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Study of Diesel Particulate Emission from Bio-diesel (Waste Cooking Oil) in DI Engine Adding Fuel Additive

T.Shanmuga Vadivel, C.G.Saravanan, P.Balashanmugam

Abstract**—*****The need for improvement of fuel quality in respect of stabling, ignition and combustion quality and injector celandines has been recognized. New standard to define the optimum fuel quality have evolved and are involving with development of relevant test methods. In transport fuels, multi functional additives are being used a proven cost effective means to improve fuel quality, especially to meet the requirements of new engine designs and stringent emission standards well designed "ash less" additives offer the option to address the quality of heavy fuel for use in engine especially with the constraints in improvement process changes.***

Over the last few years biodiesel has gained importance as an alternative fuel for diesel engines. Manufacturing biodiesel from plant oil is relatively easy and possesses many environment benefits. Besides, what makes biodiesel all the more attractive is that it can be derived from waste cooking oil produced in large quantities in public eateries. The purpose of this project is to analyze the potential of waste cooking oil (WCO) for their suitability as feed stock for biodiesel preparation and to compare the fuel properties of the derived esters of WCO (WCO-biodiesel) with those esters of fresh oil and baseline diesel fuel. The palm oil based WCO – biodiesel and ester of fresh palm oil are transformed into respective biodiesel, by transesterification process. The investigation will be carried out in the single cylinder water cooled DI diesel with the sole fuel and the performance, emission and combustion characteristics analyzed. In case of palm oil the maximum brake thermal efficiency is 28% at maximum load.

Index Terms**— *****Particulate emission, WCO, biodiesel, transesterification***

I. INTRODUCTION

Recently, the biomass resources are being considered as alternative fuels and effective use of these fuels is gaining prominence as a substitute way to solve the problem of global warming and the energy crisis. Among the biomass resources, vegetable oils are observed to be good alternative fuels for use in diesel engines and are also attractive because of renew ability. However, there are fundamental problems of engine performance and exhaust emissions due to high viscosity and low volatility of the pure vegetable oil.

Several works have been reported to improve the performance of engines fuelled by vegetable oils with proper modifications by preheating the oil, use of hot surface ignition, blending with the diesel oil, emulsions with lighter alcohols and by transesterification.

Pure vegetable oil blends can be used in diesel oil directly without any engine modification. But increase in the percentage of vegetable oil in the blend creates problems like cooking and gum formation. That is the reason why the diesel oil cannot be replaced by neat vegetable oil without engine modifications. As many of the problems associated with the use of pure vegetable oil in diesel engines are mainly due to high viscosity, reduction of viscosity of the vegetable oil may help in possible replacement. Hence transesterification is the most effective method, which reduces the viscosity of the vegetable oil and for possible replacement to diesel fuel in internal combustion engines.

1.2. Waste Cooking Oil

Fried food items are very popular in the coastal regions of India. Generally cooking oil used for frying are sunflower oil, palm oil, coconut oil etc. as they are easily available, and especially so of the coconut oil which is abundantly available in south India. It is well known fact that, when oils such as these are heated for an extended time, they undergo oxidation and give rise to oxides. Many of these such as hydroperoxides, epoxides and polymeric substances have shown adverse health/biological effects such as growth retardation, increase in liver and kidney size as well as cellular damage to different organs when fed to laboratory animals [1]. Thus, used cooking oils constitute a waste generated from activities in the food sectors (industries and large catering or community restaurants), which have greatly increased in recent years. Most of the waste (overused /abused) cooking oil are disposed inappropriately, mostly let into the municipal drainage, leading to water pollution. The primary end use of WCO in existence now is to utilize it as a fuel in residential and industrial heating devices. An alternative to prevent inappropriate disposal of WCO is by recycling it. The main use of recycled WCO is in the production of animal feeds and in a much smaller proportion in the manufacture of soaps and biodegradable lubricants. Some health risks can be traced from the use of recycled cooking oils in animal feeding, such as undesirable levels of contaminants, particularly PAHs (Polycyclic aromatic hydrocarbons), PCBs (Polychlorinated biphenyls), dioxins and dioxin related substances [2]. By consumptions of animal origin foodstuffs like milk, meats, poultry and other products, these undesirable contaminants enter the human body and cause serious long term health hazards. As these contaminants are lip soluble, they accumulate in organic lipids and finally in the body, and thereby their concentration increases gradually over the years.

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In other words, the body is exposed not only to a single acute action, but also to a chronic action of bioaccumulation of these hazardous compounds over the years [2]. Hence utilizing the recycled WCO in any way is not advisable from health standpoint.

1.3. Previous work

Kaiser (1991), they reported the characteristic parameters and the evolution of continuous diesel sprays injected against a high density gas have been investigated using high speed photography and phase Doppler anemometry. **Culshaw et al.** (1993), they investigate the potential of biodiesel made from rapeseed oil as a transport fuel in the United Kingdom with respect to its economics, technology and environmental implications. Demand of renewable and clean energy to replace diesel world is big and urgent. However, edible crop oil as raw material is limited and its price is expensive and unstable. We want to look for new suppliers of raw materials, which should be cheap and supply stable to replace edible oil such as rapeseed and euphorbia extract. This study shows, the best for this purpose is Euphorbia tirucalli. It can be feasible and efficient to produce biodiesel in plant as stocks which contain terpenoids. Based on economic situation of oriental (Iran, UAE, Oman), several suggestions have been listed for development and promotion of biodiesel from E. tirucalli. These lands can be used to grow biodiesel feed stocks plant and to produce non-food biodiesel feedstocks for the domestic energy market to diminish imports. Biodiesel is non toxic and environmental friendly as it produces substantially less carbon monoxide and 100% less sulfur dioxide emissions with no unhurt hydrocarbons and consequently it is ideal fuel for heavily polluted cities. Biodiesel reduces serious air pollutants such as particulates and air toxicity. This material can be used directly by a diesel-powered car. Also, biodiesel extends the life of diesel engines.

Jose et al. (1999), they concluded that the study of to evaluate the potential of rape oil methyl ester (RME) to improve the combustion process in a high-speed direct injection (HSDI) Diesel engine equipped with high-pressure common-rail injection system. They reported that, based on the comparison of three different fuels (standard gas-oil, RME and 30% RME/gas-oil mixture), takes into account the main aspects that control Diesel combustion, from the injection rate characteristics to the spray behaviour characterised using an optical pressurised chamber.

Ayhan Demirbas, (2009), Biodiesel production facilities from vegetable oil and animal fats" have investigated biodiesel production from vegetable oils, animal fats and used cooking oil including triglycerides. The authors reviewed that biodiesels have higher cetane number, higher viscosity and higher cloud and pour points compared to diesel fuel. The authors concluded that due to its biodegradable nature and essentially no sulphur and aromatic contents, offers promise to reduce particulate and toxic emissions and is considered to be an alternative transportation fuel for use in environmentally sensitive applications. The authors also reported that adding small amounts of biodiesel to conventional diesel could improve fuel lubricity, extend engine life and increase fuel efficiency.

Rakopoulos et al. (2011),they Conducted an experimental to evaluate the use of sunflower, cottonseed, corn and olive straight vegetable oils (SVO) of Greek origin, in blends with diesel fuel at proportions of 10 vol.% and 20 vol.%, in a fully instrumented, six-cylinder, turbocharged and after-cooled, heavy duty (HD), direct injection (DI), 'Mercedes-Benz', mini-bus engine installed at the authors' laboratory. The series of tests are conducted using each of the above blends, with the engine working at two speeds and three loads. Fuel consumption, exhaust smokiness and exhaust regulated gas emissions such as nitrogen oxides (NO_x), carbon monoxide (CO) and total unburned hydrocarbons (HC) are measured. With reference to the corresponding neat diesel fuel operation, the vegetable oil blends show reduction of emitted smoke with slight increase of NO*x* and effectively unaffected thermal efficiency. Theoretical aspects of diesel engine combustion, combined with the very widely differing physical and chemical properties of the vegetable oils against those for the diesel fuel, aid to the correct interpretation of the observed engine behavior.

II. METHODALOGY

Three kinds of test material were used in the present study, first test material is a petroleum diesel obtained for local petrol bunk. Second test material is a biodiesel derived from WCO through transesterification reaction. Third test material is the waste cooking oil blend with fuel additive. The WCO samples used this study were of palm oil since its most commonly used oil in the restaurants and hostel kitchens. The fatty acid composition of palm oil is dominate by palmitic, oleic, and steraric fatty acids and in addition to it much less proportions of myristie, lauric, linolenic and capric acids[8].The waste cooking oil, (WCO) samples collected were allowed to stand for about 2-3 days so that impurities would settle down. Then WCO was filtered to remove food residues and solid precipitate in the oil. Table 1 shows the properties of diesel fuel, raw WOC and WOC biodiesel. For comparing the diesel fuel shows marginal increase in the values of specific gravity, kinematic viscosity and calorific value.

Table 1 Properties of diesel, biodiesel blend and fuel additives

Properties	Diesel	WOC Raw oil	WOC Biodiesel (B100)
Specific gravity	0.8298	0.9171	0.8823
Kinematic viscosity @ 40°C in CST	2.57	20.97	5.62
Flash point °C	37	298	160
Fire point°C	40	315	170
Gross calorific value in kJ/kg	44738.09	41803.00	41924.43

(Source: Laboratory Evaluation at Etalab –Chennai)

The methodology adopted is outlined below step by step

1. Developing an experimental setup with necessary instrumentation to study the performance, emission and combustion characteristics of the diesel engine fuelled with sole fuel.
2. Baseline readings of the test engine using diesel fuel at varying loads were taken

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3. The performance and emission characteristics engine using base fuel (Diesel) readings were plotted
4. WCO (Palm oil) is converted into biodiesel by transesterification process.
5. Physical and chemical properties of fuel blends were annalysed
6. In second phase experiments were conducted in diesel engine using biodiesel blended with fuel additives.
7. To identify best concentration of fuel blend based on the performance, emission and combustion characteristics.

2.1. *Experimental setup and procedure*

The experimental investigation was carried out in single cylinder water cooled DI diesel engine with 87.5 mm bore, 110 mm stroke, and 17.5 : 1 compression ratio. It is shown in the figure 1. The test engine was coupled with eddy current dynamometer to apply different engine loads. The engine specifications are given in the Table.2.

The engine was started on sole diesel fuel and allowed to run in steady state conditions while the engine cooling water temperature was maintained at 40° C. The fuel injection pressure was maintained at 220 bar throughout the experiment. Then the fuel consumption, exhaust gas temperature and exhaust emission of NOx, CO, HC, smoke density, combustion parameters were measured and recorded for different loads at each operating point and stored in computer for post processing of the results. The experimental work started with sole diesel fuel to determine the engine operating variables and emission levels, constituting the 'baseline'.

Table 2 Specification of the test engine

Type	:	Vertical, Water cooled, Four stroke
Number of cylinder	:	One
Bore	:	87.5 mm
Stroke	:	110 mm
Compression ratio	:	17.5:1
Maximum power	:	5.2 kW
Speed	:	1500 rev/min
Dynamometer	:	Eddy current
Injection timing	:	23° before TDC
Injection pressure	:	220kg/cm^2

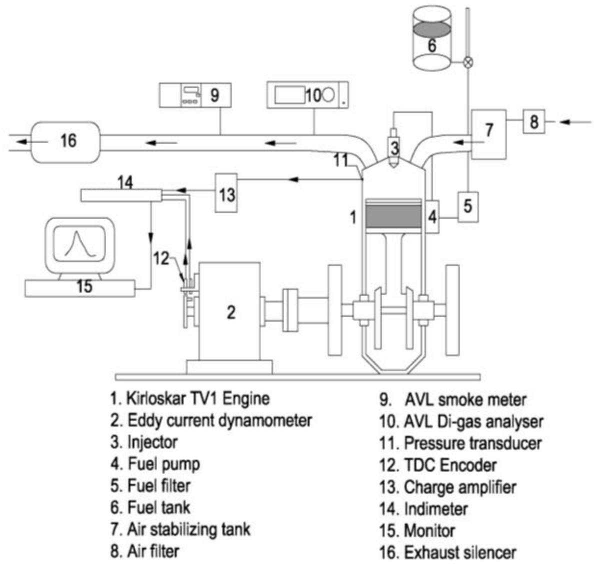

Figure 1 Experimental set-up

III. RESULTS AND DISCUSSIONS

The experimental investigations were conducted on sole fuel at various loads from no load to maximum load at a rated speed of 1500 rpm standard injection timing on Kirlosker TV I engine. From the experimental investigation conducted on Kirloskar TV I engine the following results are obtained. The variation of specific fuel consumption with brake power of the engine shown in figure 2. The SFC is low for B20 blend at all loads uniformly when compared to other blend.

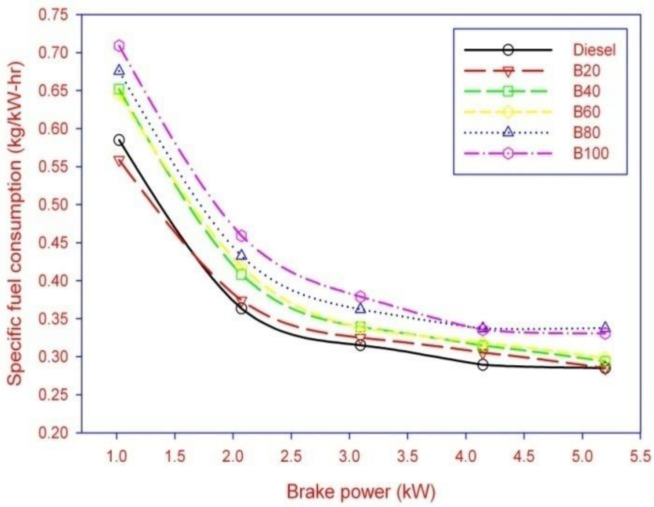

Figure 2 Specific fuel consumption against brake power

The figure 3 indicates the variation of brake thermal efficiency with brake power of the engine. The brake thermal efficiency is increased for B20 blend at the full load condition the maximum value attained by B20 when compared other blends including sole fuel.

This is due to proper atomization of the fuel.The exhaust gas temperature as shown in figure 4 in lower for B20 when compared to sole fuel. The maximum temperature of exhaust gas at maximum power is 340 °C. This is due to low viscosity of the stock.

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The variation of smoke level with brake power of the engine is shown in figure 5.The smoke level is slightly increased for B20 when compared to diesel at all loads when compared to other blends B20 is having lower value. The figure 6 indicates the variation of particulate emission with brake power of the engine. It is seen from the graph the particulate emission is reduced with B20 blend.

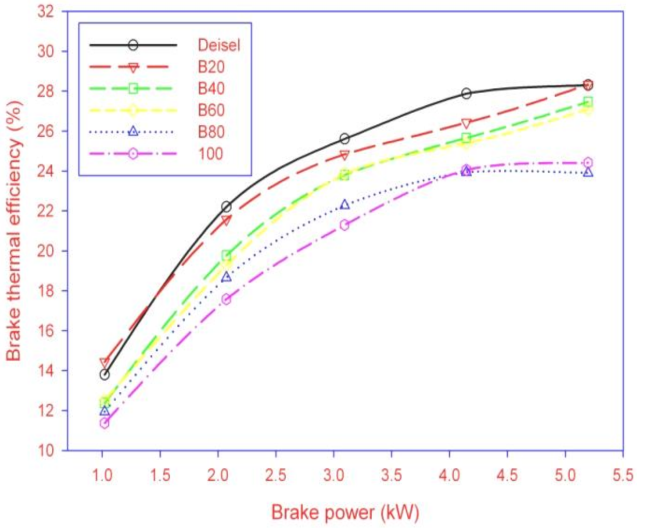

Figure 3 Brake thermal efficiency against brake power

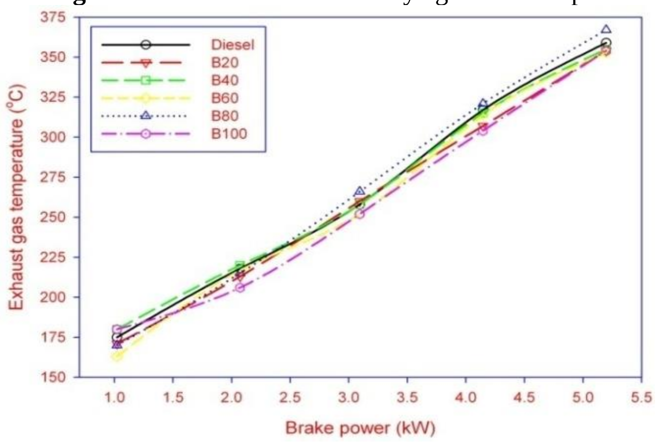

Figure 4 Exhaust gas temperature against brake power

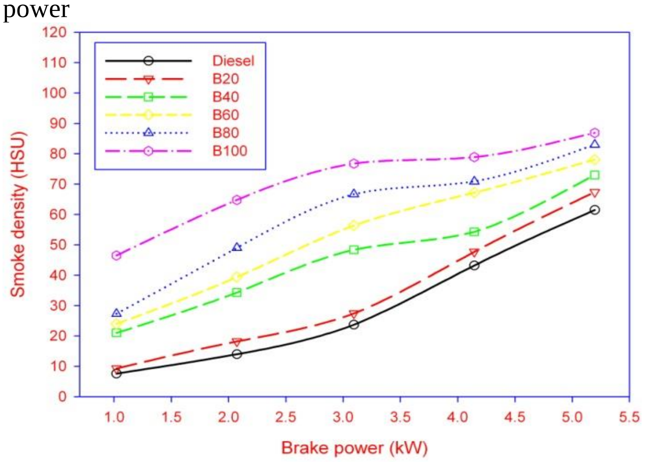

Figure 5 Smoke density against brake power

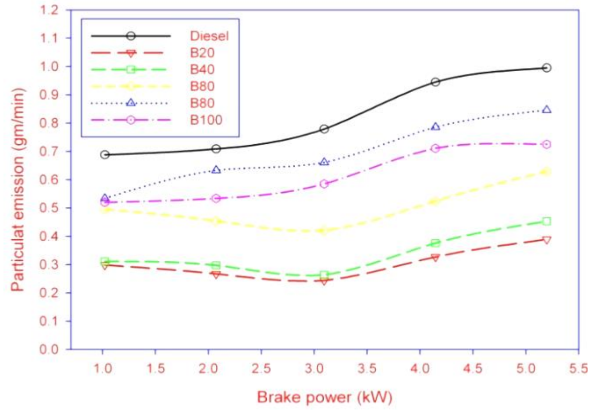

Figure 6 Particulate emission against brake power

The figure 7 shows the variation of NOx emission with brake power of the engine. It is seen that for B20 blend emits lower NOx level compare to standard diesel. The reduction of NOx emission on mainly associated with the reduced premixed burring in rate following the delay period the palm oil.

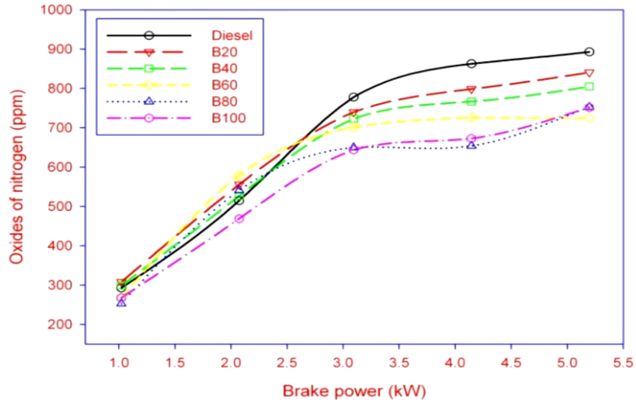

Figure 7 Oxides of nitrogen against brake power

Thus the peak temperatures and NOx level are lower. The figure 8 shows the CO emission with brake power of the engine the CO level for all blends are less than the sole fuel at full load B20 blend having lower value for part load condition when compared to other blends**.**

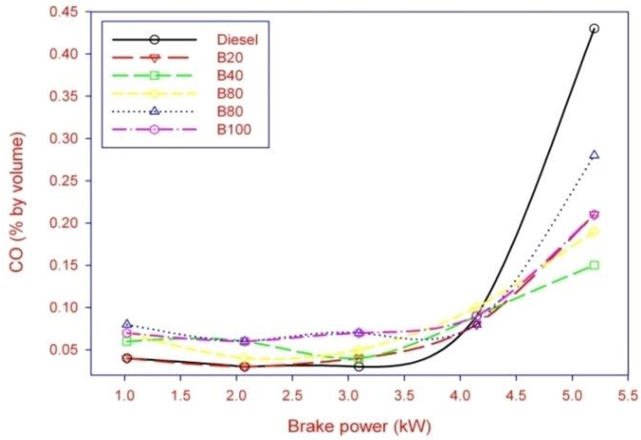

Figure 8 CO against brake power

The variation of HC emission with brake power of the engine figure 9. It is very clear HC emission for B20 is lower at all loads when compared to sole fuel.

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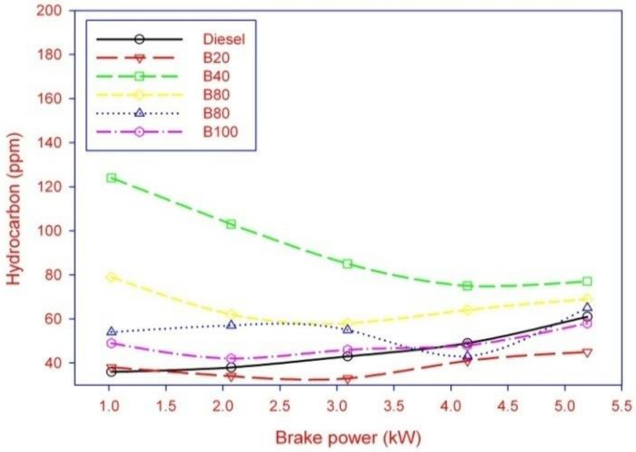

Figure 9 Hydrocarbon against brake power

Based on the above parameter B20 blend is identified as the best blend for further investigation by adding fuel additives. We have tried two fuel additives for the improvement of performance and reduction of emission. Among the two the method one is performed well because of following reasons. The variation of SFC with brake power of the engine shown in figure 10. The blend B20+2ml having less SFC at all loads when compared to B20.

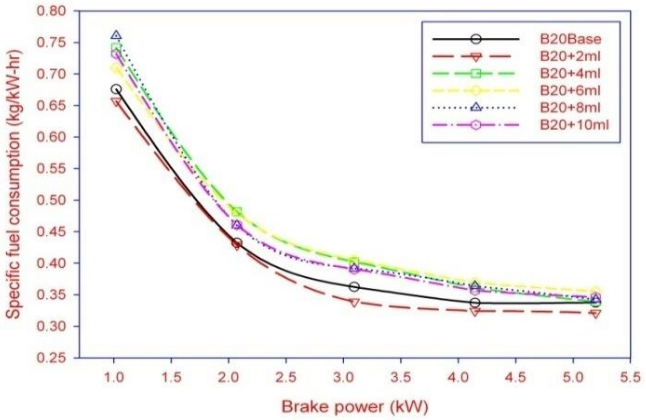

Figure 10 Specific fuel consumption against brake power (Additive)

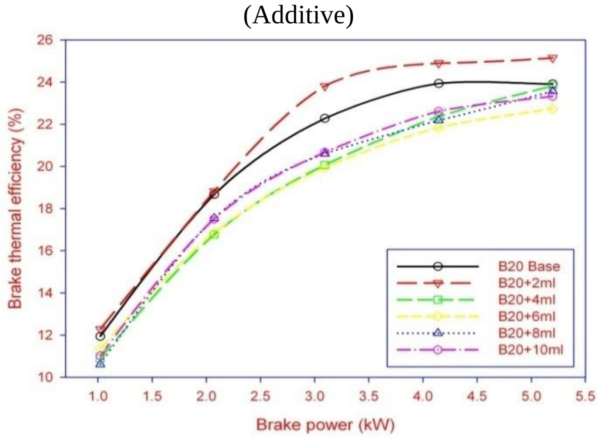

Figure 11 Brake thermal efficiency against brake power (Additive)

The figure 11 has shown the variation brake thermal efficiency with brake power of the engine. The brake thermal efficiency is more for al loads for compared to other blends the B20+2ml fuel when compared to other blends. This is due to the additive having enough oxygen content for complete combustion.

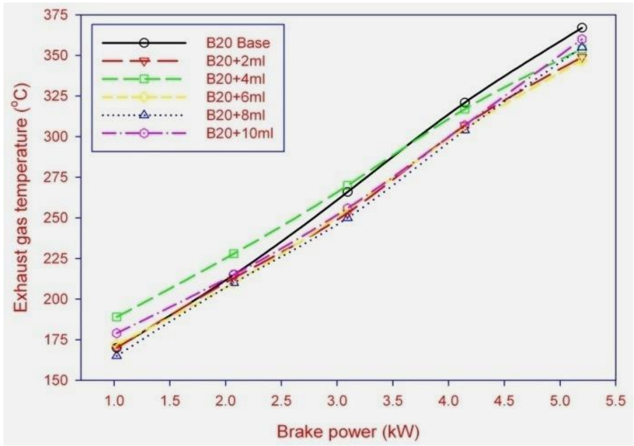

Figure 12 Exhaust gas temperatures against brake power (Additive)

The exhaust gas temperature as shown in figure 12 is lower for blend B20+2ml when compared to B 20.

The variation of smoke emission with brake power of the engine is shown in figure 13. The staring and part load the blend B20+2 ml the smoke emission is low compared to B20 blend.

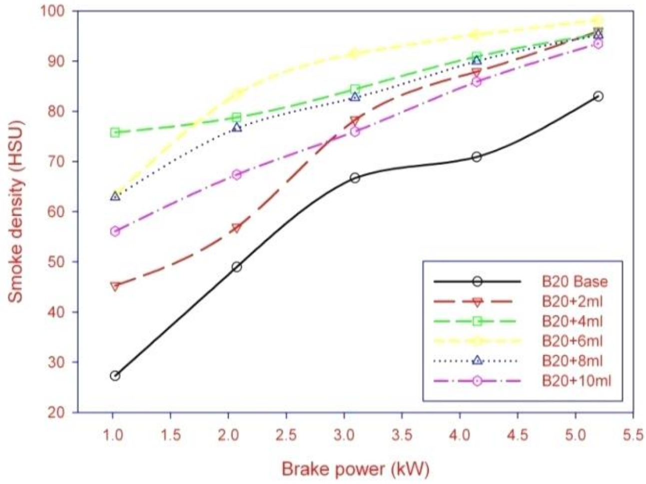

Figure 13 Smoke density against brake power (Additive**)**

The figure 14 indicates the variation of particulate emission with brake power of the engine. The particulates emission is low for B20+2ml when compared to B20.

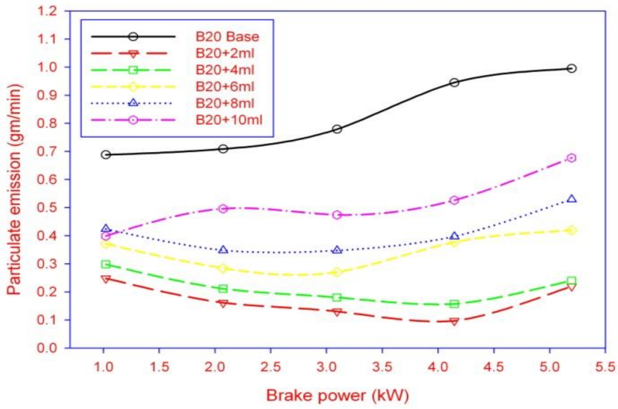

Figure 14 Particulate emission against brake power (Additive)

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IV. CONCLUSION

A single cylinder diesel engine was operated using different percentages of biodiesel (Palm oil) sole fuel and fuel additives. The following conclusions are arrived based on the experimental results.

i. The smoke density is reduced 20 HSU with B20% biodiesel.
ii. The particulate emission lower with B20%. Biodiesel when compared to sole fuel.
iii. The NOx emission slightly decreases with the effect of biodiesel.
iv. In case of Palm oil the maximum brake thermal efficiency is 28% at maximum load. These are no appreciable changes in brake thermal efficiency.
v. The peak pressure and rate of heat release slightly increase for biodiesel. This is due to increase in combustion rate due to combustion of Palm oil by flame propagations.
vi. B20+ 2ml in the case of CO and NOx emission are low at full loads by adding the additive.

By referring the above investigation based on performance and emission, the best blend with additive (B20+2ml) will be identified as the best fuel.

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