PERFORMANCE AND COMPARISON OF CI ENGINE USING NEEM BIO DIESEL AND DIESEL AS FUEL WITH DIFFERENT BLENDS

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ABSTRACT: Biodiesel now a days is rising as an elective fuel which is a decent substitution to the oil diesel. Biodiesel is basically gotten from fats and oils by various strategies, for example, weakening, pyrolysis, small scale emulsification and transesterification however nowadays most business technique utilized for biodiesel creation is transesterification. Neem oil biodiesel was readied utilizing transesterification process by improving the creation boundaries, for example, liquor to oil molar proportion, impetus focus and so forth. Motor plan likewise assumes a significant job as though it is improved it diminishes fuel utilization and give better execution boundaries. In this proposal the primary accentuation has been laid on ideal creation of biodiesel from neem oil and afterward utilizing the biodiesel mixes with diesel contemplating the near fumes emanation attributes and motor execution and furthermore advancing the pressure proportion and the mixes produced using the biodiesel with diesel. A four stroke variable pressure proportion single chamber pressure start motor was utilized to gauge execution and emanation boundaries. Biodiesel (fire point and calorific worth) added to the diesel (fire point and calorific worth) at four distinctive volume focuses for example 10, 20, 30 and 40% of biodiesel. In view of the examination of execution and outflow boundaries the biodiesel mix B10 was discovered ideal for the most productive activity of the motor. The CR 14 was discovered ideal by contrasting the exhibition boundaries, for example, BTHeff, BSFC, and EGT and so forth for all the pressure proportions.

1 INTRODUCTION

The utilization of vegetable oils and its subordinates has been utilized as elective diesel fills. From the hours of oil emergency in 1970 as the requests and costs has been expanded step by step more interests are seen towards replacement of petroleum products with biodiesel. Additionally biodiesel creation has been in extraordinary interests in light of concern seen towards world developing condition issues over the most recent couple of decades (Balat et al. 2008). Presently a days biodiesel is developing as an elective fuel as feasible option in contrast to oil diesel. Such a significant number of techniques are utilized for creation of biodiesel ordinarily, for example, pyrolysis, miniaturized scale emulsification, weakening, transesterification and so forth. (Khandelwal et al. 2012).

1.1 Biodiesel

The specialized meaning of biodiesel is: "The mono alkyl esters of long unsaturated fats got from sustainable lipid feedstock, for example, vegetable oils or creature fats, for use in pressure start (diesel) motors" (National Biodiesel Board, 1996). The vegetable oils and creature fats used to deliver biodiesel basically have triacylglycerol's Labels Artificially, TAG are delegated esters of unsaturated fats (FA) with glycerol (1, 2, 3-propanetriol). Presently these TAG comprise of various FA (unsaturated fats) further every unsaturated fat connected to a glycerol. These FA present in TAG have various profiles or structures which further have a significant job in choosing the physical and compound properties of the FA which further impact the properties of comparing creature fats and vegetable oils.

Methods used for Biodiesel processing

1.1.1Micro-Emulsification

The micro emulsions can be defined as thermodynamically stable transparent colloidal equilibrium dispersions whose droplet diameter ranges from 1±150 nm. The micro emulsions formed with vegetable oils reduce the viscosity thus solving the problem. A micro emulsion can be formed with an ester and dispersant in vegetable oil or an alcohol and surfactant with vegetable oil both by mixing and non-mixing of diesel fuels in it. Water tolerance can be increased of micro emulsion with presence of water by using lower proof ethanol.

1.1.2Dilution

In dilution it can be achieved with materials such as ethanol, diesel fuels and solvent. This can be done by diluting vegetable oil with petroleum diesel to run theengine.

1.1.3Transesterification

The most common method for biodiesel production is transesterification. It is also called alcoholysis which as the name suggests is the displacement of an alcohol from an ester by another alcohol i.e. basically conversion of one ester into other. In the process the equilibrium reaction takes place by mixing the reactants. It can be enhanced by raising temperature up to certain limits, adding catalyst to it and further by using excess of alcohol to achieve high yields of esters.

The most influencing parameters in the transesterification process:

1. Oil temperature

2. Reaction temperature

3. Catalyst and concentration

4. Alcohol to oil ratio

5. Mixing intensity

6. Purity ofreactants

7. Stirring effect

8. Moisture and water content effect

1.2 Raw materials used for production of biodiesel

1.2.1 Vegetable oils

The oil used should be free from moisture because with the moisture present in it the catalyst can be consumed by it which then reduce catalyst concentration. It should be free of impurities and sediments as they get collected at bottom of vessel in which reaction is taking place and then hinder in the separation of phases of glycerol during the biodiesel recovery. FFA content of oils should be less than 1% although high FFA oils are also used but the yield depends on the catalyst and oil type.

1.2.2 Alcohol

Methanol and ethanol are used in near to absolute purity. Methanol is used more in reactions as compared to ethanol because of simple structure hence easy transesterification reaction.

1.2.3 Catalyst

Mostly used catalyst in the reactions are sodium and potassium hydroxides but also the alkalides of the both can be used instead. It is seen that the best grades of potassium hydroxides have 14-15% water in it that can't be removed. As the carbonates cause cloudiness in final ester so the catalyst should be low in carbonates. Also it is seen that sodium hydroxide pallets give good results when used. As the catalyst amount used is less in the reaction so good quality of catalyst can be used.

1.2.4 Animal fats

The animal fats that are presently used in biodiesel production are lard, tallow, beef, guang- pi. The most commonly used animal fat is tallow as it has high saturated fats which cause its melting point more than ambient temperatures.

1.2.5 Waste vegetable oils

Throughout the world millions of tonnes of waste cooking oil is stored every year and is considered as a never ending source of energy. These oils constitute degraded products of vegetable oils and other materials. Also by testing these oils it is seen that there is very less difference in used and unused oils and also with the simple heating and solid waste removal from the oils make them ready for the use in biodiesel production. The cetane number of the esters produced from these frying oils is seen to be close to the esters of the vegetable oils.

1.3 Storability and Handling

Biodiesel and its blends should not be treated as petro diesel. Biodiesel cannot give rise to poisonous fumes as there are no volatile organic compounds present in it also no traces of lead and sulphur are present so as to produce harmful or corrosive gases. On eye contact to biodiesel it can cause eye irritation. As per fire hazard is concerned then the firefighting measures should be taken as classified. Also for the storage of biodiesel it is recommended according to experience that it should not be kept more than 6 months or else some anti- oxidant additives must be added for long term storage. It is recommended that as biodiesel being a mild solvent it creates sediments in the tanks it is stored so the tanks used for storage must be made of steel, aluminum etc. so as to avoid it. It is also seen that the viscosity and FFA increases in some cases in the biodiesel storage.

1.4 Stability of biodiesel

As compared to fossil fuel diesel the maturity in biodiesel comes faster due to the chemical structure formation of the esters contained in it. Three stability criteria are generally seen its stability i.e. oxidation stability, storage stability and thermal stability.

1.5 Objectives

1. Preparing the neem oil biodiesel using transesterification process byoptimizing the production parameters.

2. Investigation of performance and exhaust emission characteristics of biodiesel blends on variable compression ratio compression ignition engine.

3. Optimizing and finding out the best compression ratio and biodiesel blend considering the performance and exhaust emission parameters.

2. LITERATURE REVIEW

Mustafa Balat and Havva Balat 2008 depicted that the issues with subbing triglycerides for diesel energizes were for the most part connected with their high viscosities, low volatilities and polyunsaturated character. The thickness of vegetable oils, when utilized as diesel fuel, can be decreased in at any rate four unique ways: (1) weakening with hydrocarbons (mixing), (2) emulsification, (3) pyrolysis (warm splitting), and (4) transesterification (alcoholysis). Transesterification was the most well-known technique and prompts monoalkyl esters of vegetable oils and fats, presently called bio-diesel when utilized for fuel purposes. The principle factors influencing transesterification were molar proportion of glycerides to liquor, impetus, response temperature and weight, response time and the substance of free unsaturated fats and water in oils. The ordinarily acknowledged molar proportions of liquor to glycerides are 6:1–30:1. Bio-diesel is a cleaner-consuming diesel substitution fuel produced using normal, sustainable sources, for example, new and utilized vegetable oils and creature fats. Much the same as oil diesel, bio-diesel works in pressure start motors or Diesel motors. The bio-diesel was described by deciding its thickness, consistency, high warming worth, cetane record, cloud and pour focuses, qualities of refining, and glimmer and ignition focuses as per ISO standards. Consistency is the most significant property of bio - diesel since it influences the activity of the fuel infusion gear, especially at low temperatures when the expansion in thickness influences the smoothness of the fuel. Figure 2.1 shows the flow diagram of biodiesel production from non-edible oils.

Fangrui Mama et al. 1999 created biodiesel with the assistance of utilized cooking oils as crude material and by adjusting of constant transesterification process, prompts recuperation of excellent glycerol from biodiesel result (glycerol). In this strategy glycerol were essential alternatives to be thought of, so as to bring down the expense of biodiesel. There were four essential approaches to make biodiesel, direct use and mixing, small scale emulsions, warm splitting (pyrolysis) and transesterification. The most normally utilized technique is transesterification of vegetable oils and creature fats. The transesterification response is influenced by molar proportion of glycerides to liquor, impetuses, response temperature, response time and free unsaturated fats and water substance of oils or fats. The component and energy of the transesterification show how the response happens and advances. The procedures of transesterification and its downstream tasks are additionally tended to.

Prajapati and Sudan 2012 computed brake thermal efficiency of different blends produce from soya and mustard oils. The computed brake efficiency was compared with commercially available fuel (petrol) at different engine loads in a well-defined computerized variable compression ratio multi-fuel (CVCRM). The result showed that the 15-PRS exhibit lower thermal brake efficiency as compared to 20-PRS having highest value of brake thermal efficiency, at an applied load of 7.5 kg. It was also observed that the computed values of brake thermal efficiency was approximately equivalent to the brake thermal efficiency of commercially available petrol fuel, at different loads. Sathya and Manivannan 2013 used edible oil for the production of biodiesel with the help of methanol and in the presence of alkaline catalyst. The crude neem oil used in this study had large content of free fattyacids(FFA) i.e. 6 %, which could react with the catalyst to form soaps. These soaps were that main obstacle for the separation of the ester and glycerin. They employed transesterification process in order to produce biodiesel form high FFA content neem oil. The volume of oil used was 100 ml and suitable pretreatment conditions were 45 v/v ratio of methanol to oil, catalyst concentration 0.5 % v/w of H2SO4 and reaction time was 45 minutes, at 50 0C temperature. Further, transesterification process was started on pretreated neem oil. For the process the neem oil to methanol molar ratio was 0.3:1, in the presence of 1% KOH catalyst for one hour, at 55 0C. The results showed that the maximum average yield determined was 90 ± 2%. They also investigated the 21 impact of molar ratio, catalyst and reaction time in each processing step for theproduction of biodiesel. This study concluded that production cost increases with the increase of H2SO4 content. Tanwar et al. 2013 revealed that the creation of biodiesel essentially relies on the preowned feedstock. As the expanded costs of the eatable oil, it got difficult to create biodiesel from eatable oil. In this way, the utilization of non-palatable oil, for example, neem oil tackled the reason for the creation of biodiesel. This oil can be effectively changed into biodiesel, in the wake of refining process since it had higher FFA substance and dampness content. This trial work considered soil to oil level, so as to remunerate different issues identified with the creation biodiesel from neem oil. They assessed extraction boundaries of neem oil, refining of crude oil and to decide perfect conditions for transesterification of neem oil. The outcomes indicated that practically complete change of neem oil into biodiesel was finished. Additionally, different properties of the readied biodiesel were as per ASTM, IS and ES measures for biodiesel.

Ashraful et al. 2014 survey the likely hotspots for the biodiesel creations. They revealed that the biodiesel can be gotten through various species, for example, Pongamia pinnata (karanja), Calophyllum inophyllum (Polanga), Maduca indica (mahua), Hevea brasiliensis (elastic seed), Cotton seed, Simmondsia chinesnsis (Jojoba), Nicotianna tabacum (tobacco), Azadirachta indica (Neem), Linum usitatissimum (Linseed) and Jatropha curcas (Jatropha). This examination concentrated on the various parts of nonconsumable feedstock viz. science, circulation and science, physicochemical properties of acquired biodiesel. Additionally, the impact of arranged biodiesel from various species on motor execution and emanation. They found that the fuel properties were altogether relies on the feedstock. Further, the exhibition investigation indicated that the warm brake proficiency was improved for the vast majority of the biodiesel created from various species. The outcomes uncovered that the particular brake fuel utilization was decreased in practically totally acquired biodiesel. It was found in the writing that the diesel motor filled with biodiesel demonstrated unrivaled properties and delighted productive emanation guideline with the use of various biofuels (karanja, mahua, elastic seed, and tobacco) and their mixes in a diesel motor. Agarwal et al. 2007 revealed creation, portrayal, properties and momentum research on the creation of biodiesel from vegetable oils. Various properties were concentrated by different examination gatherings, for example, ozone harming substance outflow, motor execution, and changeability of biodiesel, effectiveness of a biodiesel, foundation, accessibility and impact of greases. They saw that ethanol develop as a possible substitute 28 for ordinary diesel fuel. Furthermore, ethanol is acquired from inexhaustible asset and can be oxygenated, because of which discharge from motor get decreased. They likewise announced explicit subtleties and different attributes of ethanol mixed with gas and diesel fuel. This investigation considered the similarity of material and execution alongside discharges in a motor energized with regular diesel and biodiesel. The different hotspots for the creation of biodiesel were methyl or ethyl ester got from unused and utilized vegetable.

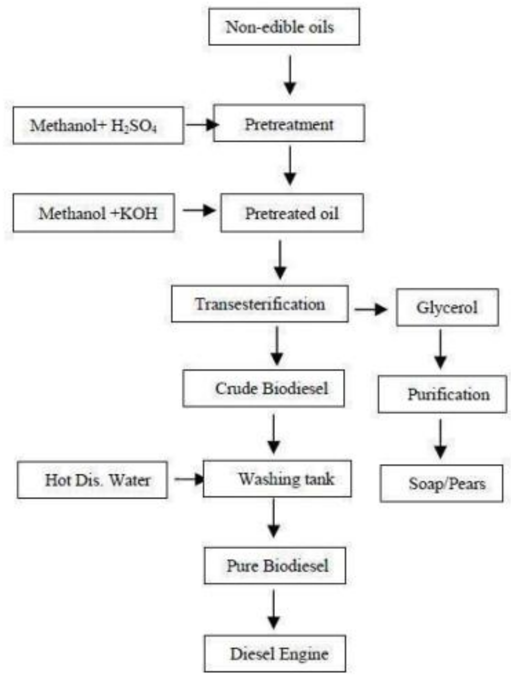

Fig 1 Process of bio diesel

3. METHODOLOGY ANDMATERIALS

The increasing demands of fuels these days due increasing automobiles on planets has increased the risk of depletion of fossil fuels in the world. Also the increasing health problems around the world due to automobiles and use of fossil fuels as due to increase in pollution has reached to the demands of a clean burning and less polluting fuel so due to these demands as an alternative fuel biodiesel has emerged as a very good fuel in the automobile sector. The biodiesel cannot be used as direct fuel in the currently used engines without modification so it is preferred to be used as blends with petro diesels. So this chapter deals with the methodology opted for biodiesel production and then forevaluation of the exhaust emission and performance on the variable compression ratio engine using the different blends of biodiesel. The biodiesel was produced in the School of Energy and Environment labs at Thapar University Patiala, Punjab (India) and the engine experiments and testing was done in internal Combustion Engine Laboratory, Department of Mechanical Engineering, Thapar University, Patiala, Punjab (India). Further the methodology is divided in to two parts:

1. First part shows the optimum production of biodiesel from non-edible oil i.e. neem (Azadirachta indica) oil.

2. Second part shows the emission and performance of the biodiesel blends tested on an engine.

3.1 Methodology for the production of biodiesel from

Neem oil:

Here in this from starting the raw materials used for biodiesel production is discussed and after it with the each step with which the whole production process was undergone. The biodiesel properties are also discussed in this section.

3.1.1Raw materials

1. Crude neem oil

2. Methanol (methyl alcohol)

3. Potassium hydroxide (KOH) as base catalyst

4. Sulphuric acid (H2SO4) as acid catalyst

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Dewaxed and degummed crude neem oil was bought from the local general store. The Methanol (methyl alcohol), Potassium hydroxide (KOH), Sulphuric acid (H2SO4) were available in the School of Energy and Environment laboratories, Thapar University, Patiala. The transesterification was then carried out in the labs on a hot plate magnetic stirrer.

3.1.2 Biodiesel preparation

As the crude neem (Azadirachta indica) oil was used for the preparation of biodiesel therefore due to high Free Fatty Acid FFA content of neem oil i.e. approx. 7% the transesterification process was carried out in two stages. The first stage included an acid catalyzed transesterification reaction and in second the base catalyzed transesterification reaction was carried out.

3.2 Neem oil biodiesel transesterification process (two stage process) First stage (acid catalyzed transesterification reaction)

1. The known quantity of crude neem oil was taken in a conicalflask.

2. Then the oil in the flask was heated on a heating plate up to 65^0C temperature.

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

Fig 2 Pre heating of neem oil on magnetic stirrer with hot plate.

1. The preheated oil mixture was constantly stirred for 35 min at a constant temperature of 50^0C 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.

Fig 3: Two layers formed after the acid catalyzed stage.

3.3 Second stage (base catalyzed transesterification reaction)

1. The oil remained in the separating funnel was again measured and then pre heated up to 65^0C.

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 50^0C 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 ofglycerol was made on the bottom which was separated and removed.

6.The remaining in the funnel is methyl ester (biodiesel) of neem 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.

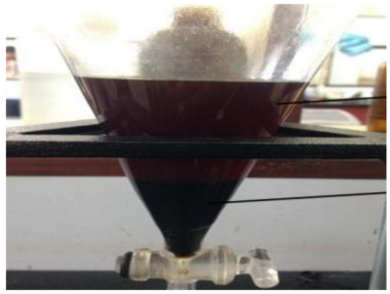


Fig 4 Separated layers after base catalyzed stage.

Fig 3.4: Final methyl ester of neem oil formed after the hot water washing.

The various properties of a methyl ester i.e. biodiesel are evaluated with different methods are shown in the table for the neem oil methyl ester (neem oil biodiesel)

3.4 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 "**Enginesoft**" 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.
18. The computer aswell as the engine so as to stop the experiment.
19. After that in few minutes also stop the water supply. Operational Procedure followed

3.5 SPECIFICATIONS OF THE ENGINE

Make Type: Kirloskar

Engine Type: Single Cylinder 4-Stroke, Water Cooled Compression ratio: Variable ranging from 12 to 18 Rated power: 3.75 kW@1500 R.P.M

Stroke: 110 mm Bore: 87.5 mm

Connecting rod length: 234 mm

Loading device: Eddy current dynamometer Load indicator: Digital, Range 0-50 Kg, and Supply 230V AC Load sensor: Load cell, type strain gauge, range 0-50 Kg Speed indicator: Digital with non-contact type speed sensor

Temperature sensor: Thermocouple,

Type K Rotameter: Engine cooling 40-400 LPH;

Calorimeter 25-250 LPH 43

For the varying compression ratio a tilting cylinder block arrangement is used without stopping engine. Necessary instruments are provided in the setup for combustion pressure measurements. Necessary provisions are made for load, interfacing flow, fuel flow, temperature measurements. A standalone panel box is there in the setup consisting air box, process indicator and engine indicator manometer, fuel measuring unit, transmitters for air and fuel flow measurements, fuel tank. An Engine Performance Analysis software package

4. Exhaust emission evaluation Apparatus and parameters investigated

Two equipment were used to measure the exhaust emission parameters both having individual sensors attached to them. The figure and figure shows the horiba analyzer and flue gas analyzer

Fig 5 Emission evaluation Apparatus

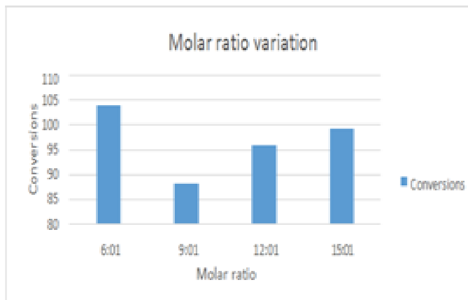
Evaluated parameters

- Brake power (BP)
- Brake thermal efficiency (BTE)
- Brake specific fuel consumption (BSFC)
- Brake mean effective pressure (BMEP)
- Mechanical efficiency (ME)

5. RESULTS AND DISCUSSION

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

5.1 Production Parameters



Molar ratio variation

Fig 6 molar ratio variation

It shows the variation of catalyst concentrations for 6:1 molar ratio acid catalyzed oil at temperature of 50°C for 35 mins for the molar ratios of 12:1 and 15:1 for base catalyzed stage and conversions and FFA are obtained. From the figures it can be seen that conversions for 12:1 molar ratio of base catalyzed stage has increased with each step although the increase is slight whereas with the molar ratio 15:1 a decreasing trend can be seen. Also for the FFA it can be seen that FFA has a decreasing trend for both the molar ratios i.e. 12:1 and 15:1 but with increase in catalyst concentration the decrease is more in 15:1 molar ratio as compared to 12:1 having very slight changes. Also it is seen that with molar ratio 15:1 in base catalyzed stage and catalyst concentration of 1.5% soap formation was seen.

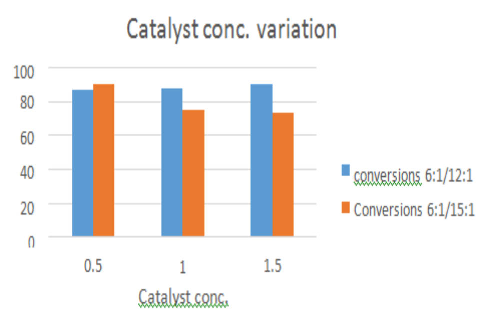


Fig 7 variation of conversions with catalyst concentration for the 6:1 molar ratio of acid catalyzed oil for base catalyzed stage of molar ratio 12:1 and 15:1.

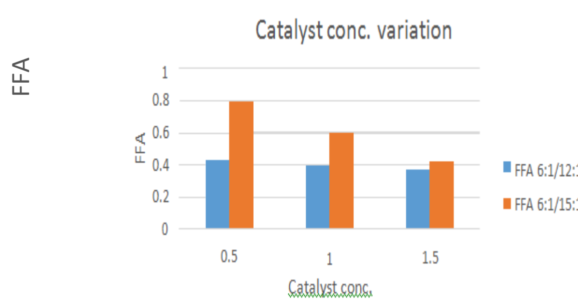


Fig 8 variation of FFA with catalyst concentration for the 6:1 molar ratio of acid catalyzed oil for base catalyzed stage of molar ratio 12:1 and 15:1

6. CONCLUSIONS

Biodiesel was prepared from the neem 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^{o}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^{o}C temperature for the production of biodiesel.

Experiments were performed on the duel fuel diesel engine using diesel and neem 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 higher loads. No change in the brake thermal efficiency was found on additionof 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 has 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 20% 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 20% 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 (B10). The CO emissions has slightly increased on addition of B10 however it was less as compared to emissions obtained for other blends. A slight decrease in NOx emission was observed at B10 whereas NOx emission has increased for all other blends. Also CO2 emissions were similar to that of diesel for this blend (B10) however these have increased on further addition of biodiesel. From this it can be concluded that the blend B10 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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