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Performance Characteristics of Diesel Engine using Different Biodiesel Blends

M. Kumar, P.P. Shantharaman, N.Magesh,

Department of Mechanical Engineering, Kings College of Engineering, Punalkulam, Pudukkottai,
Tamilnadu, India

ABSTRACT: Now days Biodiesel is emerging as an alternative fuel which is a good replacement to the fossil fuels like diesel. Biodiesel is mainly derived from fats and oils by different methods such as dilution, pyrolysis, micro emulsification and transesterification but these days most commercial method used for biodiesel production is transesterification. Annona oil biodiesel was prepared using transesterification process by optimizing the production parameters such as alcohol to oil molar ratio, catalyst concentration etc. Engine design also plays an important role as if it is improved it reduces fuel consumption and give better performance parameters. In this is the main emphasis has been laid on optimum production of biodiesel from Annona oil and then using the biodiesel blends with diesel studying the comparative exhaust emission characteristics and engine performance and also optimizing the compression ratio and the blends made from the biodiesel with diesel. A four stroke variable compression ratio single cylinder compression ignition engine was used to measure performance and emission parameters. Biodiesel (fire point and calorific value) added to the diesel (fire point and calorific value) at four different volume concentrations i.e. 5, 10, and 15 % of biodiesel. Based on the analysis of performance and emission parameters the biodiesel blend B11 was found optimum for the most efficient operation of the engine. The CR 14 was found optimum by comparing the performance parameters such as BTHEff, BSFC, and BVE etc. for all the compression ratio

I. INTRODUCTION

The use of vegetable oils and its derivatives has been used as alternative diesel fuels. From the times of petroleum crisis in 1970 as the demands and prices has been increased day by day more interests are seen towards substitution of fossil fuels with biodiesel. Also biodiesel production has been in great interests because of concern seen towards world growing environment problems in the last few decades (Balat et al. 2008). Now a days biodiesel is emerging as an alternative fuel as viable alternative to petroleum diesel. So many methods are used for production of biodiesel conventionally such as pyrolysis, micro emulsification, dilution, transesterification etc.

Parameters effecting transesterification process

The most influencing parameters in the process:

1. Oil temperature
2. Reaction temperature
3. Catalyst and concentration
4. Alcohol to oil ratio
5. Mixing intensity
6. Purity of reactants
7. Stirring effect
8. Moisture and water content effect

1. Oil temperature

The oil temperature which is to be mixed with catalyst and methanol is pre heated up to certain temperature as it affects the reaction. As it is observed that by pre heating the oil the oil to biodiesel conversion and recovery increases to an extent. Also the tests were conducted by pre heating the oil to 60°C as above it process may result in methanol losses due to low boiling temperature of methanol.

2. Reaction temperature

The reaction temperature has a significant effect on rate of reaction if done on room temperature given enough time it can proceed to completion whereas by attaining a certain reaction temperature it increases the rate of reaction. Generally the reaction is conducted at atmospheric pressure near the boiling point of methanol (60 to 70 C). On further increase in temperature a negative effect is seen on conversions. Studies shows that by giving enough time

at ambient temperatures the reaction goes satisfactorily using alkaline catalyst. Also it was observed that at low temperatures conversion was unaffected but bio diesel recovery was significantly affected.

3. Catalyst type and concentrations

In transesterification reaction as compared to acidic catalyst the alkaline catalyst are more efficient. Sodium alkoxides are most effectively used for the purpose also potassium alkoxides can be used either. The transesterification reaction rate increases a several times in presence of alkaline catalyst than the reaction taking place in same amount of acidic catalyst. Alkaline catalyst also have an advantage over the acidic as they are less corrosive to equipment used hence mostly the reactions are carried out with alkaline catalyst instead of acidic catalyst. The optimum alkaline catalyst age by weight is taken 0.5 to 1% as after increasing the catalyst concentration it will not increase conversion but it will only add to the cost of reaction as the catalyst has to be removed at the end of process from reaction at the time of recovery. Also if high concentration of catalyst is used then the conversions are reduced due to generation of more glycerol during recovery. It was seen that for high FFA content oils high amount of catalyst was required to have efficient conversions.

4. Alcohol to oil ratio

Ratio of alcohol to oil is another important factor affecting the ester yield. As according to stoichiometry of transesterification reaction the molar ratio of 3:1 of alcohol to triglycerides is required to give 3:1 molar ratio of fatty ester to glycerol. Also by increasing the molar ratio of alcohol to triglycerides i.e. by increasing alcohol amount the yield and reaction rate can be increased but up to some limits of molar ratio after that with further increase in alcohol the conversion is increased but there is hindrance in the separation of glycerol. So studies seen that optimum molar ratios are required and that depends on the quality and type of oil used.

5. Mixing intensity

Mixing intensity is a significant tool if applied during correct stage of transesterification reaction because as the single phase is established mixing becomes in significant. So it can be used as a wise tool to scale up the process. So in the studies it is seen that after adding alcohol and catalyst to the oil if the stirring is done for 5 to 10 mins then it results in high rate of conversions and recovery of ester.

6. Purity of reactants

Purity of reactants in a considerable factor that affect the conversion levels in the transesterification reaction. The free fatty acids in oils with impurities have difficulty in conversion to esters but can be overcome at high temperatures and pressure. It is seen that 67% to 84% conversions are there in esters using crude oils whereas in refined oils it 94 to 97% under same operating conditions. Also it is observed that refined and crude oils shows equally good conversions of esters as if the oils are filtered. Quality of oil is also important in this aspect. Also the recovery of biodiesel is less from the oil settled down having impurities in it like wax etc.

7. Stirring effect

It is also an important tool in yield of biodiesel. An optimum rate of stirring is required to have a good yield of esters i.e. if it is less than a certain limit then the reaction can be incomplete while by increasing it more can lead to no changes in yield from a certain speed. The mode of stirring also has a role in stirring i.e. whether it is mechanical stirring or the magnetic stirrer is used.

8. Moisture and water content effect

With the presence of water in the oil it put a great negative effect on the yield of esters. The effect of presence of water in oil has much worse effects than having FFA in it. As a very small amount of water can reduce the ester yield. Due to the presence of water and FFA there is much reduction in alkyl ester yields because they form soap, consume catalyst and make catalyst ineffective. The removal of moisture content from oil is done by heating it on 383K.

II. BIODIESEL PREPARATION

ANNONA oil biodiesel transesterification process (two stage process)

First stage (acid catalyzed transesterification reaction)

1. The known quantity of crude ANNONA oil was taken in a conical flask.
2. Then the oil in the flask was heated on a heating plate up to 65°C temperature.

3. A mixture of a known amount of methanol and sulphuric acid as acid catalyst was added to the flask and mixed with the pre heated crude ANNONA oil in the flask.

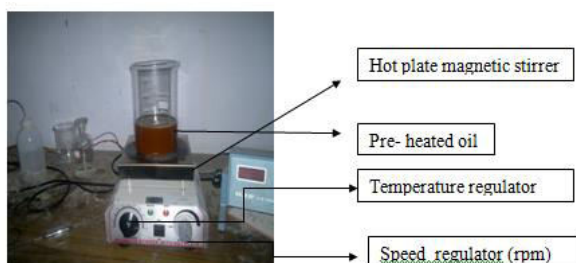


Figure 1: Pre heating of ANNONA oil on magnetic stirrer with hot plate.

1. The preheated oil mixture was constantly stirred for 35 min at a constant temperature of 50 C on the magnetic stirrer with hot plate.
2. After the constant stirring of 35mins at constant temperature the mixture as for the impurities to settle down was poured in separating funnel. After 5-6 hours the impurities settled down were separated from the remaining oil

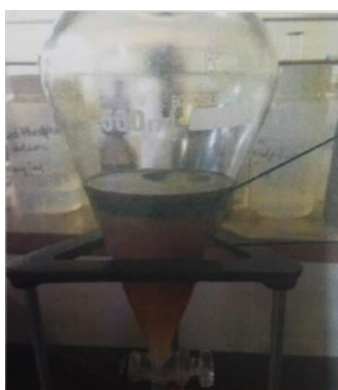


Figure 2: Two layers formed after the acid catalyzed stage,

1. The oil remained in the separating funnel was again measured and then pre heated up to 65°C
2. After that the known amount of methanol and potassium hydroxide mixture was added in the preheated remaining oil.
3. After that a constant stirring of 35 mins was again subjected at a constant temperature of 50°C on the pre heated remaining oil in the flask on a hot plate magnetic stirrer.
4. After the constant stirring of 35 mins the mixture was poured in separating funnel to glycerol produced to settle down.
5. After 3-4 hours of settling down a layer of glycerol was made on the bottom which was separated and removed.
6. The remaining in the funnel is methyl ester (biodiesel) of ANNONA oil i.e. yield 93% approximately which is further purified by hot water washing and drying to remove the excess of methanol, water, KOH from the oil.
- 7.

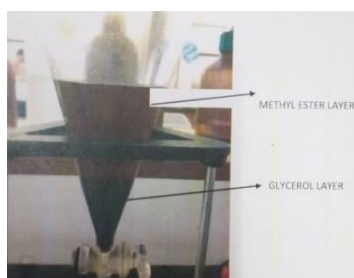


Figure 3: Separated layers after base catalyzed stage.

Table 1: Properties parameters of ANNONA oil methyl ester

PARAMETERS	TEST METHOD	Units	ANNOVA OIL METHYL ESTER (BODIESEL)
Calorific value	IS: 1350(PART II), 1970, reaff. Nov. 2010 (Bomb Calorimeter)	kcal/kg	9965
Ash Content	IS:1448 (PART-4)	% by mass	0.02
Flash Point	Pensky Martens Closed Cup Test (PMCC)	°C	250
Fire Point	Pensky Martens Closed Cup Test (PMCC)	°C	255
FFA content	Titration with 0.1N NaOH	%	0.311
Cloud Point	Cloud and Pour point apparatus, IS: 1448 [P: 10]: 1970	°C	6.8
Pour Point	Cloud and Pour point apparatus, IS: 1448 [P: 10]: 1970	°C	-2
Iodine value	SP:18 (PART 13)-1984		58.40
Moisture	Dean-Stark Method		Not Detected
Kinematic Viscosity @40°C	Redwood Viscometer, IS: 1448 [P: 25] 1976		5.88

Table 2: Fatty acid composition of ANNONA oil(Khandelwal)

Fatty Acid	Structure	Amount %
Palmitic acid	16:0	17.8
Stearic acid	18:0	14.4
Oleic acid	18:1	51.3
Linoleic acid	18:2	14.7
Arachidic acid	20:0	1.6
Myristic acid	14:0	0.03

II. METHODOLOGY FOR THE EXPERIMENTAL TESTING OF EMISSION AND PERFORMANCE ON AN ENGINE

The second part of methodology deals with the method used for the experimental testing on the engine using different biodiesel blends. The different apparatus and method used in the process is discussed and also the different performance and exhaust emission parameters are discussed.

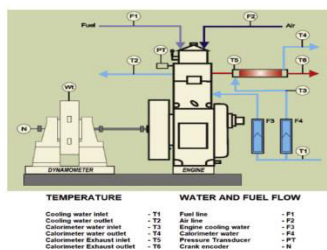
2.1 Evaluation of engine performance

Evaluation of engine performance is explained as

- Firstly an engine description
- Secondly the method or operation scheme used
- Thirdly the parameters that are evaluated.

Engine description

The picture of the engine on which the experiments are carried out is shown i.e. of the variable compression ratio compression ignition engine along with the online performance evaluation system is shown in figure.

**Figure 4:** Flow line diagram of variable compression ratio compression ignition engine

Procedure followed in experiments

1. Firstly fill the diesel in fuel tank.
2. Then initially adjust the compression ratio 12:1 of the engine.
3. After that water supply is started. As the cooling water flow for engine is setup at 250 LPH and calorimeter flow at 75 LPH.
4. Ensuring the adequate water flow rate for piezo sensor cooling and dynamometer.
5. Check the electrical connections and then start the power supply to the computer Through UPS.
6. The lab view engine performance analysis software package "Enginesoff" id Opened for the performance evaluation on the screen.
7. By opening the valve at the burette the diesel is supplied to the engine.
8. The value of calorific value and specific gravity is adjusted through the configure Option present in the software.
9. After that select the run option on software and start the engine and let it run for few minutes.
10. Then choose the log option in the software. Fuel supply is turned on. After that in 1 minute the display changes to input mode at that time values of water flows in cooling jacket and calorimeter are entered and the file is named (for first reading only) in the software. At that time for no load conditions the first reading gets logged on. Then the fuel knob is turned back to previous (normal) position.
11. Then the experiment is repeated for different loads.
12. The different reading corresponding to the different load will display on the Monitor after that which are saved for a particular compression ratio..
13. The compression ratio is then changed by adjusting the screw arrangement.
14. Then the same experiment is repeated for the different compression ratio and the Readings are saved for the same.
15. Now for the next fuel blend testing change the fuel in the fuel tank and then Accordingly adjust the calorific value and specific gravity of the fuel in the software.
16. Repeat the procedure for different fuel at different compression ratio and record The readings in the computer.
17. After that bring the engine to no load condition and turn off the computer as well As the engine so as to stop the experiment.
18. After that in few minutes also stop the water supply.

III. RESULT AND DISCUSSION

Result and discussion is divided in two parts. First objective is to produce the biodiesel from ANNONA oil by optimizing the different parameter that significantly affects the production i.e. molar concentration of methanol to oil, catalyst concentration taken etc. the second objective of result and discussion is to optimize the compression ratio and to obtain a best out of all the blends used by considering the performance and emission parameter. Firstly production parameters are discussed with results obtained.

Performance parameters

Brake Power VS Specific Fuel Consumption

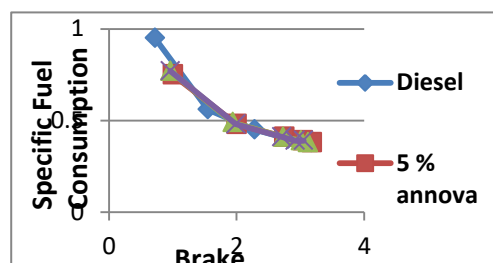
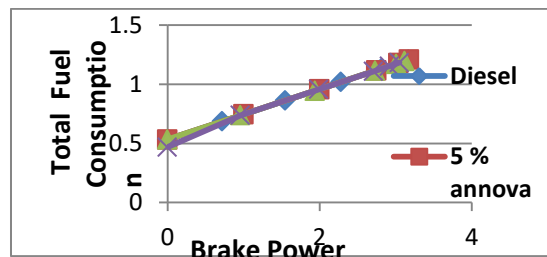


Figure variation of Brake Power VS Specific Fuel Consumption for diesel and Different biodiesel blends at compression ratio 12:1

The above figure shows the brake power variation at different loads of the diesel and different biodiesel blends. The SFC vs BP graph shows that at first of all at no load condition the BP is same for all the diesel and biodiesel blends but as the SFC increases the BP of diesel increases more as compared to others because of having higher heating value than biodiesel blends. At part SFC the BP of biodiesel blends decreases than diesel because of having higher viscosity

and density but low heating value than diesel and such decrease further on increasing biodiesel amountage). Hence maximum HP can be achieved by using diesel other than B11, B21, 831, and B41. An exception in CR12 with B41 has shown more BP all the SFC in comparison to BP obtained for all other blends and diesel. Now on increasing the CR there is no much change in trends as shown by above figures with using CR14 and 16 ie the diesel heating value is more so the BP produced by diesel in CR14 and 16 is more than biodiesel blends because of the same reason stated above.

Brake Power VS Total Fuel Consumption**Figure** variation of Brake Power VS Total Fuel Consumption for diesel and Different biodiesel blends at compression ratio 12:1

The above figures show the brake power variation at different loads of the diesel and different biodiesel blends. The TFC vs BP graph shows that at first of all at no load condition the BP is same for all the diesel and biodiesel blends but as the TFC increases the BP of diesel increases more as compared to others because of having higher heating value than biodiesel blends. At part TFC the BP of biodiesel blends decreases than diesel because of having higher viscosity and density but low heating value than diesel and such decrease further on increasing biodiesel amountage). Hence maximum HP can be achieved by using diesel other than B11, B21, 831, and B41. An exception in CR12 with B41 has shown more BP all the TFC in comparison to BP obtained for all other blends and diesel. Now on increasing the CR there is no much change in trends as shown by above figures with using CR14 and 16 ie the diesel heating value is more so the BP produced by diesel in CR14 and 16 is more than biodiesel blends because of the same reason stated above.

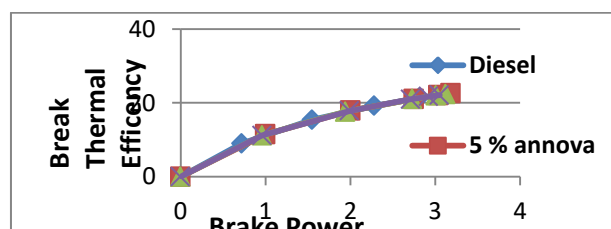
Brake Power VS Break Thermal Efficiency

Figure variation of Brake Power VS Break Thermal Efficiency for diesel and Different biodiesel blends at compression ratio 12:1 The above figures shows the variation of brake thermal efficiencies with load. The brake thermal efficiency has increased with increase in the load. The rate of increase was more at lower loads whereas it has decreased with increasing the load further. Dhar et al and Heroor et al. 2013 has also obtained similar trends for brake thermal efficiency using ANNONA oil biodiesel. Nayak et al. 2014 and Sakthivel et al. 2014 also showed similar variations for brake thermal efficiency using mahua oil biodiesel and fish oil biodiesel. At all the CR highest values of brake thermal efficiency was obtained for B21 for all the loads. This trends is because at higher load the rate of increase of BP decreases whereas the rate of increase of fuel consumption remain almost constant. So the decrease in rate of increase of BP at higher loads leads to decrease in rate of increase of brake thermal efficiency. Variation of brake thermal efficiency has shown that CR negligible influence on the Brake thermal efficiency at different loads for different blends.

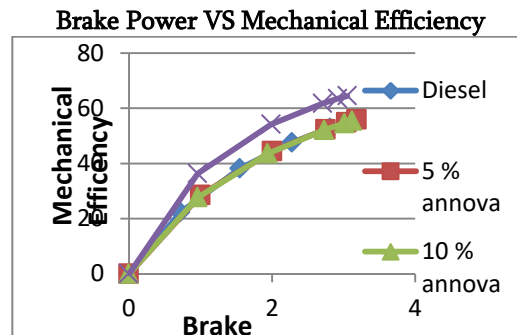


Figure variation of Brake Power VS Mechanical Efficiency for diesel and Different biodiesel blends at compression ratio 12:1

These figures show the variation of mechanical efficiency with load of diesel and different biodiesel blends. The mechanical efficiency has shown increasing trends with increase in the load at all the CR for all the blends. The rate of increase is more at low loads as compared to the rate of increase at higher values of load. This is due to the fact that at higher loads the increase in BP is less as compared to lower loads whereas IP power increases with the same rate at all loads. At higher loads the temperature of engine increases which leads to decrease in viscosity of the lubricating oil hence frictional power losses increases with more rate at higher loads. From the figures it can be seen that the CR has not much affected the mechanical efficiency. The mechanical efficiency obtained for B11 blend was maximum at higher loads for all CRs.

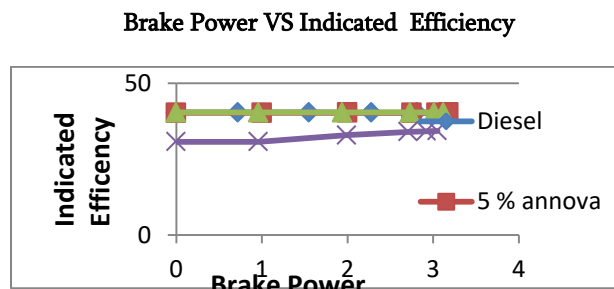


Figure variation of Brake Power VS Indicated Efficiency for diesel and different biodiesel blends at compression ratio 12:1

The above figures show the variation of diesel and biodiesel blends Indicated efficiency with the load. It is seen that with increase in load volumetric efficiency has shown decreasing trend but the amount of decrease is very small when the load was varied from no load to full load conditions. Not much change in trends of Indicated efficiency was seen with the increase in CR. The max Indicated efficiency was obtained with diesel whereas minimum Indicated efficiency was recorded for the B31 blend.

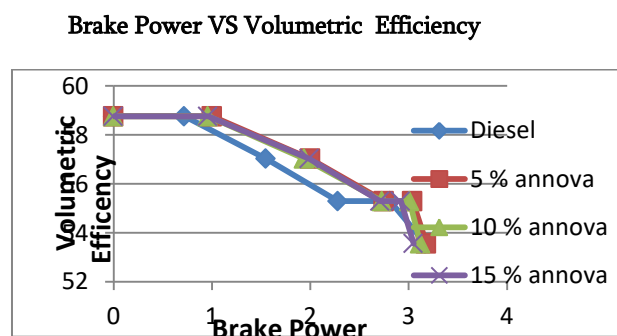


Figure variation of Brake Power VS Volumetric Efficiency for diesel and different biodiesel blends at compression ratio 12:1

The above figures shows the variation of Volumetric Efficiency with load of diesel and different biodiesel blends. As the load increases in the above figures the Volumetric Efficiency decreases at lower loads and then it remains decreases.

In the previous work Dhar et al. 2012 using neem oil biodiesel has shown similar trends in the BSFC. Nayak et al. 2014 has also shown similar trends in BSFC using mahua oil biodiesel blends. Ashraful et al. 2014 using ANNONA oil biodiesel has shown trends as slight increase for B20 and for all other biodiesel the Volumetric Efficiency is nearly close to the diesel fuel on engine-Cylinder DI, CR: 17.5:1, RP. 44 kw, 1600 rpm similar to that of above trends. As the load increases firstly the rate of increase of BP compared to fuel consumption is more and as the load moves towards full load conditions the rate of increase of BP and fuel consumption remains same

IV. CONCLUSION

Biodiesel was prepared from the ANNONA oil using transesterification process which includes a two stage process first stage is acid catalyzed stage and the second stage is base catalyzed stage. In the process it was seen that the molar ratio optimum for the acid catalyzed stage was 9:1 at 1% catalyst concentration and 50°C was found to be the optimum temperature for the process. Further it was seen by considering the affecting factors i.e, conversions and FFA values that for the second stage i.e. base catalyzed stage the optimum molar ratio was found to be 15:1 and catalyst concentration of 1% at 50°C temperature for the production of biodiesel. Experiments were performed on the dual fuel diesel engine using diesel and ANNONA oil based biodiesel at different volume concentrations. Performance and exhaust emission parameters were measured during investigation at different loads and compression ratios. It has been found that the brake power has shown increasing trend with the load at all the compression ratios. Similar trend was observed for diesel as well as the biodiesel as fuel at all the concentrations. BSFC has shown decreasing trends with the load at all the compression ratios also at lower loads decrease in BSFC is more due to higher rate of increase of brake power at lower loads as compared to rate of increase in fuel consumption. Brake thermal efficiency has shown linear increasing trend with load at lower loads whereas the curve becomes almost flat at higher loads due to the small rise in the brake power at higher loads. No change in the brake thermal efficiency was found on addition of biodiesel because the biodiesel has almost same heating value and fire point to that of diesel. The mechanical efficiency has increased with increase in the load at all the compression ratios. Volumetric efficiency has shown decreasing trend with increasing load due to high engine temperatures at higher loads. The exhaust gas temperatures have increased with increase in the load due to the use of rich air fuel mixtures at higher loads. Carbon monoxide emissions has increased on addition of biodiesel to the diesel whereas NOX emissions has increased up to 19% volume concentrations and after that it has increased on further addition of biodiesel this is due to the maximum temperatures obtained in the engine because of proper combustion of air fuel mixture at this concentration. CO₂ emissions has become almost thrice to that of CO₂ emissions obtained for diesel, at 21% volume concentration of biodiesel whereas it has decreased on further addition of biodiesel. After analyzing the performance parameters it has been found that the brake thermal efficiency, mechanical efficiency have maximum BSFC and exhaust gas temperatures were also obtained for the same biodiesel blend (B11). The CO emissions has slightly increased on addition of B11 however it was less as compared to emissions obtained for other blends. A slight decrease in NO_x emission was observed at B10 whereas NO_x emission has increased for all other blends. Also CO₂ emissions were similar to that of diesel for this blend (B11) however these have increased on further addition of biodiesel. From this it can be concluded that the blend B11 is optimum for the variable compression ratio compression ignition engine considering performance and exhaust emission parameters. Also it was seen that the variation in performance parameters for different compression ratios was seen to be constant at all the loads when it was seen for a particular biodiesel blend except the EGT and BSFC. These two parameters i.e. EGT and BSFC were seen to be lowest at all the loads for a particular biodiesel blend hence it can be concluded that CR 14 is optimum for the operation of the engine.

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