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RESEARCH ARTICLE

EXPERIMENTAL INVESTIGATION OF A SINGLE CYLINDER C.I ENGINE USING SOYA BEAN OIL AS A BIODIESEL

*[1]Senthilkumar, R., [2]Manimaran, R. and [3]Prabu, M.

[1]Research Scholar, Mechanical Engineering, Annamalai University
[2]Research Scholar, Mechanical Engineering, Pondicherry Engineering College
[2]Assistant Professor, Mechanical Engineering, Prist University, Kumbakonam

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ABSTRACT

The main objective of this paper is to provide the analysis of the diesel engine such as performance & characteristic curves, fuel economy, power developed and exhaust emission levels; when the four stroke internal combustion compression ignition diesel engine is fueled with soybean biodiesel (B100 with 5% ethanol) and petroleum diesel. The various parameters have been evaluated for each of the fuel used such as brake power developed, specific fuel consumption, indicated thermal efficiency, brake thermal efficiency, mechanical efficiency and exhaust emission gas levels of CO, HC, CO2, O2 and NOx and comparisons of them have been given. In addition to B100 and petroleum diesel, different blends of pure biodiesel such as B25, B50 and B75 have also been analyzed, compared among each other and shown. The aim of this paper is to prove that *Soybean Oil: Biodiesel* is the most sustainable alternative and renewable fuel, which not only shows similar performance characteristics, fuel consumption & efficiencies with respect to petro-diesel, but also shows reduction in amount of pollution causing gases in exhaust when compared with the same.

INTRODUCTION

Soybean Biodiesel, is made from vegetable oil (Soybean Oil) reacted with methanol and a catalyst, yielding biodiesel (fatty acid methyl esters) and glycerin as a by-product. It can be used in any diesel engine without any modifications and can be substituted for petroleum-diesel fuel in diesel engines, as there is a need for alternative fuel sources, which is biodegradable, economical to produce, eco-friendly to use due to the depletion of the world petroleum reserves, increase in global warming and environmental concerns.[2,5,9] Biodiesel is a clean green and renewable fuel which is considered to be the best substitution for diesel fuel supported by the facts such as to reduce the Energy dependency over the pollution causing Fossil Fuels, to protect the Mother Earth from Ozone Destruction. [3,12,18] Soybean oil, a promising renewable energy resource, comprises 73% of biodiesel in addition to other industrial applications. Among the legumes, the soybean, also classed as an oilseed, is pre-eminent for its high (38-45%) protein. This oilseed, when compared to other oil crops has a higher yield and contains about 19% of oil in it. Biodiesel is going to play an extremely important role in meeting country's energy needs.[1,6,8]

ANALYSIS OF THE FUEL PROPERTIES

The experimental work has been carried over a single cylinder 5 H.P diesel engine by fueling it with petroleum-diesel, B100 (with 5% ethanol) and different blends of Biodiesel such as B25, B50 and B75. [11,15,19] All the blends of biodiesel has been added an additive of 5% ethanol to keep the charge temperature lower than its usual level and to drop the temperature of the combustion chamber, as the higher temperature enhances NOx production in exhaust. Biodiesel blends composition that have been used during the experimental work are, B25 (25% biodiesel + 70% petro-diesel + 5% ethanol), B50 (50% biodiesel + 45% petro-diesel + 5% ethanol) and B75 (75% biodiesel + 20% petro-diesel + 5% ethanol). [4,6,13] The basic fuel properties such as Flash & Fire point and Kinematic viscosity have also been found out using Pensky-Martin apparatus (closed cup method) and Say bolt viscometer, for the fuels used including biodiesel and its blends.[16,18] The main idea behind this flash & fire point experiment is, when a fuel is heated sufficiently to higher temperature, it decomposes chemically; thereby breaking up of hydrocarbons cause it to form a volatile combustible gases. [10,14,16] The *Flash point* is the temperature to which the fuel must be heated to give of sufficient vapor to form an inflammable mixture. [7,9] The *Fire point* is the lowest temperature at which the production of combustible gas from the oil is sufficient enough to maintain a steady combustion after ignition. The Flash & Fire point must be known before handling the fuel in engines or in storage tanks in order to handle it within defined safe limits.[8,19] The Flash & Fire point must be met by the standards of ASTM (*American Society of Testing and Materials*) to begin using the fuel in internal combustion engines. ASTM defines the Flash point of the B100 (Biodiesel) to have a maximum of 150ºC, as it depends upon the oil used for transesterification and catalyst utilized, whereas in Diesel it ranges from 60ºC to 80ºC. Viscosity is the measure of relative resistance between layers of flowing fluid. In order to prevent high or low viscous fuel problems such as fuel injector blockage or metering of flow in an engine, ASTM has defined the limits of kinematic viscosity values, so that the necessity of using the optimum values has been exercised.

Table 1. shown with kinematic viscosity values for biodiesel and its blends

Name of the fuel	Temperature (ºC)	Time for collection of 60CC of fuel (seconds)	Kinematic viscosity (centistokes)
B25	40	33	1.35
B75	40	35	2.12
B100	40	36	2.50

***Corresponding author:** R. Senthilkumar
Research Scholar, Mechanical Engineering, Annamalai University

Table 2. shown with different properties of Biodiesel blends

Name of the Fuel	Flash point(ºC)	Fire point (ºC)	Density (Kg/m3)	Calorific value (KJ/Kg)
B25	38	58	838	42,195
B50	42	62	848	40,345
B75	54	80	858	38,495
B100	74	110	866	37,015

The values shown above have been analyzed using standard equipments in Thermal laboratory of Annamalai university, Chidambaram. It has been noted that as the percentage of biodiesel increases in the mixtures from B25 to B100 has shown that kinematic viscosity (the ratio of inertial force to the viscous force) increases as blends concentration increases. ASTM defines the kinematic viscosity of biodiesel to be in between 1.9 to 6.0 and the above mentioned tabulated results fall right between them.[9,13] Similarly flash & fire point decreases from B100 to B25 as the presence of diesel in their blends increases. Readings for flash & fire point have been noted with a regular interval of 2ºC. The engine performance tests have been carried out in Thermal laboratory at Annamalai University, Chidambaram. This test is performed over a four stroke single cylinder internal combustion compression ignition diesel engine coupled with Rope Brake dynamometer, fueled with petroleum diesel, B100 and its blends; in order to determine the behavioral characteristics of the engine with these fuels their parameters are compared. The parameters that have been analyzed are Brake power, Brake thermal efficiency, Mechanical efficiency, indicated thermal efficiency and specific fuel consumption.

Table 3.Engine Specifications

No. of cylinders	single
Cooling system	Water cooled
Loading device	Rope brake dynamometer
Brake power	5H.P
Bore diameter	80mm
Stroke length	110mm
Engine speed	1500rpm
Compression ratio	16:1
Air orifice diameter	24mm
Brake drum radius	165mm

The performance plots have been drawn to show their characteristics:

Brake thermal efficiency

It can be inferred from the plotted graph that Brake thermal efficiency of B100 mixture leads petro diesel and various other blends till 2KW but it lags after crossing that point. Petroleum-diesel and B25 blend almost shows similar characteristics as the curve almost coincides from the beginning to the end. The maximum load applied on the engine is 12kg i.e. 3.05KW of brake power.

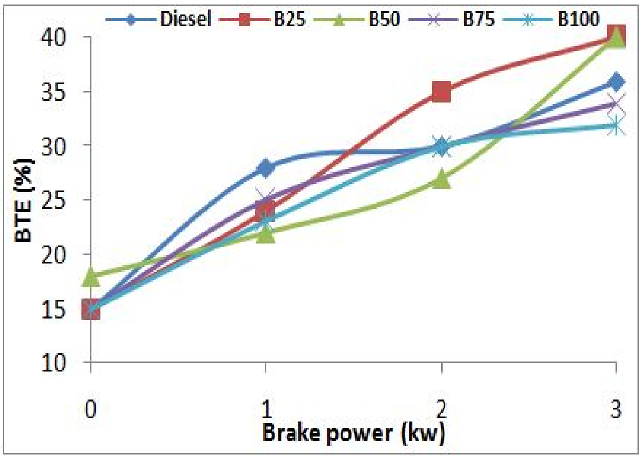

Fig. 1. Brake power Vs BTE

B100 gives better performance than B75 at maximum load. B100 shows increase in efficiency but after half load, the increase is not as steep as before, but continues to rise as load applied on the engine increases, unlike diesel which gives steep rise till maximum load. The brake thermal efficiency is the ratio of brake horse power to heat energy supplied by the fuel during the same interval of time. It could be seen from the graph that B100 blend has shown competency performance with respect to diesel, when brake thermal efficiency is considered for that reason.

Indicated thermal efficiency

It can be inferred from the graph that indicated thermal efficiency (which is the ratio of indicated power to the heat energy supplied by the fuel during combustion) of B100 mixture shows a lead than diesel and blends of biodiesel. Indicated thermal efficiency depends on both brake power produced by the engine as well as frictional power offered by the engine, as it is the summation of both. Diesel curve leads all the blends of biodiesel as load applied on an engine increases, except B100. Diesel curve also shows a smooth linear curvature. B100 shows a characteristic curve of increase from the start till 1.52KW, but after that it decreases then increases with minor raise till the end. B25 shows a smooth linear curve overall. Among the blends B75 leads B50 and B25 till half load of 2.5H.P (1.82KW). Thus B100 has shown competent and satisfactory performance characteristics results when compared mainly with petroleum-diesel and other blends of biodiesel.

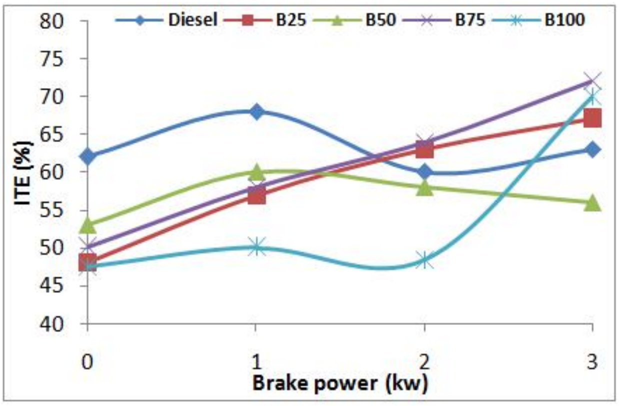

Fig. 2. Brake power Vs ITE

Mechanical efficiency

It can be studied from the graph of η_{mech} vs. B.P, that the mechanical efficiency (the ratio of B.H.P to I.H.P) of biodiesel and petro-diesel follows a smooth linear curvature, and almost crosses near each other for a same brake power. B50 leads all other blends of biodiesel and shows a higher hand to others, even though the difference among them for a given brake power is less appreciable. Thus the comparison between B100 and petroleum-diesel has shown that biodiesel gives concordant results with diesel

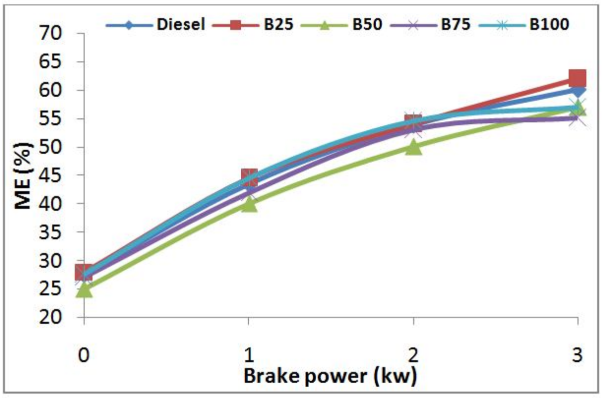

Fig. 3 Brake power Vs ME

Specific fuel consumption

It can be seen from the graph of specific fuel consumption vs. B.P, that the specific fuel consumption (mass flow rate of the fuel consumed per unit KW of brake power produced) decreases as load applied on the engine increases i.e. as brake power increases. In referral with the graph, it can be seen that consumption of biodiesel is more than diesel, because it has 20% lesser calorific value than diesel, thereby heat supplied by the combustion of biodiesel is lesser comparable to diesel, as a reason the power produced by 1 liter of diesel can only be met by using 1.2 to 1.3 liters of biodiesel. The biodiesel could have higher consumption of fuel than diesel but the heats produced by both of them are almost similar, which would be shown in the heat balance sheet.

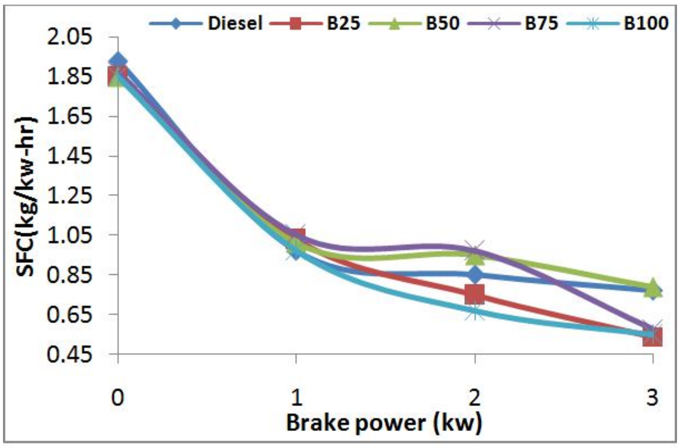

Fig. 4. Brake power Vs SFC

HEAT BALANCE SHEET

The Performance of an Engine is generally given by heat balance sheet. The various quantities involved such as the amount of total Heat produced by the combustion of the fuel, to produce brake power, Heat driven away by the usage of coolant and the surroundings: have been found out and the corresponding results of them are compared to display their Efficacy. The main concept of this sheet is, all the heat energy produced during the combustion of the fuel is not converted into useful work: which is harnessed at the crank shaft of the engine, some goes as wastage as described above. The various results obtained have been plotted in pie-charts and the inference has been discussed hereby. It can be noted from the pie-chart that B100 has higher utilization of heat produced from the combustion of the fuel inside the engine, to produce Brake power than diesel. Of all the blends of biodiesel B100 has shown more productive for the transmission of output power. Heat loss unaccounted are produced due to conductive, convective and radiation losses; more heat has been enhanced by the engine when fueled with B100 than diesel, thereby the heat taken away by the exhaust gas can be utilized by using exhaust gas recirculation technique to increase the thermal and volumetric efficiency of an engine.

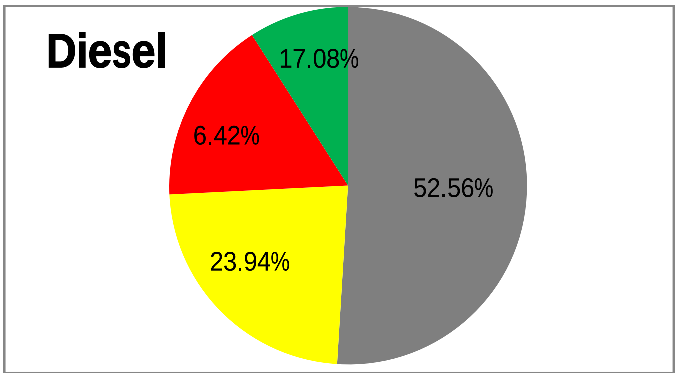

Fig. 5. Diesel

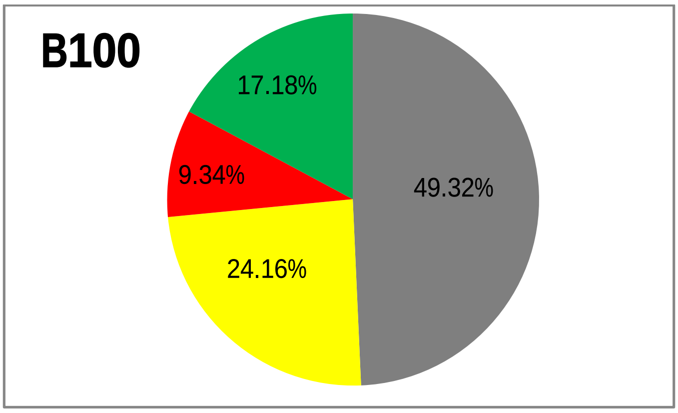

Fig. 6. B100

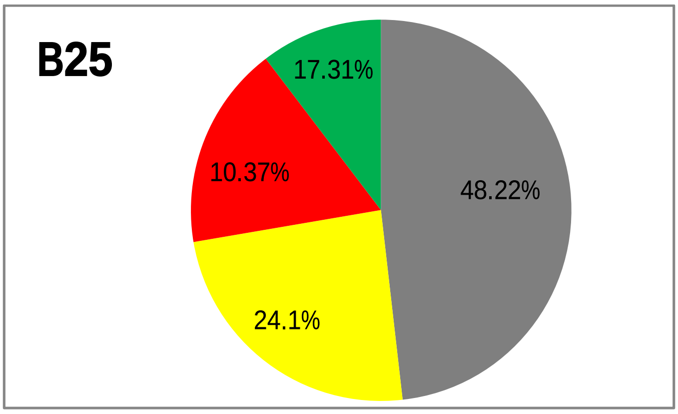

Fig. 7. B25

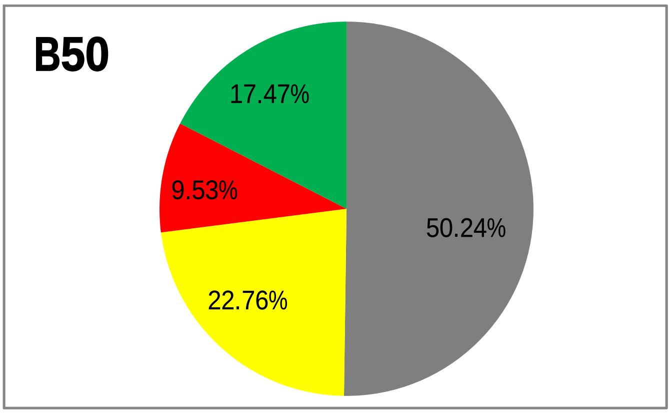

Fig. 8. B50

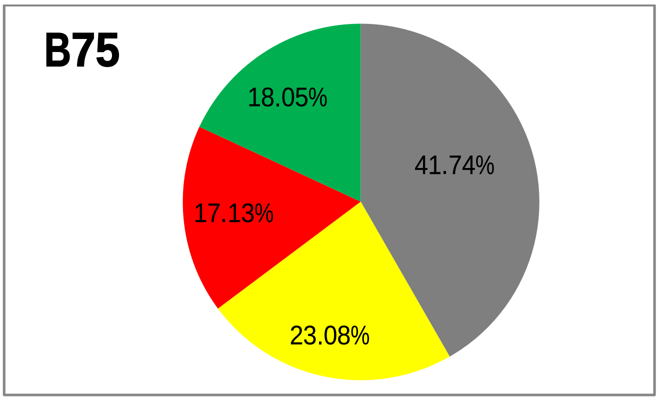

Fig. 9. B75

Among the blends of biodiesel, B25 leads more effective to B50 and B75, in overall comparison of utilization of heat. A heat balance characteristic shown by B100 is more effective when compared to diesel.

EXHAUST GAS ANALYSIS

The Exhaust emission levels have been measured using AVL exhaust gas analyzer of type DiGas 444, 2008 model, which was coupled to the diesel engine exhaust pipe. The plot shows that CO emission given by the B100 gradually decreases as load applied on it increases. B100 shows an overall of 40% lesser emission of CO to diesel, 5-15% less with respect to biodiesel blends. CO emission is more at the start because rich mixture is required initially, B100 at higher loads show a proper combustion with lesser CO in exhaust. HC emissions show that B100 gives 10-15% increase when compared to diesel, because B100 mixture is denser than diesel having longer-chains of hydrocarbons in it. Among the blends of biodiesel, B25 shows lower emission levels. CO2 emissions of B100 have more than diesel by 16%.

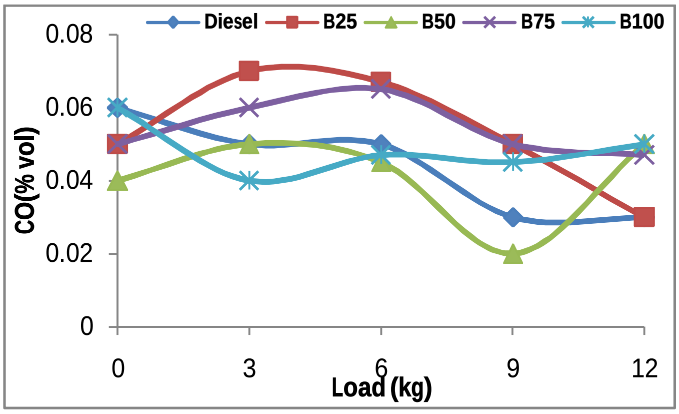

Fig. 10. Load Vs Co

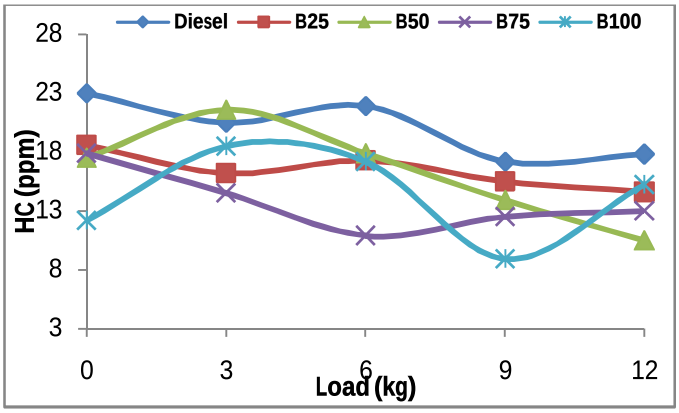

Fig. 11. Load Vs HC

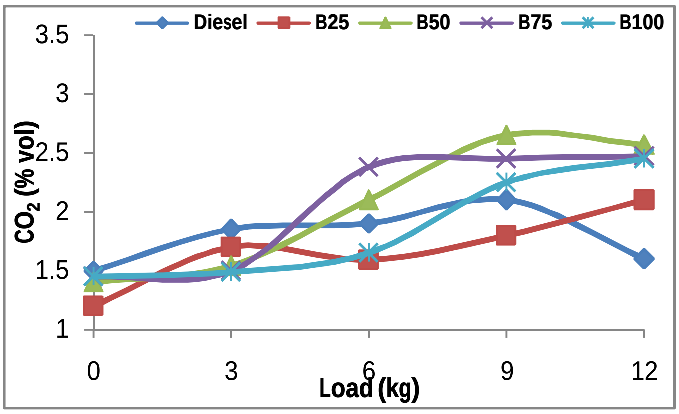

Fig. 12. Load Vs Co_2

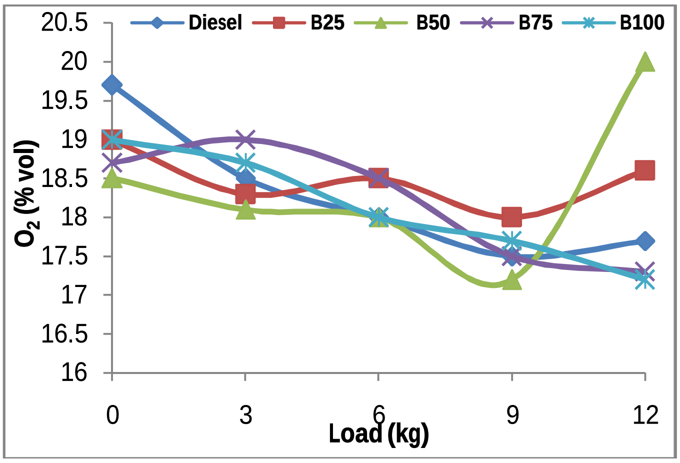

Fig. 13 Load Vs O_2

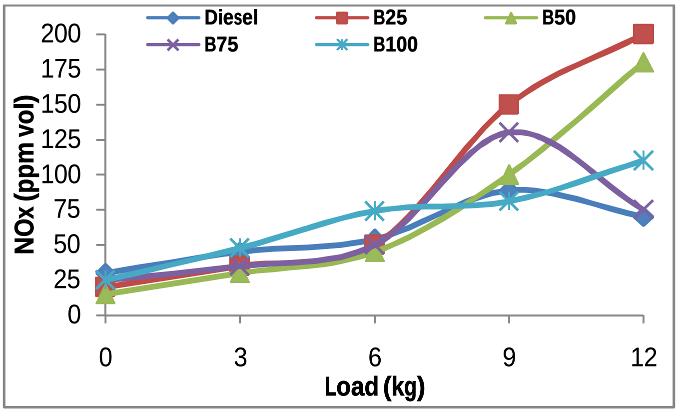

Fig. 14. Load Vs NOx

It can be seen that the blends B25 and B75 shows lower & higher levels of CO2 respectively. O2 emissions shown by B100 is the lowest of all the blends used including diesel, which means biodiesel make use of all the oxygen content in the mixture for a proper combustion to occur; the more the O2 availability in the mixture the better the burning of it. In referral with the plots, the blends of biodiesel B75, B25 and B50 give of more oxygen comparable to diesel. NOx emissions shown by B100 is more when comparable with diesel because of reaching higher temperature during combustion, eventually leads to promote NOx production; it could be controlled by adding higher amount of additives such as ethanol to keep the charge temperature, thereby NOx under control. B25 and B50 show lower NOx emissions when compared to diesel. NOx production can be controlled easily by using proper catalytic convertors. Thus the emission characteristics shown by using different fuels have been plotted and analyzed.

Conclusion

On the basis of the data obtained, during the analysis of the performance tests over a single cylinder internal combustion 5H.P diesel engine, when fueled with petroleum –diesel, Biodiesel (B100) and its blends; have given a series of satisfactory results. Also it has been shown that Biodiesel and its blends satisfy the ASTM requirements of its properties to usage as a fuel. In referral to the results shown the performance characteristics shown by biodiesel is much similar to that of the diesel, which of course needs an alternative one with greener properties. The specific fuel consumption of biodiesel and its blends have shown a higher number than diesel due to their lower calorific value of the fuel. The performance parameters shown by both diesel and biodiesel, such as Brake thermal efficiency, Mechanical efficiency, fuel consumption and Brake power have a much closer curve to each other, but Indicated thermal and brake thermal efficiency of B100 leads all other fuels and proved to show better performance abilities. The heat balance charts of biodiesel and its blends have shown a better usage of heat supplied by the combustion of the fuel, to produce brake power than comparable with petroleum-diesel, which is the important factor to define the Thermal efficiency of an engine. Exhaust emissions of diesel, biodiesel and its blends have been compared to predict that higher amount of HC and CO2 gases are given out by biodiesel due to the longer chains of hydrocarbons in biodiesel (Methyl-Ester Soybean Oil). NOx are produced due to reaching of higher temperature during combustion, but can be controlled by adding proper additives (ethanol) and usage of catalytic convertors. On the whole it could be stated that, Biodiesel have shown a better performance and heat utilization abilities than to petro-diesel, therefore with the proof of the data obtained, Biodiesel could be used as an alternative fuel in all existing diesel engines without any modifications, which is clean green, economical to produce, eco-friendly, renewable and biodegradable unlike petroleum-diesel.

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