EXPERIMENTAL STUDIES ON CI ENGINE USING KAPOK OIL BIODIESEL BLEND & TITANIUM DIOXIDE (TiO_2) AS NANO ADDITIVE USING EXHAUST GAS RECIRCULATION (EGR)

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Abstract: *Our dependence on fossil fuel grows stronger each year and with rapid industrial growth the emissions are increasing more rapidly. So, to reduce emissions and decrease the usage of fossil fuels bio diesels plays a major contribution to environment. Biodiesel which is an alternate source of diesel which is originated from renewable sources. In this study, Kapok oil has been used to synthesis biodiesel. Biodiesels are vegetable and animal oils produced through trans-esterification of vegetable oil when reacted with methanol in the presence of base catalyst. The Kapok oil is esterified to form Kapok methyl ester (KME) biodiesel, Titanium dioxide Nano particles are added as additive to improve the stability and enhance the properties of the fuel, and EGR is used to lower the NO_x emissions. Along with the kapok oil a Nano-additive was added to improve the rate of combustion and availability of oxygen during the process of combustion and increases the favorable conditions for homogenous combustion which there by decreases the emissions. Experimental investigation was carried out to analyze the effect of performance and emission characteristics of kapok oil using Titanium dioxide as Nano additive to reduce the oxides of nitrogen EGR is used. It is expected that the kapok blended bio-diesel using TiO_2 Nano additive should show better performance and emission characteristics than the fossil fuel.*

Keywords – Kapok Methyl Ester (KME), Titanium dioxide (TiO_2), Exhaust gas recirculation (EGR).

I. INTRODUCTION

Energy is the basic demand for economical and Industrial development of the country. Every segment of an Indian economy, industrial transport, agricultural equipment's, domestic and commercial needs input of energy. The most productive methods of transport normally utilized today are the Diesel engines. They took part in large portion of world's economy and drive the nation. Today diesel engines are a lot cleaner and proficient than the past adaptations, halfway on the grounds that they run on an extensively characterized diesel fuel. This makes the motor makes to tune the diesel fuel framework for improved proficiency. Biodiesel and Diesel fuel are closely resembling in their synthetic and physical qualities they have very similar characteristics so that it is suitable to use in diesel engine.

Biodiesel, an eco-friendly and indigenous source of fuel which is well substitute for diesel. Biodiesel has been gaining the consideration of researchers/analysts all over the world. It is a type of diesel fuel got from creature fats, vegetable oils and waste cooking oil. The oils which were used for the most part for generally speaking production of biodiesel are soybean oil, rapeseed oil, sunflower and palm oil, yet various oils are also used, including safflower, nut, linseed, used animal fats, and moreover vegetable oils. Plants generate biodiesel by drawing carbon dioxide (CO_2) from atmosphere, it is a carbon-neutral fuel. The use of vegetable oils as bio-diesel in diesel engine is deferred by their own setbacks such as poor volatility, high viscosity of oil and poor cold flow characteristics. Biodiesel generally produce slightly higher amounts of oxides of emissions due to the presence of excess amount of oxygen. In the procedure of selecting suitable oil for the production of biodiesel, there are numerous considerations such as cost, availability, stability and the method of production. [1]

After several investigations by considering the present-day issues relating to the choice of suitable feedstock for production of biodiesel, various studies on the biodiesel characterization form non-edible oils as alternate for diesel have been explored by many scientists/researchers. In this regard, the non-edible oil such as kapok oil (Ceiba Pentandra) could be a possible alternative resource for production of biodiesel. Kapok tree is grown in major parts in India, Malaysia and other parts of Asia, while it also has great economic importance for industrial and domestic use in Nigeria.

Kapok tree (Ceiba Pentandra) which is known for silk-cotton, is a native of America and West Africa, and these seeds were introduced into Southeast Asia by India. The Kapok tree usually grows 60-70 m tall, and the fully-grown tree produces seed pods between 1000 and 4000 at a time. The each pod of kapok tree consists of nearly 250 seeds which are surrounded by a yellowish and fluffy fibre. The below figure 1.1 shows the kapok seed pods and seeds from a kapok tree. The seed usually contains 25-28% oil content and the colour of oil is yellow with a pleasant mild odour. The kinematic viscosity of Kapok seed oil is higher than that of conventional diesel fuel, and higher density of the crude kapok oil is responsible for gum formation, sticking of unburnt hydrocarbons to cylinder liner, poor cold flow characteristics. The evaporation point of the Kapok oil explains that it has low volatile characteristics, which may also increase in the hydrocarbon emission and smoke density. So, the suitable alterations can be made in the raw Kapok oil in order to overcome the problem of volatility and viscosity. [2]

Nano additives are the nano particles, which have equipped for expanding biodiesel properties to compete with the diesel. Titanium dioxide (TiO_2) is otherwise called Titania. It is normally happening oxide of titanium. In this investigation, titanium dioxide nanoparticles are added to diesel as fuel added substance. The physiochemical properties of the scattering, for example, fire point, viscosity, thickness, and calorific value are tentatively decided. The fuel tests of diesel and bio-diesel with TiO_2 nanoparticle added substance are tested in a compression ignition engine for emissions and performance characteristics. Due to the presence of high oxide amount in the nano additive it is observed that complete combustion takes place with the evaporation of CO_2 and H_2O.

Fig: 1.1.Kapok Tree pods

Fig: 1.2.Kapok seeds in the pods

II. MATERIALS AND METHODS OF PRODUCTION

2.1. Extraction of kapok oil from seeds

Kapok woody pods are gathered in the South West district of Tamilnadu, India. The kapok seeds are isolated from smooth fiber which lies inside the woody units. These seeds are dried under the daylight until its shading changes and took care of into a giant limit holder of extractor. The extraction of kapok seed oil was finished utilizing a mechanical smasher. The crude kapok oil is gathered and separated to eliminate the contaminations. At first, the seeds, isolated from the pods, were noted to be in acceptable state of being and thusly, without exposing it to any pre-treatment measure, these seeds were taken care of into a reactor of enormous ability to hold large volume of them. After which, hot steam from a different line is passed into the reactor to soak the seeds and a small portion of oil is extracted.

2.2. Trans-esterification of Kapok seed oil

In this work the acquired crude kapok oil which is separated from the seeds contains high viscosity, and less unpredictable and it has low atomization properties so to do that we convert fatty oil to methyl ester. In this process the extracted raw kapok oil of one liter is heated in a magnetic stirrer apparatus, containing an arrangement for poring of oil and Potassium methoxide solution. The oil is warmed up to 65ºC and in equal, KOH (potassium hydroxide) pallets were disintegrated with methanol in a different vessel which tends the reaction towards the formation of potassium methoxide. The shaped potassium methoxide solution is then poured in the warmed oil. At first the oil is taken in to attractive stirrer device the kapok oil is made to warm at temperature at 65ºC. A measuring glass is taken with a methanol and KOH beds mixed it well so both blends and structure potassium methoxide solution. This potassium methoxide is poured in to the attractive stirrer contraption containing oil and mixed well, which will in general structure Kapok Methyl Ester (KME) and glycerol. The acquired blend is permitted to settle for about 3hrs with the goal that glycerine gets isolated from methyl ester. Kapok methyl ester is isolated and heated water is passed in to it, and washed so glycerine gets isolated as white fluid. [3]

(a) (b)

(c)

Fig 2.1. (a)Magnetic Stirrer apparatus, (b)Kapok methyl ester + glycerine, (c) Heating of Kapok methyl ester after washing

2.3. Sol-gel method for production of Titanium Dioxide (TiO_2)

Sol-gel method has been utilized for the production of TiO_2 Nano powder. Experiment results have set that this technique has positively delivered uniform size, un-agglomerated phase, high immaculateness and homogeneous nanoparticles. TiO_2 nanoparticles were incorporated by sol-gel utilizing $TiCl_4$ as forerunner due to its ease and simple to control hydrolysis and sharp cycle. The outcomes affirmed that this cycle is a decent strategy to plan TiO_2 nanoparticles. The systems of gelatinization of $TiCl_4$ ethanol arrangement and development of TiO_2 nanoparticles were likewise decided. TiO_2 offers the best application in photo catalysis given its superb photo activity movement, high-security, non-harmfulness, ease, and water-insoluble properties under most conditions. [6]

Average Particle Size(APS)	Purity	Crystal Structure	Colour
30-50 nm	99.95 %	Anatase	White

Table 2.1. Titanium dioxide (TiO_2) Nano particle Specification

Table 2.2. Titanium dioxide (TiO_2) Nano particles

2.4. Ultra sonication of Bio-diesel dispersed with TiO_2 nano particles

Ultra-sonication is a profoundly powerful methods for making scatterings between the nanoparticles in a fluid, fit for staying in suspension for a long time. Ultrasonic waves are created in a fluid suspension by drenching an ultrasound test or horn in to the suspension. The Nanoparticles of 100 ppm were gauged and scattered into the Kapok bio diesel mix, it is seen that from the past exploration execution tests were led with various mixes, The Ultrasonicator cycle was done at a frequency of 50 kHz, 120 W for 45 min span. The prepared fuel tests were named as B20$TiO_2$100, B30$TiO_2$100 and B40$TiO_2$100. [5]

(a) (b)

Fig 2.3. (a) B20, B30, B40 without TiO_2 nano additive, (b) B20, B30, B40 with TiO_2 nano additive

III. CHARACTERISTICS OF KAPOK OIL

The properties of crude kapok oil was estimated and compared with the diesel it is seen that the viscosity of crude kapok oil is far more greater than that of diesel which isn't appropriate to use in diesel engine without adjustment, which may bring about issues, for example, atomization, sticking of unburnt hydrocarbons so as to make the crude oil to make use in the engine without alteration is by transesterification. Transesterification is the way toward decreasing the viscosity and density which is ideal for the utilization as biodiesel in internal combustion engine. The properties of raw kapok oil and Kapok methyl ester is likely estimated. The underneath table reveals to us the properties of crude kapok oil and kapok methyl ester and diesel. It is seen that the calorific vale of kapok methyl ester is near that of diesel and the cetane number is more prominent than that of diesel.

Through the process of ultra-sonication nano particles are dispersed into the biodiesel with different proportions such as B20$TiO_2$100, B30$TiO_2$100 and B40$TiO_2$100. The properties are as follows

Property	Raw Kapok oil	KME	Diesel
Density (kg/m^3)	921.3	876	823
Kinematic Viscosity(Cst)	30.3	5.4	3.8
Flash point(°C)	170	156	74
Calorific Value(KJ/Kg)	36,590	39,400	42,700
Cetane Number	38	54	50

Table: 3.1. Properties of raw kapok oil, kapok methyl ester (KME), and diesel

Property	B20+100TiO_2	B30+100TiO_2	B40+100TiO_2
Density (kg/m^3)	853	862	868
Kinematic Viscosity(Cst)	4.43	4.6	4.62
Flash point(°C)	110	115	122
Calorific Value(KJ/Kg)	41,510	41,480	41,463

Table: 3.2. Properties of biodiesel dispersed with TiO_2 nano additive

IV. EXPERIMENTAL SETUP AND ARRANGEMENT

The test arrangement comprises of 4-stroke single chamber water cooled variable pressure diesel engine furnished with Exhaust gas recirculation (EGR) is utilized for testing of biodiesel. For applying load Eddy current dynamometer are used to apply load on engine which is connected to the flywheel to apply loads on the motor. A steady infusion weight of 200bar is kept up to infuse the biodiesel into the ignition chamber. The chamber pressure is assessed by the piezo-sensor fitted on the engine chamber head and wrench point encoded fitted on the fly wheel. The outflows UBHC, CO, CO2, and NOX are estimated by utilizing AVL-DIGAS 444 fire gas analyzer. The important performance characteristics of the engine such as brake power, brake specific fuel consumption (BSFC), brake thermal efficiency (BTE), exhaust gas temperature (EGT) and other parameters are measured for all the blends(B20$TiO_2$100, B30$TiO_2$100, B40$TiO_2$100) of biodiesel dispersed with titanium dioxide nano additive. As a part from these some of emission characteristics such as oxides of hydrocarbon (HC), carbon monoxide (CO), carbon dioxide (CO2), nitrogen

(NOx). The diesel blended with kapok methyl ester with different blend ratios and added titanium dioxide nano additive were tested for different percentage of EGR has been analyzed. The required care has been taken to maintain the accuracy by calibration whenever possible.

4.1. Technical Specifications of engine

Make	Kirloskar
Engine details	Single cylinder compression ignition four stroke water cooled diesel engine with EGR
Compression ratio	17.5
Rated power	3.5kw
Cylinder Bore and stroke	87.50mm x 110mm
Loading	Eddy current dynamometer

Table: 4.1. Technical Specifications of engine

(a) (b)

Fig 4.1. (a), (b) Computerized single cylinder VCR Engine setup with EGR

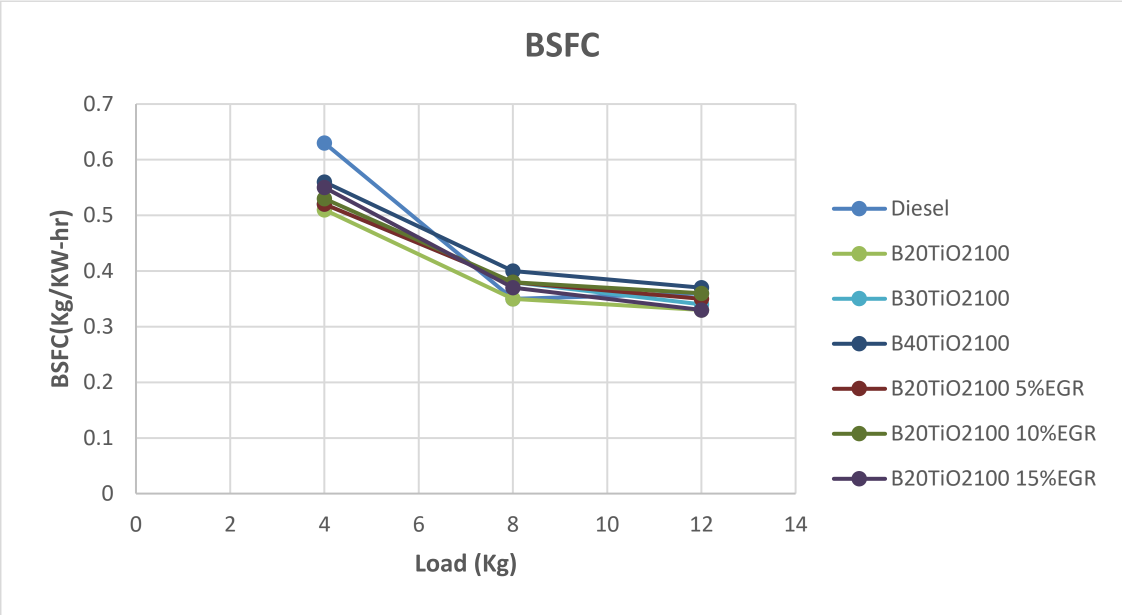
(a) **(b)**

Fig 4.2. (a) Exhaust gas Input to the EGA (b) AVL-DIGAS 444 fire gas analyzer

VII. RESULTS AND DISCUSSION

7.1. Brake specific fuel consumption (BSFC)

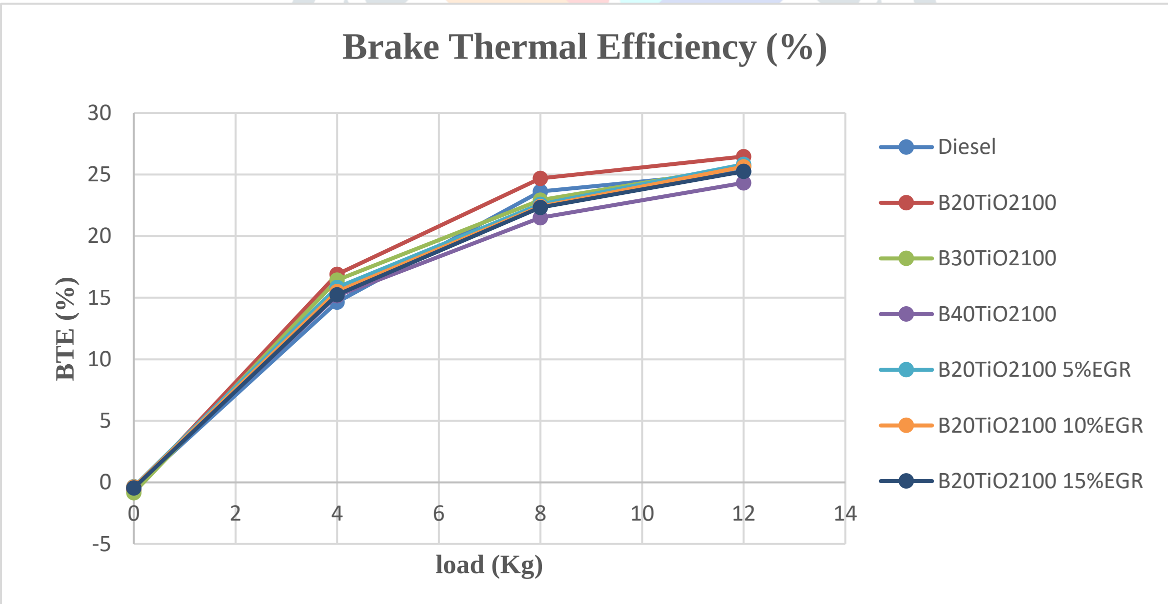
Brake specific fuel consumption (BSFC) with respect to loads for different blends were seen. It is observed that the BSFC for B20+100TiO_2 blend is similar to that of diesel. It is observed that the BSFC for B20$TiO_2$100 shows good results than that of conventional diesel fuel at lower loads this is due to calorific value of and B20$TiO_2$100 10%EGR is slightly lower than that of diesel, the improved combustion phenomenon is due to the presence of oxygen in it helps for better combustion inside the chamber. There is an additional decrease in fuel consumption due to the addition of EGR is due to the exhaust gas is allowed to enter in to the chamber which the fuel get preheated so that input heat is reduced there by the consumption of fuel reduces, which it turns in to lean mixture. [9] Moreover, the viscosity of B20$TiO_2$100 is analogous to diesel fuel, the higher blends such as B30$TiO_2$100 and B40$TiO_2$100 experiences less complete combustion, due to high viscosity and lower calorific value of kapok methyl ester. From this it is concluded that increase in BSFC is observed with the increase in biodiesel proportion. With the addition of TiO_2 nano additive due to high turbulence the BSFC is decreased tending to complete combustion. [8]



Graph 7.1. Comparison of BSFC with variation in load

7.3. Brake Thermal Efficiency (BTE)

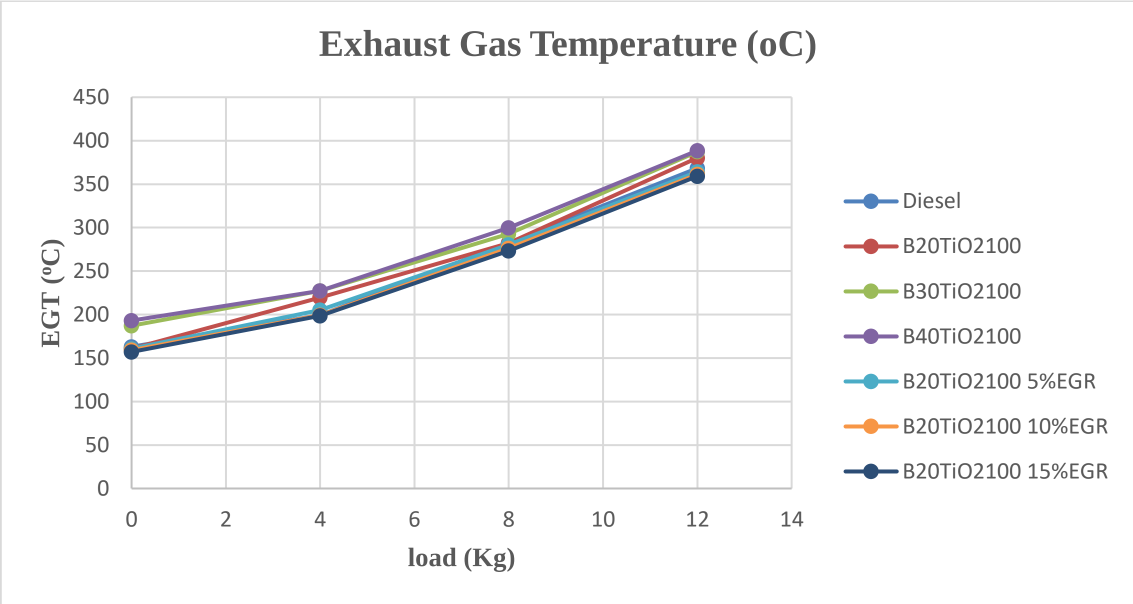
The evaluation of brake thermal efficiencies in contrast to engine loads for different blend ratios of Kapok methyl ester and diesel fuel are shown. The thermal efficiency increases at the lower loads. The maximum efficiency is 24.68 at 8kg load which is 4% more than that of diesel. If you further increases at full load the efficiency was 26.46% which is 4.6% more than that of diesel. The increases in BTE is observed because of shorter ignition delay and due to the better atomization of fuel, the combustion is complete. Due to the presence of Titanium dioxide (TiO_2) the breakage of oxide molecule is seen which is favorable for the combustion reaction to complete with the evolution of CO_2 and water vapor. If you go on increase in the KME it is seen the problems of atomization, high viscosity and high density which tends the thermal efficiency to decrease. Further with the addition of EGR the unburnt hydrocarbons are burnt again in the chamber which is favorable to reduce fuel consumption but due to the lack of hydrocarbons the required amount of heat is not produced which lowers the thermal efficiency. The better thermal efficiency is seen while increasing the percentage of EGR from 5-10%. If we go on increase the percentage of EGR the mixture becomes further lean which reduces the power developed inside the combustion chamber.



Graph 7.2. Comparison of BTE with variation in load

7.4. Exhaust Gas Temperature (EGT)

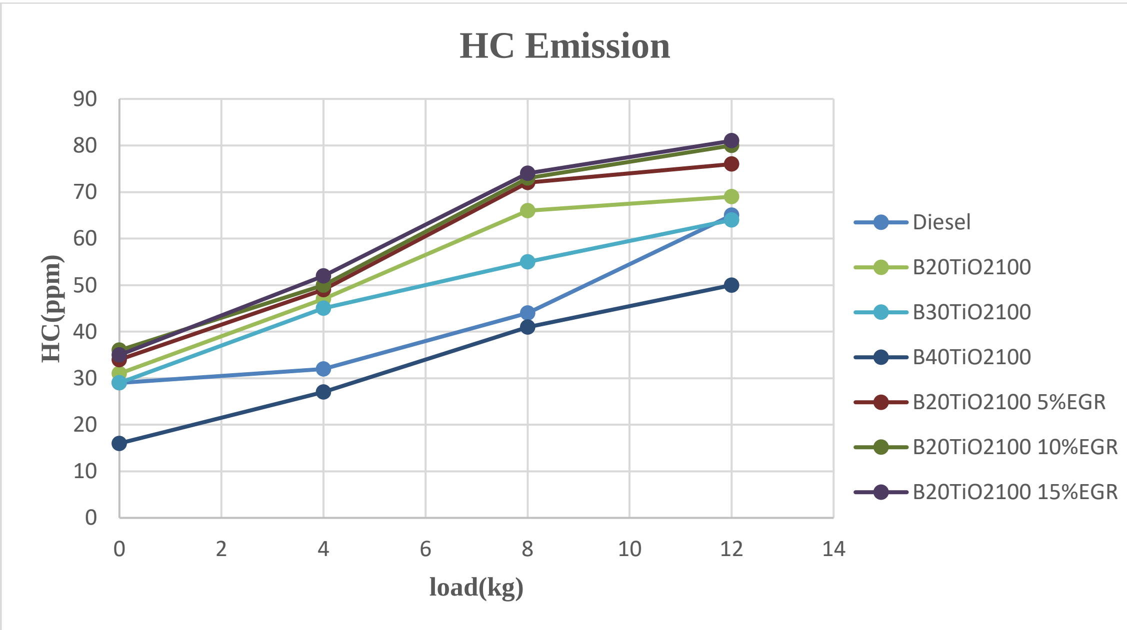
The variation in the exhaust gas temperature with the increase in the load is observed. The exhaust gas temperature of B20$TiO_2$100 is nearer to that of diesel, but it progressively increases with an increase in the concentration of KME and TiO_2 in the blends. The lean biodiesel blends are having lower exhaust temperature when compared to that of diesel. This may be due to, complete combustion, and there is minimum energy loss in the exhaust. The increase of viscosity effects the fuel atomization, poor vaporization and incomplete combustion, and hence the thermal efficiency has decreased accordingly. Additionally, the lower brake thermal efficiency (BTE) and higher specific fuel consumption of Kapok methyl ester can cause an increase in the exhaust gas temperature, and this increase of temperature which boosts the nitrogen oxide emission formation. In addition to that the when the test was conducted equipping EGR the exhaust temperature there is insufficient amount of oxygen during the process of combustion which in turn effect the temperature which is favorable for reduction of oxides of nitrogen.



Graph 7.3. Comparison of EGT with variation in load

7.5. Unburnt Hydrocarbon Emission

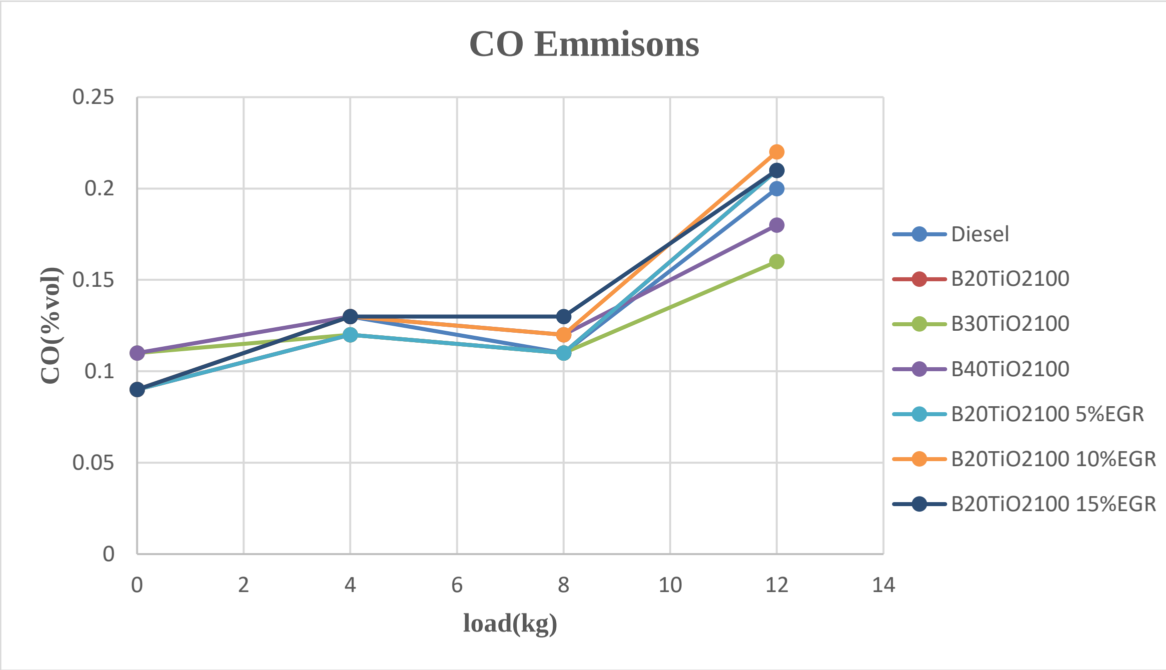
The unburned hydrocarbon emissions for the blends of Kapok methyl ester with TiO_2 and diesel are compared. The decrease of HC Emission is seen with increase in the percentage of the KME and the nano additive. It is due to the presence of inbuilt oxygen which in turn form as lean fuel mixture when blended with diesel. The rich blends of biodiesel consumed more fuel with an increase in the engine load, and therefore, produced high air-fuel ratios, which can cause a slight increment in the HC emission. The inbuilt oxygen present in the biodiesel is the major reason for reducing the HC emission. The TiO_2 breaks with the nearby hydrocarbons to form CO_2 and water vapor. However, HC emissions were found to be increased slightly with addition of EGR. The decrease in HC emissions were seen with 10%EGR of blend B20$TiO_2$100. It is observed that the optimum results are shown for the blends B30$TiO_2$100 and B40$TiO_2$100.



Graph 7.4. Comparison of HC Emission with variation in load

7.6. Carbon Monoxide (CO)

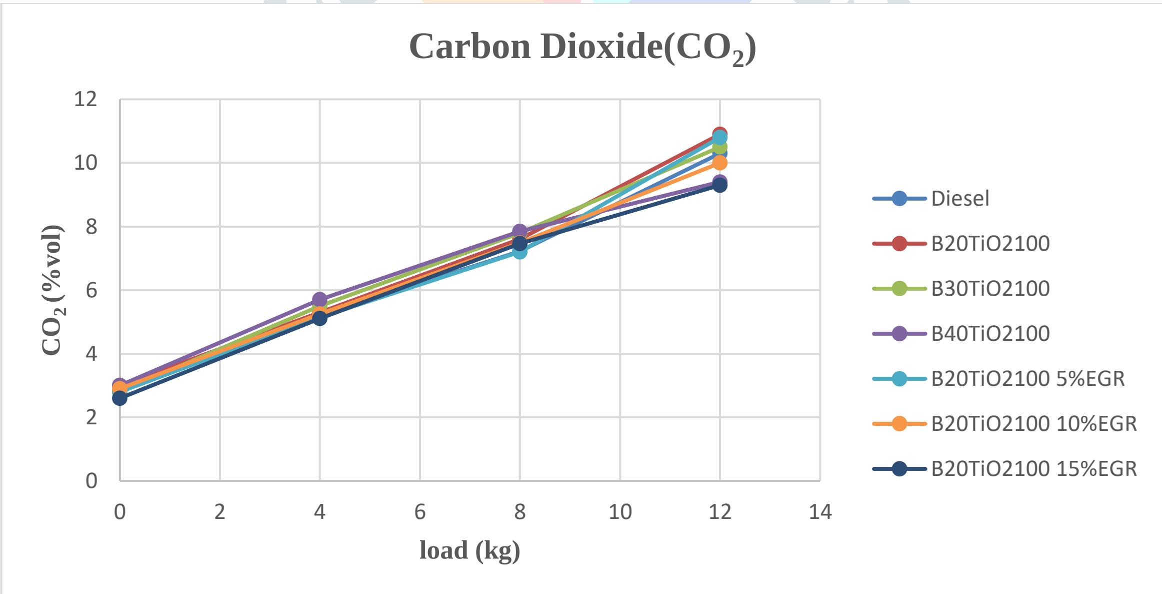
Carbon monoxide is the major emission evolved in the internal combustion engine, which is the major source for cause of greenhouse effect. It is observed that the kapok methyl ester blended with Titanium dioxide (TiO_2) nano additive decreases the Co emission because of inbuilt oxygen present in biodiesel tends to favors complete combustion. The titanium nano additive breaks at high temperature with the evolution of oxygen which is sufficient for the hydrocarbons to react, which is favorable for the formation carbon dioxide and water vapor. Additionally with the EGR further the decrease in CO is seen is because it increase in the availability of oxygen inside the cylinder chamber which tends to increase the co emission. The optimum results were seen for the blend B20$TiO_2$100 with EGR percentage ranging from 10 to 15% [10].



Graph 7.5. Comparison of CO Emissions with variation in load

7.7. Carbon Dioxide Emission (CO_2)

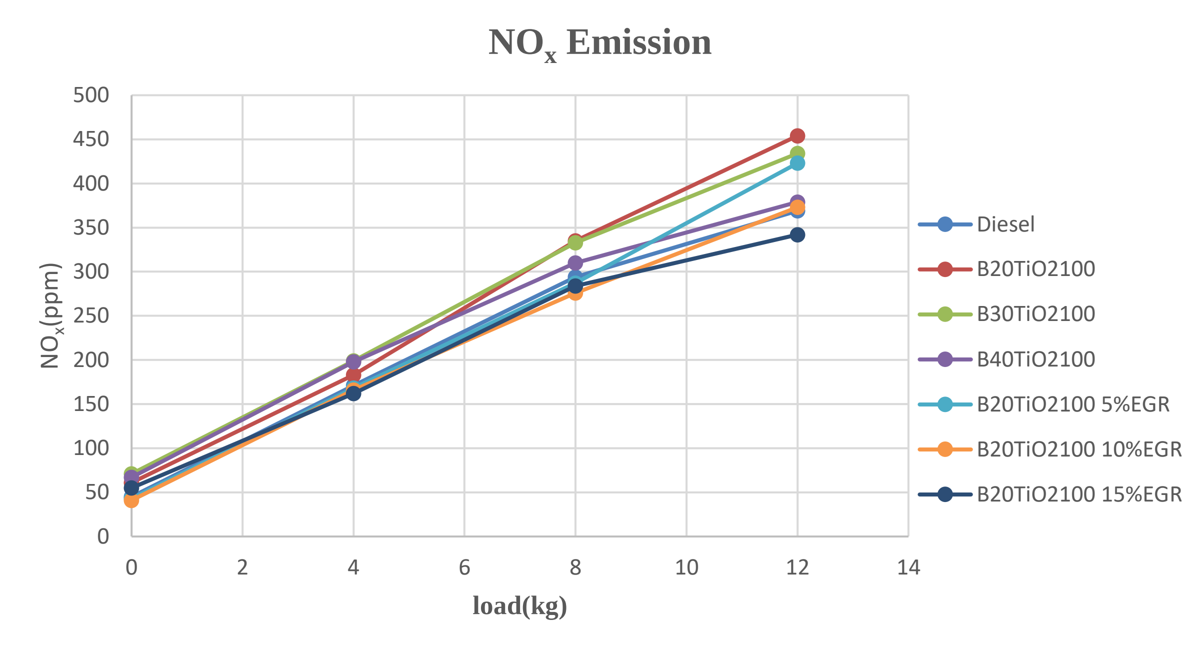
Carbon dioxide which is major by-product of the combustion phenomenon which tells us the complete combustion takes place. In this analysis it is observed that the with the addition of Kapok methyl ester and titanium dioxide (TiO_2) due to the presence of inbuilt oxygen present in the bio diesel favors for the formation of carbon dioxide and water vapor. Hence additionally the biodiesel with nano additives were tested with EGR it is shown that with increase in the percentage of EGR there is increase in the Carbon dioxide (CO_2) is observed. this is mainly due to the unburnt gasses from the exhaust gas is recirculated which makes fuel lean. Which in turn increases the CO_2 emission which represents the complete combustion taking place inside the cylinder chamber. The table shows reduce in the CO_2 with the increase in blend percentage this is due to high viscosity of the blends B30$TiO_2$100 and B40$TiO_2$100. The optimum results were seen for the blends B20$TiO_2$100 with EGR percentage range from 10 to 15%.



Graph 7.6. Comparison of CO_2 with variation in load

7.8. Oxides of Nitrogen (NOx)

The main theme of including EGR is to reduce NO_x emissions. Oxides of nitrogen are the major emissions in an internal combustion engine here in case of biodiesel such as KME consist of high amount of inbuilt oxygen where during the process of combustion the titanium dioxide molecule break at high temperature with the evolution of oxygen and this oxygen is utilized by the nearby hydrocarbons and come as by products as carbon dioxide and water vapor. Normally the nitrogen is highly stable due to the presence of 3 valence electrons in the outer most orbit. Hence due the high temperatures developing in the engine the nitrogen molecule get energized after it attains the required ionization energy the N_2 breaks and react with the oxygen to the form the oxides of nitrogen. Hence to reduce the oxides of nitrogen EGR is the technique where the exhaust gas is made to recirculate again in to the cylinder chamber to reduce the temperatures in the cylinder chamber. It is observed that increase in the percentage of EGR the oxides of Nitrogen are reduced. The maximum reduction is seen for the B20$TiO_2$100 15%EGR. It is seen that for 10%-15% EGR the results were good.



Graph 7.7. Comparison of NO_x with variation in load

VIII. CONCLUSION

The main objective of the present work is the comparative analysis of kapok methyl ester with diesel by adding titanium additives on basis of engine performance and emission characteristics of 4-stroke single cylinder VCR Engine. For this three fuel blends ($B20TiO_2100$, $B30TiO_2100$ and $B40TiO_2100$) were prepared and tested. The obtained results were compared with the conventional diesel. All the observations are drawn from experimental results corresponding to the variation from no load to full load. The viscosity of all the blends is varied with increase in blend percentage and additionally due to the addition Titanium dioxide nano additive which increases the density of blend. The addition of kapok methyl ester has reduced the calorific value of biodiesel these was overcomes by the addition of Titanium dioxide nano additive. It is seen that for blends B20, B30, B40 the calorific values has been increased with TiO_2 ($B20TiO_2100$, $B30TiO_2100$, $B40TiO_2100$).

The marginal increase in the brake power is seen with the addition of titanium dioxide nano additive. Among all the blended fuels $B40TiO_2100$ shows maximum brake power at full load. The brake thermal efficiency of the fuel has been greatly increased with addition of TiO_2 nano additive. The brake thermal efficiency of diesel is 25.24 and the maximum BTE is for $B20TiO_2100$ i.e., 26.46 due to the addition of TiO_2 which is 4.6 % more than that of diesel. The TiO_2 nano additive blended with KME+Diesel shows lower fuel consumption when compared with the conventional diesel fuel. The minimum fuel consumption is seen for $B20TiO_2100$ i.e., 0.5 kg/kW-hr at 25% of load. The higher NO_x is observed for $B20TiO_2100$ because of complete mixing of KME and TiO_2 with the diesel and good atomization and high calorific value of the fuel with the addition of TiO_2 nano additive hence this is the drawback seen here further with the addition of EGR the NO_x is greatly decreased. The maximum reduction is seen for the $B20TiO_2100$ 15%EGR. There decrease in the HC emission was seen with the increase in the blend percentage. The maximum decrement is seen for the $B40TiO_2100$. There is increase in the UNBHC is seen with the addition of EGR due to improper mixing and low combustion temperatures. The CO emissions were decreased with KME and TiO_2 addition there is decrease in the CO is seen for $B30TiO_2100$ and $B40TiO_2100$ this is due to sufficient amount of oxygen present in the biodiesel. The CO emissions of $B20TiO_2100$ and diesel are similar. Due to high oxygen availability the CO_2 were increased and it is maximum for $B20TiO_2100$.

According to the above results, $B20TiO_2100$ shows higher performance and low emission characteristics and with the addition of EGR the $B20TiO_2100$ 5-10%EGR shows lower contents of NO_x and lesser emissions when compared to the conventional Diesel. It can be concluded that the $B20TiO_2100$ shows promising results on CI Engine performance and emission and performance characteristics.

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