between the cylinder and the cylinder liner. Water circulation is by a centrifugal pump in a closed circuit, which includes heat exchanger and orifice type

flow meter. The high rate of circulation of cooling water ensures a uniform temperature in the head.

The detailed technical specifications of the engine are given in Table II. The view of the experimental setup and instrumentation are depicted in the Fig. 1. The load was displayed digitally in kg through the load signal sent by the load sensor fitted with the dynamometer. The applied load on the engine is measured by a strain gauge type load cell. To measure the flow of water to the engine and calorimeter, rotameters were provided. Six thermocouples were installed at different locations in the set-up for measuring water and exhaust gas temperature. The air flow rate was determined using air box method by measuring the pressure drop across a sharp edge orifice of air surge chamber with the help of manometer. Burette method was used to measure the volumetric flow rate of diesel. Governor was used to keep the engine rpm constant while varying the load on engine for creation of various test results.

A. Methodology:

The experimental investigation of the performance of the variable compression ratio engine was divided in two steps. In first step a series of tests were carried out to evaluate the engine generator performance while it was to be run on pure diesel. In second step a series of tests were carried out to evaluate the engine generator performance while it was to be run on cotton seed biodiesel blend. Four different blends of biodiesel were tested and optimized during this investigation, the different blends of biodiesel and diesel with notations are B10, B15, B20, & B25. For both steps, engine load was varied from zero to full load condition and compression ratio varies from 14 to 18. All relevant data viz. Brake specific fuel consumption (BSFC), Brake thermal efficiency (BTE), Break power and Exhaust gas temperature were recorded. Test sets were prepared for 0, 3, 6, 9, 12 and 15 kg load conditions. To measure BSFC and BTE at each load condition, time taken for 10 ml of fuel consumed was noted using a stopwatch. All readings were taken three times and an average of the three readings was taken for the results to increase the statistical confidence of the findings. Different graphs were plotted for various conditions for BSFC & BTE and result were analyzed.



Figure 1. Overall view of experimental setup

TABLE II. TECHNICAL SPECIFICATIONS OF THE ENGINE

Description	Specifications
Make	Technical Teaching Equipment , Bangalore (India)
Type	Vertical/Single acting, variable compression ignition diesel engine.
Power	5 HP
Rated Speed	1500 rev/min (Governed Speed)
Number of Cylinders	1 cylinder
Compression Ratio	14 to 18 (Variable Compression Ratio)
Bore* Stroke	87.5 mm*110 mm
Method of Loading	Eddy Current Dynamometer
Method of Starting	Manual Crank/Self Start
Over all Dimensions	1300 x 1200 x 1050 mm
Air Tank Size (mm)	90(H) x 195(W) x 240(D)

IV RESULTS AND DISCUSSION

The experimental investigations are carried out using the above said biodiesel and their blends on the test engine. The detailed analyses of these results of engine performance are discussed in this section.

A. Brake Thermal Efficiency

Brake thermal efficiency gives an idea of the output generated by the engine with respect to the heat supplied in the form of fuel. Generally, increasing the compression ratio improves the efficiency of the engine due to a reduction in heat loss and increase in power with increasing load. This improvement in performance of the engine at higher compression ratio is due to the reduced ignition delay [6]. Fig. 2 shows the variation of BTE for different loads and different blends of cottonseed biodiesel at compression ratio 14 and compared with pure diesel. For all blends of biodiesel the BTE increases with the load, the maximum values of BTE is obtained at 12 kg load which is 75% of full load for test engine reason for this is increase in friction losses at full load condition [7]. Maximum values of BTE are 24.09%, 17.15%, 17.93%, 20.3% & 18.77% for pure diesel, B10, B15, B20 & B25 respectively at 75% of the full load. It is clearly observed from following figure that diesel is having higher BTE compared to all blends of biodiesel at all loads because of the lower heating value and higher viscosity of biodiesel, which may affect the mixture formation process which slowdowns the combustion process[7]. Following figure also shows that the BTE increases with the increase in concentration of biodiesel and gets its maximum value 20.3% at B20 this is probably due to the molecules of biodiesel (i.e. methyl ester of the oil) contains some amount of oxygen, which take part in the combustion process and increases the combustion efficiency of the fuel [8]. The test results also indicate that the BTE is lower 18.77 % at B25 as compared to B20 because when the mass percentage of fuel oxygen exceeds beyond a certain limit, the mixture

becomes lean which leads to incomplete combustion, hence B20 gives a maximum BTE for compression ratio 14.

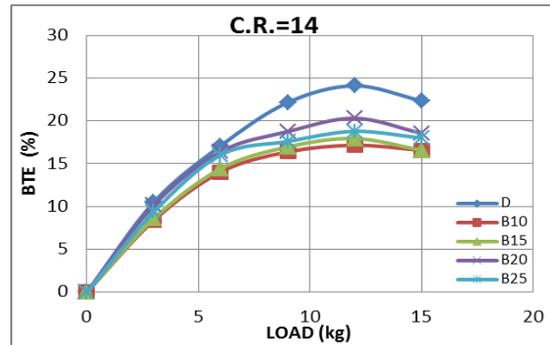


Figure 2. Brake thermal efficiency (BTE) Vs. load for C.R. = 14

Fig. 3 shows the variation of BTE for different loads for different blends of cottonseed biodiesel at compression ratio 15 and compared with pure diesel. The maximum values of BTE are obtained as 24.87%, 19.49%, 21.83%, 22.64% & 21.9 for pure diesel, B10, B15, B20 & B25 respectively. Results shows that the BTE gets maximum value at B20.

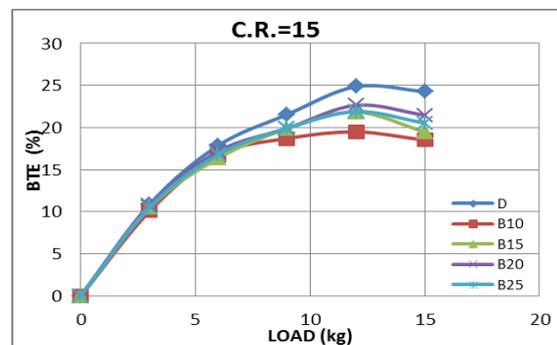


Figure 3. Brake thermal efficiency (BTE) Vs. Load for C.R. = 15

Fig. 4 shows the variation of BTE for different loads for different blends of cottonseed biodiesel at compression ratio 16 and compared with pure diesel. The maximum values of BTE are obtained as 25.64%, 21.82%, 21.83%, 23.43% & 22.68 for pure diesel, B10, B15, B20 & B25 respectively. Following figure also shows that the BTE gets maximum value.

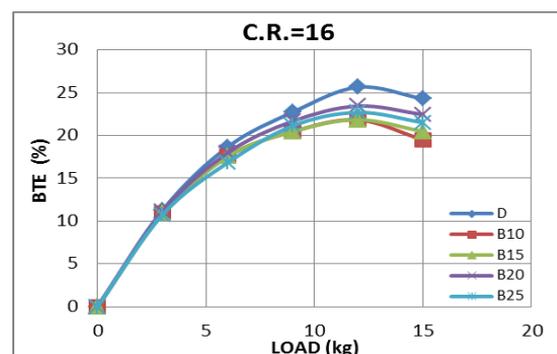


Figure 4. Brake Thermal Efficiency (BTE) Vs. Load for C.R. = 16

Fig. 5 shows the variation of BTE for different loads and different blends of cottonseed biodiesel at compression ratio 17 and results are compared with pure diesel. The maximum values of BTE are obtained as 26.42%, 23.38%, 24.17%, 25.77% & 25.03% for pure diesel, B10, B15, B20 & B25 respectively at 75 % of full load. Following figure also shows that the BTE gets maximum value 25.77% at B20.

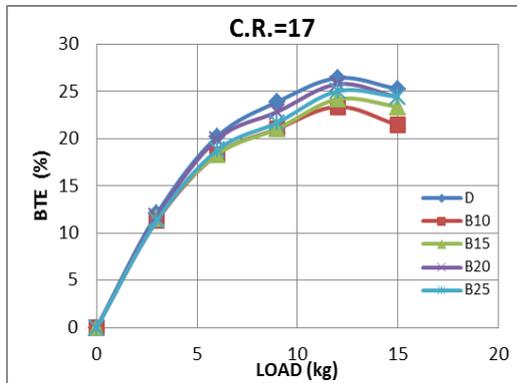


Figure 5. Brake Thermal Efficiency (BTE) Vs. Load for C.R. = 17

Fig. 6 shows the variation of BTE for different loads for different blends of cottonseed biodiesel at compression ratio 18 and compared with pure diesel. The pattern of BTE is similar to result obtained for all above discussed compression ratio's that is 27.97%, 24.16%, 24.95%, 26.55% & 25.81% for pure diesel, B10, B15, B20 & B25 respectively. The test results also indicate that the B20 gives maximum BTE for compression ratio 18.

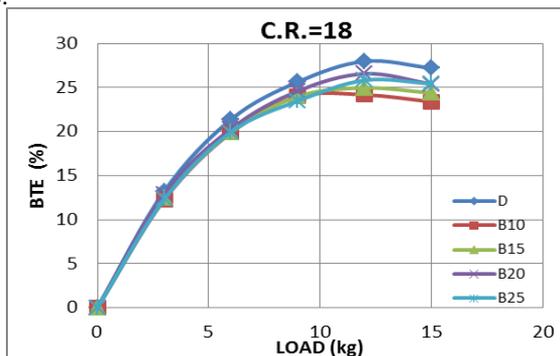


Figure 6. Brake Thermal Efficiency (BTE) Vs. Load for C.R. = 18

B. Brake Specific Fuel Consumption

The specific fuel consumption is an important parameter to measure the engine performance. It is defined as the mass of fuel required to produce unit brake power. Fig. 7 shows the variation of brake specific fuel consumption with load. For all blends of biodiesel the BSFC decreases with the load, the minimum values of BSFC is obtained at 12 kg load which is 75% of full load for test engine. Minimum values of BSFC are 0.347, 0.492, 0.4723, 0.4188 & 0.4548 (kJ/ kg.hr) for pure diesel, B10, B15, B20 & B25 respectively at 75% of full load. For all blends and pure diesel BSFC decreases with increase in load, reason for the reduction in BSFC is percentage increment of brake power is higher with load as compare

to percentage increment of fuel consumption [8]. It is clearly observed from following figure that diesel is having lower BSFC as compared to all blends of biodiesel at all loads, this trend was observed owing to the fact that biodiesel mixtures have a lower heating value than pure diesel and thus more biodiesel mixture were required to maintain same power output [8]. Following figure also shows that minimum value of BSFC is 0.4188 kJ/kg.hr obtained at B20 among all biodiesel blends this is probably due to the molecules of biodiesel (i.e. methyl ester of the oil) contains some additional amount of oxygen, increases the combustion efficiency of the fuel by participating the combustion process and increases the power output, thus lesser fuel required for producing same power output [9]. The test results also indicates that the BSFC is higher 0.4548 kJ/kg.hr at B25 as compared to B20 because when the mass percentage of oxygen contained by biodiesel exceeds beyond a certain limit, then mixture becomes lean which leads to incomplete combustion and hence the fuel consumption for producing same power output is increased, hence B20 gives minimum BSFC for compression ratio 14.

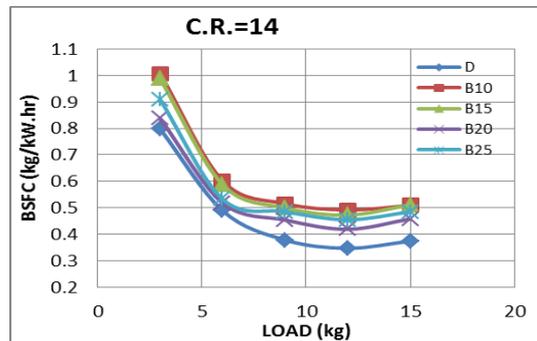


Figure 7 Brake specific fuel consumption Vs. Load for C.R. = 14

Fig. 8 shows the variation of BSFC with load at compression ratio 15. Minimum values of BSFC are 0.3366, 0.4329, 0.3879, 0.3755 & 0.3898(kJ/ kg.-hr) for pure diesel, B10, B15, B20 & B25 respectively. The minimum value of BSFC is 0.3755 kJ/kg.hr obtained at B20 among all biodiesel.

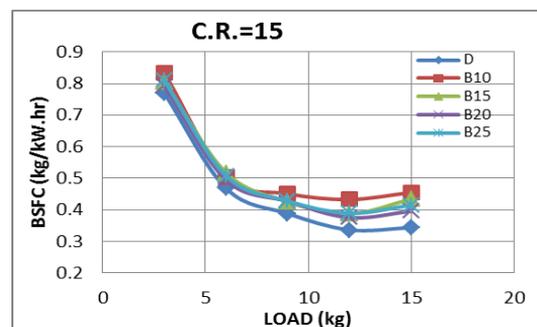


Figure 8 Brake specific fuel consumption Vs. Load for C.R. = 15

Fig. 9 shows the variation of BSFC with load at compression ratio 16. Minimum values of BSFC are 0.3264, 0.3865, 0.4023, 0.3629 & 0.3763(kJ/ kg.-hr.) for pure diesel, B10, B15, B20 & B25 respectively. The minimum value of BSFC is 0.3629 kJ/kg.hr obtained at B20 among all biodiesel blends. Hence B20 gives minimum BSFC for compression ratio 16.

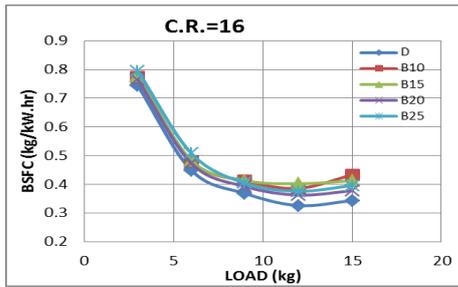


Figure 9 Brake specific fuel consumption (Bsfc) Vs. Load for C.R. = 16

Fig. 10 shows the variation of BSFC with load at compression ratio 17. Minimum values of BSFC are 0.3168, 0.3608, 0.3504, 0.3299 & 0.3411(kJ/ kg.-hr.) for pure diesel, B10, B15, B20 & B25 respectively. The minimum value of BSFC is 0.3299 kJ/kg.hr obtained at B20 among all biodiesel blends.

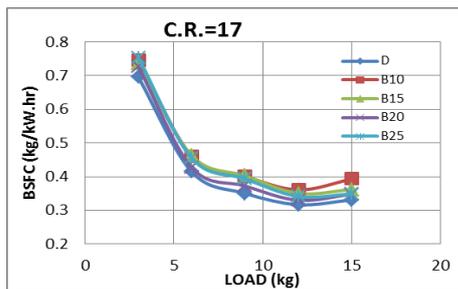


Figure 10 Brake specific fuel consumption Vs. Load for C.R. = 16

Fig. 11 shows the variation of BSFC with load at compression ratio 18. The figure clearly shows the similar pattern of BSFC as discussed for above compression ratio's that is 0.2992, 0.3492, 0.3394, 0.3203 & 0.3307 (kJ/ kg.-hr.) for pure diesel, B10, B15, B20 & B25 respectively. The minimum value of BSFC is 0.3203 kJ/kg.hr obtained at B20 among all biodiesel reason.

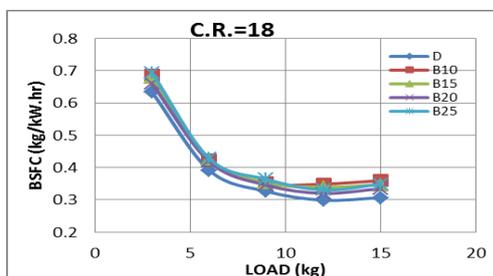


Figure 11 Brake specific fuel consumption Vs. Load for C.R. = 18

C. Comparison of Brake Power:

For biodiesel Brake Power is calculated by assuming same fuel consumption at all respective load same as taken for diesel. Fig. 12 shows the variation in brake power with change in load for diesel and different blend of biodiesel at CR 14, the brake power increase with increase in load because applied torque increase with load and brake power is a strong function of applied torque [9]. Hence maximum brake power is observed at full load for pure diesel as well as all blends of biodiesel at given

compression ratio and values are 3.467 kW, 2.551 kW, 2.541 kW, 2.833 kW and 2.678 kW for pure diesel B10, B15, B20 and B25 respectively at compression ratio 14. From the following figure it can be seen that pure diesel has higher brake power as diesel has more calorific value than the biodiesel [8]. But among all diesel blends maximum brake power obtained at B20 blend because efficient combustion take place at this blend due to availability of extra oxygen molecule with biodiesel molecule [9].

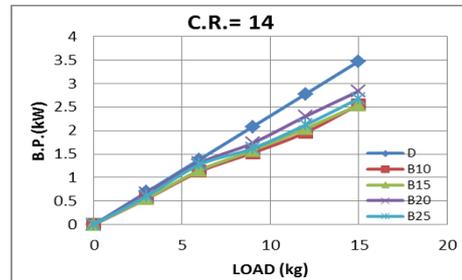


Figure 12 Brake Power Vs. Load for C.R. = 14

Fig. 13 shows the variation in brake power with change in load for diesel and different blend of biodiesel at compression ratio 15. Maximum brake power are 3.467 kW, 2.622 kW, 2.750 kW, 3.0184 kW and 2.874 kW for pure diesel B10, B15, B20 and B25 respectively at full engine load. Among all diesel blends maximum brake power obtained at B20 blend.

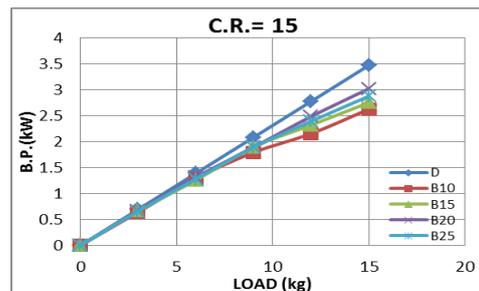


Figure 13 Brake Power Vs. Load for C.R. = 15

Fig. 14 shows the variation in brake power with change in load for diesel and different blend of biodiesel at compression ratio 16. The obtained maximum brake power are 3.467 kW, 2.752 kW, 2.879 kW, 3.145 kW and 3.002 kW for pure diesel B10, B15, B20 and B25 respectively at full engine load. Among all diesel blends maximum brake power obtained at B20 blend.

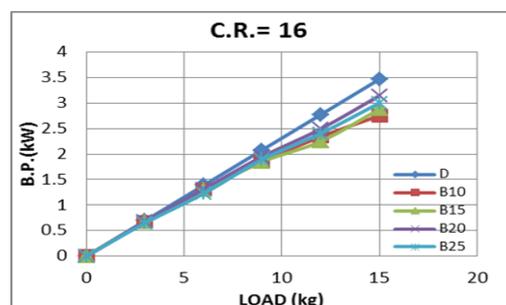


Figure 14 Brake Power Vs. Load for C.R. = 16

Fig. 15 shows the variation in brake power with change in load for diesel and different blend of biodiesel at compression ratio 17. The maximum brake power is obtained at full load and values are 3.467 kW, 2.917 kW, 3.171 kW, 3.295 kW and 3.287 kW for pure diesel B10, B15, B20 and B25 respectively. Among all diesel blends maximum brake power obtained at B20 blend.

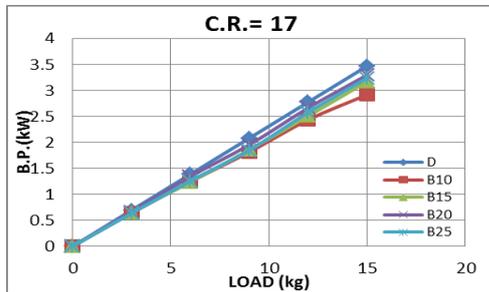


Figure 15 Brake Power Vs. Load for C.R. = 17

Fig. 16 shows the variation in brake power with load for diesel and different blend of biodiesel at compression ratio 18. The maximum brake power obtained are 3.467 kW, 2.957 kW, 3.069 kW, 3.184 kW and 3.177 kW for pure diesel B10, B15, B20 and B25 respectively. Among all diesel blends maximum brake power obtained at B20 blend.

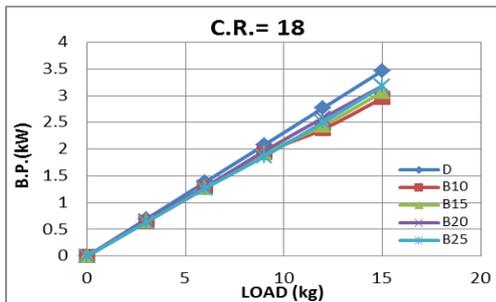


Figure 16 Brake Power Vs. Load for C.R. = 18

D. Exhaust Gas Temperature

The variation of exhaust gas temperature with engine loads for the different blends of cottonseed biodiesel and diesel is shown in following fig.17, exhaust gas temperature is increase with an increase in the engine load and it is observed through the operation for all tested fuel, because of more fuel requirement for that extra power to take up the additional loading [7]. As mass flow rate of fuel increases in the combustion chamber of engine this leads to more heat available due to the burning of extra fuel, increased heat available and increases the temperature of exhaust gases [8]. The maximum exhaust gas temperature noticed at full load condition for all tested fuel and the maximum temperatures measured at full load condition are as 370°C, 373°C, 374°C, 378°C and 389°C for pure diesel, B10, B15, B20, and B25 respectively at compression ratio 14. Above results show that EGT increases with increase in concentration of Biodiesel in the blends and maximum exhaust temperature is 389°C at B25, the value viscosity is directly proportional to the concentration of biodiesel

present in the blends and this increase of viscosity affects the fuel atomization, vaporization and combustion.

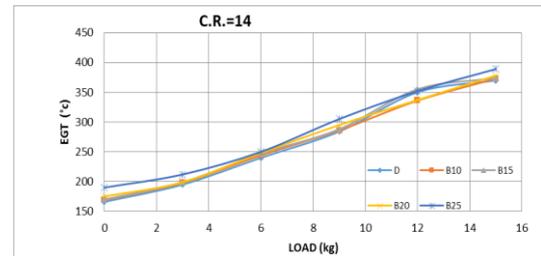


Figure 17 Exhaust gas temperature Vs. Load for C.R. = 14

Fig. 18 shows variation of exhaust gas temperature with different engine load at compression ratio of 15. Maximum exhaust gas temperature noticed at full load condition for all tested fuel and values are as 368°C, 370°C, 372°C, 376°C and 378°C for pure diesel, B10, B15, B20, and B25 respectively.

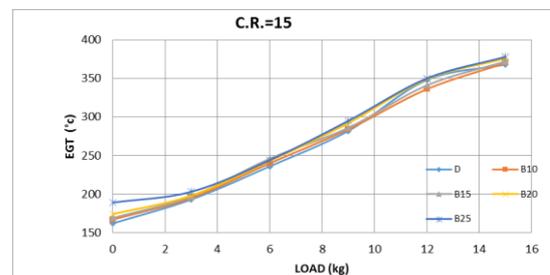


Figure 18 Exhaust gas temperature Vs. Load for C.R. = 15

Fig. 19 shows variation of exhaust gas temperature with different engine load at compression ratio of 16. The maximum exhaust gas temperature noticed at full load condition for all tested fuel and the values are as 362°C, 365°C, 372°C, 374°C and 377°C for pure diesel, B10, B15, B20, and B25 respectively.

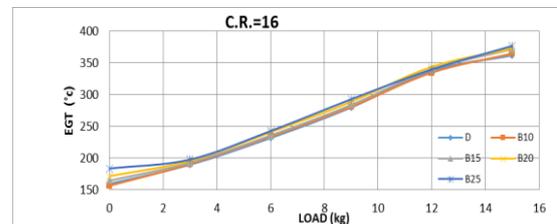


Figure 19 Exhaust gas temperature Vs. Load for C.R. = 16

Fig. 20 shows variation in exhaust gas temperature with different engine load at compression ratio 17 for all tested fuel. The maximum exhaust gas temperature noticed at full load condition are as 360°C, 362°C, 365°C, 366°C and 375°C for pure diesel, B10, B15, B20, and B25 respectively.

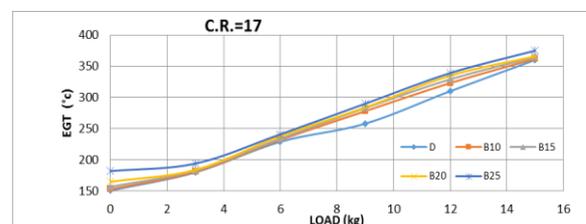


Figure 20 Exhaust gas temperature Vs. Load for C.R. = 17

Fig. 21 shows variation in exhaust gas temperature with an increase in the engine load for all tested fuel and maximum exhaust gas temperature noticed at full load condition for all tested fuel and the maximum temperatures measured at full load condition are as 348^oC, 352^oC, 354^oC, 362^oC and 368^oC for pure diesel, B10, B15, B20, and B25 respectively.

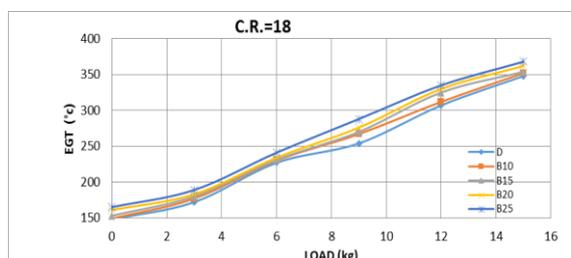


Figure 21 Exhaust gas temperature Vs. Load for C.R. = 18

V CONCLUSIONS

The performance characteristics of a single cylinder, direct injection, four- stroke, vertical, water-cooled, naturally aspirated variable compression ratio multi-fuel engine having power output of 3 to 5 HP, fueled with diesel, B10, B15, B20, and B25 blends have been analyzed and compared it with different compression ratios 14, 15, 16, 17, & 18 with those of diesel. Following conclusions can be drawn from the study:

- Highest thermal efficiency and lowest break specific fuel consumption are found for B20 (20% cotton seed + 80% diesel) blend among all other blending combination at different compression ratios.
- Blend B20 gives better results than other blends so it is an optimized blend when the compression ratio varies from 14 to 18.
- Optimized B20 blend gives very close thermal efficiency, 2.46% smaller than diesel fuel at compression ratio 17 at 75% of maximum load i.e. 12 kg.
- Among all diesel blend maximum break power was found 3.295 kW by B20 blend at compression ratio 17.
- Maximum Exhaust gas temperature was decreased with the increase of compression ratio for pure diesel and all diesel blend combinations.
- Maximum Exhaust gas temperature was found for B25 blend among pure diesel and all diesel blend combinations at full engine load (15 kg).

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