© 2015 IJSRSET | Volume 1 | Issue 4 | Print ISSN : 2395-1990 | Online ISSN : 2394-4099
Themed Section: Engineering and Technology

An Experimental Study on the Performance and Emission Characteristics of Single Cylinder Compressed Ignition Engine Using Mahua Biodiesel with Additives

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ABSTRACT

In the present research, an experiment is designed and conducted to investigate the effect of Mahua biodiesel i.e. Mahua biodiesel originating from non edible Mahua diesel fuel on the combustion performance and emission characteristics of a direct injection C.I. engine under varying engine loads (0–100%) and constant engine speed (1500 rpm). Three types of blend are tested, which consist of different blends like (B20,B40 and B100) with constant 1% of additives and labeled as B20X1,B20X2 and B20X3,B40X1,X2,X3 respectively. It is also noticed that brake thermal efficiency increases with the percentage of additive in all the test fuels. The brake specific fuel consumption decreases with increase in additive percentage. Exhaust gas temperature increases almost linearly with load for all test fuels and decreases with increase in additive percentage. It is also seen from the results that both CO and HC emissions tend to decrease with increase in additive percentage in biodiesel. Fuel additive improves engine performance and lowers pollutant emission of Mahua bio-diesel blends. Overall, it is observed that the Mahua biodiesel from low-grade conventional diesel is an appropriate alternative fuel method that can bring about greener exhaust emissions and fuel savings without deteriorating engine performance or any major engine modification.

Keywords: Conventional Diesel Fuel, Combustion Performance, Exhaust Gas Emissions, Additives, Compressed Ignition Engine (C.I. Engine)

I. INTRODUCTION

Currently Energy consumption is rising everywhere in the world. At the same time, natural resources are decreasing and pollutant emissions are becoming a real threat for the ecosystem equilibrium. The depletion of crude oil would cause a major part on the transportation sector.[1] . In the transportation sector, private vehicles, buses, trucks, and ships also consume significant amounts of diesel and petrol.[11] In the Europe, rapeseed (canola) oil and palm oil soybean oil is the most commonly Biodiesel feedstock, whereas soybean oil is the source for Biodiesel, in United States, and in tropical countries respectively.[2] The situation is very grave in developing countries like India spending 30% of her total foreign exchange on oil imports which import 70% of the required fuel.[4] Generally, recommended biodiesel for use as a substitute for ordinary diesel is produced from vegetable oil or animal fats by transesterification process.[5] some of them show very strong annual growth: (1.3 Mtoe) China, (1.1 Mtoe) Argentina, (0.83 Mtoe) Canada, (0.69 Mtoe) Thailand, (0.42 Mtoe) Colombia and (0.35 Mtoe) India. The rest of the other world corresponds to approximately 1.2 Mtoe [6] The usual range of consumption is 68% to 96% of methane and 3% to 30% of ethane in natural gas.[7] Natural gas depending on the origin gas fields and consists of 90% methane (CH_4), a other gases mixture such as ethane (C_2H_6), propane (C_3H_8), carbon dioxide (CO_2) and hydrogen (H_2).[8] There are an above number of arguments in favour of the use of natural gas as a vehicle fuel.[9] Methanol contains oxygen in structure which reduces calorific value to 18500kJ/kg.[10] In fact the biodiesel energy density is quite close to regular diesel. Biodiesel can be production by soybean and methanol via transesterification process in the presence of acid catalysts.[11] The viscosity of bio-diesel is higher (1.9 to 6.0 cSt) and is reported to result into gum formation on injector, cylinder liner etc if used in 100% pure form. [12] There are four ways to use neat vegetable oils in diesel engine. Out of the four methods, transesterification is the most popular and best way to use neat vegetable oils. [13] Mahua is perhaps the second most widely known tree in India after mango. Besides oil, flower and fruit give good economic returns. Almost all parts of Mahua tree are saleable. [16]Biodiesel can substitute fossil fuel as a "clean energy source". It can protect the environment by reducing CO2, SO2, CO, HC.[18] In India, there are several non-edible oils from different species such as Jatrofa (Jatrofa curcas), Neem (Azadirachtaindica), Mahua (Madhuca indica),Pungam (Pongamia pinnata), and Simarouba (Simarouba indica), which could be used for bio-diesel.[19]

II. METHODS AND MATERIAL

A. Transesterification

There are four ways to use neat vegetable oils in diesel engine. Out of the four methods, transesterification is the most popular and best way to use neat vegetable oils. [13] Here the process is a reaction of triglyceride with alcohol to form mono alkyl ester commonly known as biodiesel and glycerol as by product.[14] The process is simple, waste less, pollution free and effective compared with other fabulous processes. [15] the fatty acid triglycerides themselves are esters of fatty acids and the chemical splitting up of the heavy molecules, giving rise to simpler esters, is known as Transesterification.[20]

B. Materials

Mahua is perhaps the second most widely known tree in India after mango. Besides oil, flower and fruit give good economic returns. Almost all parts of Mahua tree are saleable.[16] IFTEX Clean System D is a premium multifunctional diesel fuel additive, with outstanding clean-up and keep-clean property. Most convenient to use by adding to the fuel tank in the recommended proportion. Bardahl is a brand name of a line of petroleum lubrication products used in automobiles and other internal combustion engines. Cleans fuel system of diesel engines Improves operating efficiency. A multi-functional diesel fuel additive, it improves diesel fuel ignition and combustion properties. ADON-D is a multifunctional diesel additive from TOTAL, France. It is being marketed by IOC through its Retail Outlets all over India under a collaboration agreement with TOTAL, France. DON D is a performance Enhancer Additive.

PREPARATION OF TEST FUEL BLENDS

Various test fuel blends were prepared by blending Mahua biodiesel with additive in various volume proportions. In the present work B20, B40, B100 and the diesel fuel are used as the test fuels where B20 represent 80% diesel and 20% biodiesel+additive. Similarly B40 represent 60%diesel with 40% biodiesel+additive. B100 represents pure biodiesel without additive

C. Experimentation

Single cylinder, four stroke, water cooled, direct injection CI engine is used for experimental purpose. The Rope brake dynamometer is fixed to the engine mounted on an MS. Channel frame. Panel board is used to fixed burette with coke, digital temperature indicator with selector, loading device, digital indicator and 'U' tube manometer. The specifications of the CI Engine are listed in Table 1 and the experimental set up is shown in Figure.

TABLE: 1

Engine Specification

Make	Kirloskar
General details	single cylinder four stroke diesel engine
Number of cylinders	One
Rated speed	1500 RPM
BHP	5 KW
SFC	3.7
Bore	110mm
Orifice Dia	20 mm

D. Experimental Procedure

Experiments are carried out at constant engine speed of 1500 RPM. Load is varied by changing excitation of Rope brake dynamometer. Starting from no load observations are taken for each fuel at six different loads.

Observations are taken at time when exhaust gas temperature remains steady. Various performance and emission parameters are measured at each load and test fuel are mentioned below. Using measured data, brake power, brake thermal efficiency, brake specific energy consumption are calculated for each test fuel including diesel.

Figure 1: Engines with Control Panel

TABLE 2

Properties of Test Fuels

Properties	**Diesel**	**Mahua Bio-diesel**	**B20**	**B40**
Calorific Value (Kj/kg)	42205	37056	41360	40429
Kinematic Viscosity (cSt)	2.7	5.8	3.4	3.6
Density (g/sec)	0.818	0.824	0.819	0.821
Flash Point (^{0}C)	70	130	-	-
Ash Content (% w/w)	0.002	0.012	0.0034	0.0054
Cloud Point (^{0}C)	-10	-11	-9.1	-9.3

Time taken for 10ml fuel consumption.
Exhaust Gas Temperature.
Load on Dynamometer
Carbon Monoxide
Hydrocarbon.

Engine performance with diesel is measured first followed by B20, B40 and B100. Again engine performance is measured with B20X1, B20X2, B20X3, B40X1, B40X2 and B40X3 with additive in manner mentioned above. Data measured and calculated thus used for comparison with mineral diesel. Sample calculation to calculate brake power, brake thermal efficiency and brake specific energy consumption.

Table 2 compares the flash point temperature, carbon residue and ash content for diesel, Mahua bio-diesel and various blends. Flash point of diesel is 70°C, which is lower compared to 130°C of the Mahua bio-diesel. Hence, it is comparatively safer to transport and store Mahua bio-diesel than diesel. Ash content value for diesel is 0.002% w/w and, which is very much lower compared to Mahua bio-diesel.

III. RESULTS AND DISCUSSIONS

(A) Brake Thermal Efficiency

Figures 4.9 and 4.10 shows variations in brake thermal efficiency with brake power, Mahua bio-diesel blending with different additive.

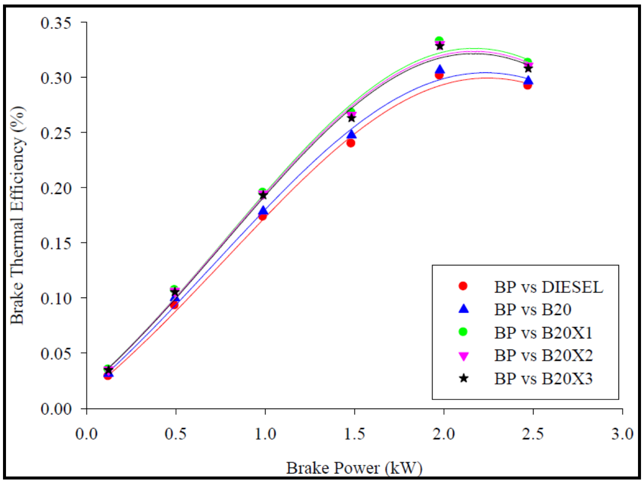

Figure 2: Variations in Brake Thermal Efficiency with Brake Power and different Additives using B20 Fuel

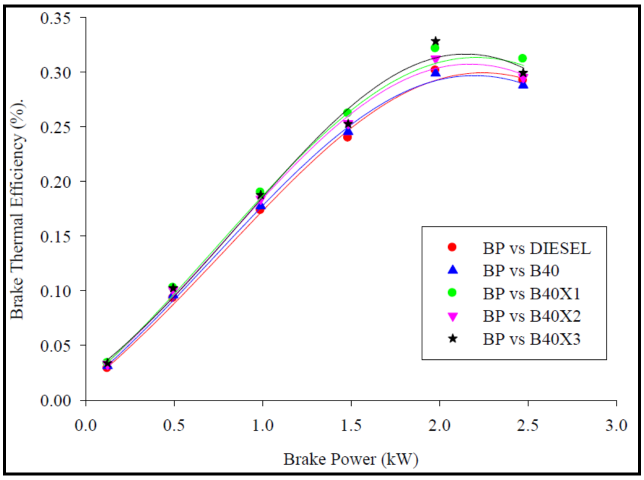

Figure 3: Variations in Brake Thermal Efficiency with Brake Power and different Additives using B40 Fuel

Maximum brake thermal efficiency using diesel, B20, B20X1, B20X2 and B20X3 fuels are 30.15%, 30.66%, 33.26%, 33.06% and 32.86% respectively. B20X1, B20X2 and B20X3 fuel with different additives show improvement in brake thermal efficiency by 10%, 9.65% and 8.98% respectively compared to diesel fuel. Also, various additives show improvement in brake thermal efficiency by 8.48%, 7.82% and 7.17% respectively compared to B20 fuel. Figure 3 shows variations in brake thermal efficiency with brake power using B40, B40X1, B40X2 and B40X3 fuels. Maximum brake thermal efficiency using diesel, B40, B40X1, B40X2 and B40X3 fuels are 30.15%, 29.89%, 32.15%, 31.25 and 32.85% respectively. B40X1, B40X2 and B40X3 fuel with different additives show improvement in brake thermal efficiency by 6.63%, 3.64% and 8.95% respectively compared to diesel fuel. Also, various additives show improvement in brake thermal efficiency by 7.56%, 4.55% and 9.90% respectively compared to B40 fuel.

(B) Brake Specific Energy Consumption

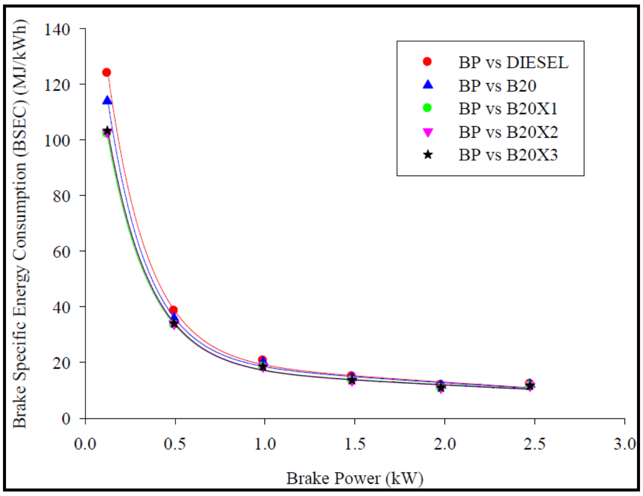

Figure 4: Variations in Brake Specific Energy Consumption with Brake Power And different Additives using B20 Fuel

Figure 4 show variations in BSEC with brake power for B20, B20X1, B20X2 and B20X3 fuels. Minimum BSEC for B20 fuel is achieved is 11.73 MJ/kWh at brake power of 1.97 kW. Minimum BSEC using diesel, B20, B20X1, B20X2 and B20X3 fuels are 11.93 MJ/kWh, 11.73 MJ/kWh, 10.82 MJ/kWh, 10.90 MJ/kWh and 10.95 MJ/kWh respectively. B20X1, B20X2 and B20X3 fuel with different additives show decrease in BSEC by 9.30%, 8.63% and 08.21% respectively compared to diesel fuel. Also, various additives show decrease in BSEC by 7.75%, 7.07% and 6.64% respectively compared to B20 fuel.

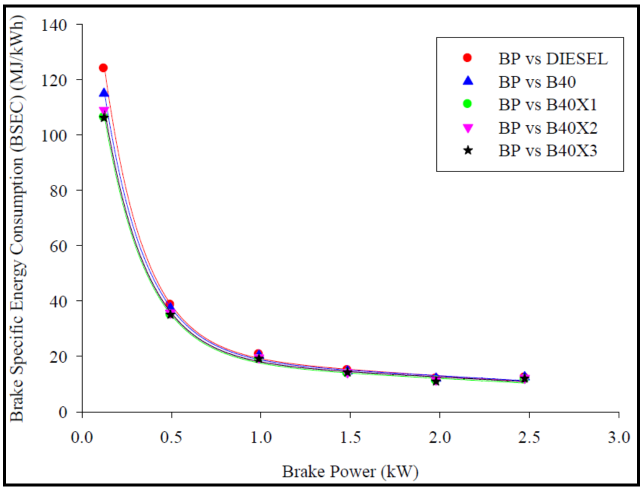

Figure 5: Variations in Brake Specific Energy Consumption with Brake Power And different Additives using B40 Fuel

Figure 5 show variations in BSEC with brake power for B40, B40X1, B40X2 and B40X3 fuels. BSEC for B40 fuel is achieved is 12.040 MJ/kWh at brake power of 1.97 kW. With using diesel, B40X1, B40X2 and B40X3 fuels, BSEC reduces to the value of 11.93 MJ/kWh, 11.51MJ/kWh and 10.95MJ/kWh respectively at brake power of 1.97 kW. B40X1, B40X2 and B40X3 fuel with different additives show reduction in brake specific energy consumption by 6.20%, 3.52% and 8.21% respectively compared to diesel fuel. Also, various additives show reduction in brake specific energy consumption by 7.05%, 4.40% and 9.05% respectively compared to B40 fuel.

(C) Exhaust Gas Temperature

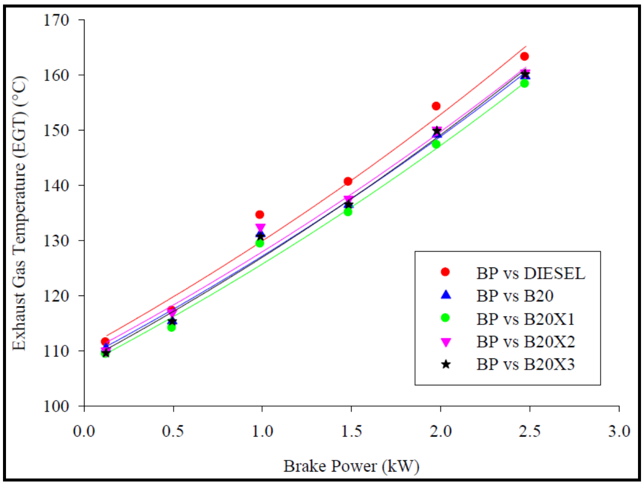

Figure 6: Variations in Exhaust Gas Temperature with Brake Power and Different Additives using B20 Fuel

Figure 6 Maximum EGT is reached at brake power of 2.47 kW for all fuels. Figure 4.13 shows variations in EGT with brake power for diesel, B20, B20X1, B20X2 and B20X3 fuels. Maximum EGT found is 163.20 °C, 159.77 °C, 158.32 °C, 160.39 °C, and 160.12 °C for diesel, B20, B20X1, B20X2 and B20X3 fuels respectively. B20X1, B20X2 and B20X3 fuel with different additives show reduction in exhaust gas temperature by 2.99%, 1.72% and 1.88% respectively compared to diesel fuel. Also, various additives show reduction in exhaust gas temperature by 0.90%, 0.38% and 0.21% respectively compared to B20 fuel.

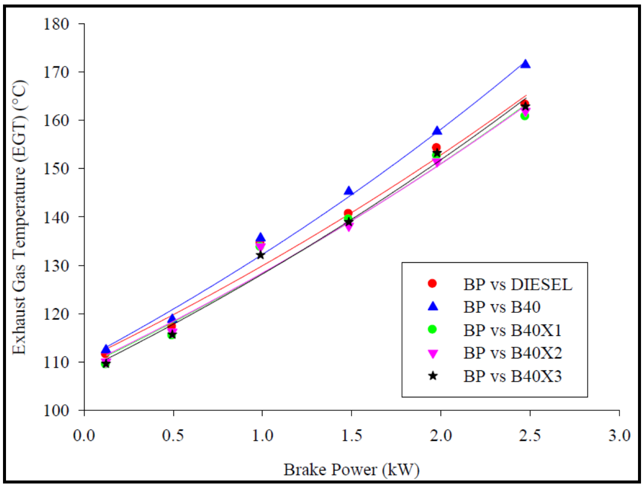

Figure 7: Variations in Exhaust Gas Temperature with Brake Power and Different Additives using B40 Fuel

Figure 7 shows variations in EGT with brake power for diesel, B40, B40X1, B40X2 and B40X3 fuels. Maximum EGT found is 163.20 °C, 171.45 °C, 160.76 °C, 161.91 °C and 162.88 °C for diesel, B40, B20X1, B40X2 and B40X3 fuels respectively. B40X1, B40X2 and B40X3 fuel with different additives show increase in exhaust gas temperature by 1.49%, 0.79% and 0.19% respectively compared to diesel fuel. Also, various additives show reduction in exhaust gas temperature by 6.23%, 5.56% and 4.99% respectively compared to B40 fuel.

(D) Carbon Monoxide (CO)

Figure 8 shows variations in CO emission by means of brake power for diesel, B20, B20X1, B20X2 and B20X3 fuels. Minimum amount of CO emission is achieved for diesel, B20, B20X1, B20X2 and B20X3 fuels are 0.0174 %/Vol., 0.0163 %/Vol., 0.0147 %/Vol., 0.0145 %/Vol., and 0.0146 %/Vol. respectively at brake power of 0.98 kW. B20X1, B20X2 and B20X3 fuel with different additives show decrease in CO emission by 9.81%, 11.04% and 10.42% respectively compared to B20 fuel. Also, various additives show decrease in CO by 15.51%, 16.66% and 16.09% respectively compared to diesel fuel.

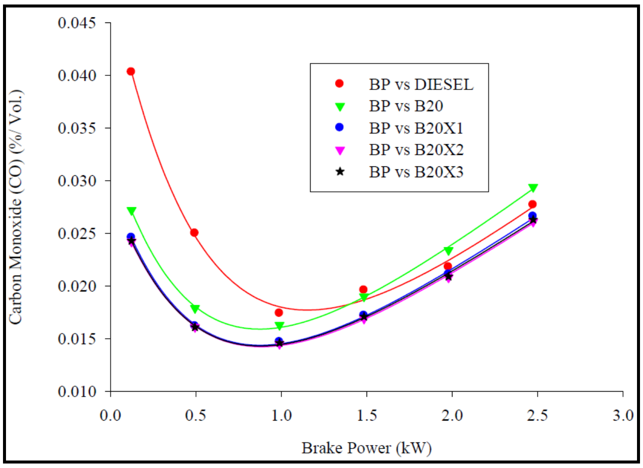

Figure 8: Variations in Carbon Monoxide Emission with Brake Power and different Additives using B20 Fuel

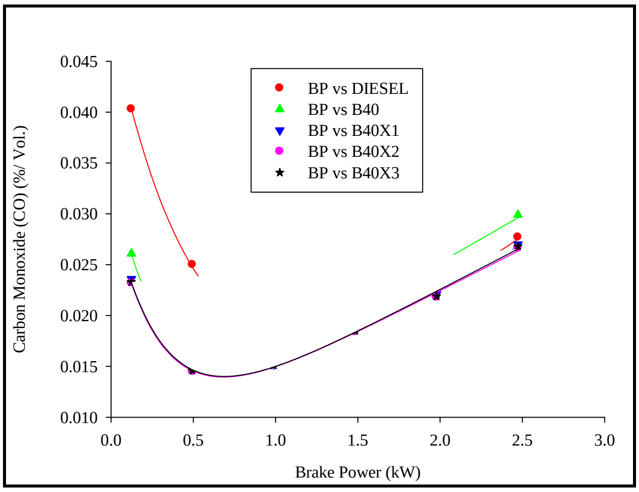

Figure 9: Variations in Carbon Monoxide Emission with Brake Power and different Additives using B40 Fuel

Figure 9 shows variations in CO emission by means of brake power for diesel, B40, B40X1, B40X2 and B40X3 fuels. Minimum amount of CO emission is achieved for diesel, B40, B40X1, B40X2 and B40X3 fuels are 0.0174 %/Vol., 0.0163 %/Vol., 0.0147 %/Vol., 0.0145%/Vol. and 0.0146 %/Vol. respectively at brake power of 0.49 kW. CO emission with B40X1, B40X2 and B40X3 fuel with different additives are lower by 9.80%, 11% and 10.4% respectively compared to B40 fuel. Also, with B40X1, B40X2 and B40X3 fuel with various additives show reduction in CO emission by

15.5%, 16.7% and 16% respectively compared to diesel fuel.

(E) Hydrocarbon (HC)

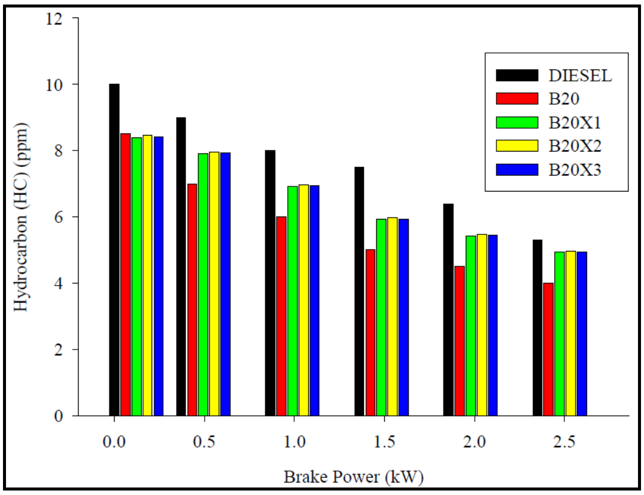

Figure 10: Variations in Hydrocarbon Emission with Brake Power and different Additives using B20 Fuel

Figure 10 shows variations in HC emissions with brake power for diesel, B20, B20X1, B20X2 and B20X3 fuels. Amount of HC emission for diesel, B20, B20X1, B20X2 and B20X3 fuels are 10 ppm, 8.50 ppm, 8.39 ppm, 8.46 ppm and 8.42 ppm respectively at no load. HC emission is decreased by 16.1%, 15.4% and 15.8% for B20X1, B20X2 and B20X3 fuels respectively compared to diesel fuel at no load. HC emission is decreased by 1.29%, 0.47% and 0.94% for B20X1, B20X2 and B20X3 fuels respectively compared to B20 fuel at no load.

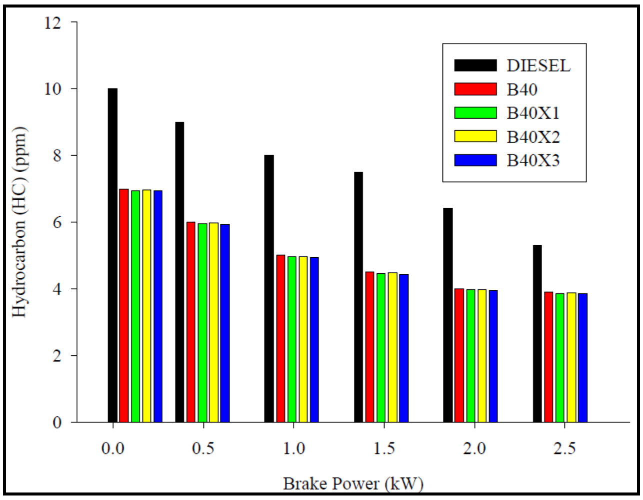

Figure 11: Variations in Hydrocarbon Emission with Brake Power and different Additives using B40 Fuel

Figure 11 shows variations in HC emissions with brake power for diesel, B40, B40X1, B40X2 and B40X3 fuels. Amount of HC emission for diesel, B40, B40X1, B40X2 and B40X3 fuels are 10 ppm, 7 ppm, 6.94 ppm, 6.96 ppm and 6.93 ppm respectively at no load. HC emission is decreased by 30.6%, 30.4% and 30.7% for B40X1, B40X2 and B40X3 fuels respectively compared to diesel fuel at no load. HC emission is decreased by 0.85%, 0.57% and 1% for B40X1, B40X2 and B40X3 fuels respectively compared to B40 fuel at no load.

IV. CONCLUSION

The below are the conclusion from the results obtained after experimentations while running single cylinder, four strokes, direct injection diesel engine fuelled with blends of Mahua bio-diesel and diesel with and without different additives. The results obtained were compared with diesel fuel.

B20X1, B20X2 and B20X3 fuel with different additives show improvement in brake thermal efficiency by 10%, 9.65% and 8.98% respectively compared to diesel fuel. B40X1, B40X2 and B40X3 fuel with different additives show improvement in brake thermal efficiency by 7.56%, 4.55% and 9.90% respectively compared to diesel fuel. B20X1, B20X2 and B20X3 fuel with different additives show decrease in BSEC by 9.30%, 8.63% and 8.21% respectively compared to diesel fuel. B40X1, B40X2 and B40X3 fuel with different additives show reduction in brake specific energy consumption by 6.20%, 3.52% and 8.21% respectively compared to diesel fuel.

B20X1, B20X2 and B20X3 fuel with different additives show reduction in exhaust gas temperature by 2.99%, 1.72% and 1.88% respectively compared to diesel fuel. B40X1, B40X2 and B40X3 fuel with different additives show increase in exhaust gas temperature by 1.49%, 0.79% and 0.19% respectively compared to diesel fuel.

B20X1, B20X2 and B20X3 fuel with different additives show reduce in CO emission by 15.51%, 16.66% and 16.09% respectively compared to diesel fuel. CO emission with B40X1, B40X2 and B40X3 fuel with different additives are lower by 15.5%, 16.7% and 16% respectively compared to diesel fuel.

HC emission is decreased by 16.1%, 15.4% and 15.8% for B20X1, B20X2 and B20X3 fuels respectively compared to diesel fuel at no load. HC emission is decreased by 30.6%, 30.4% and 30.7 % for B40X1, B40X2 and B40X3 fuels respectively compared to diesel fuel at no load.

V. ABBREVIATION

B20	20% Mahua Bio-diesel by Volume and 80% Petroleum Diesel
B20X1	20% Mahua Bio-diesel by Volume and 80% Petroleum Diesel with 1% Bardhal additive
B20X2	20% Mahua Bio-doesel by Volume and 80% Petroleum Diesel with 1% Adon –D additive
B20X3	20% Mahua Bio-diesel by Volume and 80% Petroleum Diesel with 1% system D additive
B30	30% Mahua Bio-diesel by Volume and 70% Petroleum Diesel
B40	40% Mahua Bio-diesel by Volume and 60% Petroleum Diesel
B40X1	40% Mahua Bio-diesel by Volume and 60% Petroleum Diesel with 1% Bardhal additive
B40X2	40% Mahua Bio-doesel by Volume and 60% Petroleum Diesel with 1% Adon –D additive
B40X3	40% Mahua Bio-diesel by Volume and 60% Petroleum Diesel with 1% system D additive
BSEC	Brake Specific Energy Consumption
CI Engine	Compression Ignition Engine
DI Engine	Direct Ignition Engine
HSD	High Speed Diesel
IC Engine	Internal Combustion Engine

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