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EXPERIMENTAL INVESTIGATION ON PERFORMANCE AND EMISSION CHARACTERISTICS OF A DIESEL ENGINE FUELLED WITH MAHUA BIODIESEL USING BLENDS OF BIODIESEL

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ABSTRACT

Bio-diesel is widely accepted as comparable fuel to diesel in compression ignition engines. It offers many advantages including; higher cetane number, reduced emissions of particulates, CO, NOX, and hydrocarbons, reduced toxicity, improved safety and lower lifecycle CO2 emissions. The bio-diesel fuels derived from fats or oils compounds display higher cloud points and pour points thus limiting their application. The cold flow properties of different bio-diesel were evaluated with various additives towards the objectives of improving the viscosity, pour point and cloud point. In this investigation of this research is to determine the relationship between engine performance and emissions using diesel, volumetric blends of Mahua bio-diesel and diesel and pure Mahua bio-diesel as a fuel in a single cylinder, four stroke, water cooled, direct injection CI engine at various load conditions. 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.

KEY WORDS: Diesel, Mahua biodiesel, Additive, compressed ignition engine Performance and emission.

I.INTRODUCTION

The large increase in number of automobiles in recent years has resulted in great demand for convectional products. With crude oil reserves estimated to last for few decades, there has been an search for alternate fuels. The depletion of crude oil would cause a major part on the transportation sector.[1] Everyday life Many aspects of rely on fuels, in particular the transport of goods and people. Main energy resources come from convectional fuels such as petrol oil, coal and natural gas. Convectional fuel contributes 80% of the world's energy needs. Most industries use diesel machines for the production process. In the transportation sector, private vehicles, buses, trucks, and ships also consume significant amounts of diesel and petrol.[11] . Biodiesel, derived from vegetable oil or animal fats, is recommended for use as a substitute for petroleum-based diesel mainly because biodiesel is a renewable, domestic resource with an is readily biodegradable and environmentally friendly emission profile. The use of biodiesel as a fuel has been widely investigated. Its commercial use as a diesel substitute began in Europe in the late 1980s.[3]. Recently, significant problems associated with convectional fuel like short supply, non renewability, drastically increasing price, contamination of environment, adverse effect on bio systems compels researcher to search for an alternative fuel, which promises a harmonious correlation with sustainable development, energy conservation management, efficiency. researcher found and analyse many energy sources like LPG, CNG, LNG, hydrogen,ethanol, methanol, biodiesel and many more. Among these alternative fuels, India is having scope for development of bio fuel. . The source of Biodiesel usually depends on the crops amenable to the regional climate.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] Biodiesel can be used in any mixture with ordinary diesel as it has lower exhaust emissions because it has very similar characteristics. Biodiesel has better properties than that of ordinary diesel such as renewable, non-toxic, biodegradable, and essentially free of sulphur and aromatics.[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] it has been experimentally investigated that the human health hazards are associated with exposure to diesel exhaust emissions.[5] Therefore, limited fossil fuels and intensified environment pollution, it has become a global issue to develop such clean fuel, which is technically feasible, domestically available and environmentally acceptable. Generally, recommended biodiesel for use as a substitute for ordinary diesel is produced from vegetable oil or animal fats by transesterification process.[5] these, vegetable oils like cotton seed oil, palm oil,Neem oil, Mahua oil, pongamia oil are considered as alternative fuels

II. BIODIESEL

Biodiesel is name of a cleaner burning renewable fuel for diesel engines. It is produced from domestic, agricultural co- products such as soybean oil or other fats and vegetable oils. Bio-diesel is fatty acid methyl or ethyl ester made from used vegetable oils or virgin (both edible & non-edible) and fats of animal. plant species such as Jatropha Curcas, Karanj, Neem, Mahua etc. Currently biodiesel significantly more expensive to produce than regular petroleum based diesel or ultra low sulfur diesel so the biodiesel fuel is not cost effective. However, biodiesel production could reach as high as 1.9 billion gallons, or approximately 8% of the diesel market, with government incentives.[9] Biodiesel can be produced by chemically combining fat with an alcohol such as methanol or ethanol or any natural oil. In the commercial production of biodiesel methanol has been the most commonly used alcohol.[11] 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] USA and several European countries are already working towards substituting conventional fuel by such alternatives. In 1991, the European Community proposed a 90 per cent tax 7decrease for using biofuels, including biodiesel and is targeting to reduce utilization of petroleum fuel at least by around 5 per cent, by substituting with biofuel by the year 2010 Today, India is one of the main petroleum consuming and importing countries. India imports about 70 per cent of its petroleum demands. The economic aspect is also very important while inventing a new fuel,. In Brazil, there is abundance of ethanol, but petro diesel is very expensive, so direct blending of ethanol into gasoline fuel is done. Government of Brazil has also legalized the direct blending up to 25% in gasoline in automobiles vehicle. In India, diesel costs about Rs. 60 per liter. But in India, petro diesel is an extremely subsidized fuel due to its vast use in agriculture. The raw material used in Europe like that Sunflower, rapeseed etc whereas soya bean is used in USA. USA uses blend of 20% bio-diesel with 80% petroleum diesel and pure bio-diesel, In France uses 5% bio-diesel with 95% petroleum diesel B5 as mandatory in all diesel fuel.[12]The annual estimated potential of biodiesel is about 20 million tonnes per annum.[12] Wild crops cultivated in the wasteland also form a source of biodiesel production in India and according to the Economic Survey of Government of India, out of the cultivated land area; about 175 million hectares are classified as waste and degraded land.[12] In 2008, world production of 1G biofuels is 45.9 Mtoe versus 51.8 Mtoe in 2009, that is an increase of 13% in one year. Biofuel production is dominated by three countries: the 42% of world production (US,22.0 Mtoe), 29% (Brazil,13.9 Mtoe) and the 18% (10.0 Mtoe, EU). Other countries (5.9 Mtoe, 11%) are more recent players and 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]

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] it consists of mainly methane with small percentages of ethane, propane, butane and CO2 and nitrogen. Natural gas is nearly odorless and colorless. The usual range of consumption is 68% to 96% of methane and 3% to 30% of ethane in natural gas.[7] . Biodiesel as one promising alternative to fossil fuel for diesel engines has become increasingly significant due to environmental consequences of petroleum-fuelled diesel engines and the decreasing petroleum resources. Biodiesel would be produced by chemically combining any natural oil.[19] Biodiesel can substitute fossil fuel as a “clean energy source”. It can protect the environment by reducing CO_2, SO_2, CO, HC. The low sulphur content in biodiesel. So the emission of SO_2 in the combustion process of biodiesel is much lower than normal diesel oil.[19]

Table 1 Biodiesel Specifications[28]

Fuel Property	Biodiesel	Units
Fuel Standard	ASTM D6751	
Lower Heating Value	118.70	Btu/gal
Kinematic Viscosity @ 40o C	1.9- 6	mm2/s
Specific Gravity @ 60o C	0.88	kg/l
Density	7.328	lb/gal
Water Density and Sediment	0.05 max	% volume
Carbon	77	wt. %
Hydrogen	12	wt. %
Oxygen	11	
Sulfur	00 to 0.0024	wt. %
Boiling Point	315 to 350	o C
Flash Point	130 to 170	o C
Cloud Point	-3 to 12	o C
Pour Point	-15 to 10	o C
Cetane Number	47 to 65	
Lubricity SLBOCLE	>7000	grams
Lubricity HFRR	<300	microns

The Biodiesel Policy[18]

The policy and government incentives will directly affect the development of biodiesel industry.

1) Subsidizing the cultivation of non-food crops or the usage of waste oil as feedstock
2) Mandatory biodiesel blend use in gas station.
3) Exemption from the oil tax
4) Implementation of carbon tax
5) Crop plantation in abandoned and fallowed agricultural lands

Non-edible oil Composition and its Potential in India

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]

Table 2 Potential of Tree born Non-edible oils in India

Sr. No.	Oil sources	Botanical name	Oil Content (%)	Potential (MT/Year) Seed	Potential (MT/Year) Oil
1	Neem	Azadirechta indica	30	0.50	0.100
2	Jatropha	Jathropha Curcas	30-40	0.05	0.015
3	Kusum	Scheleichera oleosa	28-30	0.08	0.025
4	Karanja	Pongamic pinnata	27-39	0.02	0.055
5	Sal	Shorea robusta	12-13	131.50	0.180
6	Mahua	Madhuca indica	35-42	0.50	0.180
7	Mango	Mangifera indica	7.5	0.50	0.045
8	Tumba	Citrulluscollocynths	-	-	0.017
9	Kokum	Garcinia indica	25-34	-	0.0005
10	Jojoba	Simmondsia chineaca	45-50	-	-
11	Chullu	Prunus armeniaca	45-50	-	0.0001
12	Nahar	Mesua ferrea L.	60-70	-	0.01
13	Pilu	Salvadora oleoides	38-42	-	0.017
14	Rice bran	bran Oryza sativa	15-23	-	0.474
15	Phulwae	Cheura	60-62	-	0.003

III. TRANSESTERIFICATION

The present study is based on biodiesel production which consists of reaction where an ester reacts with alcohol to form another ester and another alcohol. Ester here is the vegetable oil which consist triglyceride. 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] Transesterification is a chemical reaction that occurs between triglyceride and alcohol in presence of catalyst to obtain methyl ester and glycerol as by product. Transesterification mainly depends upon the amount of alcohol and catalyst, pressure, time, FFA Free fatty acid and amount of water. [14] Pyrolysis is a process of conversion of one substance into another by mean of heat or by heat with the aid of the catalyst in the absence of air or oxygen . 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. The triglycerides are reacted with a suitable alcohol (Methyl, Ethyl, or others) in the presence of a catalyst under a controlled temperature for a given length of time.[20[The chemical reaction of the Tri-glyceride with Methyl alcohol is shown below Figure 1

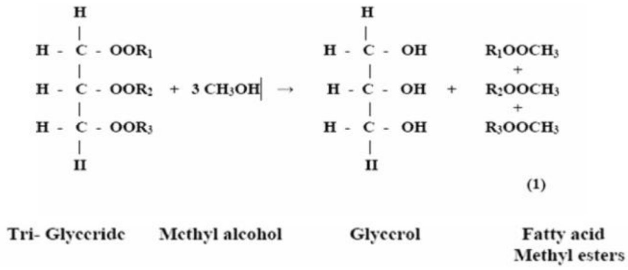

Figure 1 chemical reaction of the Tri-glyceride with Methyl alcohol

IV. MATERIALS

Mahua (MadhucaIndica) oil

Raw Mahua oil is generally collected from the kernel of mahua tree. It is basically a medium size tree found in different parts of India. It is available in most of the rural areas in India. Mahua tree is a deciduous tree which grows to a height of 60- 70 feet and has a life span of 7- 20 years and fruits till 55 years. Each of these trees produces approximately around 20-40 kg of seeds per year. The average Mahua oil yield per annum is 1, 35,000 million tons in India. [14] 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]

V. 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 B20represent 80% diesel and 20% biodiesel+additive. Similarly B40 represent 60%diesel with 40% biodiesel+additive. B100 represents pure biodiesel without additive.

VI. EXPERIMENTATION

The Test Engine

Table 3 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

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. biodiesel was passed through various tests to determine its physical and chemical properties like kinematic viscosity, specific gravity, flash point, fire point, cloud point, pour point, ash content, calorific value etc... After the test is over, Mahua biodiesel was blended with additive in various proportions like B20, B40, B100, etc…where B20 indicates 20% biodiesel and 80%+ additive. Various performance and emission parameters are measured at each load and test fuel. Performance parameters such as brake power, brake thermal efficiency, brake specific fuel consumption and exhaust gas temperature and also to measure the emission parameters like carbon monoxide, unburnt hydrocarbon for both diesel and the prepared test fuels with the help of gas analyzer.

VII. RESULTS AND DISCUSSIONS

Properties and Characteristics of Fuel and blends

diesel fuel calorific value is 42205 kJ/kg and that of Mahua bio-diesel is 37056 kJ/kg. Calorific value for different fuel blends B20, B40, B20X3, B40X3 have been measured. B20 has calorific value of 41360 kJ/kg which is comparable to diesel.

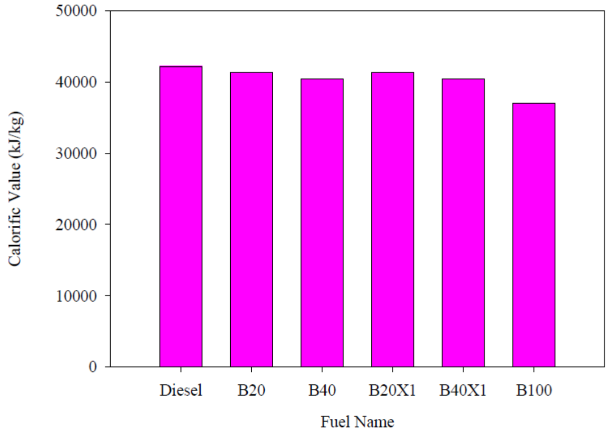

Figure 2 Calorific Values of Various Fuels

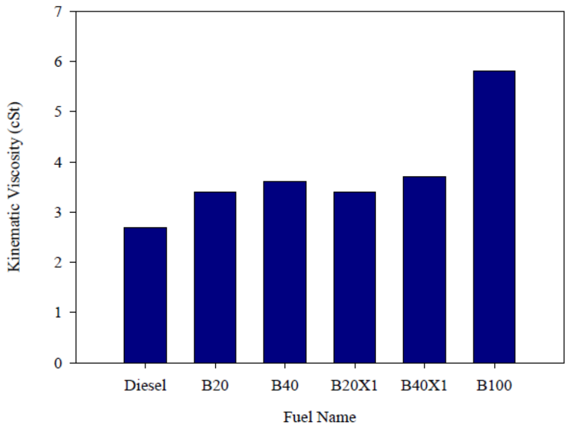

Figure 3 Kinematic Viscosity of Various Fuels

Kinematic viscosity for pure Mahua bio-diesel and B20 are 5.8 cSt and 3.4 cSt respectively, whereas for diesel kinematic viscosity measured is 2.7 cSt. This is shown in figure 3 Mahua bio- diesel has 1.9 times higher kinematic viscosity compared to diesel. Density of Mahua bio-diesel is 0.824 g/cc where as diesel has density of 0.818 g/cc. Due to higher density of Mahua bio-diesel, specific fuel consumption will be less than diesel

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/cc)	0.818	0.824	0.819	0.821
Flash point (°C)	70	130	-	-
Ash Content (%w/w)	0.002	0.012	0.0034	0.0054
Cloud point (°C)	-10	-11	-9.1	-9.3

Brake Thermal Efficiency

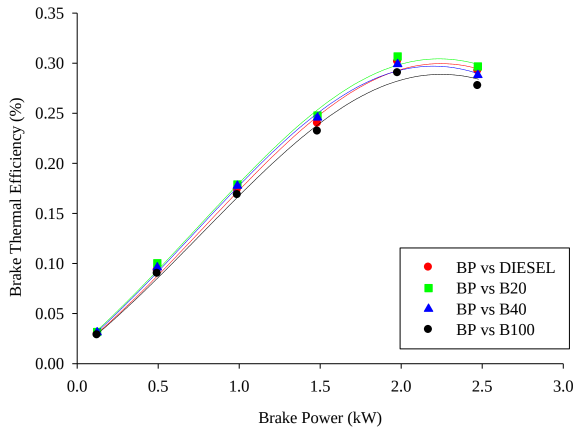

Figure 4 Variations in Brake Thermal Efficiency with Brake Power and Bio-diesel Percentage in blend

Figure 4 clearly indicates, as brake power increases the brake thermal efficiency increases for all fuels like diesel, mahua bio-diesel and its blends. Maximum value of BTE with diesel fuel obtained is 30.15% at brake power of 1.97kW. For B20 fuel, maximum brake thermal efficiency obtained is 30.66% at brake power of 1.97 kW. Peak value of BTE for diesel, B20, B40 and B100 are 30.158%, 30.66%, 29.89%, and 29.3% respectively. The reduction in brake thermal efficiency for B100 is 2.84% compared to diesel.

Brake Specific Energy Consumption

BSFC decreases for all the test fuels with increase in load. Minimum BSEC for diesel, B20 and B40 fuels are 11.93 MJ/kWh, 11.73 MJ/kWh and 12.04 MJ/kWh respectively. B20 fuel has lowest BSEC followed by B40 and diesel fuels. B20 and B40 fuels show approximately 1.67% and 0.91% reduction in BSEC compared to diesel fuel. Lowest BSEC for B100 fuel is approximately 4% higher compared to lowest BSEC for diesel fuel.

Exhaust Gas Temperature

EGT increases with increase in brake power for all fuels. Maximum EGT Measured is 188°C using B100 fuel at brake power of 2.47 kW. Lowest EGT measured is 159.77°C using B20 fuel at brake power of 2.47 kW. B20 fuel shows approximately 15.01% reduction in EGT as compared to B100 fuel. Maximum EGT measure for diesel and B40 fuels are 163.20°C and 171.45°C respectively at brake power of 2.47 kW. At part load, increase in EGT for Mahua bio-diesel blends is lower compared to at full load. At no load, using B20 and B100 as fuels the EGT are 110 °C and 115°C respectively.

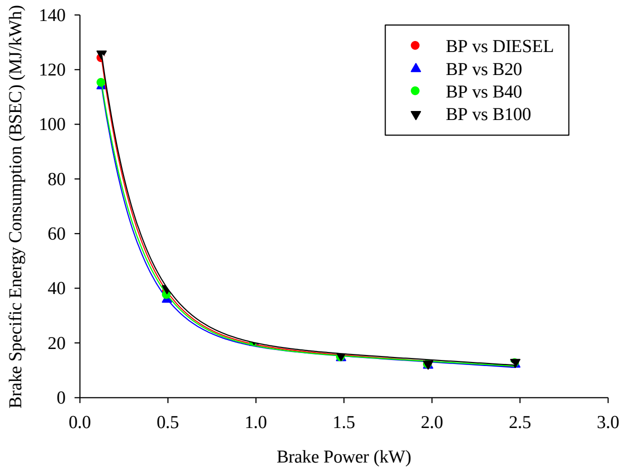

Figure 5 Variations in Brake Specific Energy Consumption with Brake Power and Bio-diesel Percentage in blend

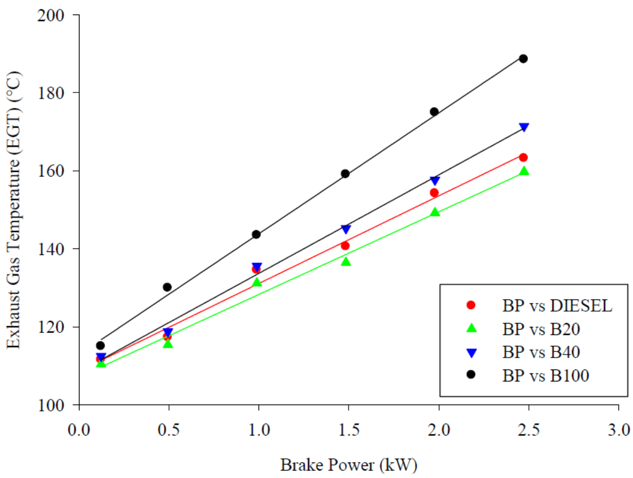

Figure 6 Variations in Exhaust Gas Temperature with Brake Power and Bio-diesel Percentage in blend

Carbon Monoxide

Emissions of CO at 0.12 kW part load for diesel, B20, B40 and B100 fuels are 0.0403%/Vol., 0.0272%/Vol., 0.0261 %/Vol. and 0.0225 %/Vol. respectively. Minimum emission of CO with diesel, B20, B40 and B100 fuels are 0.0174%/Vol., 0.0163%/Vol., 0.0169 %/Vol. And 0.0178 %/Vol. respectively at brake power of 0.99 KW. At maximum brake power of 2.47 kW, emission of CO with diesel, B20, B40 and B100 fuels are 0.0277 %/Vol., 0.0294%/Vol., 0.0299 %/Vole and 0.031%/Vol. respectively.

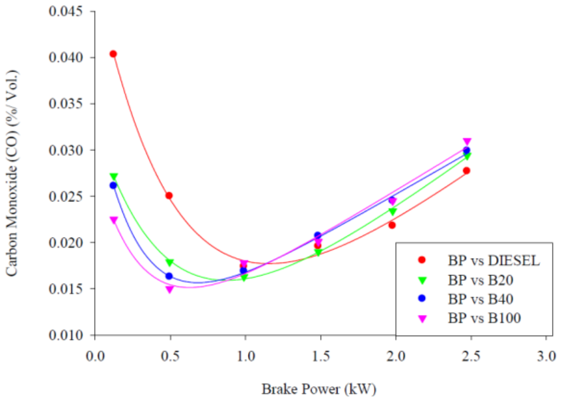

Figure 7 Variations in Carbon Monoxide Emission with Brake Power And Bio-diesel Percentage in blend

Hydrocarbon

HC emissions are lowest at brake power of 2.47 KW for all fuels. HC emissions are highest at no load and decreases with increase in brake power or load. Highest HC emissions for diesel, B20, B40 and B100 fuel are 10 ppm, 8.50 ppm, 7 ppm and 6.5 ppm respectively at no load.While using B100 fuel emission of HC reduces approximately half the value of HC emissions using diesel fuel.

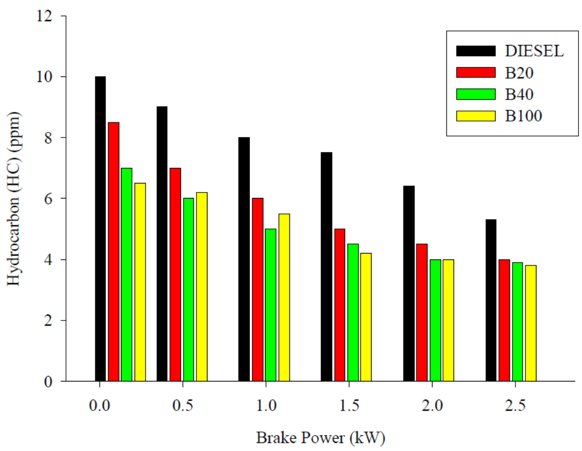

Figure 8 Variations in Hydrocarbon Emission with Brake Power And Bio-diesel Percentage in blend

Conclusion

An increase in biodiesel concentration is greatly increased the density and viscosity of the biodiesel blend fuel, B20. Brake thermal efficiency with fuels B20 are 30.66%.which are higher compared to 30.15 % of diesel. Minimum BSEC for diesel, B20 and B40 fuels are 11.93 MJ/kWh, 11.73 MJ/kWh and 12.04 MJ/kWh respectively. B20 fuel has the lowest BSEC followed by B40 and diesel fuels. Maximum EGT determine for diesel, B20, B40 and B100 fuels are 163.20 °C, 159.77°C, 171.45 °C and 188.56°C respectively at full load. Except B20, other blends shows higher EGT compared to diesel fuel. Minimum emission of CO with diesel, B20, B40 and B100 fuels are 0.0174 %/Vol., 0.0163 %/Vol., 0.0169 %/Vol. and 0.0178 %/Vol. respectively at brake power of 10.16 KW. Among all compared fuels, CO emission for B20 is lowest followed by B40, diesel and B100. Highest HC emissions for diesel, B20, B40 and B100 fuel are 10 ppm, 8.5 ppm, 7 ppm and 6.5 ppm respectively at no load. While using B100 fuel emission of HC reduces approximately half the value of HC emissions using diesel fuel.

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