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ENHANCING PERFORMANCE OF VCR DIESEL ENGINE USING TITANIUM DIOXIDE (TIO2) NANOPARTICLES BLENDED WITH COTTON SEED BIODIESEL

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Abstract: The primary aim of this study is to assess the impact of Titanium dioxide (TiO2) nanoparticles on the performance enhancement, combustion efficiency, and emission reduction of cotton seed oil biodiesel (B20) in a single-cylinder 4stroke VCR diesel engine under varying loads (3, 6, 9, & 12 kgf) and a constant pressure of 180 bar. TiO2 nanoparticles were incorporated into B20 at concentrations of 25, 50, and 75 parts per million (ppm). Remarkable enhancements in engine operating parameters were observed with the utilization of Nano fuel, particularly across different load conditions. At a load of 9 kgf, key combustion parameters such as net heat release rate (NHRR), mean gas temperature, cylinder pressure, and brake thermal efficiency (BTE) exhibited notable increases of 18.46%, 5.74%, 12.29%, and 10.72% respectively. Moreover, the brake-specific fuel consumption (BSFC) decreased by 7.69% with B20 containing 75 ppm TiO2. Compared to conventional diesel, there were significant reductions in emissions, including carbon monoxide (CO), hydrocarbons (UHC), and smoke opacity, showing decreases of 74.46%, 10.78%, and 42.24% r .

Index Terms – Cottonseed Biodiesel, Titanium dioxide, Performance parameters, Combustion characteristics, Emission

ABBREVIATIONS

B100	100% Cottonseed Biodiesel	B20	20% Cottonseed Biodiesel
B20+ 50 NPs TiO_2	20% Cottonseed Bio	D100 ppm	Pure diesel Parts Per Million
	diesel+25NPs Titanium dioxide nanoparticles	NaOH	Sodium hydroxide
B20+ 75 NPs TiO_2	20% Cottonseed Bio	BTE	Brake thermal efficiency (%)
	diesel+50NPs Titanium	BSFC	Brake specific fuel consumption (Kg/kWh)
	dioxide nanoparticles		
B20+ 100 NPs TiO_2			
	20% Cottonseed Bio	NHRR	Net heat release rate (J/^{O}CA)
	diesel+75NPs Titanium	CP	Cylinder pressure (bar)
	dioxide nanoparticles	UHC	Hydrocarbons (ppm)
TiO_2	Titanium dioxide	NO_X	Nitrogen oxides(ppm)
IP	Injection pressure		
		NPs	Nanoparticles

I. INTRODUCTION

In recent decades, there has been a concerted effort to develop renewable energy sources as a substitute for traditional fossil fuels. This attention stems from the imperative to address both the escalating energy demand and the mounting concerns regarding environmental pollution [1]. One significant avenue for mitigating the greenhouse effect and enhancing environmental protection lies in recycling the carbon dioxide generated during biodiesel combustion through photosynthesis. Biodiesel offers a range of benefits, including exceptional lubrication performance, biodegradability, low sulphur content, and superior safety attributes, all of which contribute to reducing engine wear and extending its lifespan [2]. The utilisation of cotton seeds, considered inedible oil, for biodiesel production holds promise, particularly in regions like India, where it circumvents potential fuel conflicts with food sources [3]. Numerous studies have conducted comparative analyses of the effects of biodiesel on engines, examining factors such as efficiency, energy consumption, durability, and emissions. These investigations consistently demonstrate significant reductions in particulate matter, hydrocarbon, and carbon monoxide emissions, alongside improvements in energy consumption, albeit with a noted increase in nitrogen oxide emissions [3]. Titanium dioxide nanoparticles (TiO2NPs) have emerged as a preeminent material, surpassing various alternatives in terms of abundance, non-toxicity, and stability [4]. The synthesis of B/Sm(TiO2) nanoparticles via the sol-gel method underscores the versatility of titanium oxide (TiO2) in various applications, particularly as a photocatalyst, due to its stable physicochemical properties [5, 6]. Recent analyses have also explored the potential of TiO2 in internal combustion engines [7]. The integration of variable compression ratio (VCR) systems represents a novel approach to balancing performance and efficiency in internal combustion engines, with optimisation techniques such as response surface methodology (RSM) enhancing engine process parameters [8, 9, 10]. Projections from the International Energy Agency suggest significant growth in bioenergy and lowemission hydrogen, underscoring the increasing importance of alternative energy sources [11]. Furthermore, the study of nano catalysts for biodiesel production, such as Fe3O4@UiO-66-NH2, highlights ongoing innovation in this field [12]. Exploring alternative sources of biofuel, such as animal waste, presents a modern paradigm for sustainable energy production. Fish waste, containing substantial fat content, offers potential for biodiesel production, with studies demonstrating the feasibility of blending with extracted biodiesel for improved efficiency and reduced emissions [13, 14, 15].The pursuit of alternative fuels and innovative engine technologies is pivotal in improving fuel efficiency and minimizing environmental pollution. The utilization of TiO2 nanoparticles is significant, as their activation energy facilitates the combustion of carbon particles, thus reducing hydrocarbon (HC) emissions. Notably, fuels enhanced with doped TiO2-SiO2 exhibit superior brake thermal efficiency (BTE) compared to traditional diesel, attributed to better heat release. Nevertheless, this advantage is offset by an increase in NOx emissions, resulting from heightened cylinder peak pressures, earlier injection timings, and reduced ignition delays [16]. Further research into alternative feedstocks highlighted the viability of waste transformer oil for biodiesel, with blends varying from 10% to 100% with diesel tested in a 4.4 kW engine under diverse loads. These blends demonstrated a notable rise in peak pressure and exhaust gas temperatures. A specific blend, containing 60% diesel and 40% waste transformer oil, was identified as optimal, offering enhanced performance and lower emissions than other tested ratios [17]. Addressing the associated challenges, various strategies are being explored, such as dual-fuel combustion, variable compression ratios (VCR), dilute combustion methods (including water injection and EGR), variable valve actuation (VVA), and lowtemperature combustion (LTC) [18]. The VCR or CVCR engine, in particular, offers increased operational flexibility, potentially improving combustion efficiency while simultaneously reducing emissions and fuel consumption. However, to mitigate the risk of knocking combustion, the compression ratio (CR) in VCR spark ignition (SI) engines is generally limited to a maximum of 13, a precaution against excessive in-cylinder temperatures and heat release rates preceding ignition [19]. This narrative is further enriched by the annual production of used cooking oil (UCO), sourced from food preparations worldwide, with significant volumes reported in the USA (0.74 Mt), Europe (4.1 Mt), and India (0.07 Mt) [20].

BIOFUELS

- Biodiesel is defined as long-chain fatty acid monoalkyl esters derived from vegetable oils or animal fats that meet ASTM D6751 specifications for use in diesel engines. Biodiesel is the pure fuel before it is blended with diesel.
- Biodiesel is an environmentally friendly, cleanburning, nontoxic, biodegradable fuel that can be used in any compression ignition engine (diesel engine).

MAKING OF BIOFUELS

Making Biodiesel is not as difficult as it sounds and anyone that wants to can make quality biodiesel right at their own homes. The biodiesel making process can be broken down as follows.

- Preparation
- Reaction (Biodiesel Transesterification)
- Settling and Separation
- Biodiesel Washing
- Biodiesel Storing &Using

IMPORTANCE OF BIOFUELS

Bio-diesel is the most valuable form of renewable energy that can be used directly in any existing, unmodified diesel engine.

- Smaller trade deficit
- Energy independence
- Economic growth
- Cleaner air
- Less global warming

II. LITERATURE SURVEY

It was found that the ratio of mixed oil is an important factor in terms of conversion and quality of biodiesel. It is also revealed that the application of the ML technique is essentially useful to optimize production efficiency. The utilization of mixed oils will overcome the issues related to the non-availability of feed stocks and reduce the overall cost with improved quality of biodiesel [1]. The experimental results showed that increase in blends of rice bran biodiesel with diesel reduces the carbon monoxide and increases the carbon dioxide and hydrocarbon in emission [2]. The results indicate that 20% biodiesel blend leads to a lower ignition delay at higher loads which in turn increases the rate of vaporization of the fuel as it has higher cetane number. Moreover, the HCs, COx and NOx emissions decrease as the load increases since the increase in fuel atomization promotes the combustion process and thereby decreases the amount of unburnt biodiesel components[3]. Based on the experimental investigation the blends of crude rice bran bio-diesel can be used as fuel in diesel engine without making any modification to the diesel engine[4] The engine test results concluded that the lower blends of biodiesel increased the brake thermal efficiency and reduced the fuel consumption. From the results, it has been established that 20-40% biodiesel blends can be used as a substitute for diesel without any modifications in the engine. 30% coconut oil and 70% diesel (B30) gave the optimum results[5]. Coconut oil biodiesel is a mixture rich in medium chain saturated methyl esters that exhibits similar properties to diesel. It is mostly within the limits set by ASTM and EN standards for biodiesel. The higher calorific value is 17% lower than diesel [6]. The blend containing 20% rice bran oil biodiesel and 80% petro diesel fuel, both in volume, could be the most effective composition considering the technoeconomic aspects of diesel engines[7]. The brake thermal efficiency is improved marginally when the injection timing was advanced. Decreased smoke, NOx emissions and increased CO emissions were observed for dual fuel mode for all the fuel combinations compared to single fuel operation [8]. G. Lakshmi Narayana Rao.,the ignition delay for JTME and its blends were found to be lower than that of diesel oil due to the inherent oxygen content of JTME and The rate of pressure rise is found to be higher for diesel and lower for JTME [9].Numerous research studies have highlighted the favorable performance and emission characteristics of B100, and their blends [10,11]. Pramanik et al., Acceptable brake thermal efficiency and specific fuel consumption were achieved with the blends containing up to 50% Cottonseed oil. Blends with a lower percentage of Cottonseed oil showed higher exhaust gas temperatures when compared to an engine running with diesel, but lower than the neat Cottonseed oil in all cases [12]. Forson et al., Cottonseed oil, diesel and their blends exhibited similar performance and emission characteristics under comparable operating conditions [13]. Palaniswamy et al., Improvement in performance characteristics and reduction in emissions were observed by preheating Cottonseed oil. [14]. Reddy and Ramesh et al., A significant improvement in the performance and emissions was observed by optimizing the injector opening pressure, injection timing, injection rate and enhancing the swirl level when a diesel engine is to be operated with neat Cottonseed oil. [15]. Sundarapadian and Devaradjane et al., Performance and emission characteristics of JTME are superior when compared to other methyl esters produced from other feedstock, Peak pressure is higher for Cottonseed oil methyl ester compared to diesel [16]. Based on various emissionrelated studies, Mofijur et al. [17] reported that hydrocarbons (HC), particulate matter (PM), carbon monoxide (CO) have decreased with biodiesel, whereas carbon dioxide (CO_2) and NOx emissions got increased. Net CO2 emissions are expected to be lesser as it is absorbed during the crop growth, whereas NOx emissions can be reduced with technologies like exhaust gas recirculation [18]. The high efficiency and cost effectiveness of diesel engines have made them to be widely used in most internal combustion engines. Their efficiency is due to high compression ratio that creates heat and cause spontaneous ignition of fuel [19]. The incessant recognition of diminishing petroleum fuel reserves and possibility of using readily available low cost non-edible plant and waste-oils as sources of environment-friendly renewable substitutes have created a lot of interest in biodiesel research [20]. Biodiesel consists of alkyl esters of fatty acids and can be easily prepared from animal fats, plant or vegetable seed and restaurant waste oils [21-22]. Base catalysed trans-esterification reactions employing sodium hydroxide (NaOH) or potassium hydroxide (KOH) which are extensively used in commercial production of biodiesel are pretty fast but are sensitive to presence of water and free fatty acids[23]. The most commonly employed biodiesel, fatty acid methyl esters are usually produced by trans-esterification of oils/fats with methanol in the existence of an alkaline substance [24-25]. The Cottonseed oil used here as a biofuel as a fuel in CI engine and the trans-esterified oil was compared with diesel. The trans-esterified Cottonseed oil is blended with diesel by proportion of B25 and B25 blend shows almost same fuel consumption, higher mechanical efficiency, higher indicated thermal efficiency and higher brake thermal efficiency by load variations than that of conventional diesel[26]. It is clearly seen that biodiesel blend has very low CO and CO 2 emission percentage than diesel. HC emission of B25 is also found to be less in biodiesel than diesel. NO_x and O_2 content present in exhaust emission is also less than the conventional diesel [27].

III. COTTON SEED OIL BIODIESEL

We have oil plants that come with seeds and they include soybeans, rapeseed, mustard, sunflower, peanut, palm oil, and cotton amongst others. All these products are important for commercial purposes and for domestic use, can be used for cooking oil, salads, and margarine. Their by-products can also be useful, such as the ***cottonseed***, it's by product linter can be used for making string, balls paper, and cellulose products among other. Certainly, the one of the most important purposes of cottonseed plantation is to produce cottonseed oil.

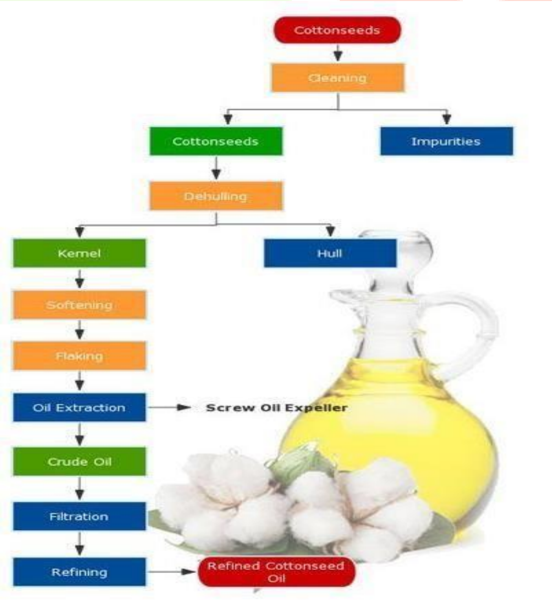


Figure 1 Mechanical Cottonseed Oil Manufacturing Process

Mechanical Cottonseed Oil Manufacturing Process

- Cleaning & Husking
- Softening
- Flaking
- Oil Extraction
- Oil Refining

PREPARATION OF BIODIESEL

The process of making biodiesel from crude cotton seed oil involved several steps. First, 500 ml of the oil was heated to 50°C, and then 150 ml of methanol with a small amount of NaOH catalyst was added and heated to 60°C. A condenser apparatus collected the evaporating methanol, while a magnetic stirrer kept the mixture wellmixed during the 60-minute process. Afterward, glycerol and methyl ester were separated using an isolation funnel. The methyl ester was purified through water washing and heating to remove remaining moisture, and finally stored in a container.

TRANSESTERIFICATION PROCESS

Biodiesel was prepared from the waste cooking oil by transesterification of the crude-oil with methanol in the presence of NAOH as catalyst. Vegetable oils can be transesterified by heating them with a large excess of an hydrous methanol and an acidic or basic reagent as catalyst. Both the acid as well as alkaline esterifications were subsequently performed to get the final product. A catalyst is usually used to improve the reaction rate and yield. NaOH was found to be a better catalyst than KOH in terms of yield.

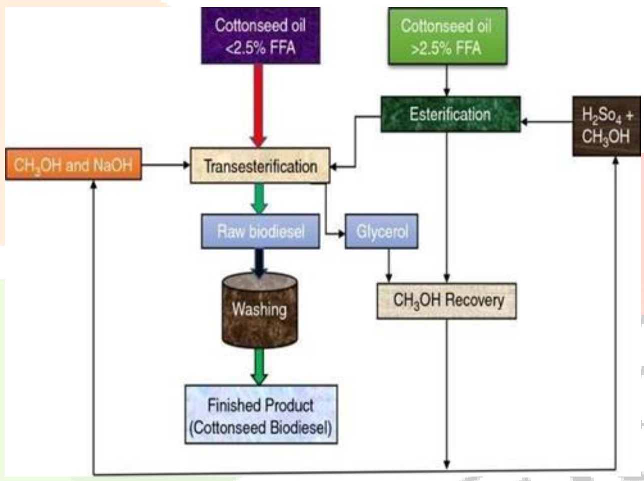


Figure 2 Transesterification process of cotton seed oil

In a transesterification reaction, a larger amount of methanol was used to shift the reaction equilibrium to the right side and produce more methyl esters as the proposed product. Several aspects including the type of catalyst (alkaline, acid, or enzyme), alcohol/vegetable oil molar ratio, temperature, purity of the reactants (mainly water content) and free fatty acid content have an influence on the course of the transesterification. A maximum conversion of 94% (oil to ester) was achieved using a 1: 10 molar ratio of oil to methanol at 60 to 65 degrees C important fuel properties of methyl esters of cotton seed oil (biodiesel) compare well with ASTM standards. When catalyzed by an acid catalyst, this reaction proceeds via the conversion of the carbonyl group through the donation of a proton to it. On the other hand, base catalysts take a proton away from the alcohol group, resulting in the formation of a highly nucleophilic alkoxide ion. It can be noted that methyl & ethyl esters can be used to form esters with relatively large alkoxy groups via the process of transesterification. This is usually done by heating the ester (methyl or ethyl) with the acid/base catalyst and the alcohol having a large alkoxy group, and subsequently evaporating off the smaller alcohol in order to drive the equilibrium reaction in the required direction.

Properties	Cottonseed Oil–Biodiesel
Acid value (AV)	0.3
Saponification value (SV)	199
Iodine value (IV)	76
Peroxide value (PV)	12.52
Higher heating value (HHV),	40.131
Cetane number	56.63

Table 1 Properties of cotton seed oil

Nowadays, in CI (compression ignition) engines, biodiesel is the popular alternative fuel used. It can be used without further variations in the engine's present design due to its sulfur-free, biodegradable and nontoxic nature. In the current era, diesel engines are more commonly used in the transportation field when compared to gasoline engines due to their advantages like wider torque range, low maintenance cost, and high power.

Figure 3 Diesel and Cotton seed oil

The concerns over global warming are closely tied to the rising need for energy. Direct injection (DI) diesel engines generally offer an improvement in efficiency over indirect injection (IDI) systems. Direct injection system of diesel engine (DI) provides low fuel consumption compared with divided-chamber combustion system (in other words indirect injection system) (IDI), because of undivided combustion chamber and no loss at the throat. Hence, DI system is the main stream for automobile diesel engine. On the other hand, DI system is subjected to severe tradeoff between NOx and PM in exhaust emission and additionally creates more white or blue smoke compared with IDI system, which requires reduction of these harmful substances from the viewpoint of global environmental protection.

EXPERIMENTAL SETUP

The setup consists of single cylinder, four stroke, and Diesel engine connected to eddy current type dynamometer for loading. It is provided with necessary instruments for combustion pressure and crank angle measurements. These signals are interfaced to computer through engine indicator for Pressure crank angle-PV diagrams. Provision is also made for interfacing airflow, fuel flow, temperatures and load measurement.

Figure 4 AVL smoke meter and experimental setup

The set up has stand alone panel box consisting of air box, fuel tank, manometer, fuel measuring unit, transmitters for air and fuel flow measurements, process indicator and engine indicator. Rota meters are provided for cooling water and calorimeter water flow measurement. The setup enables study of engine performance for brake power, indicated power, frictional power, BMEP, IMEP, brake thermal efficiency, indicated thermal efficiency, Mechanical efficiency, volumetric efficiency, specific fuel consumption, A/F ratio and heat balance. Lab view based Engine Performance Analysis software package "Enginesoft" is provided for on line performance evaluation. While on line testing of the engine in RUN mode necessary signals are scanned, stored and presented in graph. Stored data file is accessed to view the data graphical and tabular formats. The results and graphs can be printed. The data in excel format can be used for further analysis.

UTILITIES REQUIRED

- **Electric supply**

  230 +/- 10 VAC, 50 Hz, 1 phase

- **Computer**

  IBM compatible with standard configuration

- **IV. Water supply**

  Continuous, clean and soft water supply @ 1000 LPH, at 10 m. head. Provide tap with 1” BSP size connection

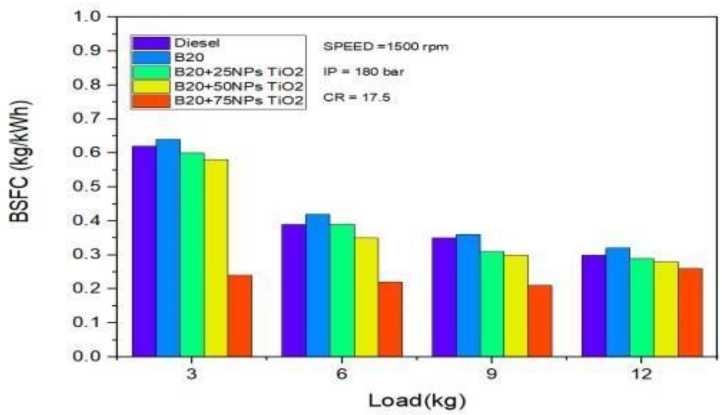
TEST NOMENCLATURE

In this analysis engine is operating at constant injection pressure of 180bar, at an injection timing of 23°btdc, at CR value of 17.5.

- D100- pure diesel
- B20- mixture of 20 % Cotton oil biodiesel and 80% Diesel of total 100% volume
- B20+25NPs Tio_2
- B20+50NPs Tio_2
- B20+75NPs Tio_2

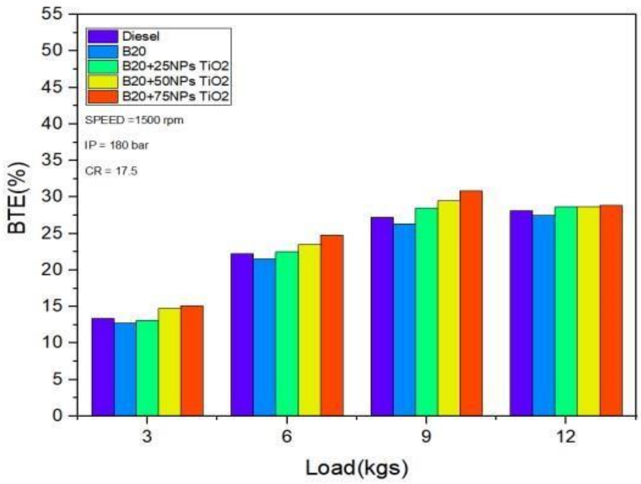
V. RESULTS AND CONCLUSION

- ***Brake specific fuel consumption***



Graph 1 brake specific fuel consumption vs. load

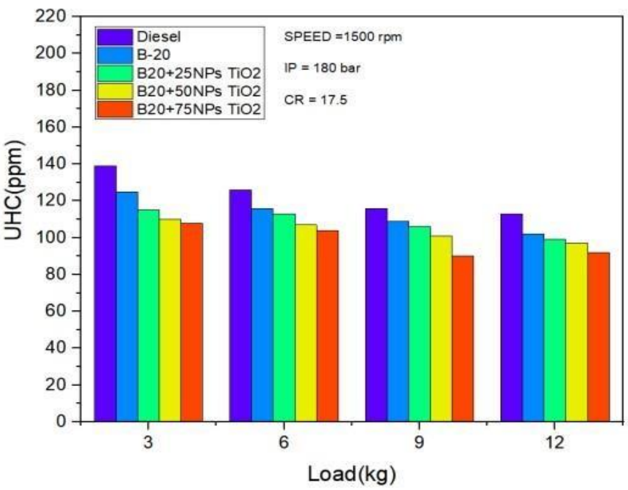
Figure shows the variation in brake specific fuel consumption (BSFC) with increasing engine load for the various fuels D100, B20, and COTTON SEED OIL at 240 bar injection pressure and at 25°bTDC injection timing at rated engine speed 1500 rpm for the various fuels D100, B20, and COTTON SEED OIL . With an increase in load, the specific fuel consumption for all fuels drops. As shown in the figure, bio fuel blends reports a higher BSFC than that of diesel. This may be due to higher density and lower calorific value of biofuel blends.



Graph 2 brake thermal efficiency vs. load

A comparison of the brake thermal efficiency of various fuels D100, B20, and COTTON SEED OIL at 240 bar injection pressure and 25°bTDC injection time at rated engine speed 1500 rpm at various loads is shown in the figure. For all fuels, the brake thermal efficiency improves as the load increases. With a rise in the proportion of COTTON SEED OIL in the mix, the braking thermal efficiency of Cotton seed oil and kerosene blends falls. The loss in thermal efficiency as the percentage of COTTON SEED OIL - diesel mixes grows is due to the earlier start of burning than diesel, which increases compression effort. Because the engine operates with constant injection progress, COTTON SEED OIL's shorter ignition delay causes combustion to begin far before TDC. This increases the compression work as well as heat loss, lowering the engine's efficiency.

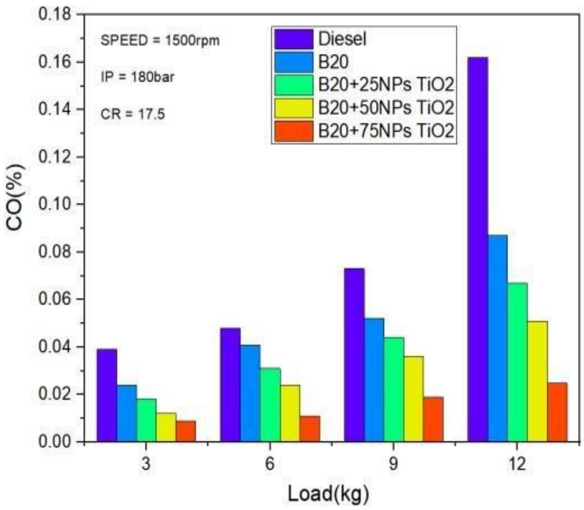
- ***Unburned hydrocarbon (UBHC) emissions:*** Figure shows unburned hydrocarbon emissions at various loads. For the entire test fuels HC emissions increased with increase in load.



Graph 3 Hydrocarbons Vs Load

Similarly, though at lower loads the HC emission was low for diesel, as the load increases emission was also increasing. At higher loads HC emissions were reduced with increase in percentage of kerosene in the blends. At lower loads the HC emission for diesel is low compared to the test blends.

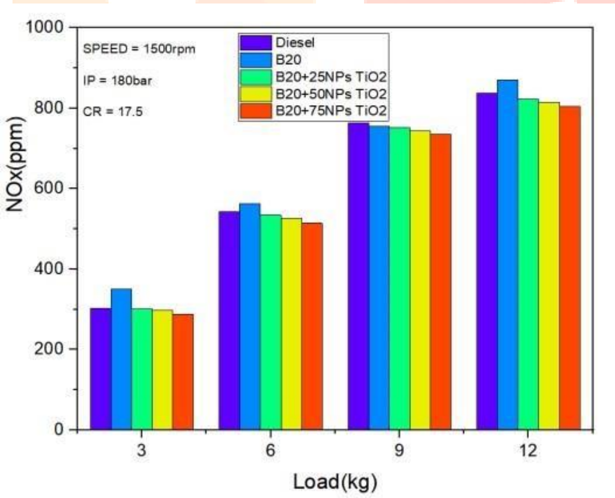
- ***Carbon monoxide (CO) emissions:***



Graph 4 Carbon monoxide Vs Load

Carbon monoxide is produced due to incomplete combustion owing to deficiency of for diesel fuel CO emissions were increasing with increase in load. This is because of more fuel injection at higher loads for kerosene blends CO emission was reduced with increase in load and increase in percentage of kerosene. This Oxygen in the combustion chamber. This is mainly due to complete combustion of blends due to higher volatility of kerosene.

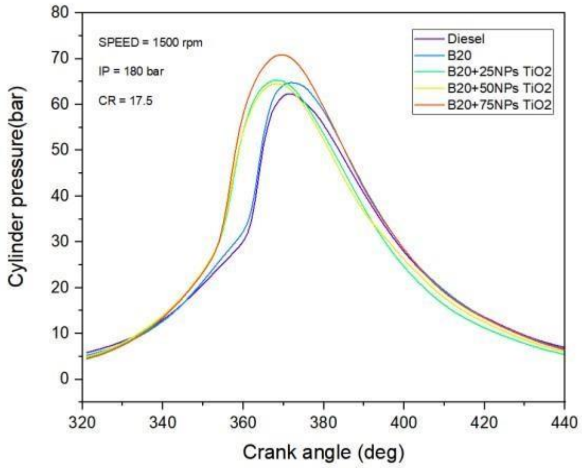
- ***Nitrogen oxide (NOx) emissions:***



Graph 5 Oxides of nitrogen Vs Load

A comparison of NOx emissions of diesel fuel with various COTTON SEED OIL blends at varying loads is shown in the figure. For all of the test fuels, NOx emissions increase as load increases. This is due to an increase in the amount of fuel consumed with load, which causes the combustion temperature to rise. It's also been discovered that as the amount of COTTON SEED OIL in the mix increases, so does the amount of NOx emissions. This increase could be attributable to the fact that COTTON SEED OIL is an oxygenated fuel, which allows for greater combustion and, as a result, a higher combustion temperature. The generation of NOx is aided by the increased temperature.

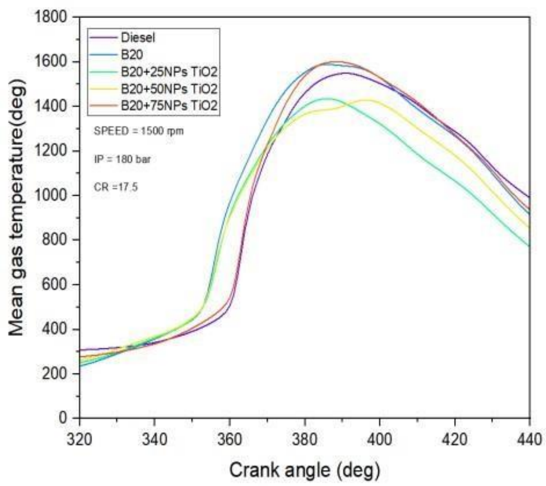
- ***In cylinder Pressure:***



Graph 6 In cylinder pressure Vs Crank Angle

As the engine load increases, more fuel is injected into the cylinder and the in-cylinder pressure increases. Consequently, the pressure in the cylinder increases with increase in engine load and reaches a peak at high engine loads.

- ***Mean gas temperature:***

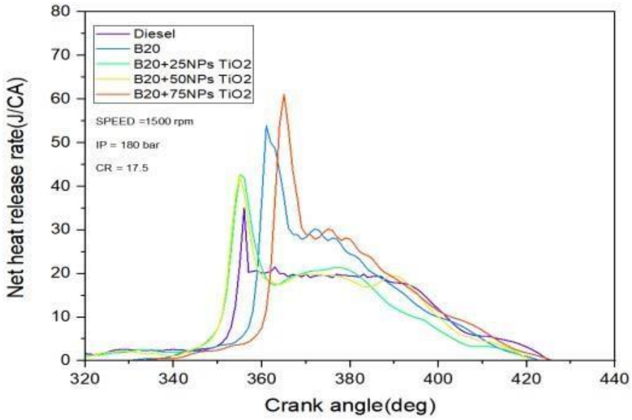


Graph 7 Mean gas temperature Vs Load

The graph depicts the differences in exhaust gas temperature for various test fuels as a function of load. The temperature of the exhaust gas rises with load because more fuel is burned to supply the power demand at higher loads. In addition, for all loads, the exhaust gas temperature rises as the percentage of COTTON SEED OIL in the test fuel rises. This could be owing to the COTTON SEED **OIL's** high oxygen concentration, which promotes combustion and hence raises exhaust gas temperature.

- ***Rate of heat release***

The rate of heat release per degree of crank angle for the fuels at full load condition is depicted in Figure. It is observed that the value of maximum heat release rate decreases with the increase of JTME in the fuel. This is due to the lower ignition delay of the explanation is similar to that of the rate of pressure rise.



Graph 8 Heat release rate Vs Crank angle

Figure depicts the rate of heat output per degree of crank angle for the fuels at full load. With an increase in COTTON SEED OIL in the fuel, the maximum heat release rate is shown to decrease. This is due to the smaller ignition delay of the, with the same explanation as the rate of pressure rise. The maximum heat release rate for 10% and 20% biodiesel fuels is roughly 6° CA bTDC, while the maximum heat release rate for conventional fuels is approximately 5° CA bTDC, according to the same figure.

VI. CALCULATIONS

- ***Maximum load calculation***

  Maximum load (W) = $\frac{BP \times 60 \times 1000}{2\pi N Rm}$ = ---- N = **---kgf**

  BP = Rated power in kw

  N = Rated speed = 1500 rpm

  Rm = Radius of the dynamometer arm length in m

- ***Brake power (BP) =*** $\frac{2\pi N(W \times 9.81)Rm}{60 \times 1000}$ **= ----** ***kw***

  N = speed of the engine in rpm

  W = Applied load in 'N'

  Rm = Radius of the dynamometer arm length in m

- ***Indicated Power (IP) =*** $\frac{IMEP \times LAN/2 \times 10^5}{60 \times 1000}$ **= ----** ***kw***

  IMEP = Indicated mean effective pressure in bar

  L = Stroke length in m D = Cylinder diameter in m A

  = Cylinder area in m²

  Where, A = $\frac{\pi \times D^2}{4}$ = --- m²

- ***Total fuel consumption (TFC) = (q x Density of the fuel)/t = -----kg***

  Where, q = volume of fuel consumed = 10 x 10-6 m³

  t = time taken for 10g of fuel consumption in sec

- ***Specific fuel consumption (SFC) = TFC/BP = kg/kwh***

  Where, TFC = Total fuel consumption

  BP = Brake power in kw

- ***Mechanical efficiency (ηm) = (BP / IP) x 100 = --- %***

- ***Brake thermal efficiency (ηbt) = BP / (TFC x Cv) x 100 = %***

VII. CONCLUSIONS

The performance, emission, and combustion characteristics of a single cylinder four stroke diesel engine running on diesel D100 and Cotton seed oil blends B20, COTTON SEED OIL at an injection pressure of 180bar & at constant injection timing of 23°bTDC at engine rated speed of 1500 rpm are investigated. The key results are summarized below:

1. Due to the inherent oxygen content, the ignition delay of Cotton seed oil and its blends B20 and COTTON SEED OIL was found to be less than that of diesel oil D100.
2. The rate of pressure rise is higher for diesel D100 and lower for the blends B20 and COTTON SEED OIL blends. The rate of pressure rise decreases with an increase in the percentage of percentage volume of Cotton seed oil in the fuel.
3. Calorific value of the blend increases with increase in the percentage of kerosene. As the percentage volume of biodiesel from COTTON SEED OIL in the fuel increases, the rate of pressure rise lowers.
4. Emission of carbon monoxide reduced with increase in kerosene percentage in the blend. The carbon monoxide emissions for blends, which is lower than diesel.
5. The present study showed that the unburned hydrocarbon emission for COTTON SEED OIL blend is lower than the diesel fuel respectively.
6. The emission test was conducted using a 437C smoke meter and an AVL DIGAS 444N, with the findings being recorded. It can readily be observed that blends emit a far lower percentage of CO than diesel.
7. Based on the findings, it is concluded that the COTTON SEED OIL blend consumes about the same amount of fuel, has a greater mechanical efficiency, and has a higher brake thermal efficiency under load fluctuations than the traditional diesel D100. The brake thermal efficiency of the COTTON SEED OIL biodiesel and its blends B20 and COTTON SEED OIL are slightly lower than that of diesel D100 due to the early start of combustion of COTTON SEED OIL biodiesel and its blends, which increases the compression work.
8. A sudden rise in in-cylinder gas pressure is seen after a 75 percent load condition.
9. The exhaust gas temperature of blends is more compared to diesel this is due to the complete combustion which increases the combustion chamber temperature.
10. The CO and HC emission are lower for Cotton seed oil bio-diesel when compared to diesel this may be due to the fact that biodiesel contains more oxygen.
11. The NO x emission is seen continuously increasing when load on engine is increased, which may be due to increase in cylinder temperature. Emission of oxides of nitrogen increased for blends when compared to diesel fuel, which is the common characteristic of any biofuel, and also one of its drawbacks.
12. The developed bio-fuels B20 and COTTON SEED OIL blend is showing an inspiring result with minimum emissions and its thermal efficiency is well comparable with that of diesel.
13. Cotton seed oil and kerosene COTTON SEED OIL blend B20 is an innovative biofuel, which can be commercially used without any engine modification.

VIII. SCOPE FOR FUTURE WORK

1. There is a vast future scope of study on this work by changing the biodiesels and changing the injection timings and injection pressures, the performance, combustion and emission characteristics of diesel engine can be evaluated to obtain the better performance.

2. Further, as a future scope, performance, combustion and emission characteristics of an engine can be evaluated using ternary fuels with addition of low reactivity fuels (alcohols) to the diesel and biodiesel.

3. To reduce Nitrogen oxides, we can use exhaust gas recirculation as a method in further experimentation.

IX. REFERNCES

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