PERFORMANCE AND EMISSION EVALUATION OF DIESEL ENGINE WITH WASTE COOKING OIL-DIESEL BLENDS

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Abstract: Due to the awareness of adverse effects of non-renewable Fossil fuels to environment, frequent rise in crude oil's price and its depletion, the need for sustainable and environment friendly alternate source of energy has gained importance in recent years. Biodiesel is proved to be the best replacement for diesel because of its unique properties like significant reduction in greenhouse gas emissions, non-sulphur emissions, non-particulate matter pollutants. The current impending energy and environmental crises have revitalized the need to find more viable renewable resources.

An attempt made in this paper to do the experimental work on Kirloskar make DI Diesel Engine with Computerized Five Gas Analyser of Bio-Diesel with different blends of Waste Cooking Oil (WCO) namely B20, B40, and B60 to analyse the Performance and Emission Characteristics. The results are observed that the Brake Thermal Efficiency of B40 Blend is found to be 0.1% higher than Diesel at full load conditions. At all load conditions, B20 and B40 gives near similar BSFC values when compared to Diesel. The CO emissions of B20 at particular loads are comparatively lower than Diesel fuel. At all load conditions, B20 and B40 gives nearly low smoke values when compared to Diesel. The NOx values of B40 at particular loads are slightly lower than Diesel.

Index Terms - **Biodiesel, Transesterification, BSFC, BTE, Emission, Vegetable Oils.**

I. INTRODUCTION

Compression Ignition (CI) Engine is one type of IC Engine where compressed fuel is injected into Engine cylinder after end of compression stroke and combustion takes place. Only air (and possibly recycled combustion products for NO, control by EGR) is drawn into the cylinder through the intake valve. Fuel is injected directly into the cylinder of the Diesel Engine, beginning toward the end of the compression stroke. As the compression heated air mixes with the fuel spray, the fuel evaporates and ignites. Present compression ignition with Diesel fuel is mostly used combination in worldwide for commercial transportation of goods and people on road, rail and water. But due to depletion of fossil fuels and also gradually increasing price there is a need find the renewable energy fuel.

Bio-Diesel is a non-toxic, biodegradable and renewable alternative fuel that can be used in Diesel Engines with little or no modification. Bio-Diesel will play an increasing role in fulfilling the world's energy requirement. The world has experienced negative effect from the fossil fuel such as global warming and acid rain etc. With the increase in consumption of Bio-Diesel, its impact on environment has raised a discussion around the world. These fuels have properties similar to fossil Diesel oils and have reduced emissions from a cleaner burn due to their higher oxygen content. The current impending energy and environmental crises have revitalized the need to find more viable renewable resources. Bio-Diesel is currently expensive but would be more cost effective if it could be produced from low-cost oils (restaurant waste, frying oils and animal fats).

The production of Bio-Diesel from Waste Cooking Oil offers a triple-facet solution: economic, environmental and waste management. The term "Waste Cooking Oil" (WCO) refers to vegetable oil which has been used in food production and which is no longer viable for its intended use. India's Bio-Diesel processing capacity is estimated at 600,000 tons per year Vegetable oil is used commonly in cooking and is needed particularly to fry food. After using the same oil over and over again, the remaining oil becomes spoiled with old food remains and can no longer be used for cooking the food. If this waste used cooking oil is disposed into a surrounding which can be a big problem Rickeard et al [1]. Instead of disposing we can use this Waste Cooking Oil in Diesel Engines as a fuel if it is cleaned and properly converted to combustible Diesel oil Demirbas et al [2]. If a large amount of Waste Cooking Oil is used in the Diesel Engine, it can reduce the large amount of using petroleum fuel Nwafor et al [3]. The used cooking oil is fundamentally a waste product and for that reason it is cheaper than unused (virgin) vegetable oil. The some of the vegetable oil or Cooking oils are used for frying are sunflower oil, palm oil, coconut oil etc. these are easily available India Rakopoulos et al [4]. The Waste Cooking Oil samples used for the purpose are of usually palm oil because it is usually used oil in the restaurants and hostel kitchens. The Waste Cooking Oil is generated from the Fraying of food with high temperatures are generated due to this changes in its chemical and physical composition, as well as in its organic properties which affect both the food and oil quality. Used cooking oil is normally black, a strong odorDorado et al [5].

Environmental problems for disposing Waste Cooking Oil Pugazhvadivu et al [6].

1) When this Waste Cooking Oil is dumped into river or any water source which can react with water and increases organic pollution in the water, and which alters the ecosystem.

2) This Waste Cooking Oil is causes problem in the pipes drain obstructing them and creating odors and increasing the cost of wastewater treatment.

3) The hazardous odors create a negative impact on health, mainly by hydrogen sulfide (H_2S), which can cause irritation of the respiratory tract, skin problem, headaches and eye irritation

Instead of disposing we can use this Waste Cooking Oil in Diesel Engines as a fuel if it is cleaned and properly converted to combustible Diesel oil with some mechanism.

II. LITERATURE SURVEY

Karikalan.L and Chandrasekharan. M [7], they reported that to optimize CI Engine with WCO (Waste Cooking Oil) Bio-Diesel as fuel through experimental investigation through brake power, fuel economy and smoke emissions. Performance and discharge features were studied using the different WCOB Blends and standard Diesel. They observed that the maximum BTE for WCOB 40 at maximum load is 34.48%, which is 2.9% more than Diesel fuel. High BSFC noticed for higher percentage of WCO Blends due to lower heating value, density and viscosity of the fuel. They concluded WCOB could replace the fossil fuel in the case of shortages in the near future.

Penugonda Suresh Babu, Venkata Ramesh Mamilla [8], have discussed the significance of Bio-Diesel as IC Engine Fuels. They found the production and characterization of vegetable oil as well as the experimental work carried out in various countries in this field. They concluded Bio-Diesel fuel has better properties than that of petro Diesel fuel such as renewable, biodegradable, non-toxic, and essentially free of sulphur and aromatics.

Jagdeesh S Bali and ChannamallikarjunSankanna[9], They experimented Performance and emission characteristics of Waste Cooking Oil as Bio-Diesel in CI Engine. They said Bio-Diesel is produced from Waste Cooking Oil by a method of Transesterification, after this, the Bio-Diesel is Blended with Diesel in proportion of 20%, 40%, 60%, and 80%, on quantity basis along with pure Bio-Diesel, are analyzed and compare with Diesel.. They results show that the lower Blends of Bio-Diesel there is a raise in brake thermal efficiency, mechanical efficiency; volumetric efficiency and BSFC are well comparable with Diesel. And there is reduce of CO, CO2, and HC as compare with Diesel.

PuneetVerma, M.P. Sharma [10], are reported on impact of Bio-Diesel on performance and emission characteristics of Diesel Engine. Performance results reveal that most of the Bio-Diesel, give higher brake thermal efficiency and lower brake-specific fuel consumption. Emission results showed that in most cases, NOx is increased, and HC, CO, and PM emissions are decreased. B20 Blend of Bio-Diesel with Diesel was found the best suitable Blend for Engine. Bio-Diesel is an appropriate inherent source for alternative fuel, with environmental benefits .

From the literature review it was found that there is a need to search for suitable alternative fuels to be used in diesel engines that are environment friendly in this attempt made in this paper to do the experimental work on DI Diesel engine with computerized fire gas analysis of different blends of waste cooking oil namely B20, B40, and B60 to analyse the performance, Heat Balance and emission characteristics.

III. METHODOLOGY

Waste Cooking Oil (palm oil and soybean oil) was collected from local restaurants, food industrial or domestics, which not only harms human's health but also causes environmental problems. This oil is collected with low cost and is used to treat the oil for production of Bio-Diesel.

The Waste Cooking Oil (WCO) has properties different from the properties of refined / crude fresh cooking oils. During frying process there is a presence of heat and water which accelerates the hydrolysis of triglycerides and increases content of free fatty acids in oil. The Oxidation stability of the oil is disturbed because of the contact of hot oil with food, and peroxide value of oil increases Huzayyin et al [11]. Viscosity of oil increases significantly, because of the formation of dimeric and polymeric acids and glycerides. Also density increases, due to its high viscosity, this oil get chemically modified into esters whose properties resemble those of fossil fuels. These chemically modified processes are called TransesterificationJothi et al [12]. This process requires heat and a strong catalyst (alkalis, acids, or enzymes) to achieve complete conversion of the vegetable oil into the separated esters and glycerin Agarwal et al [13]. During the Transesterification reaction, glycerin is obtained as a by-product. Before this, first the the oil is collected and filtered .

TRANSESTERIFICATION PROCESS

The whole process can be done by four steps:
1) Add the catalyst to neutralize the free fatty acids
2) Preparation of methoxide solution
3) Formation of Bio-Diesel and glycerol
4) Clean the obtained Bio-Diesel

STEP-1:

1. In this step, find out the amount of catalyst required to neutralize the free fatty acids. This can be done by titration process.
2. The following are required for doing the titration process:1 ml of oil, 1 litre of distilled water, 10 ml isopropyl alcohol, 1 gm of catalyst, 2 drops of color indicator (phenapthelene).
3. First prepare the stock solution by adding 1gm of KOH in a perfect measured one liter of distilled water.
4. Then this value becomes 1gm/1000ml or 0.001 alkali. Fill the stock solution in 25ml burette.
5. Then take 1 ml of oil using pipette and dilute this in 10 ml of iso propyl alcohol. Add two drops of phenapthelene colour indicator and keep it closed.
6. Then start the titration process.
7. Then the colour of the oil changes into pink colour.
8. Then watch the burette how much ml is consumed.
9. If suppose it is consumed by 5 ml, then there is a 5% of free fatty acids and we require 20 gm of catalyst to neutralize fatty acids.
10. In this our oil has 1% of FFA. Thus it requires 5gm of KOH with 200 ml of methanol.

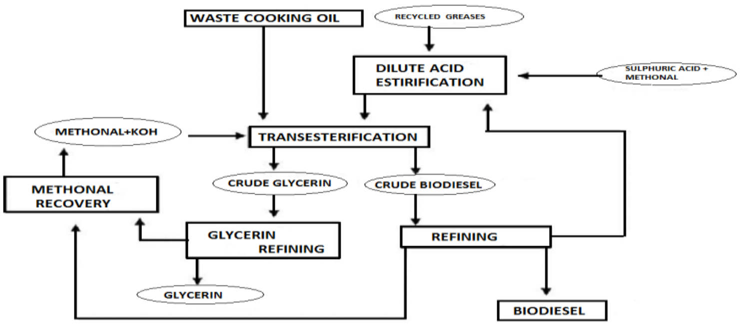

Figure 1.Transesterification Process of Bio-Diesel

STEP-2:

1. Prepare the methoxide solution by mixing of methanol with potassium hydroxide.
2. Mix the 5gm of KOH with 200 ml of methanol and keep it safely.

STEP-3:

1. Take the one liter of oil, heat the oil up to 65° C and react with methoxide solution fastly by using a glass rod.
2. Then pour the oil in a separate vessel and allow sufficient time for separation of Bio-Diesel and glycerol.
3. After some time, we find two layers which are maximum at top and minimum at bottom.
4. The top layer is called Bio-Diesel or methyl ester and the bottom layer is a byproduct called glycerol.

Figure 2.Separation of Bio-Diesel and Glycerin

STEP-4:

1. Clean the oil with the distilled water for two or three times.
2. First clean the oil with distilled water to remove the untreated methoxide and then heat the oil to remove any water traces.
3. Finally we obtain a clear Bio-Diesel.

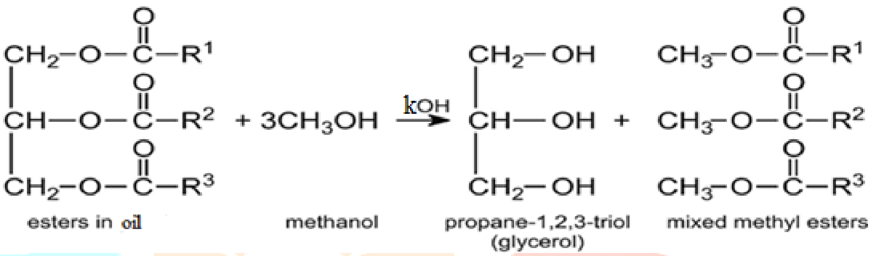

Figure. 3 Schematic Representation of Transesterification Reaction

The following are the proportions for Tansesterification process of Waste Cooking Oil with no free fatty acids.

Table 1.Chemical proportion of WCO

S.NO	CHEMICAL	PROPORTION
1	Waste Cooking Oil	1000ml
2	Catalyst-KOH	5 gm
3	Methanol	200 ml

Table 2. Properties of standard Diesel and Bio-Diesel

S.NO	Property	WCO	Bio-Diesel	Diesel
1	Kinematic Viscosity At 40 ^{O}C (mm^2/s)	39.7	6.58	2.4
2	Calorific Value(MJ/kg)	34.23	37.64	42.5
3	Cloud Point (^{O}C)	0	2	-5
4	Pour Point (^{O}C)	-40	-8	-20
5	Flash Point (^{O}C)	278	180	75
6	Density (kg/m^3)	910	890	840

IV. EXPERIMENTAL SET-UP AND PROCEDURE

The Engine chosen to carry out experimentation is a single cylinder, four stroke, vertical, water cooled, direct injection type CI Engine. This Engine can withstand higher pressures encountered and also is used extensively in industrial sectors .

Table 3.Engine Specifications.

manufacturer	Kirloskar Oil Engine Ltd.
Type	Single cylinder Diesel Engine
Model	TV1
Type of cooling	Water cooling
Arrangement of cylinder	Vertical
Bore	87.5 mm

Length	110 mm
Compression ratio	17.5:1
Speed	1500 rpm
Rated power	7HP
Lubricant	SAE 30/SAE 40

BLENDS PREPARATION:

Generally blends are prepared by volume basis, for example B10 blend means (10% Bio-Diesel+90% Diesel), associated with using Bio-Diesel scale with the percentage of Bio-Diesel contained in the fuel blend.

B20 i.e., blend 20 has been prepared by adding 200 ml of waste cooking oil and 800 ml of Diesel vigorously for obtaining homogeneous blend. Similarly B40 (40%waste cooking oil+60% Diesel), B60 (60%waste cooking oil+40% Diesel) has been prepared for testing.

EXPERIMENTAL PROCEDURE

- The flow of air, the level of lubricating oil and the fuel level are checked before starting the Engine.
- The Engine is cranked by keeping the decompression lever and the fuel cut off lever of the fuel pump in the ON position.
- When the Engine starts, the decompression lever is disengaged and the speed of the Engine is increased to 1500 rpm and maintained.
- The Engine is allowed to run for 15 minutes to reach the steady state conditions.
- The time taken for 10 cc of fuel consumption for every load charge is recorded. Also at each load B.P, I.P, IMEP, BMEP, Mechanical, Volumetric, Brake and Indicated thermal efficiencies are calculated.
- Under each load, by the exhaust gas analyzer, CO, CO_2, HC, O_2, NO_X, and by smoke meter, intensity of smoke and exhaust gas temperature are measured and recorded.
- The above two steps are repeated for different loads from no load to full loads.

The above procedure is repeated for Blends B20, B40, B60 on the engine. While starting the engine, the fuel tank is filled in required fuel proportions up to its capacity. The engine allowed to run for 15 minutes for steady state conditions and procedure is repeated.

V. RESULTS AND DISCUSSIONS

Results of the experiments in the form of brake power, brake thermal efficiency, specific fuel consumption for different load conditions for various blends of jatropha methyl esters are compared with the petroleum diesel in the form of graphs.

Performance Characteristics:

Brake Thermal Efficiency(kg/h): This figure shows The variation of brake thermal efficiency with respect to load for Waste Cooking Oil Blends and Diesel are shown in Fig.3. It can be seen from graph that the B40 fuel Blend incidentally gives equal efficiency with Diesel at maximum load. The Diesel fuel produced the lowest thermal efficiency at all loads. The higher thermal efficiency of the Bio-Diesel Blends may be due to their low heat input requirement for a given Engine load. The brake thermal efficiency of B40 Blend are increased around 0.1% at full load condition when compared to Diesel.

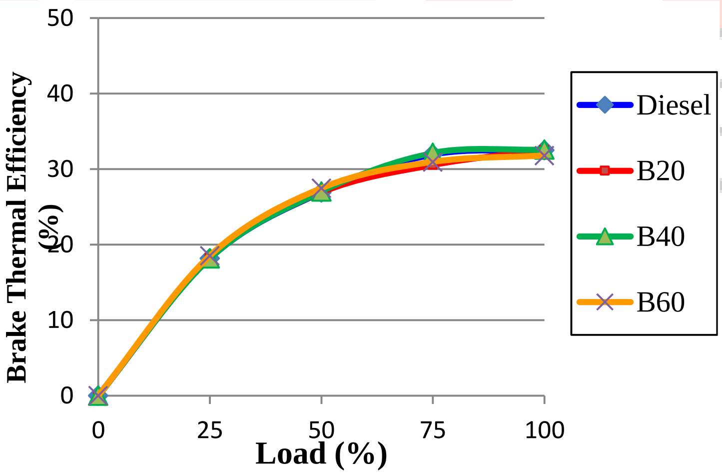

Figure 3. Load V/S Brake Thermal Efficiency

Specific Fuel Consumption (kg/hr): This figure the variations in the brake specific fuel consumption (BSFC) with load is presented in the Fig.4. Brake-specific fuel consumption (BSFC) is the ratio between mass flow rate of the tested fuel and brake power. In general, the BSFC is found to increase with raising the Bio-Diesel quantity with the Blends under all ranges of Engine load. The BSFC of a Diesel Engine depends on the relationship among fuel injection system, fuel specific gravity, viscosity and heating value. When increasing Bio-Diesel proportion in Blends, calorific value decreases and leads to increase the flow rate of the Blends for maintaining the same operating conditions. At all load conditions, B20 and B40 gives near similar BSFC values when compared to Diesel.

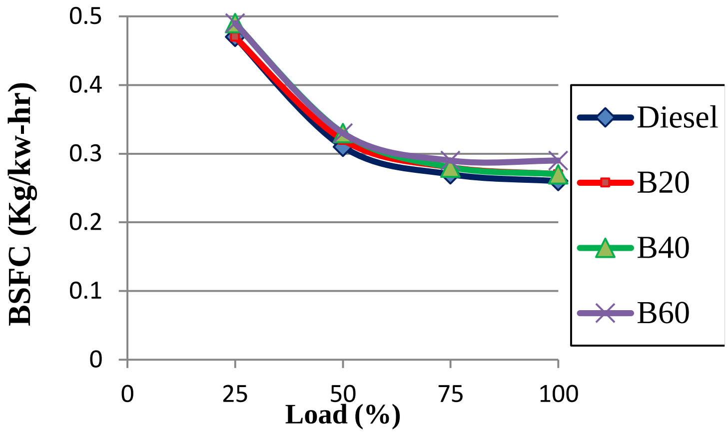

Figure 4. Load V/S BSFC

Volumetric Efficiency(%): The variation of volumetric efficiency with respect to load for Waste Cooking Oil Blends and Diesel are shown in Fig.5 Volumetric efficiency defined as the ratio of volume flow rate of air into the intake system to the displacement volume. It indicates the breathing ability of the Engine. It is noted that utilization of air is going to determine the power output of the Engine and hence an Engine must be able to take as much air as possible. From the graph it is clear that there is no significant variation in the volumetric efficiencies of Bio-Diesel Blends with the Diesel fuel.

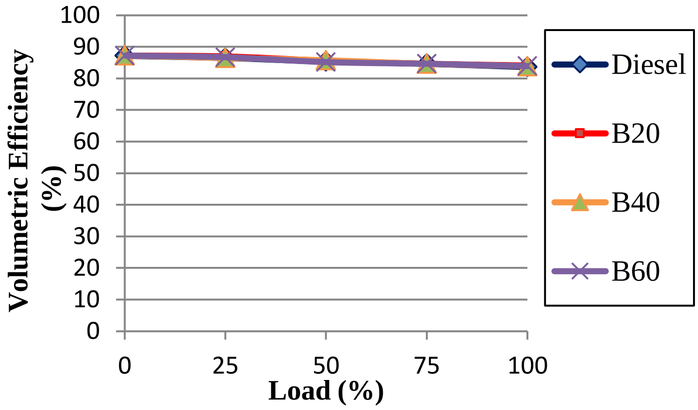

Figure 5. Load V/S Volumetric Efficiency

Indicated Mean Effective Pressure(bar):IMEP with respect to loads for all the test fuels can be observed from the Fig.6 At full load, indicated mean effective pressure for the Diesel is 7.32 bar, whereas for biofuel Blends B20, B40, B60 are 7.37 bar, 7.36 bar and 7.36 bar respectively. Linear variations of indicated mean effective pressure can be observed and there is no significant deviation in indicated mean effective pressure for the Waste Cooking Oil fuel Blends from that of Diesel.

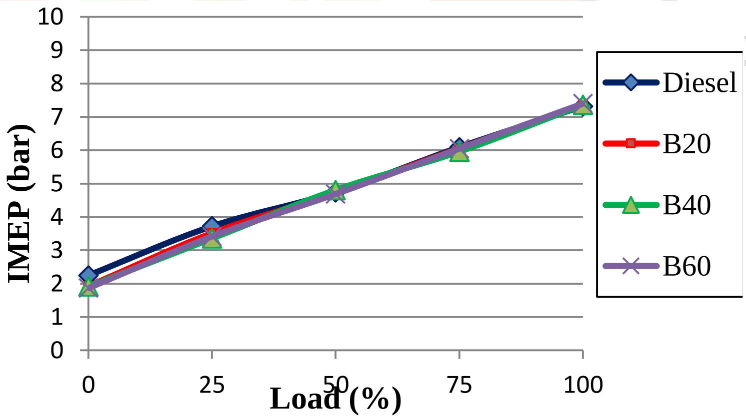

Figure 6. Load V/S IMEP

Indicated Thermal Efficiency (%): The variation of indicated thermal efficiency with respect to load for Waste Cooking Oil Blends and Diesel are shown in below figure.Indicated thermal efficiency gives an idea of the output generated by the Engines with respect to heat supplied in the form of fuel. The indicated thermal efficiencies of Blends and Diesel at full load conditions are nearly equal and is shown in Fig 7.

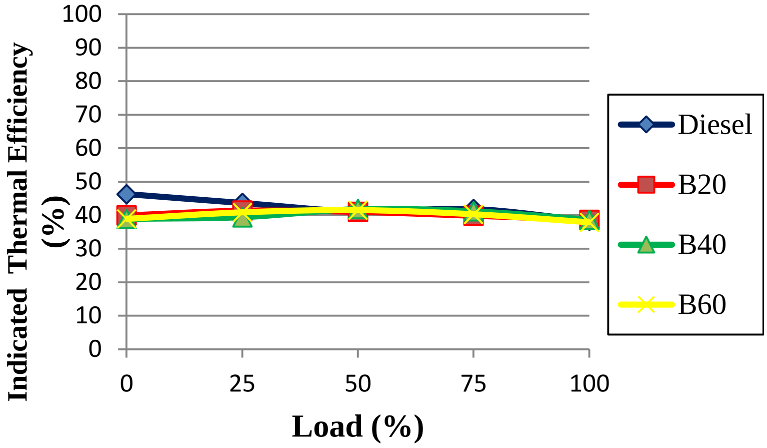

Figure 7. Load V/S Indicated Thermal Efficiency

Emission Characteristics:

Carbon Monoxide (%): The Fig.8 shows the variation of carbon monoxide (CO) emission of Waste cooking bio Diesel with Diesel at various load conditions. It is well known that better fuel combustion usually resulted in lower CO emissions. The carbon monoxide, which arises mainly due to incomplete combustion, is a measure of combustion efficiency. It has been observed from graph that the CO emissions are increased with increase in Engine load. But the CO emissions of B20 at particular loads are evidently lower than Diesel fuel.

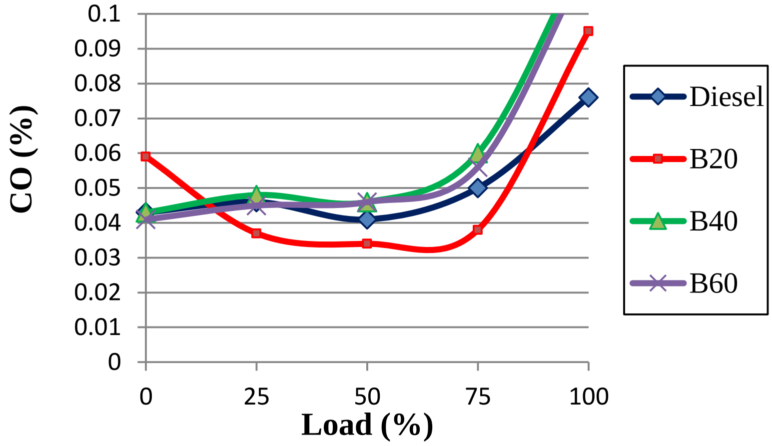

Figure 8. Load V/S CO

Unburned Hydrocarbons (ppm): The variation of un-burnt hydrocarbons with respect to load for tested fuels is depicted in Fig.9 it is an important parameter for determining the emission behavior of the Engine. From the results, it can be noticed that increasing Bio-Diesel in the Blends also increases significantly UHC emissions comparatively to Diesel.

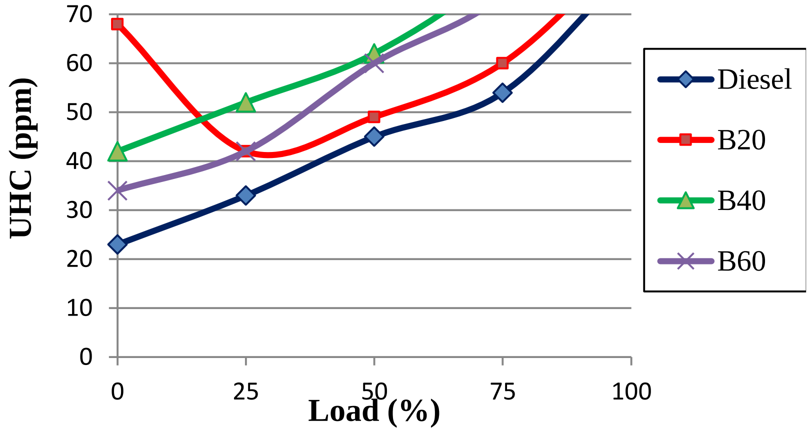

Figure 9. Load V/S UHC

Nitrogen Oxides (ppm): Fig.10.Shows the variation of nitrogen oxides (NOx) emission with different loads for the different Blends. There are mainly three factors namely oxygen concentration, combustion temperature, and time which affects the NOxemissions. As the load increases, the concentration of NOx is also increasing. The graph clearly shows the Diesel NOx is slightly lower than the Bio-Diesel. At particular loads NOx emissions of Bio-Diesel Blend B40 is comparatively lower than Diesel fuel. Higher values of combustion temperature and presence of oxygen with Bio-Diesel result in an increase in NOx generation

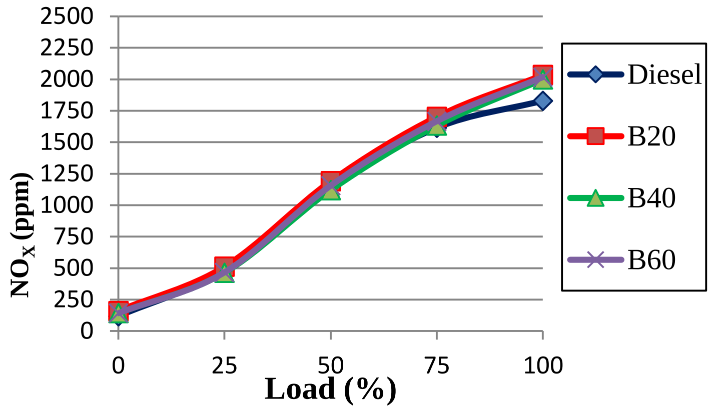

Figure 10 . Load V/S NOx

Smoke Value (%): The variation of smoke emission with different loads for Diesel fuel and Blends is shown in Fig.11. Generally, smoke is formed due to incomplete combustion. Improvement of combustion will cause decrease in smoke density. For Bio-Diesel mixtures, smoke value is less compared to Diesel fuel for particular Blends. Due to heterogeneous nature of Diesel combustion, fuel-air ratios, which affect smoke formation, tend to vary within the cylinder of a Diesel Engine. Smoke formation occurs primarily in the fuel-lean zone of the cylinder, at high temperatures and pressures. From the graph, it is clear that at all load conditions, B20 and B40 gives lower smoke values when compared to Diesel.

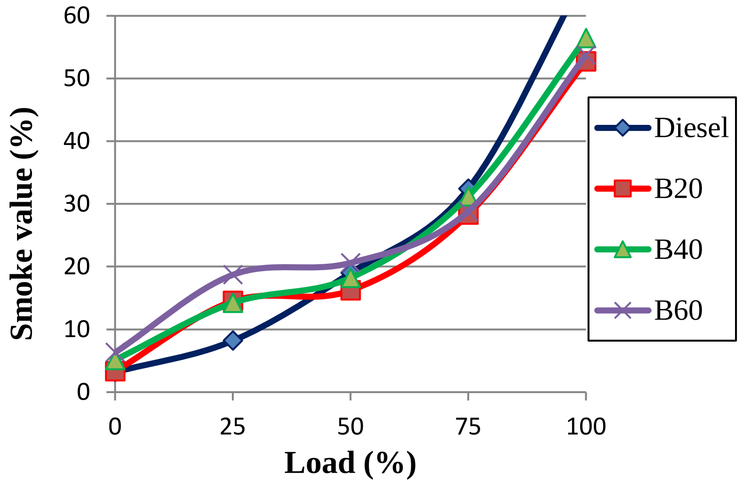

Figure 11 . Load V/S Smoke

VI.CONCLUSION

PERFORMANCE CHARACTERISTICS:

1. The brake thermal efficiency of B40 Blend are increased around 0.1% at full load condition when compared to Diesel.
2. At all load conditions, B20 and B40 gives near similar BSFC values when compared to Diesel.
3. The indicated thermal efficiencies of all Blends and Diesel at all full conditions are almost give equal values.
4. There is no significant variation in indicated mean effective pressure for the Waste cooking fuel Blends from that of Diesel.

EMISSION CHARACTERISTICS:

1. The CO emissions of B20 at particular loads are comparatively lower than Diesel fuel.
2. At full load condition for all the Blends, there is increasing Bio-Diesel in the Blends also increases significantly UHC emissions comparatively to Diesel.
3. At all load conditions, B20 and B40 gives nearly low smoke values when compared to Diesel.
4. The NOx values of B40 at particular loads are slightly lower than Diesel.
5. The maximum EGT was obtained at full load conditions and was 346.5°C, 347.24°C, 347.87°C and 336.31°C with Diesel, B20, B40 and B60 respectively.

From the above analysis the main conclusion is that the waste cooking oil is a renewable alternate source and its Diesel Blends B20 and B40 are suitable substitute for Diesel as they give better performance and produces less emissions than Diesel.

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