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Performance, Combustion & Emission Analysis of the Single Cylinder CI Engine using Karanja Oil Methyl Ester Blends

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Abstract - *Expanding the utilization of Petroleum products and the value climb of petroleum fuel day to day is really creating problems for developing countries who are dependent on oversea suppliers and pay huge amount of import bill, It bring down our Economy. Other than the economy and development, use of fossil fuel also leads to a major problem like global warming and climate change. The emission of unsafe gasses like CO, NOx, CO2, and HC (Hydrocarbons) causes acid rain, health hazard and also global warming. In the last few years interest & activity has grown up around the globe to find a substitute of fossil fuel. The objectives of this study are the production process, fuel properties, oil content, engines testing and engine analysis of biodiesel from Karanja oil which is known as (KOME). The Parameters like Combustion, Performance and Emission characteristics of blends are evaluated and compared with Diesel fuel. There was not any difficulty faced at the time of starting the engine and the engine ran easily over the range different Load condition at Constant Speed. All the parameters were under the range of the acceptable conditions. The range of B10 to B20 is considered to be the better fuel. Hence Biodiesel from Karanja Oil is quite suitable as an alternative fuel to the diesel fuel.*

Key Words: Karanja oil methyl ester (KOME), Karanja, performance, Bio-Diesel Blends, CO, NOx, HC & CO2, Blends.

1. INTRODUCTION

In the early 19the century the Dr. Rudolf diesel has invented the biodiesel from the peanut oil and it was experimented for the compression Ignition Engine. But then, due easily accessibility of the crude oil, the demand is reduced for using biodiesel in the CI engine. In the present world as we are suffering from the oil crisis. And rise in the price of petroleum product. There is need to find some alternate fuels for the diesel in the Compression Ignition Engine.

Karanja is a drought tolerant, versatile for various Seasons, semi-deciduous tree. A medium measured hairless tree with a short stem and spreading crown up to 5-21meter height with a big shade which distributed uniformly wide. Apart from these advantages are Karanja oil can be used as the as alternative fuel for pure diesel. In the country like India, domestic utilization of the petroleum products around 16 percentage of the total imports. And total import is around 3.4 thousand crores Indian Rupees (half billion dollar) is spent for the mineral diesel products in the year 2012. This degrades our Economic conditions due to consumption of more amount of diesel fuel. As there is increase in the demand for the Petroleum products and degradation of fossil fuels, there requirement of the alternative fuel for the diesel fuel or the diesel fuel can be blended with the known proportion of the other oils of fuel. And also, with increasing the demand of the petroleum products specially in the diesel fueled heavy engines, there is increase in the emission of toxicant gasses (Hydro Carbons, NOx & Carbon monoxide) to the atmosphere and causes severe health issues to the human life as well as the other living beings. In the developing country like India, non-edible oil like Karanja oil can be used as the raw product for the making of the biodiesel which are similar properties of the pure diesel. This process is formation of simple ester products from the tri-glyceride non-edible oil.

2. DETERMINING THE PROPERTIES OF THE BLENDS

In the Preparation of Biodiesel, Blends of biodiesel and conventional hydrocarbon-based diesel are produced by mixing biodiesel and diesel in suitable proportions under appropriate conditions. Commonly, it is known as the "B" element to define the percentage of biodiesel in any fuel mixture.

From below fig, it has been noticed that the Calorific Value decreased by increase in the ratio of the KOME blends, the reason is due to the presence of the Un-saturated (Alkenes & Alkynes structure) Hydro-Carbon & Oxygen Residue is going to increase by increasing the Blend percentage.

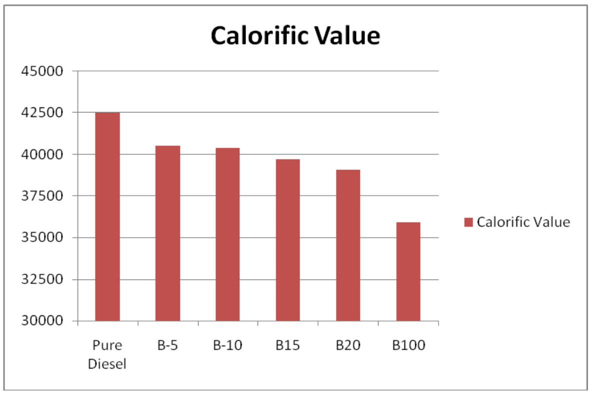

Fig -1: Variation in the Calorific Value of the different Blends

The Dynamic Viscosity & Kinematic Viscosities were found out at the 40°. The Viscosity of the Pure Diesel is less as compared to the Biodiesel. The viscosity will increases by increase in the Percentage of the Blend as shown in the below Figure.

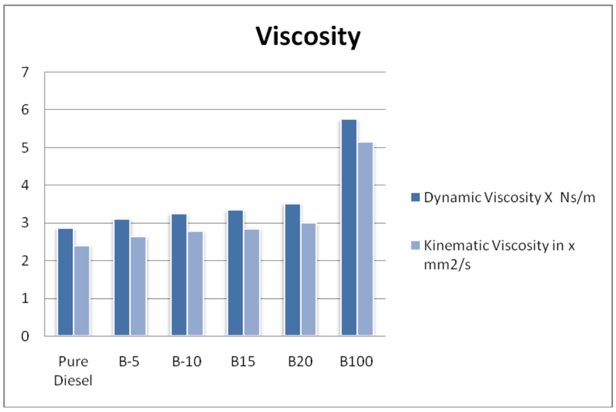

Fig -2: Variation in the Viscosities of the different Blends

The Flash Point is defined as the minimum temperature at which the Fuel starts igniting generation of the spark occurs; The Fire point is the least temperature at which the Vaporization of the fuel continues after burning the fuel. The Flash Point& Fire Point is determined for the Diesel & the Different Biodiesel Blends, it is found out that as the Percentage of the Biodiesel increases the Burning of the Fuel occurs at higher temperature i.e., The Flash & Fire point is going to increase as shown in the below Fig-3, this is due to the viscous nature of the fuel & presence of the Un-Saturated Hydro Carbon bonds exists in the Biodiesel.

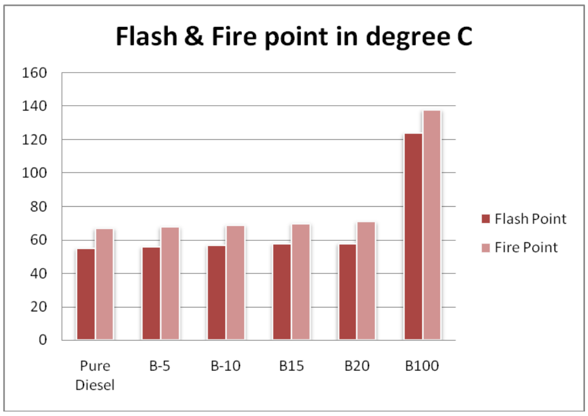

Fig -3: Variation in the Flash & Fire Point of the different Blends

The Engine which is needed to be tested is available in the Energy lab, which is digitally operated. And so IC Engine Software is installed to it which is called as "ENGINE SOFT", to measure the parameters Performance, Emission parameters. The Following is the Detail of the Diesel Engine as shown in the following Table -1.

Table -1: Engine Setup

Sl. No.	ENGINE PARAMETERS	SPECIFICATION
1	Manufacturer	Kiloskar
2	Stroke	4
3	No. of cylinder	1
4	Stroke length(L)	110mm
5	Bore diameter (D)	87.5mm
6	Rated Power	3.5 kW at 1500rpm
7	Diameter of orifice	20mm
8	Length of Connecting Rod	234 mm
9	Compression Ratio	12 to 18

3. EXPERIMENTAL SETUP

The CI Engine is Engine is connected to the Computer, the Software "ENGINE SOFT" installed in it, to record the Combustion & Performance Data through this software. The Setup Experiment is shown in Figure below.

Fig -4: IC Engine Setup

Engine is connected to the Sensor which is linked to the Control System. In the Exhaust Manifold connected to the Exhaust Gas Tester (Gas Analyzer) probe to measure the Exhaust gas contents. Due to the variation in the load the fuel is supplied in the Fuel Burette (average Fuel Tank). The Performance like (BTE BSFC & Mech. Eff.) & Combustion parameters (Rate of Pressure Rise Net Heat Transfer & Cumulative Heat Transfer) is obtained by the IC Enginesoft software. And the Exhaust Parameters (HC Emission, O_2, CO_2, CO & NOx) are obtained by the Exhaust Gas Analyzer Tester. And the final Results were plotted for different blends of the KOME & Diesel Fuel. The capacity of diesel Engine is 12 kg (3.5 kW).

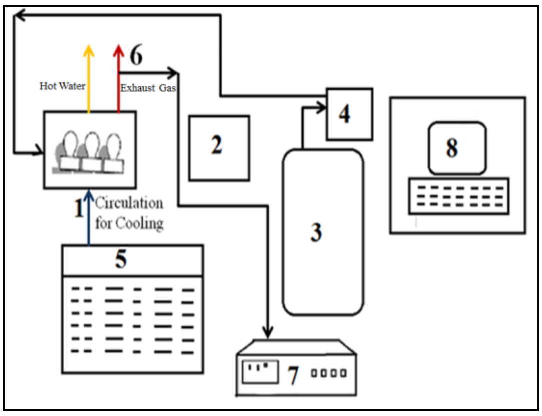

Fig -5: Block Diagram for the IC Engine Setup

Table - 2: Engine Setup

Sl. No.	Description
1	Single Cylinder 4-Stroke CI Engine
2	Dynamometer
3	Engine Load Regulator
4	Fuel Tank
5	Water Storage
6	Exhaust Manifold
7	Gas Analyzer
8	Control System (Computer)

Engine is connected to the Sensor which is linked to the Control System. In the Exhaust Manifold connected to the Exhaust Gas Tester (Gas Analyzer) probe to measure the Exhaust gas contents. Due to the variation in the load the fuel is supplied in the Fuel Burette (average Fuel Tank). The Performance like (BTE BSFC & Mech. Eff.) & Combustion parameters (Rate of Pressure Rise Net Heat Transfer & Cumulative Heat Transfer) is obtained by the IC Enginesoft software. And the Exhaust Parameters (HC Emission, O2, CO2, CO & NOx) are obtained by the Exhaust Gas Analyzer Tester. And the final Results were plotted for different blends of the KOME & Diesel Fuel.

4. RESULTS & DISCUSSION:

4.1 Performance Parameters:

4.1.1 Load % Vs. Brake Thermal Efficiency (BTE):

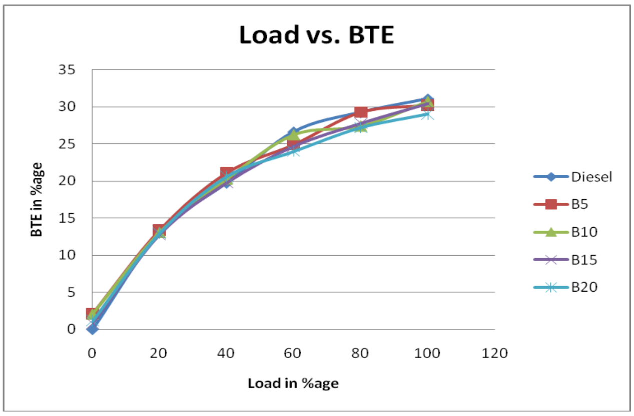

Fig -6: Variation of the Brake thermal Efficiency with Load

The above Fig shows the variation of the BTE with respect to load percentage for KOME biodiesel Blends and pure diesel, the load variation is according to the Table 4. Brake thermal efficiency increases with increasing Load. It is due to decrease in heat loss & output Power increases [10]. At full load condition, BTE values are 31.06, 30.21, 30.69, 30.45 & 29.05 for the Diesel fuel, B5, B10, B15 & B20 respectively. Lower Calorific Value of the KOME blend tends to decrease in the Brake Thermal Efficiency [3]. And also possible reason is due to increase in viscosity, volatility & delay in air-fuel mixing rates for the KOME blends the leads to decrease in BTE[16].

4.1.2 Load Vs. Brake Specific Fuel Consumption

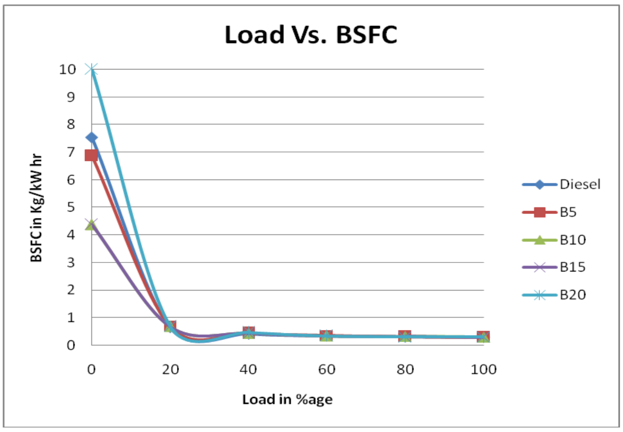

Fig -7: Variation of the BSFC with Load

The above Fig -7 shows the variation of the BSFC of Different blends of KOME & Pure Diesel at variable Load Condition. Due to incomplete combustion in the lower loading conditions, less Power is developed and requires extra air and fuel mixture to develop the power. It is observed from the above graph that the BSFC for B20 is more as compared to that of pure diesel due to low calorific value [1], but the increase in the BSFC is not appreciable, it is due to the accessibility of the oxygen in the blends of KOME may be the cause for the almost similar BSFC [3].The value of BSFC for Pure Diesel is 0.29 Kg/kW hr where as for B20 KOME is 0.31 Kg/kW hr at full load condition, So there is only 3.33% of increase in the BSFC for the B20 Blend. Due to lesser calorific value of the fuel and engine utilizes additional quantity of the fuel in turn to generate output Power.

4.1.3 Load Vs. Exhaust Gas Temperature

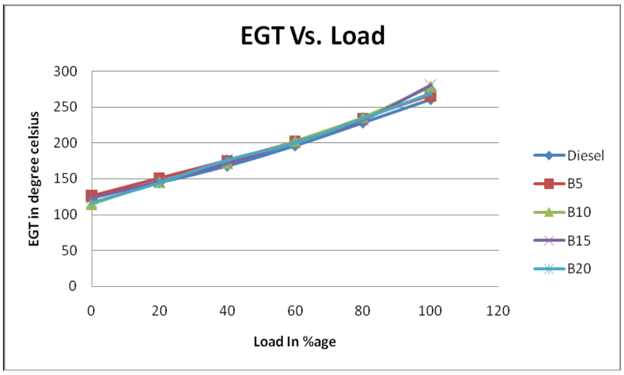

Fig -8: Variation of the EGT with Load

The above Fig - 8 shows the nature variation of the EGT at variable engine load conditions for the KOME blends and pure diesel. The variation obtained in EGT is form 115° C to 280°C, if the load is increased from 0 to 100%. The increase in EGT with respect to the load is clear from the fact that more content of fuel is required at higher load to develop more amount Power. The EGT for the pure diesel is found to be 260°C where as for the B15 is Maximum of 280°C. For the B20 KOME biodiesel Blend EGT is 269°C, hence there is increase in 7.7% of EGT for B20 W.R.T to pure diesel. Combustion occurs at the later part and heat is released after the combustion process [5].

4.1.4 Load Vs. Mechanical Efficiency

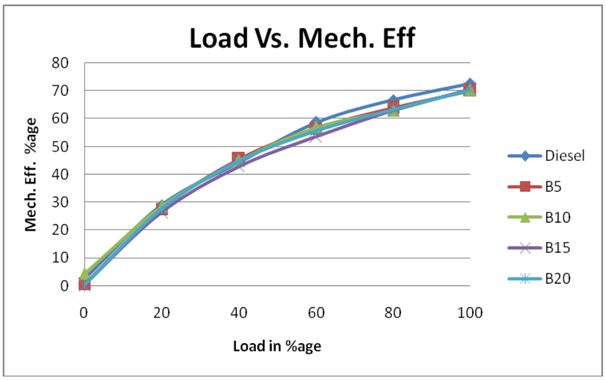

Fig -9: Variation of the Mechanical Efficiency with Load

The above Fig -9 shows the variation of the Mechanical Efficiency at different engine load conditions for the KOME blends & pure diesel. The Mechanical Efficiency is referred as the Output Power generated at the Crankshaft to the Power generated at the cylinder after the combustion of fuel. From the above graph, the similar nature of curve is generated for all the KOME blends and for the pure diesel. It is obvious that, as the load increases the Mechanical Efficiency also increases, because of the ability to develop the power in engine is also increases. And heat losses are going to be reduced [10]. At Full Load condition, The Mechanical Efficiency for the Pure Diesel, B5, B10, B15 and B20 is 72.5, 70.06, 70.51, 70.71 & 70.26 respectively. For Diesel, due to more heating value of the fuel more Power is developed in the Engine. So the Mechanical Efficiency for the Diesel is more compared to the KOME blends, but is not appreciable, it is due to the Lubrication provided in the Piston & Cylinder wall by the Blends. It has been seen that the Mechanical Efficiency is more in the B30 compared to the Pure Diesel & other Blends [10].

4.2 Combustion Parameters
4.2.1 Crank Angle Vs. Pressure Variation

For the CI engine, when fuel is injected inside the cylinder, it takes time to become fine droplets, decomposes and then mixes with the air uniformly to make a combustible mixture. The pressure is due to the rate of fuel burning in the premixed burning phase.

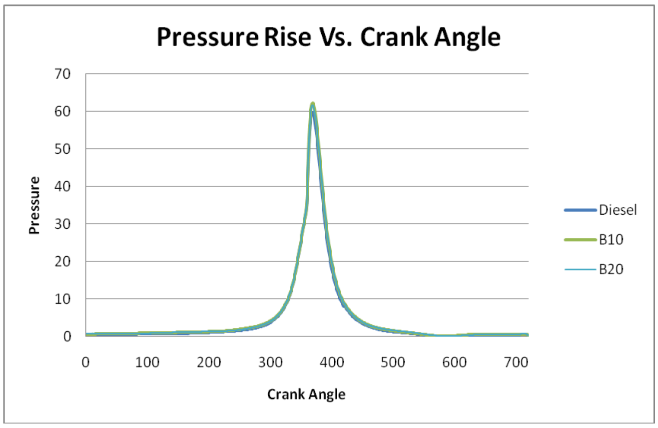

Fig - 10: Variation of the Pressure with Crank Angle

The above Fig shows the variation of Pressure rise against crank angle for pure diesel & the KOME blends during the full load condition. From the above Fig, it is obvious that the peak cylinder pressure is reduced with the increase in the addition of KOME blends. Nonetheless, the combustion process of the test fuels is similar, consists of a premixed combustion phase followed by diffusion phase (mixed combustion). Premixed combustion phase is regulated through ignition delay period and spray envelope of the introduced fuel. Due to this reason the combustion of the diesel fuel occurs early compared to the blends. Hence, Viscosity and volatile nature of the fuel have very significant part to increase atomization rate and to enhance air-fuel entrapment. The cylinder peak pressure is slightly higher for KOME blends than that of pure diesel, because KOME biodiesel blends has high viscous and low volatile nature. And the peak value of the pressure shift towards the right side for the blends. Hence the Peak Pressure is slightly on the higher side [13]. The Peak pressure is 59.73 bar, 62.8 bar & 61.58 bar for Diesel, B10 & B20 respectively.

4.2.2 Crank Angle Vs. Net Heat Release (NHR)

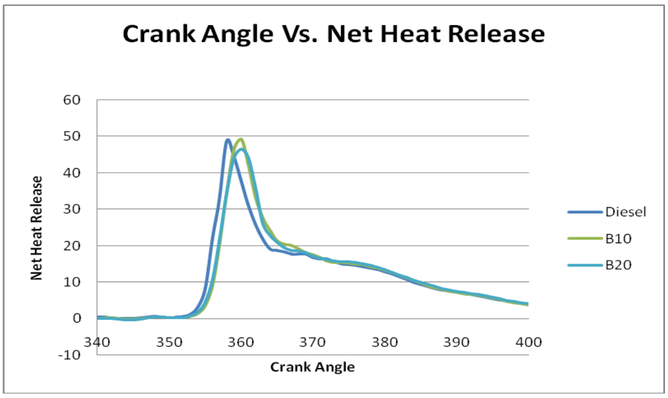

Fig - 11: Variation of the NHR with Crank Angle

The Fig-11 shows the variation of heat release rate with crank angle at full load for the pure diesel & the KOME blends. From the above Fig, the rate of Net Heat Release for the pure diesel (B0) is more & reduces for the KOME biodiesel blends. This may be due to non-viscous and better atomization property of diesel fuel (higher hydrocarbon fraction for the diesel fuel) as compared to the B10 & B20 [18]. The Peak Heat release values are 48.62 at 358°, 49.23 at 360° & 46.52 J/Degree at 361° for Diesel fuel, B10 & B20 respectively. The peak value is Maximum for B10 with respect to the diesel fuel. This is due increased delay period of fuel during the relatively longer delay period caused in higher rate of heat release. On the other hand, the peak heat release rate is lower for B20with respect to B10 and pure diesel. This may be due to the lower volatile, high temperature flash point and higher viscosity of KOME blends, that leads to a reduction in fuel-air mixing ratio, causing in smaller content of fuel is ready for premixed combustion stage after ignition delay [18].It can also be witnessed that the diffusion burning indicated by the area under second peak is dominant for B20. This may be due to the complete combustion occurs at the late combustion phase. Hence for the B20 Heat release is increased at End of the Power Stroke.

4.3 Emission Parameters

4.3.1 Load Vs. CO Emission

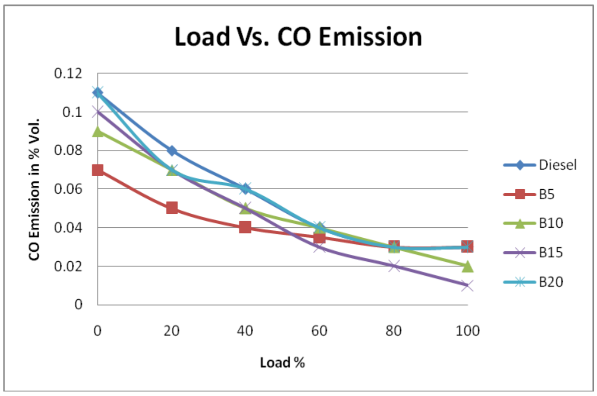

Fig -12: Variation of the Emission of CO with Load

The above Fig -12 shows the variation of the CO emission for different blends of KOME & pure diesel at variable load condition. The CO formation refers to the incomplete combustion in the Engine Cycle. At the Higher Loads, more the Power is developed in the engine. Hence there is decrease in the traces of CO emission percentage due to the complete combustion. The Variation of the CO emission for the KOME blends is less at the lower Loads, because of the Oxygen atoms [14].At the higher loads, the CO emission for KOME B15 is minimal value.

4.3.2 Load Vs. HC Emission

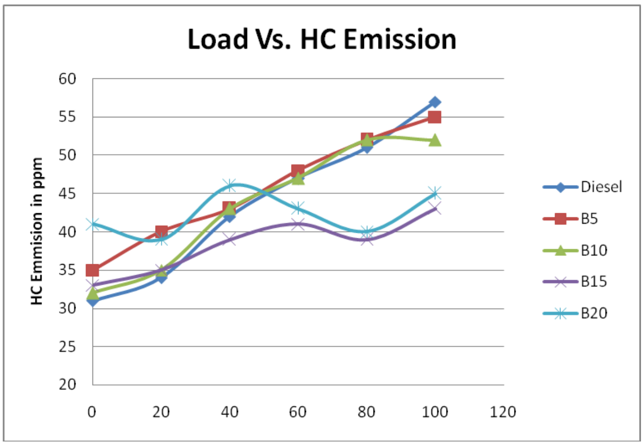

Fig -13: Variation of the Emission of HC with Load

The above Fig-13 shows the variation of the HC emission of Different Blends OF KOME & Pure diesel at variable load condition. The Hydrocarbons (HC) Emissions is very harmful to the environment. HC emission is due to the unburnt in-complete combustion of Carbon-Hydrogen compounds in the fuel. HC emission is increased if the load is increased, because of the more availability of the fuel in the combustion chamber at different location. So there is a chance of incomplete burning of the fuel at the different regions of the combustion chamber. The value of HC emission decreases with increase in quantity of KOME blends. This may be due to the availability of the oxygen atoms & lesser CH bonds in the KOME Blends helpful for the complete burning of the fuel and emits lesser amount of HC [1] & [16].

4.3.3 Load Vs. CO_2 Emission

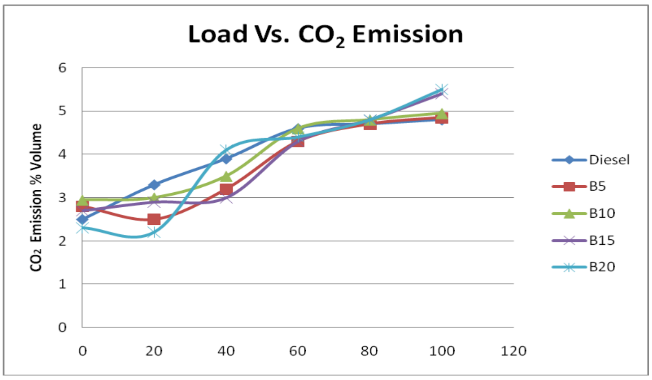

Fig -14: Variation of the Emission of CO_2 with Load

The above Fig shows the variation of the CO_2 Emission of Different Blends of KOME blends & pure diesel at variable load Condition. The Emission of the CO_2 is because of the fuel is undergoing complete combustion. Hence, more amount of the Power in generated after fuel is burnt completely. At higher load, the requirement to develop the Power in engine is increases, thus the fuel undergoes complete Combustion. From above Fig -14, CO_2 emission is higher for the due to the oxygen content in the KOME blends as compared the diesel fuel. And diesel has a lower elemental carbon to hydrogen ratio as compared to the KOME blends [17]. So emission of CO_2 is more in KOME Blends as compared to the pure diesel fuel.

4.3.4 Load Vs. NOx Emission

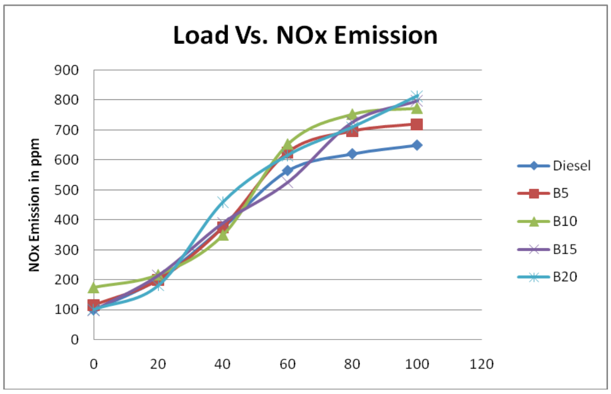

Fig -15: Variation of the Emission of NOx with Load

The above Fig shows the variation of the NOx Emission of different blends of KOME & Pure Diesel at variable load condition. Temperature & Oxygen are two main factors of the NOx Emission in the engine [12]. Due to increase in the loading, in order to develop more amount of the Power, the temperature inside the cylinder increases due to combustion of the more amount of fuel. As we can see in Fig-8, the Exhaust Gas Temperature is maximum during the Power stroke leads to increase in NOx. For KOME blends, due to availability of the unsaturated Hydrocarbon, there is delay in the ignition of the fuel. So the Power is developed just at the later stage, which results higher temperature. And this phenomena supports for the emission of more amount NOx. And also the due to the traces of oxygen present in the in the KOME blends, there will be possibility of more NOx Emission, as the traces Oxygen reacts with Nitrogen and form Nitrous Oxide & Nitric oxide at higher temperature. At the full load condition, the NOx for the B20 is 814 ppm where as for the Pure Diesel is 650ppm. From the above graph the NOx Emission will increases with increase in the proportion KOME blend in fuel.

6. CONCLUSIONS

In this paper, he experimental work c on a single cylinder Four stroke Diesel Engine using biodiesel derived from Karanja Oil termed as the Karanja Oil Methyl Ester (KOME) Biodiesel as an alternate fuel. The conclusions were drawn from this analysis are listed below

- The brake thermal efficiency of the engine with the blends of the KOME blend was slightly lesser than that of neat diesel fuel.
- The Brake Specific Fuel Consumption (BSFC) for the Diesel is marginally less than the KOME blends.
- Exhaust Gas Temperature (EGT) for is found to increase with concentration of KOME in the fuel blend with respect to the pure diesel due to poor atomization and overdue (delay) combustion. For the B15 the EGT is found out to be Maximum.
- The Mechanical Efficiency of the pure diesel is marginally high compared to the other blends of the KOME, is due to the High Calorific Value, more Power in Developed less, heat losses will be less compared to the other Blends.
- The Pressure variation with the crank angle will be steeper for the Diesel and peak value gets shifted towards the right side for the Blends due to the delay period of the Ignition and due to high heat release rate in the premixed combustion, the Pressure will be marginally higher side for the blends.
- The rate of Net Heat Release (NHR) with the crank Angle is rapid & maximum change in the curve for pure diesel, due to viscous nature of the other KOME blends, there will be delay in combustion occurs. For B10 Peak value is maximum due to the

longer delay in combustion which consequences high rate of heat release in the later stage.

- The Carbon monoxide (CO) emission refers to the incomplete burning of the fuel mixture inside the combustion chamber. The Carbon monoxide (CO) emissions were less in case of KOME concentration compared with the pure diesel.
- The Hydrocarbons (HC) Emissions is very harmful to the Environment. The results have been obtained that there is decrease in the emission of HC for the KOME blends compared as along with the pure diesel.
- The emission of the Carbon dioxide refers to the complete burning of the fuel mixture. From the above results the CO2 emission is high for the KOME blends compared to the Pure Diesel.
- The NOx emission considered to be one of the high toxicants emitted by engines in to the Environment. Due to the availability of the traces oxygen compound, emission of the NOx concentration increases with increase in the proportion of the KOME blends compared to that of pure diesel.
- The Biodiesel production can be done locally, Rural & the areas where the less rain is showered. By producing biodiesel in the draught affected regions, we can reduce our unemployment in the local region. From all these results, the range of B10 to B20 is considered to be the better fuel. Hence Biodiesel made with Karanja Oil is fairly suitable as an alternative fuel to the pure diesel fuel.

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