Experimental Investigation of Performance and Emission Characteristics of Jamun Seed Oil Methyl Ester (JOME) in Single Cylinder Compression Ignition Engine

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Abstract— **Petroleum based fuels play a vital role in rapid depletion of conventional energy sources along with increasing demand and also major contributors of air pollutants. Major portion of today's energy demand in India is being met with fossil fuels. Hence it is high time that alternate fuels for engines should be derived from indigenous sources. The purpose of this work is to investigate the performance and exhaust emission of various blends of jamun seed oil methyl ester (JOME) in a small - unmodified single cylinder diesel engine and to compare them with that of a reference diesel fuel (D100).**

I. INTRODUCTION

Diesel engines usually exhaust higher amounts of particulate matter (PM) than spark ignition engines. Alkyl esters of vegetable oils and animal fats, called biodiesel, hold promise as fuel alternatives for diesel engines. A number of researchers have shown that biodiesel has fuel properties and provides engine performance that is very similar to diesel fuel. The primary incentive for using biodiesel is that it is a nontoxic, biodegradable, and renewable fuel. Further advantages over petroleum based diesel fuel include a high cetane number, low sulfur, low aromatics, low volatility and the presence of oxygen atoms in the fuel molecule. These features of biodiesel lead to its greatest advantage, which is its potential for emission reduction including CO, HC, solid carbon particles (SOL) and PM. A number of research studies have proved the positive benefits of Biodiesel on diesel engine emissions. The severe emission regulations in the world have placed design limitations on heavy duty diesel engines. The trend towards cleaner burning fuel is growing worldwide.

The results obtained so far show that the biofuel has good overall behavior, with performance and emission levels comparable to diesel fuel. Engine deposits, injector coking and ring sticking have been detected in long term usage when neat vegetable oil was used. Recently Tranesterification to form methyl, ethyl or butyl ester has been used as a means to reduce the long terms effects. In particular methyl esters derived by the reaction between triglycerides and methanol. The process gives generally a purity product with very small content of sulphur (up to 10-20 ppm) and a cetane number that is very similar to that of commercial fuels. Because of the absence of sulphur in the product and the presence of oxygen in their formula these fuels are considered very promising to reduce pollutants.

A recent review on the argument shows that some authors, when comparing vegetable oils with commercial diesel fuels, claim a reduction in particulate when vegetable oils are used while, someone show the rise of it when biofuels are employed. Over the last years, emissions of fine particles from internal combustion engines have received increased attention due to their negative effects on human health.

II. SCOPE OF THE PROJECT

The process involved evaluating the potential for biofuel production and impact on employment, agricultural production, environment, trade and economic growth, and the potential bottlenecks that need to be addressed. The findings of the project were overwhelming in terms of the potential and keenness to develop biofuels in the region and in order to decrease the hazardous emissions of the engines and to improve the combustion and thermal efficiency jamun oil methyl ester has been chosen as biodiesel.

III. OBJECTIVE OF THE PROJECT

- Selecting suitable biodiesel for replacing diesel.
- Conversion of vegetable oil into bio-fuel by Tranesterification process.
- Investigation of fuel properties (calorific value, flash point, fire point, viscosity, density, specific gravity, cetane number, pour point).
- To increase the efficiency of the engines with different multi fuel combinations.
- Investigation of JOME with various blends and to find the performance and emission characteristics.
- The experiments for various blends of bio diesel and diesel will be carried out in single cylinder diesel engine.
- Investigation of the performance and emission characteristics with blends of JOME B-10, B-20, B-30, B-40, B-100 and D100 at standard compression ratio and flow rate.

IV. BIODIESEL

Biodiesel is an alternative fuel formulated exclusively for diesel engines; it’s made from vegetable oil or animal fats. Biodiesel can be mixed with petroleum diesel in any percentage, from 1 to 99, which is represented by a number following a B. For example, B5 is 5 percent biodiesel with 95 percent petroleum diesel, B20 is 20 percent biodiesel with 80 percent petroleum diesel, or B100 is 100 percent biodiesel, no petroleum diesel.

V. BIODIESEL IN WINTER

Like petroleum diesel fuel, biodiesel clouds when the weather gets cold, filling with little crystals of wax that can clog the fuel filter. When it gets colder still the biodiesels are solid and won't flow or pour. But petroleum diesel fuel, especially winterized can take colder than biodiesel.

VI. **BIODIESEL** IN GASOLINE ENGINES

Biodiesel can also be used in gasoline (spark-ignition) engines, both 2-stroke and 4-stroke, but only as an additive. Users have reported good results with it, but it's still experimental, there are no guarantees.

VII. METHODS OF USING VEGETABLE OIL AS A FUEL IN DIESEL ENGINE

There are at least three ways to run a diesel engine on vegetable oil:

- Mixing it with petroleum diesel fuel, or with a solvent, or with gasoline;
- Using the oil just as it is usually called SVO fuel (straight vegetable oil) or PPO fuel (pure plant oil);
- Converting it to biodiesel.

VIII. BIO DIESEL ADVANTAGES

Biodiesel has some clear advantages over SVO:

- It works in any diesel engine, without any conversion or modifications to the engine or the fuel system.
- It also has better cold-weather properties than SVO (but not as good as petro-diesel)
- Unlike SVO, it's backed by many long-term tests in many countries, including millions of miles on the road.

IX. DIFFERENCE BETWEEN METHYL ESTER AND ETHYL ESTER

Any of a class of organic compounds corresponding to the inorganic salts and formed from an organic acid and an alcohol. This is called ester .An ester that forms methanol when hydrolyzed, that is called methyl ester and this process carried out by using ethanol, which forms the ethyl ester.

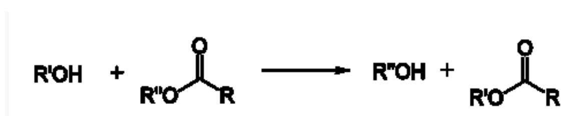
X. LIMITATIONS OF THE BIO-DIESEL

Biodiesel alone should be avoided in newer vehicles with PF (particulate filters) fitted because it reacts with the chemical additive injected into the fuel system at intervals by the ECU (engine control unit) so that it produces more NOx emission when compared to Diesel.

Biodiesel is an excellent solvent and will clean out the fuel system, fuel lines, injectors and the fuel tank. Although not a bad thing, it does mean that the cleared gunk often gets dumped into the fuel filter, which may clog and create rough running or a drop in performance. Consumer and manufacturer confidence reaches the right level through testing biodiesel in a variety of engine sizes and shapes, then it won't be widely available and so people are forced to manufacture their own supplies.

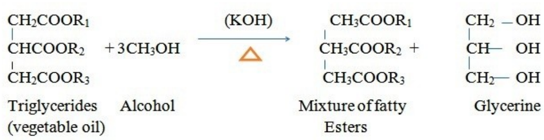
XI. TRANSESTERIFICATION

Tranesterification is the process of exchanging the organic group R″ of an ester with the organic group R′ of an alcohol. These reactions are often catalyzed by the addition of an acid or base catalyst. The reaction can also be accomplished with the help of enzymes (biocatalysts) particularly lipases.

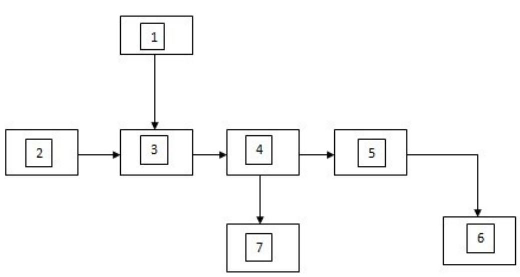


Strong acids catalyse the reaction by donating a proton to the carbonyl group, thus making it a more potent electrophile, whereas bases catalyses the reaction by removing a proton from the alcohol, thus making it more nucleophilic. Esters with larger alkoxy groups can be made from methyl or ethyl esters in high purity by heating the mixture of ester, acid/base, and large alcohol and evaporating the small alcohol to drive equilibrium.

In this process the triglycerides (vegetable oil) are heated to a temperature of 80-85^{o}c by placing it in water bath. Similarly alcohol (methanol) is heated to 65^{o}c in the presence of potassium hydroxide. Both vegetable oil and alcohol are combined together at a temperature of 60-65^{o}c. The reaction results in the formation of esters and glycerine. If water is mixed to the mixture soap oil will be formed, which reduces the formation of bio-diesel. The chemical reaction is shown.



XII. TRANSESTERIFICATION FLOW CHART



1- Vegetable oil/Animal fat/waste
2- Methanol+catalyst
3- Transesterification
4- Crude jamun seed oil
5- Refining
6- Biodiesel
7- Crude glycerin

Simple alcohols are used for Tranesterification and this process is usually carried out with a basic catalyst (NaOH, KOH) in the complete absence of water. The bonding of alcohol and organic acid produces ester. An excess of alcohol is needed to accelerate the reaction. With methyl alcohol glycerol separation occurs readily. If water is present, soap is the bi-product, which results in decreasing yield of ester. In the Tranesterification process alcohol combines with triglyceride molecule from acid to form glycerol and ester. The glycerol is then removed by density separation. Tranesterification decreases the viscosity of oil, making it closer to diesel fuel in characteristics.

XIII. JAMUN SEED OIL

The jamun tree is native to India and its bordering countries like Nepal, Pakistan, Bangladesh Sri Lanka and even Indonesia. In 1911, this tree was introduced in Florida by the USDA.The tree grows equally well in both the tropical and the sub tropical regions. Though organized cultivation is not done much, a lot of trees are grown individually by people having land in their backyards. In the wild however, it grows all over India. It is a large and hardy evergreen tree and lives for over a hundred years. It starts flowering in the month of March and continues till May. Thereafter, with the onset of monsoon in June it starts bearing fruit. The flowers are white and have a sweet fragrance. The fruits do not ripen at the same time and are picked daily. Jambul fruits resemble grapes and are oblong or ovoid in shape. Only ripe fruits are picked as they do not ripen once they are picked. They have a single seed and a soft dark purple colored almost black skin and a lighter purple flesh. When eaten, the fruits coat the mouth and the tongue a deep purple color that stays for a few hours. The fruit is sweet and tart and leaves a slight astringent action in the mouth.

A. Nutrients in Jamun or Jambul

- The ripe Jambul fruit contains Glucose & Fructose are the major forms of sugar. It also contains Vitamins C & A, riboflavin, nicotinic acid, choline, folic acid, malaic acid, sodium ,potassium, calcium, phosphorus, manganese, zinc and iron. Anthocyanins are present in appreciable quantities and are the reason for the antioxidant activity of the fruit.
- The stem & bark contains tannin, gallic acid, resin, phytosterols.
- The seed contains the glycoside, jamboline, gallic acid and essential oils.

B. WHY JAMUN SEED OIL

Bio-diesel which have been used before by the researches for finding the emission and performance characteristics of the engine includes

1) PALM	5) MAHUA
2) JATROPHA	6) MANGO
3) NEEM	7) COCONUT
4) TAMANU	

We have verified the properties of some other oils which have been not yet used and jamun seed oil stands well within the ASTM standards of bio-diesel and have proceeded with it.

XIV. SINGLE CYLINDER DIESEL ENGINE

A. DIESEL ENGINE

The diesel engine is an internal combustion engine that uses compression ignition, in which fuel ignites as it is injected into the air inside the combustion chamber. The combustion chamber compresses the air to temperature high enough to cause the fuel to ignite.

B. FUEL INJECTION IN DIESEL ENGINE

The modern diesel engine is a combination of two inventor's creations. In all major aspects, it holds true to Diesel's original design that of igniting fuel by compression at an extremely high pressure within the cylinder. Diesel original engine injected with the assistance of compressed air, which atomized the fuel and forced it into the engine through a nozzle.

This is called air-blast injection's size of the gas compressor needed to power such a system made early diesel engines very heavy and large for their power outputs, and the need to drive a compressor lowered power output even more. Advantages of the diesel engines are numerous. It burns considerably less fuel than a gasoline engine performing the same work. It has no ignition system to attend to. It can deliver much more of its rated horsepower on a continuous basis than a gasoline engine. The life of a diesel engine is generally longer than a gasoline engine. Although Diesel fuel will burn in open air, it will not explode. Some disadvantages to diesel engines are that they're very heavy for the horse power they produce, and their initial cost is much higher than a comparable gasoline engine.

C. EMISSION

Diesel engines produce very little carbon monoxide as they burn the fuel in excess air even at full load, at which point the quantity of fuel injected per cycle is still about 50% of stoichiometric.

However they can produce black soot(or more specifically diesel particulate matter)from their exhaust, which consists of unburned carbon compounds. This is often caused by worn injectors, which do not atomize the fuel sufficiently, allowing more fuel to be injected than can be burned completely in the available time.

D. POWER AND TORQUE

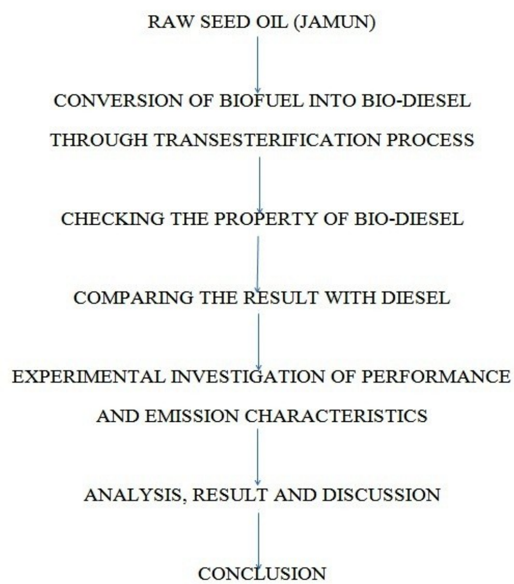
Diesel engines tend to have their torque peak quite low in their speed range (usually between 1600-2000 rpm for a small-capacity unit, lower for a larger engine used in a truck).This provides smoother control over heavy loads when starting from rest, and, crucially, allows the diesel engine to be given higher loads at low speeds than a petrol engine, making them much more economical for these applications. This characteristic is not desirable in private cars, so most modern diesel engines used in such vehicles use electronic control.

XV. EXPERIMENTS CONDUCTED

A. METHODOLOGY

- Tranesterification process of Jamun oil.
- Study the effect of fuel properties after Tranesterification.
- Determining the effect of process parameters on the engine performance.
- Testing the engine with various parameters and various blends ratios (B10, B20, B30, B40, B100) and Comparing the result for each blend ratio with pure diesel.
- Monitoring and reading the various performance parameters, emission characteristics of single cylinder diesel engine.
- With monitored test data, the performance characteristics of the stream can be tabulated as required for the evaluation of the thermal performances data.

B. WORK FLOW CHART



XVI. SPECIFICATIONS OF THE ENGINE

Make	: Kirlosker SV-1
Type	: Vertical cylinder, Diesel engine
No of cylinder	: 1
Bore diameter	: 87.5mm
Stroke length	: 110mm
Compression ratio	: 19:1
Cycle	: Diesel cycle
Speed	: 1800 rpm
Rated brake power	: 5.9KW/8BHP
Cooling system	: Water
Fuel	: Diesel
Fuel injection pressure	: 185bar

XVII. RESULTS AND DISCUSSION

A. SPECIFIC FUEL CONSUMPTION

The variation of specific fuel consumption with power output for biodiesel and diesel shown in the figure 1. The specific energy consumption is the product of specific fuel consumption and calorific value. The improvement in combustion enhances the fuel conversion efficiency and results in decrease in specific fuel consumption. Calorific value and specific fuel consumption are inversely proportional.

If calorific value increases obviously specific fuel consumption decreases. This is due to the fact that esters of vegetable oils have lower heat value, when compared to diesel and therefore more biodiesel is needed to maintain the power output. B 100 is having higher specific fuel consumption compared with diesel at full load condition which is 9.3% high then D 100.

But compared to diesel at full load condition B30 has a specific fuel consumption of 0.195 which is 8.8% lesser than diesel.

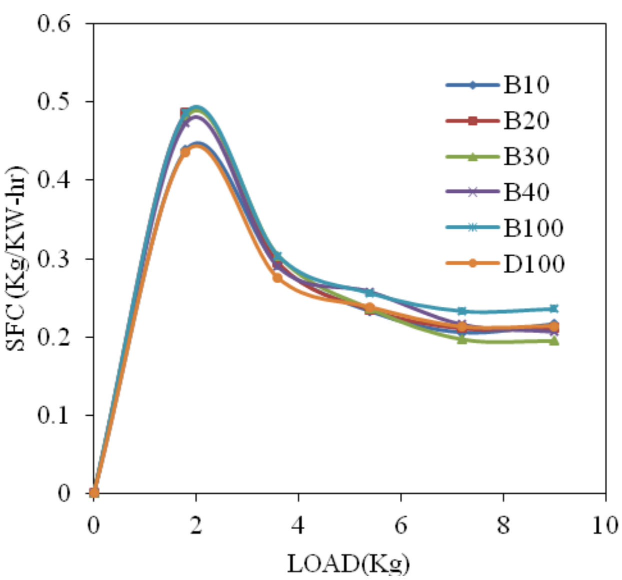


Figure 1: SFC Vs Load

B. BRAKE THERMAL EFFICIENCY

The variation of brake thermal efficiency with load for biodiesel and diesel are shown in the figure 2. From the graph it is analyzed that the brake thermal efficiency of B30 is higher than that of the diesel at full load condition. The maximum brake thermal efficiency of the diesel at full load condition is 40%, whereas in bio-diesel (B30) the brake thermal efficiency is 43.5%. So the outcome of this research work is that the brake thermal efficiency B30 is 3.5% higher than D100.

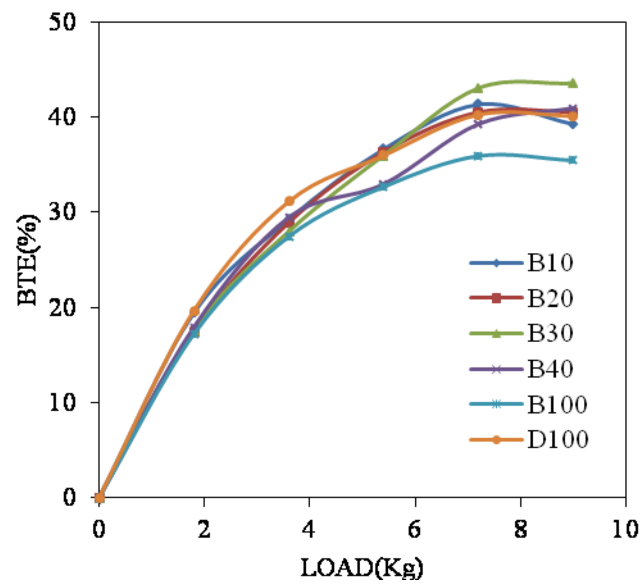


Figure 2: BTE Vs Load

C. *TOTAL FUEL CONSUMPTON*

The variation of total fuel consumption with load for biodiesel and diesel are shown in the below figure 3. The total fuel consumption of the fuel depends on the specific gravity of the fuel used. From the graph it is analyzed that total fuel consumption of B30 blend is 8.0% lesser than that of the diesel (D100).

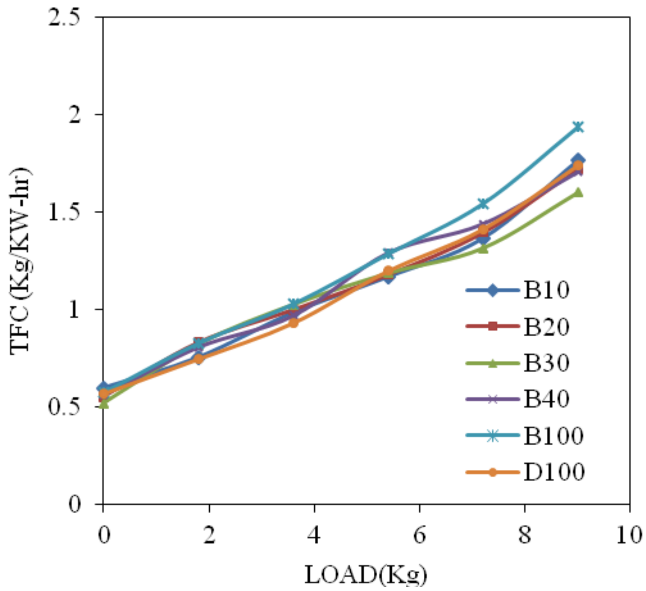


Figure 3: TFC Vs Load

XVII. EMISSION CHARECTERISTICS

A. *CARBON MONOXIDE (CO)*

The percentage of variation in the carbon monoxide emission with diesel and biodiesel is shown in the figure 4. Co production depends up on the mixture strength., i.e. Oxygen quality and fuel viscosity, at low load range air- fuel ratio is high, availability of an Oxygen is more, and hence production of CO a emissions also low.(Reference: Study on the performance parameters of an experimental CI engine, science direct, online journal 24th may 2007)

Generally the cause for smoke in diesel is due to the presence of heavy petroleum oil residues in it. In case of biodiesel, there is no presence of such residues and that result in less emission compared with diesel. The emissions of CO increases with increasing the load and it decreases the brake thermal efficiency .From the CO graph conclude that D 100 having more emission compare to blended biodiesel used as a diesel in compression ignition (CI) engine. Emission is less with biodiesel at full loads, because the biodiesel is oxygenated in the molecular structure and that helps in complete combustion to carbon dioxide. From the CO graph it is concluded that diesel has more CO emission compared with bio-diesel blends at full load conditions. The CO emission is minimum for B30 at full load condition.

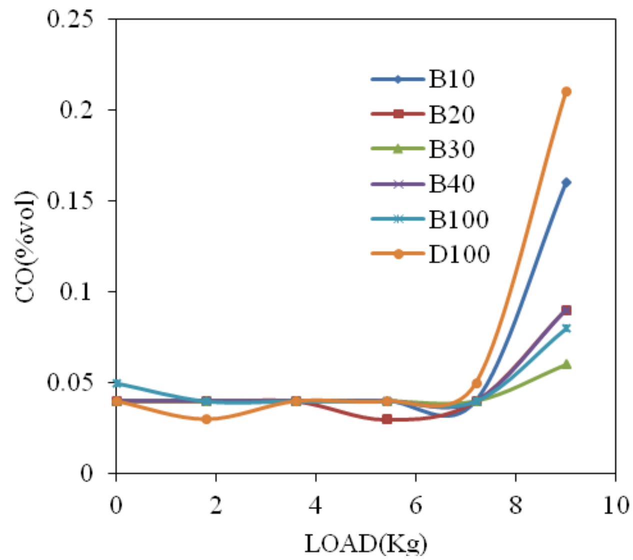


Figure 4: CO Vs Load

B. *CARBON DIOXIDE (CO_2)*

In the carbon dioxide emission with diesel and biodiesel shown in the figure 5. The emissions of CO_2 increase with increasing the load and it decreases the brake thermal efficiency. The emission is less with biodiesel at lower and full loads, because of complete combustion of carbon dioxide. At maximum load condition the CO_2 emission is more for blend B10. The maximum reduction of carbon dioxide (CO2) was observed by 11.5% in case of biodiesel (B30) operation compared to diesel at full load condition. From the graph it is analyzed that the CO_2 emissions increases with the increasing load and at full load condition the CO_2 emission is minimum for blend B30.

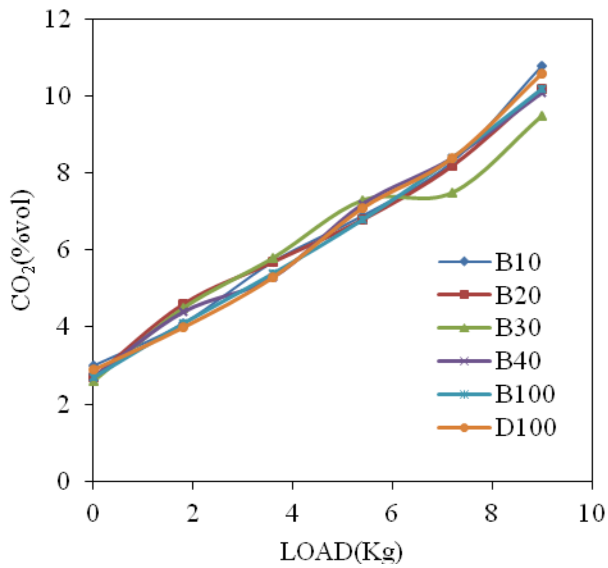


Figure 5: CO_2 Vs Load

C. *HYDRO CARBON (HC)*

The percentage of variation in the Hydro Carbons with diesel and biodiesel are shown in figure 6. HC production depends up on the mixture strength. i.e. Oxygen quality and fuel viscosity, at low load range air- fuel ratio is high, availability of an Oxygen is more, and hence production of HC emissions also low

From the graph it is analyzed that at low load condition the emission of hydro carbon is less for bio-diesel compared with diesel.

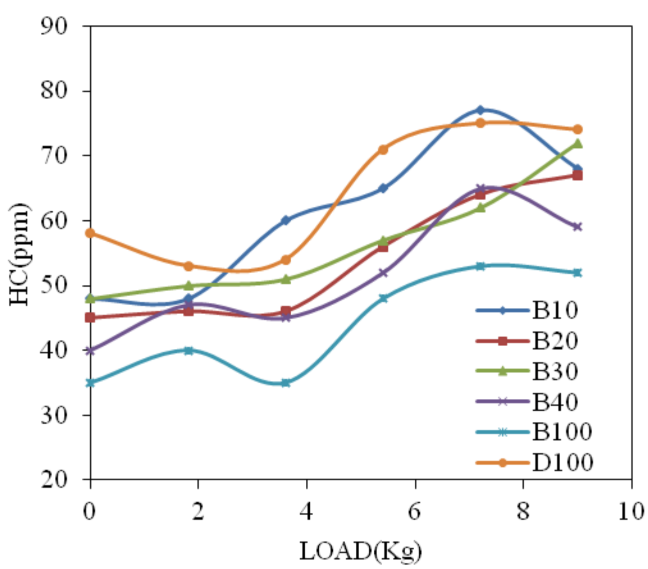


Figure 6: HC Vs Load

XVIII. CONCLUSION

The outcome of the project shows that JOME yields better results than diesel at full load condition. Among the various blends of JOME (B10, B20, B30, B40, B100) B30 shows better performance and emission characteristics than diesel. The B30 blend yields 3.5% more brake thermal efficiency than diesel and the specific fuel consumption decreases by 8.8%. In emission characteristics B30 blend shows considerable reduction in CO, CO_2, HC, Smoke density particularly NO_X emission of B30 decreases by 32% when compared to diesel.

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