Experimental Study of Performance and Emission Characteristics of Rubber Seed Oil Using a Nano Additive

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Abstract: This study is an attempt to develop the alternative fuel which is economical, environment friendly and a simple technology which is easy to understand and to implement. From the study of many researchers we came to know that, biofuels are having the potential need to serve as a fuel in compression ignition engine. In the present study, Rubber seed oil biodiesel and Graphene nanoparticles blends with diesel were used as a fuel. Performance parameters such as brake specific fuel consumption (BSFC), brake thermal efficiency (BTE) and brake power (BP) and emission were investigated in a direct injection (DI) diesel engine. The test results shown that the Rubber seed oil biodiesel and Graphene nanoparticles blends at 0.5gm in B20 blend is having good performance with low emission, except for emissions of oxides of Nitrogen. The test results are also showed that performance and emissions of Rubber seed oil biodiesel and Graphene nanoparticles blends are very near to that of diesel and can be used as an alternative.

Keywords: Biodiesel, Rubber seed oil, Graphene nanoparticles, Diesel, blending.

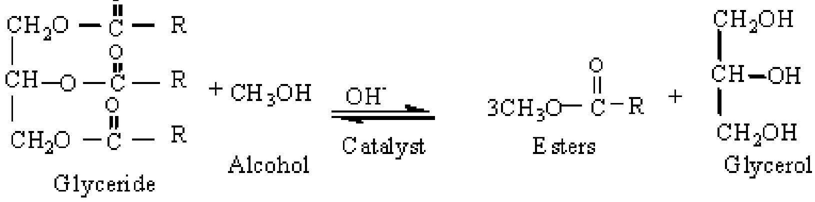
I.INTRODUCTION

The smartest technologies deliver benefits to multiple interests, including improved economy, and a positive impact on the environment and governmental policies. Energy demand is increasing day by day and our dependency on fossil fuel has reached its peak position, it is believed that crude oil and petroleum products will become very scarce and costly in the coming days. Increase in number of vehicles has started dictating the improvement of engine efficiency is very much important. If this is not addressed then in the future gasoline and diesel will become scarce and costly. With increasing in the use of fossil fuels and also the depletion of fossil fuels, the alternate fuel technology will become more common in the next coming days.

Another reason for the development of alternate fuels for the IC engine is the concern over the emission problems of automobile engines such as gasoline and diesel engines. In 70s world had faced huge energy crises and people realize that if we continue to use diesel like fuels for our engines in future day will come when there will not be any more fuel for use. Also at the same time engineers started to test gases emitted by Vehicle engines and their effect on humans and environment. They've realized that Carbon monoxide (CO), Unburned Hydrocarbons (HC), Oxides of Nitrogen (NOx), Particulate Matter (PM), Sulphur Oxides (SOx) are main pollutants which effects environment. After 70s, researchers started to work on oils which are mainly produced from seeds or animal fat to use them as fuels in CI engines. But they had faced a big problem, which was viscosity of oil. Viscosity of oil is always more than that of diesel. CI engine mainly made for to run with diesel fuels only whose viscosity is less than 5 centistokes (cst). To reduce the viscosity of oil they started to use chemical methods and product was called as Biodiesel. It can be produced from vegetable oils, it may be edible or Non-edible, animal fat, waste oils, algae. Biodiesel fuel is a good alternative final for CI engine since its properties are similar to that of diesel fuel.

Biodiesel is a fuel which is mainly produced from vegetable oil, algae or animal fat. It consists of long chain alkyl esters. It may be Methyl ester, Ethyl ester or Propyl ester depending on the alcohol used while processing oils. The major intension of using alcohol is to convert triglycerides to alkyl esters. Biodiesel is a flesh burning fuel compared to normal diesel and hence emissions of polluting gases are always less than that of diesel fuel. It is also found from the experiments by researchers that Cetane number of biodiesel is more than that of diesel and hence we can use pure biodiesel in CI engines also like diesel.

Vegetable oil plants like Neem, Karanja, Mahua, Jatropha, Rubber seeds etc. contains more than 30% oil contents in their seeds can be used for biodiesel production in large quantity. Biodiesel is finest for CI engine is mainly because of its properties like viscosity and density. Biodiesel can be easily mixed with diesel since the density of diesel and biodiesel are very much near to each other in many cases. If we utilize vegetable oils extracted from seed for biodiesel production then there will be a positive energy balance in the environment. This is because plants mainly utilize $C0_2$ and sunlight for the production of energy for its growth to yield leaf, fruits and seeds. CO is released to atmosphere during combustion of Biodiesel will be utilized by these plants and hence there will be a balance of CO in the environment. Biodiesel is also a Bio-degradable fuel which easily degrades in water.



II. LITERATURE SURVEY

[1] A. Prabhu, Nanoparticles as additive in biodiesel on the working characteristics of a DI diesel engine. Department of Mechanical Engineering, National Institute of Technology. emission characteristics of a single cylinder direct injection (DI) diesel engine with three fuel series: biodiesel–diesel (B20), biodiesel–diesel–nanoparticles (B20A30C30) and biodiesel–nanoparticles (B100A30C30). The nano_particles such as Alumina (Al_2O_3) and Cerium oxide (CeO_2) of each 30 ppm are mixed with the fuel blends by means of an ultra Sonicator, to attain uniform suspension. Owing to the higher surface area/volume ratio characteristics of nanoparticles, the degree of mixing and chemical reactivity are enhanced during the combustion, attaining better performance, combustion and emission attributes of the diesel engine. The brake thermal efficiency of the engine for the nanoparticles dispersed test_fuel (B20A30C30) significantly improved by 12%, succeeded by 30% reduction in NO emission, 60% reduction in carbon_monoxide emission, 44% reduction in hydrocarbon emission and 38% reduction in smoke emission, compared to that of B100.

[2] Jolius Gimbun et al. The potential of limestone based catalyst for transesterification of high free fatty acid (FFA) rubber seed oil (RSO). Pre-calcinated limestone known as clinker was activated using methanol and transesterification was performed under reflux with constant stirring. Mineral composition of the catalyst was analysed using x-ray fluorescence (XRF) with in build x-ray diffraction (XRD). The rubber seed oil was obtained using both microwave and soxhlet extraction using hexane as solvent. FFA content and fatty acid methyl ester content were determined using gas chromatography mass spectrometry (GC-MS). The results showed an efficient conversion (up to 96.9%) of high FFA rubber seed oil to biodiesel. The results suggest that the catalyst employed in this work is not negatively affected by moisture and free fatty acids and can be recycled very easily without significant loss in its activity. The highest conversion of 96.9% was achieved from catalyst activated at 700°C, with catalyst loading of 5 of methanol to oil molar ratio of 5:1; reaction temperature of 65°C and reaction time of 4 hours. The biodiesel produced in this work is within the limits of specification described by American standard test method (ASTM D6751). Biodiesel has been touted as a viable alternative to the traditional petroleum-derived fuels due to environmental concern and sustainability issue. There are several sources of vegetable oil suitable for production of biodiesel such as palm oil, jatropha, soy bean and some selected species of forest seeds. Recently, the European Union is critical to the biofuel production using edible oils such as palm oil, corn, soy bean and maize, which are also consumed as food. These open a new avenue of producing a biodiesel using a non-food source crop such as the seed of the rubber tree (Hevea Brasiliensis). Malaysia has an estimated acreage of 1,021,540 hectares of rubber plantation in 2009 [1] producing an estimated average of more than 120 thousand tons of rubber seeds annually and this project aims to utilize these unused seeds to produce biodiesel. The rubber seed contain approximately about 40% kernel with 20-25% moisture. The dried kernel contains 40-50% of oil [2] which translates to a potential production over 20 million liters of oil per year. The rubber seed oil has a high free fatty acid content, which mean the use of alkaline catalysts such as sodium hydroxide to produce biodiesel is unfavorable [2] because of the formation of relatively large amounts of soaps, leading to product loss and difficulty in the separation and purification of the biodiesel produced [3]. Thus, this work aims to overcome this issue by using a limestone based heterogeneous catalyst. Heterogeneous base catalysts have advantages of being reusable, noncorrosive, show greater tolerance to water and free fatty acids (FFAs) in feedstock, improve biodiesel yield and purity, have a simpler purification process for glycerol and are easy to separate from the biodiesel product [4-7]. Calcium oxide (CaO) is one of the most common used heterogeneous base catalysts for the transesterification of vegetable oil. Producing biodiesel using CaO as a solid base catalyst has many advantages, such as higher activity, mild reaction conditions, reusable and low cost [4-7]. Liu et al. [6] shows that CaO powder can give about 95% conversion of soybean oil to biodiesel in present of excess methanol (12:1) at temperature of 60 °C and reaction time of 3 hours. Hsiao et al. [7] achieved 96.6% of conversion of soybean oil to biodiesel using a microwave assisted transesterification with 3% wt. of nano powder CaO catalyst, methanol/oil ratio of 7:1, reaction temperature of 65°C and residence time of 1 hour. Use of nano powdered CaO has several drawbacks because the nano powder is not readily available and hence require a high energy to manufacture, furthermore, catalyst recovery or separation will be challenging for nanoparticle. This work aims to prepare a cheaper catalyst from limestone that is easy to recover apart from providing an efficient conversion of vegetable oil to biodiesel.

[3] Medha M. B et al. In this study of rubber seed derived biodiesel as an alternative fuel, fatty acid methyl ester was successfully produced from crude rubber seed oil. According to the results of the project, there is a 2.5% increase in Brake Specific Fuel Consumption in the case of B5 blend, and a 14% increase in BSFC in the case of B30 blend when compared to that of petroleum diesel. When it came to Brake Thermal Efficiency, there is a 0.08% decrease in the case of B5 blend, and 8.08% decrease in the case of B30 blend. When it comes to Emissions, there is a 0.23% decrease for B5 blend, and 0.28% decrease for B30 blend in the case of Carbon Monoxide emission, and a 0.54% decrease for B5 blend, and 0.42% decrease for B30 blend in the case of Hydrocarbon emissions when compared to that of petroleum diesel. In the case of smoke opacity, there is a decrease of 0.1% for B5 blend, and 0.08% decrease for B30 blend when compared to that of petroleum diesel. From the observations, it is evident that the lower blends are suitable for use in Compression Ignition engines with none or minimum modifications. Even though rubber-seed oil biodiesel-mineral diesel blend is a suitable alternative fuel, further research is required in order to increase its efficiency

In the face of the upcoming energy crisis, biofuels have come up as a promising alternative for mineral fuels like diesel and gasoline. With the prospect of developing a suitable alternative fuel, rubber seeds were collected and the kernel was separated from the shells using an expeller. From the dried kernels, oil was extracted using a soxhlet extractor. The extracted oil was tested for its FFA content, before subjecting for esterification in the presence of methanol and conc. sulphuric acid catalyst. The esterified oil was further subjected to trans-esterification in the presence of methanol and NaOH to obtain methyl ester and glycerin. The resulting methyl ester was washed to remove the retained impurities, and then dried to evaporate the water content present in the biodiesel. The rate of conversion from crude oil to biodiesel was almost 80%. The biodiesel was then tested for its fuel properties according ASTM standards, and then tested for its performance parameters in a four cylinder, four stroke CI engine test rig. It was further tested for its emission parameters. According to the results of the project, there was an increase in Brake Specific Fuel Consumption in the case of biodiesel blends when compared to that of petroleum diesel. When it came to Brake Thermal Efficiency, there was a slight decrease in the case of biodiesel blends. When it came to Emissions, the lower blends and emissions lower than that of mineral diesel, whereas the blends with greater proportion of biodiesel had higher emission rate than petroleum diesel. When tested as a substitute fuel in a CI engine powered vehicle, it showed a decrease in performance proportional to increase in biodiesel in the blend.

The burgeoning industrial development and the rise in traffic has resulted in an incessant demand for energy. As a result, the pressure on fossil fuels has increased. What with the depleting wells of petroleum and natural gas, it has become difficult to meet this demand, and this has led to the energy crisis. Even today, fossil fuels are the major sources of energy, especially in the transportation sector, mostly because of their established availability and cost effectiveness when compared to other forms of energy. But the limited reserves of non-renewable fuels have necessitated the need for investing in alternative fuels that can eventually replace fossil fuels. Renewable alternative fuels will not only assuage the effects of the energy crisis by balancing supply with demand, but will also help in strengthening the economy by reducing dependency on petroleum producing countries for crude oil. With these developments in the field of energy, biofuels have emerged as one of the potential alternatives.

Diesel fuel has maintained its status and one of the most prominent sources of fuel because of its high thermodynamic efficiency. The most common form of diesel is derived from fractional distillation of crude petroleum oil. But with the development of alternative sources, other forms of diesel have emerged, such as biodiesel, gas to liquid diesel, coal to liquid diesel, biomass to liquid diesel, etc. Its origin dates back to late nineteenth century, when a German inventor Rudolf Diesel invented the compression ignition engine. He experimented with coal dust, vegetable oil, and many other sources to find the most efficient fuel for his engine. During the World Exhibition in Paris, 1900, he used 100% peanut oil to run the engine. He stated that, “diesel engine can be fed with vegetable oil, and this would help considerably in the development of agriculture of countries which use it.”

III. Problem Definition

Biodiesel is one of the alternatives for conventional fuels. In order to make it commercially viable it is necessary to address disadvantages. One such disadvantage which is identified is Oxidation Stability of biodiesel. Through various studies it is observed that use of anti-oxidants, Nano additives there is a possibility of reducing oxidation problems with regard to biodiesel. Our study focuses on this aspect by considering Rubber Seed biodiesel.

IV. Objectives

The following objectives were drawn based on literature survey and problem definition.

l. Determine the following fuel properties of Rubber Seed oil and its biodiesel: viscosity, density, calorific value, flash point and fire point
2. Find out the overall fuel efficiency of Rubber Seed biodiesel with and without additive and compare that to conventional.
3. To find out the effect of different blends of Rubber Seed biodiesel on the performance and emission characteristics of CI engine.
4. To investigate the Performance and exhaust emission characteristics of a Compression ignition engine fuelled with blends of diesel, Rubber Seed methyl ester at different engine loads from no load.
5. To determine the Performance parameters like BP, BSFC & ISFC as well as emissions like CO, HC & N0x for all cases of biodiesel with and without Nano additive and comparing them with each other and also with pure diesel results.

V. Methodology

1) METHODOLOGY 0F BIODIESEL PRODUCTION

1. Selections of Raw Materials and Chemicals

The Selection of raw material play a major role in many research as far as biodiesel is concerned seed selection and the way the oil has to be processed for the manufacture of biodiesel are most important aspects. The Raw material is collected from various geographical locations and stored in such a condition that are not varied by external factors like humidity, moisture etc. If, variation adds up, then it leads to process complications.

- Moisture content in the seeds should be maximum 3 to 5%
- Oil content should be minimum 32%,
- The raw oil should be free from moisture, sediments and floating impurities. It should be unadulterated and clear.

2. Pure Rubber Seed Oil

Pure Rubber Seed Oil was purchased from Index International, Madhurai, Tamilnadu. **Rubber seed oil** is oil extracted from the seeds of rubber trees. In the latex manufacturing process, rubber seeds are not historically collected and commercialized. Recent analysis shows that rubber seed oil contained the following fatty acids:

- Palmitic (C16:0) - 0.2%
- Stearic (C18:0) - 8.7%
- Oleic (C18:1) - 24.6%
- Linoleic (C18:2) - 39.6%
- Linolenic (C18:3) - 16.3%

3. Extraction of Oil from the Seeds

The process of extraction is the first step in the refining process. Oils and fats are extracted from the Rubber seeds using a mechanical expeller. In this case the oil is extracted directly from the seeds by means of mechanical press. This process is known as cold pressing.

➢ Mechanical Expeller Method

An Expeller is a screw press type machine that presses oil seeds through a cage banner Expeller pressing is a Mechanical method for extracting oil from raw materials. Seeds enter one side of the press and pressed cake exits the other side. The machine uses fiction and continuous pressure from the screw to move and compress the seeds which is continuous in operation. The oil purges through the small openings in the caged barrel that do not allow seeds to pass through.

Normally the oil cake contains about 8-10% of oil that can be extracted only by solvent extraction process. The expeller mainly consists of three sections namely control feeding section, crushing chamber and drive assembly.

4. Determination of Free Fatty Acid Content in Raw Oil (Feed Stock)

The determination of the free fatty acid content of the raw oil becomes the most critical aspect of the biodiesel manufacturing. Listed below are the steps taken and the method to arrive at the free fatty content of the raw oil.

5. Titration and Calculation of free Fatty acid content in Raw Oil

2 litre of oil was taken in the reaction vessel, preheated to 60°C to remove moisture and volatile impurities and then set to a temperature of 55°C. 1ml of oil is taken in a conical flask and 10ml of propanol is added to it. 2 drops of Phenolphthalein Solution is added (indicator) to the solution. Titration is done using 0.1N NaOH, pale pink color didn't appeared. FFA is found out to be greater than 5.

6. FFA Calculation

If the free fatty acid (FFA) content of the raw oil is more than 4%, double stage (alkali base +alkali based catalyst) process has to be undertaken. Maintain the temperature at 60˚C methanol 150ml and concentrated H_2SO_4 as per lab calculation, H2SO4 should be added with the methanol first and then it is to be added to oil, very slowly and carefully. Agitate the mixture in the reaction vessel (3-neck flask) at 60°C for 1 to 1 ½ hours.

FFA value of Rubber Seed Oil was found to be 2.256%. Since this value is less than 4% therefore single stage transesterification is used.

7. Recovery of Methanol from Biodiesel

Transfer the biodiesel into the reaction vessel, make the necessary arrange for the distillation setup like heating, stirring and fixing the double wall condense along with the recovery flask, maintain the rpm speed at 1000rpm and the temperature at 70˚C.Methanol starts evaporating. Collect the methanol condensate, measure the quantity and record it. Switch off the system when the methanol condensation stops.

8. Washing of Biodiesel

Transfer the biodiesel after methanol recovery into the plastic washing funnel specially assembled for this purpose, spray 300ml of warm water slowly into the biodiesel without any agitation. Allow to settle for 15 minutes. A bottom layer of soap water will slowly start to form, drain the bottom layer carefully. Repeat the above procedure (300ml water) for third time and shake vigorously and allow it to settle for 1 hour and drain the soap water. Check up the pH value of the third drained soap water using the pH paper. Continue washing with the warm water till the biodiesel reaches a pH value of 7.

9. Drying of Biodiesel

Transfer the washed biodiesel from the washing funnel to the 1 liter beaker, add the magnetic pellet and adjust rpm to suitable speed. Heat the biodiesel to a temperature of 100'C, allow the biodiesel to cool gradually, measure the final finished biodiesel. Record the quantity and store it in a clean, dry container.

2) Preparation Of Blends

The blends are done with the help of clean measuring jars. Based on the blend percentage the required quantity of biodiesel (rubber seed) and diesel are calculated and taken. It is then mixed together to form the blend. For example the blend B20+D80 (here 'B' stands for biodiesel and 'D' stands for Diesel) ie. 20% of Biodiesel is mixed with 80% of Diesel.

Table: Percentage composition of blends

Sl No.	Blends	Composition in %	-
		Rubber Seed Biodiesel	Diesel
1	B20+D80	20%	80%

Table: Quantity of Blends

SL No.	Blends	Composition	(ml)
		Rubber Seed Biodiesel	Diesel
1	B20	120ml	480ml
2	B40	240ml	360ml

3) Engine Testing in a 4-stroke Single Cylinder Engine

Figure shows the schematics diagram of the complete experimental setup for determining the effects of the Rubber Seed biodiesel fuel on the performance and emission characteristics of compression ignition engine. It consists of a single cylinder 4 - stroke water cooled compression ignition engine connected to an Eddy current dynamometer. It is provided with temperature sensors for the measurement of jacket water, calorimeter water and calorimeter exhaust gas inlet and outlet temperature. It is also provided with pressure sensors for the measurement of combustion gas pressure and file injection pressure. The built in program in the system calculates Break Power, Break Thermal Efficiency and Break Specific Fuel Consumption.

Fig 4-stroke Single Cylinder Diesel Engine

4) Mixing of Graphene in B20 Blend (Sonicator Device)

Sonication is the act of applying sound energy to agitate particles in a sample, for various purposes such as the extraction of multiple compounds from plants, microalgae and seaweeds. The enhancement in the extraction of bioactive compounds achieved using sonication is attributed to cavitation in the solvent, a process that involves nucleation, growth, and collapse of bubbles in a liquid, driven by the passage of the ultrasonic waves. Ultrasonic frequencies (>20 kHz) are usually used, leading to the process also being known as ultra-sonication.

Fig: Sonicator Device

5) EMISSION TESTING

The exhaust of automobiles is one of the major contributors to world's air pollution problem. Recent research and development has made major reductions in engine emissions, but a growing population and a greater number of automobiles mean that the problem will exist for many years. Four major emissions produced by internal combustion engines are hydro carbons (HC). Carbon Monoxide (CO), Oxides of Nitrogen (NOx) and solid particulates.

Fig: Emission Test

VI. OBSERVATIONS

The recorded Performance and emission data of the blends of Rubber seed biodiesel and with and without additive is collected from the system and tabulated in the table for each performance and emission parameter.
The performance parameters include Brake Power, Brake Specific Fuel Consumption and Brake Thermal Efficiency and emission parameter includes Unburned Hydrocarbon. Carbon Monoxide and Oxides of Nitrogen for the blends of Rubber seed biodiesel and Graphene at three different compression ratios are tabulated as shown below.

VII. RESULTS AND DISCUSSION

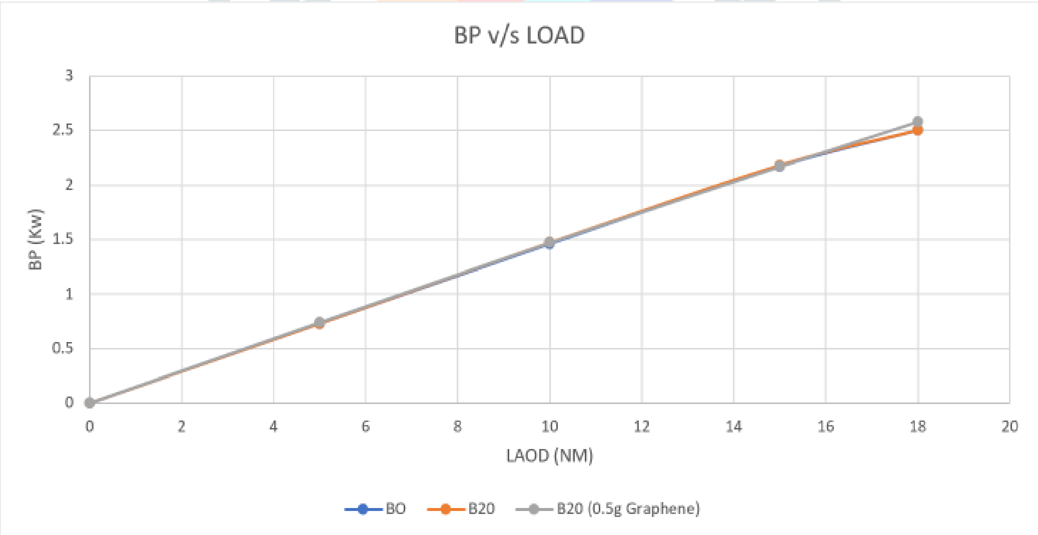
In this study the performance characteristics are studied and experiment is carried out by testing the Kirloskar AVI, single cylinder, 4-stroke CI engine fuelled with Diesel (DI0) and with Rubber Seed Biodiesel blends namely B0, B20, B40, and with the composition of Nano additive mixed with blends with the help of Sonication device. The amount of Nano additives that were added was 0.5g.

The tests were made at different torque of 5Nm, 10Nm, 15Nm, & 18Nm. The corresponding BP, BSFC, BTE and emissions HC, CO and NO, were recorded. The results are compared at different compression ratios for different performance and emission parameters

- ➢ Effect and Performance characteristics of Rubber Seed Biodiesel with and without Nano additives and different blends with Diesel at different Torque.

PERFORMANCE CHARACTERISTICS

1) BP v/s LOAD
FUEL TYPE: B0, B20, B20 (0.5g Graphene)

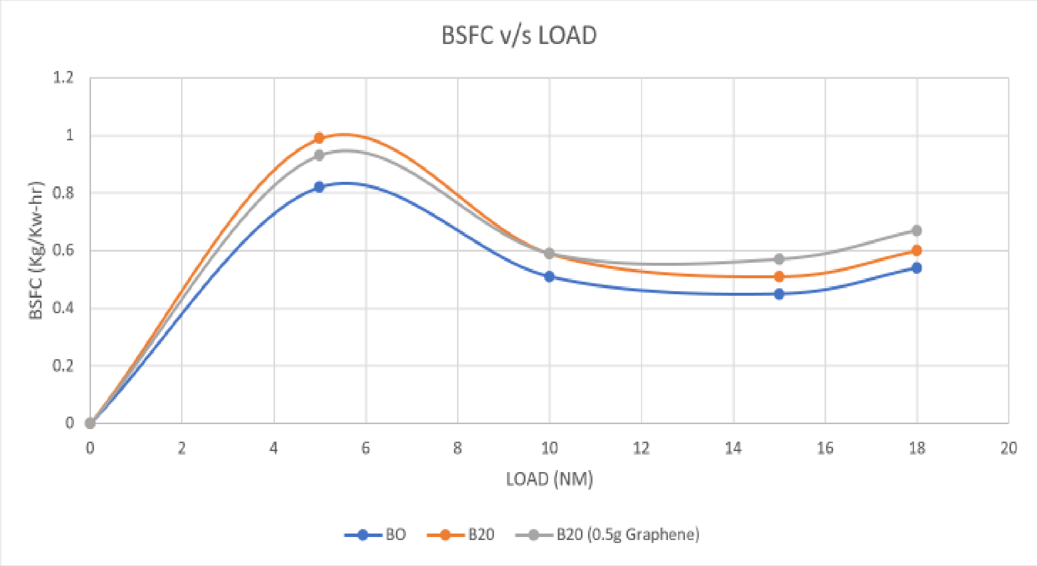


- ➢ As we can analyse in the BP v/s Load graph, that the BP for all the fuel type is the same upto 16Nm torque and after which the BP of blend B20 with 0.5g of Graphene increases with increase in torque.

There by we can conclude that there is better BP with 0.5g of Graphene nano additive.

2) BSFC v/s LOAD

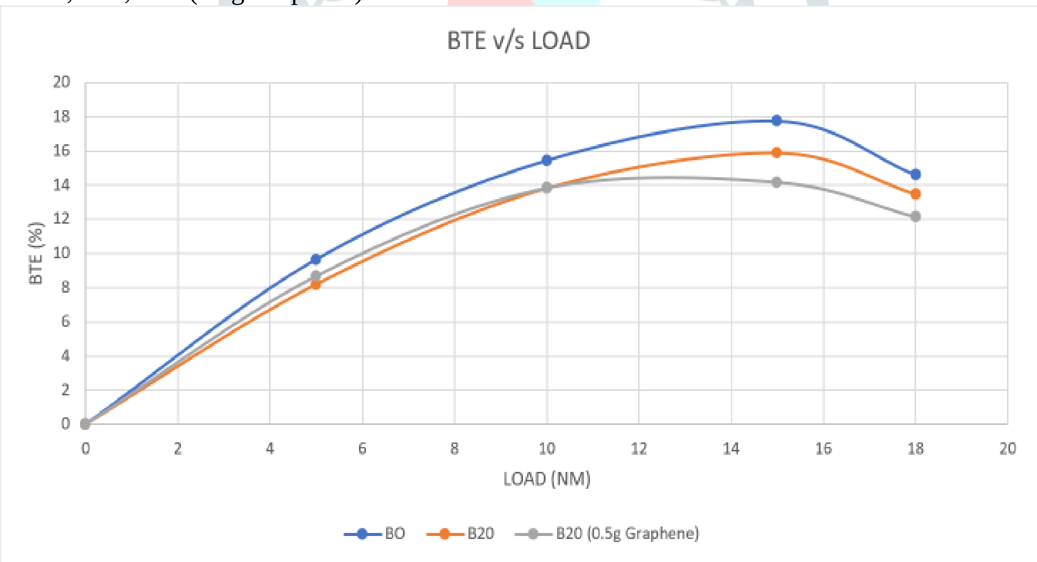
FUEL TYPE: B0, B20, B20 (0.5g Graphene)



- From the graph above we can analyse that the curve of B20 blend has more BSFC upto 55% load after which it decreases for maximum load.
- The curve of diesel i.e. B0 shows less BSFC compared to other fuels.
- The curve of B20 with 0.5g additive shows less BSFC than that of blend B20 upto 55% load, after which it increases. This could be due to low accuracy of sonicator device at IISC and the temperature variation.

3) BTE v/s LOAD

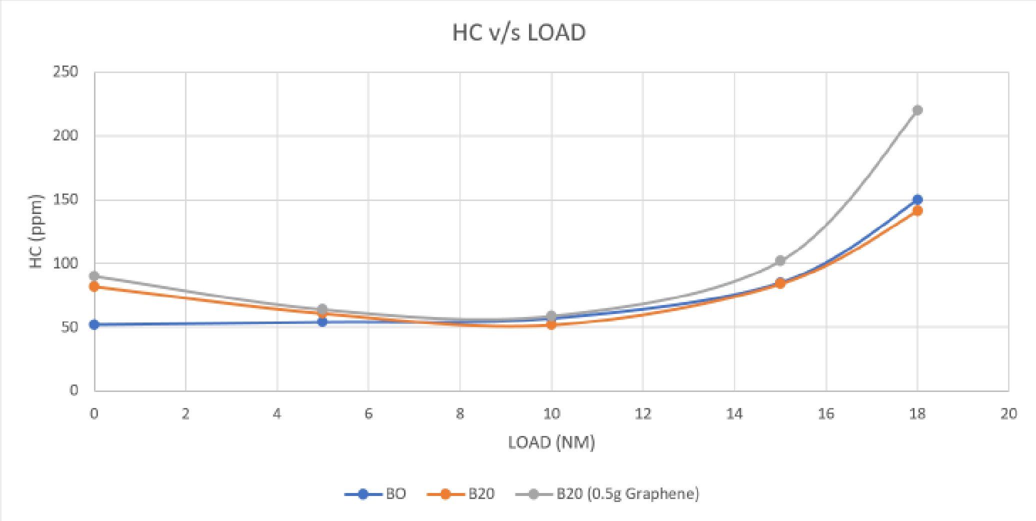
FUEL TYPE: B0, B20, B20 (0.5g Graphene)



- From the above graph, we can analyse that the Brake thermal efficiency of B20 & B20 with 0.5g additive is less when compared to diesel (B0). This could be due to the BSFC which is responsible for low efficiency.

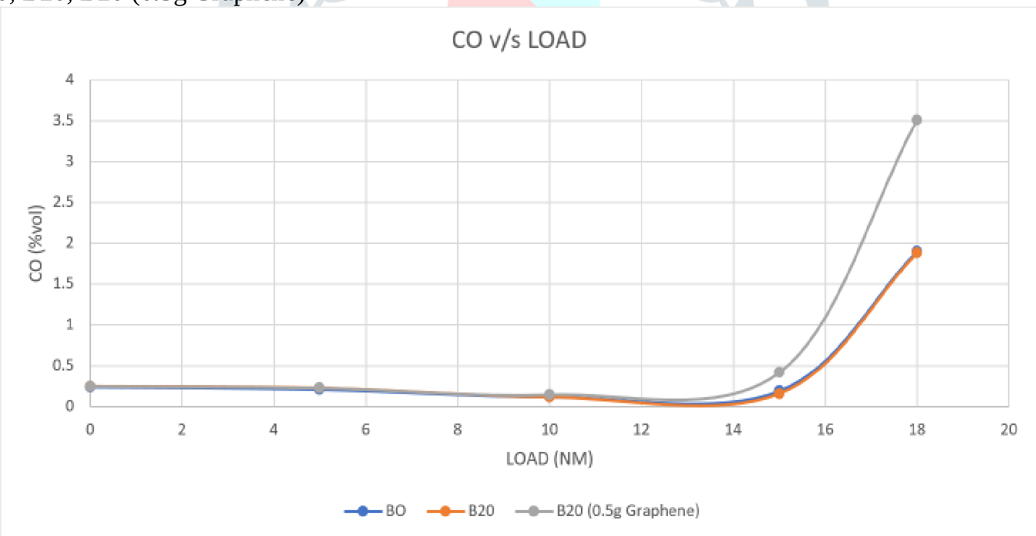
EMISSION CHARACTERISTICS

1) HC v/s LOAD
FUEL TYPE: B0, B20, B20 (0.5g Graphene)



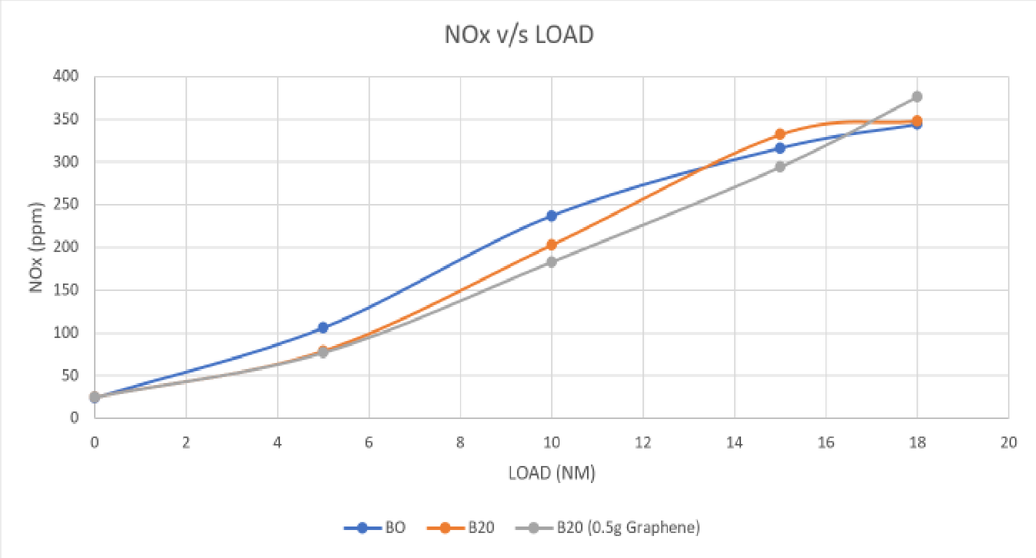
- From the above graph we can analyse that the hydro carbon emission of the Blends B20 & B20 with 0.5g additive shows high emissions at the initial stage which decreases for 55% load and then the emissions increases for B20 with 0.5g additive due to improper mixing of additives or inaccuracy of Sonicator.
- But, the emissions of B20 for maximum load stay less than that of diesel.

2) CO v/s LOAD
FUEL TYPE: B0, B20, B20 (0.5g Graphene)



- The above graph shows carbon monoxide emission for B0, B20 & B20 with 0.5g additive.
- We can analyse that the CO emission for all the blends remains same upto 72% load.
- Emissions of B20 with 0.5g additive increases while B0 & B20 remains same. The major reason behind the increase of B20 with additive is that the Graphene additives are carbon components which increases the CO emissions.

3) NOx v/s LOAD
FUEL TYPE: B0, B20, B20 (0.5g Graphene)



- ➢ The above graph shows emissions of Oxides of Nitrogen with increasing load.
- ➢ From the above graph we can analyse that the NOx of B20 with and without additive is less than the diesel (B0). At 95% load the NOx of B20 with additive increases and that of B0 & B20 decreases.

VIII. CONCLUSION

The performance of single cylinder 4-stroke diesel engine (kirloskar AVI) fuelled with biodiesel blends of Rubber seed oil and graphene nano particles have been investigated. The experimental results showed that the performance like BP,BSFC and BTE and emission parameters like CO, HC and NO, were varied with respect to blending, From the experimental result the following conclusions were made:

l. The properties of blends of Rubber seed oil and graphene nano particles are nearer to that of Diesel.
2. The direct injection diesel engine runs smoothly for all the blends of Rubber seed oil and graphene nano particles used in the experiment.
3. The main use of Graphene nano additive is to have “High surface to Volume ratio” which is responsible for automization, vaporization, & mixing.
4. The Brake power output for all the biodiesel blends used in the experiment is very closer to that of pure Diesel at all the Torque considered. Overall among all the biodiesel blends the best (highest) brake power value of 2.58 kW at full load condition is found for B2O at 0.5gm.
5. BSFC of the diesel B0 is less for all the values of load applied. At maximum load condition the BSFC of the Blend B20 is very closer to that of diesel.
6. The Brake Thermal Efficiency for all blends is found to be less than the diesel due to increase in CO and HC emission. This is due to high carbon content.
7. The Brake thermal efficiency of B20 & B20 with 0.5g additive is less when compared to diesel (B0). This could be due to the BSFC which is responsible for low efficiency.
8. Overall among all the blends, The CO emissions of biodiesel with additive remains similar to that of diesel upto 10Nm torque, after which it increases. Due to the use of Graphene as this is a derivative of carbon.
9. The hydrocarbon emission of the Blends B20 & B20 with 0.5g additive shows high emissions at the initial stage which decreases for 55% load and then the emissions increases for B20 with 0.5g additive due to improper mixing of additives or inaccuracy of Sonicator.
10. The N0x emission was found to be decreased for all the biodiesel blends compared to that of Diesel. Overall among all the biodiesel blends B20 with 0.5gm is having a low NOx emission.
11) Further study has to be carried out with different additive and sonication.

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