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RESEARCH ARTICLE

CI Engine Performance Analysis using Sunflower and Peanut Bio-Diesel Blends

Manjunatha, M[1]., Rakesh, R[2]., Y.T. Krishne Gowda[3], and G. Panduranga Murthy[4]

1. Research Scholar, Department of Mechanical Engineering MIT Mysore, Karnataka
2. Assistant Professor, Department of Mechanical Engineering MIT Mysore, Karnataka
3. Professor, Department of Mechanical Engineering MIT Mysore, Karnataka
4. Professor, Department of Chemistry MIT Mysore, Karnataka

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Corresponding Author

Prof. Manjunatha M

Abstract

The availability of energy resources plays a pivotal role in the progress of a country. Over the last few decades, there is an increase in the consumption of energy worldwide resulting in the depletion of fossil fuels. This necessitates dependency on other countries for energy resources. Therefore, a renewable eco-friendly alternate fuel has to be replaced in place of fossil fuel which can be vegetable oils as a substitute fuel for diesel. Since, oils are more viscous it cannot be used directly in CI engines without any engine modification thus; a conversion of vegetable oils to biodiesel is done by a Transesterification process. The present paper is restricted to Bio fuel substitute for the production of diesel which can be achieved from a number of edible and non-edible oil resources. The oil obtained from these seeds of different categories was transesterified by suitable method depending on their FFA content to achieve the optimum level of biodiesel. Further, the obtained biodiesel was used to operate CI-Engine and analyzed with all the standard parameters. Finally, the blends of Sunflower and Peanut Bio-Diesel were used to evaluate the efficiency of CI-Engine system by employing variable reaction mixtures inorder to determine the recitation of the CI-Engine using transesterified peanut and sunflower oil methyl esters blends with diesel.

INTRODUCTION

ENERGY is the chief carter of profitable growth and plays a vital role in sustaining the modern economy and society. The energy crisis and environmental pollution are of alarming concern worldwide. Hence, energy security is an important global policy issue for more than four decades. The global energy markets have relied heavily on fossil fuels like coal, crude oils and natural gas which provides most of the world's supply of primary energy needs, being non-renewable, they brought with them global de-stabilizing price shocks. The extensive worldwide use of fossil fuels not only threatened to energy security but also resulted in serious environmental problems particularly, climatic detrimental changes. One of the key challenges facing the world is how to meet the growing energy needs and sustain economic growth without contributing any pollutants which alters the climate harmfully. The cleaner renewable sources of energy with cost-effectiveness are the ultimate solution to combat the issues of global energy crisis. India faces a dreadful challenge in meeting its energy needs and in providing sufficient energy of preferred quality in various forms into a sustainable manner and at competitive prices.

The renewable energy sources in general and bio-fuel energy in particular is capable of reducing our dependency on foreign import thereby, increasing the security of energy supply to meet the country needs. The ethanol and bio-diesel are the two liquid bio fuels that can replace/substitute gasoline /diesel respectively. The first use of vegetable oil in a compression ignition engine was first demonstrated through Rudolph Diesel who used peanut oil in his diesel engine [1]. The long term use of vegetable oils leads to injector clogging and the thickening of crankcase oil which resulted in piston ring sticking. Therefore, vegetable oils are not used in Spark Ignition Engines because of endurance issues [2]. The production and utilization of bio fuel would generate the new economic opportunities in term of creation of job opportunities in rural areas apart from better management of the environment.

CHEMICAL CONVERSION

Vegetable oils are generally called as Tri-Glycerides. These Glycerides are long chain of fatty acids. The composition of fatty acids must be ensured before conversion. The amount of fatty acids affects the quality of oil, longer the chain of fatty acids oil will be more viscous in nature. The FFA (Free Fatty Acid test) test determines the composition by titrating the oil with base with known normality.

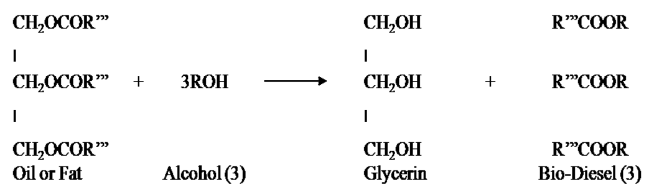
Initially FFA test is carried out by taking 10g of oil, 50ml of isopropyl alcohol and 2 to 3 drops of 0.1N NaOH which is a base catalyst is added to a conical flask which is then heated upto 60°C, shake the mixture and allow it to cool upto room temperature. After that add 2 to 3 drops of phenolphthalein indicator to the mixture which speed up the reaction. Titrate the mixture against 0.1N NaOH through burette until faint pink colour appears. Note down volume of NaOH consumed from burette and calculate the FFA using the formula

$$FFA\ (\%) = 0.282V$$

If amount of FFA is less than 4% single stage Transesterification Process is Preferred and If amount of FFA is greater 4% Double stage is Preferred.

CONVERSION PROCESS

The Transesterification is the process used for preparation of Bio-Diesel using vegetable oils. Bio-Diesel is a mono-alkyl esters of long chain fatty acids derived from vegetable oils. It is chemically called Free Fatty Acid-Alkyl Ester. Eventhough, "diesel" is part of its name, there is no petroleum or other fossil fuels in biodiesel. Biodiesel refers to the pure fuel before blending with diesel fuel. The Reaction is as follws.



Bio-diesel is a substitute fuel for Compression-Ignition internal combustion engines. It is produced by the transesterification of waste or vegetable oils and animal oils, or fats with lower alcohols. Bio-diesel is a clean burning fuel made from vegetable oils. Bio-diesel is made up of almost 10% oxygen, making it a naturally "oxygenated" fuel. It is obtained by reaction of vegetable oil with alcohol in presence of catalyst.

The NBB (National Board of Bio-Diesel) has also formed the National Biodiesel Accreditation Commission that has put into place an accreditation program for companies selling bio-diesel and bio-diesel blends. It has approval for bio-diesel marketers and provides the consuming public with additional assurance and confidence that bio-diesel purchased form a Certified Biodiesel Marketer (CBM) will meet ASTM specifications. Once the program has been fully implemented, NBB recommends that, all bio-diesel marketers become certified, and that all bio-diesel consumers specify the purchase of bio-diesel from NBAC Certified Marketers. [8]

MATERIALS AND METHODOLOGY

The survey was conducted in the regions of Tumkur district to obtain first hand informations from lead farmers followed by merchants respectively. The samples were procured from seed and oil merchants during 2014-15 for further study.

Oil extraction from the seed samples

The selected and collected seed samples were subjected for oil extraction using suitable blenders and unit. The oils were statistically evaluated for its quality and quantity using stanadard procedure.

Transesterification process

After extraction of oil from the seed samples, the oil samples were subjected for transesterification process. The transesterification experimental setup consists of automated Water bath with Temperature Control, Air-cooled Condenser, Round Bottom flask (1000ml), Separating funnel (1000ml), Electronic weighing machine, Conical flask, Test tube, Burette and Stirrer.

The Chemicals used in the transesterification process were of Methanol (CH_3OH), Sodium Hydroxide (NaOH) pallets, Iso-propyl alcohol (C_3H_7OH) and Phenolphthalein indicator. The steps involved in this process are described below.

Preparation of Catalyst with alcohol:
Approximately 3.5-6g of NaOH pallets was weighed and dissolved in a 300ml methyl alcohol and stirred it well for about 5 to 8 minutes. Then the solute particles were dissolved into solvent and form a solution having base catalyst which is a methoxide mixture.

Reaction process:
The 1litre of vegetable oil was taken in round bottom flask and heated upto 60^0C to 65^0C with continuous stirring. At 60^0C to 65^0C, 300ml methoxide mixture (300ml CH_3OH per litre of vegetable oil plus appropriate quantity of NaOH pallets) was added. The heating process was continued for 30min., the color change from turbid orange to chilly red was observed. The sample was taken in a test tube and allow it to settle (2 Distinct layers are observed due to density difference) as shown in figure 3.1. Run the process for another 1½ hour.

Separation process:
The mixture was transfer to a separating funnel and allows glycerin to settle for 2 hours. Then precipitation of oil on bottom of the separating funnel was formed and the bio-diesel was stays at the top which is as shown in Figure 3.2. Finally, the bio-diesel is separated and it contains glycerin and catalyst. The glycerin layer was drained and stored at controlled conditions. Later, the biodiesel was transferred to plastic washing apparatus.

Removal of glycerine:
Technically, the glycerin phase is much denser than biodiesel phase and these two phases were separated through gravity principle. Then, the glycerin was simply drawn off the bottom of the settling vessel. In some cases, a centrifuge will be used to separate these two materials faster as shown in figure 3.3. Finally, the acid wash is done inorder to remove impurities if any and at impurities will be neutralized.

Removal of catalyst and water:
The bio-diesel is mixed with approximately 2 to 5ml of suitable concentrated acid (HCl or H_2SO_4) and the mixture was allowed to separate in a separating funnel for about 1-2hrs as shown in figure 3.4. This leads to neutralization reaction leaving salt and water. Then, the salt was separated and biodiesel was washed with warm water at 40^0C. Subsequently, it was heated upto 110^0C in order to remove water by the process of vaporization. Finally pure bio-diesel was obtained.

Fuel Preparation process:
The trans-esterified bio-diesel was chemically added with conventional diesel. It was evident that, the dilution or blending of vegetable oils with other fuels like diesel fuel would bring the viscosity will be closer to a specification range. Therefore, Jatropha oil was blended with diesel oil in varying proportions with the intention of reducing its viscosity [4, 5]. Using this fuel, the engine test is performed in the Bioenergy Research laboratory for various proportions and the generated results were represented in the tables, graphs, figures and statistical calculations.

B PROPERTY ANALYSIS

In the Laboratory, CI-Engines were designed to run with Bio-diesel as fuel, alternative to Petroleum diesel. The analyzed properties of Biodiesel were closer to that of Diesel. Because a large variation in properties of tested fuel may lead to erratic running of engine and may cause damage to the engine system along with poor performance. The following are some of the properties analyzed.

1. Flash and Fire Point
2. Specific gravity and Density
3. Viscosity
4. Calorific Value

Flash and Fire Point:
The flash point of oil was the minimum temperature at which vapor was given off at a sufficient rate to form an inflammable mixture but not supporting continuous combustion. The Fire Point of oil was the minimum temperature at which, rate of evaporation was sufficient to provide for continuous combustion. Knowledge of these two points was used to safeguard the system against the risk of fire when the oil is exposed to high temperature in service. Both Ignition delay and combustion pattern will have their dependency on flash and fire point of the tested fuel which as shown in the figure 3.5.

Specific Gravity and Density
Specific gravity is also called as relative density which is defined as the weight of liquid sample to weight of standard liquid. Generally distilled water is chosen as standard liquid. The specific gravity for bio-diesel is given by density of the liquid is defined as the ratio of weight per unit volume for liquids. The density can be calculated by using specific gravity *i.e.,* Density = 1000 x Specific Gravity asper the following formula.

$$SG = \frac{\text{Weight of the liquid sample}}{\text{weight of standard liquid}}$$

Viscosity:
Viscosity is that property of the liquid that resists a change in its shape; it is also referring to as internal friction. The viscosity decreases with an increase in temperature. The viscosity is determined by say-bolt viscometer which as shown in the figure 3.6.

Calorific Value:
Calorific value decides heat; the energy released during combustion and is defined as of heat liberated in KJ or Kcal. by the complete combustion of 1 Kg of fuel. The combustion process generates water vapor and certain techniques may be used to recover the quantity of heat contained in this water vapor by condensing it. There are two types of calorific values which is defined is as follows,
Higher calorific value is the total heat liberated in KJ or Kcal by the complete combustion of 1 Kg of fuel.
Lower calorific value is the difference of higher calorific value and heat absorbed by the Water vapors
The below table 3.1 shows the test results of diesel relating to characteristic features of Sunflower oil, Peanut oil, Sunflower Oil Methyl Ester (SOME), Peanut Oil Methyl Ester (POME) respectively.

PERFORMANCE TEST

The Engine performance is an indication of the degree of success of the engine performs its assigned task, *i.e.*, the conversion of the chemical energy contained in the fuel into the useful mechanical work. The performance of an engine is evaluated on the basis of the following parameters [3].

Brake Power (B.P): The power developed at the output shaft of the engine is termed as Brake Power; it is the power available at the crankshaft of the engine.

Specific Fuel Consumption (SFC): It is defined as the ration of fuel consumed per unit time to power output.

Brake Thermal Efficiency (BTE): It is the ratio of output shaft power (Brake power) to the Heat input supplied to the engine.

Brake Mean Effective Pressure (BMEP): Mean effective Pressure is defined as a hypothetical pressure which is thought to be acting on the piston throughout the power stroke. If the mean effective pressure is based on Brake power then it is called as Brake Mean Effective Pressure (BMEP).

A FORMULAE USED FOR CALCULATIONS

1) Quantity of fuel used , $m_f = \frac{Xcc \times SG}{1000 \times t}$ Kg / Sec

Where Xcc = Volume of fuel Consumed (10cc)
SG = Specific Gravity of the fuel
t = Time taken for 10 cc of Fuel consumed

2) Heat supplied to the Engine, $Q_f = m_f \times CV$ in kW; Where CV = Calorific Value Of fuel in (KJ/Kg)

3) Brake Power Output, B.P = $\frac{2\pi NT}{60{,}000}$ in kW

Where, T = Torque in (KN-m) = P*r*9.81
P = Net Load in Kg
r = Radius of rope (0.15m)
N = Rated rpm of the Engine (1500rpm)

4) Specific Fuel Consumption, S.F.C = $\frac{m_f \times 3600}{BP}$ Kg/KW-Hr

5) Brake Thermal Efficiency (BTE), $\eta_{BTE} = \frac{BP}{Q_f}$

6) Brake Mean Effective Pressure (BMEP)

$$BMEP = \frac{60 * BP}{100 * L * A * N * k * n * 100} \text{ bars}$$

Where, L = Stroke Length (0.11m)

D = Bore diameter (0.08m)

A = Area of Cylinder ($A = \pi D^2 / 4$) (=5.02E-03m ^{2})

k = Stroke type (4 Stroke K=0.5) and n = Number of Cylinders (n=1)

EXPERIMENTAL TEST RIG

The test rig was used in the analysis; it consists of a four-stroke greaves make Diesel engine, coupled Mechanical dynamometer. The engine is water-cooled type and therefore both load test as well as Heat balance sheet can be conducted. It runs at a Maximum speed of 1500 rpm. The test rig is complete with base, air measurement system, and fuel measurement system and temperature measurement arrangement using thermocouples to measure temperature digitally

The following are the specifications of diesel engine test rig used in the study is as shown in figure 4.1

Cylinder Bore	D = 80 mm
Cylinder Stroke	L = 110 mm
Brake Horse Power	B H P = 10HP
Rated Speed	N = 1500 rpm
Make	Kirloskar
Type	Naturally aspirated
Loading Type	Mechanical

The experimental procedure for performance analysis of CI engine was to check the lubrication system of the engine on priority basis and fuel tank level. The water was allowed to circulate through the cylinder block and Calorimeter then start the engine using the push button. After that, the load was applied on the engine and the readings of Engine speed, Time taken for 10 cc of Fuel consumed and Net brake load were recorded. The procedure was repeated for different loads. Finally, the engine was stoped by removing the load on the engine and then the fuel supply was made off and the experimentation for about different load trials was continued.

RESULTS AND DISCUSISSION

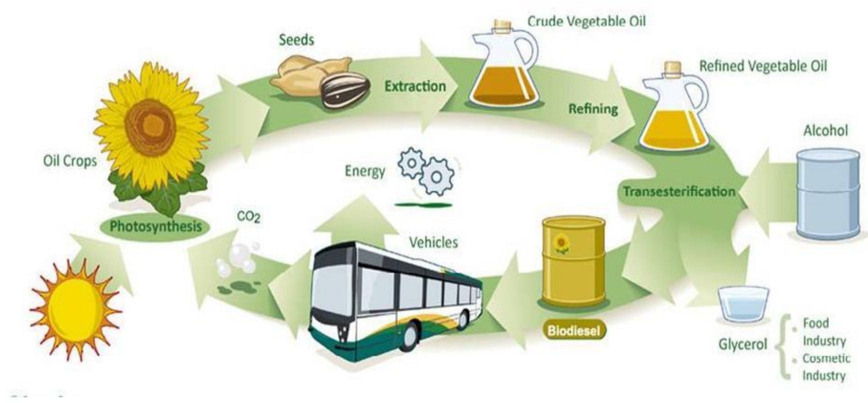


Figure 1.1: Bio-Diesel cycle

Figure 3.1: Chemical reaction

Figure 3.2: Separation of Bio-diesel (Gravity Separation)

Figure 3.3: Removal of glycerin

Figure 3.4: Removal of glycerin

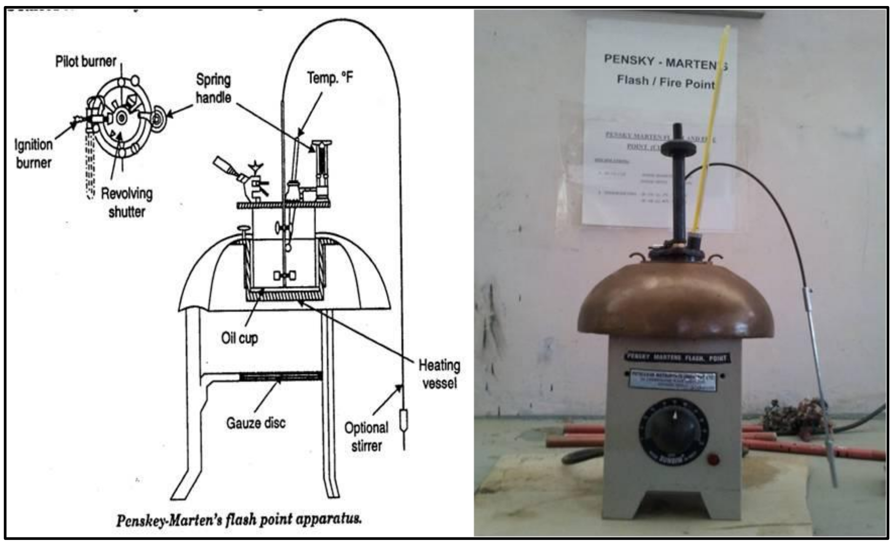


Figure 3.5: Flash Point and Fire point Experimental Apparatus

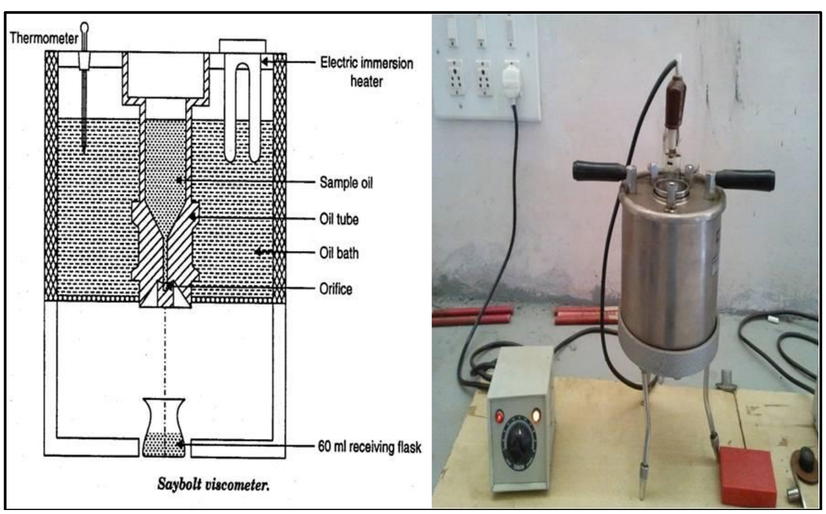


Figure 3.6: Viscosity Apparatus (Saybolt Viscometer)

Oils	Flash Point(°C)	Specific Gravity	Kinematic Viscosity at 40^{O}C	Calorific Value kJ/kg
Diesel	65	0.814	15.38	42000
Sunflower	123	0.864	13.47	39618
Peanut	125	0.897	13.56	36562
SOME	63	0.834	14.02	35462
POME	64	0.821	14.86	34838

Table 3.1 Properties test results of SOME and POME

Figure 4.1: Diesel engine Test rig

1. **Diesel and Sunflower Blends**

a. BMEP V/S BSFC

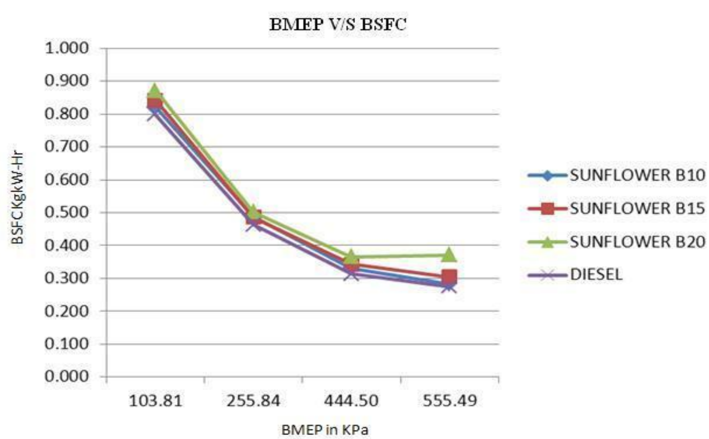


Figure 5.1: BMEP V/S BSFC for SOME with Diesel

The Figure 5.1 shows the variation of BMEP with respect to BSFC for Diesel and Sunflower biodiesel blends namely B10, B15 and B20. From the graph it is clear that BSFC decreases with increase in BMEP. This variation occurs for the increment loads. The B10 SOME has less BSFC at higher loads and pressures. Thus B10 is best compare to other blends of SOME.

b. BMEP V/S BTE

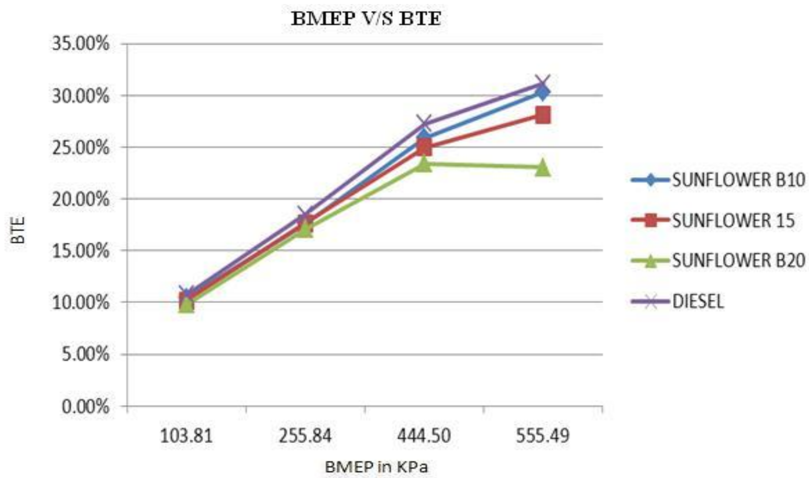


Figure 5.2: BMEP V/S BTE for SOME with Diesel

The figure 5.2 shows the variation of BMEP with respect to BTE for various loads of SOME blends. From the graph it is clear that BTE increases with increase in brake mean effective pressure. B10 SOME slightly greater values of BTE compare to other blends but it is almost equal to that of conventional Diesel fuel.

2. Diesel and Peanut Oil Blends
   a. BMEP V/S BSFC

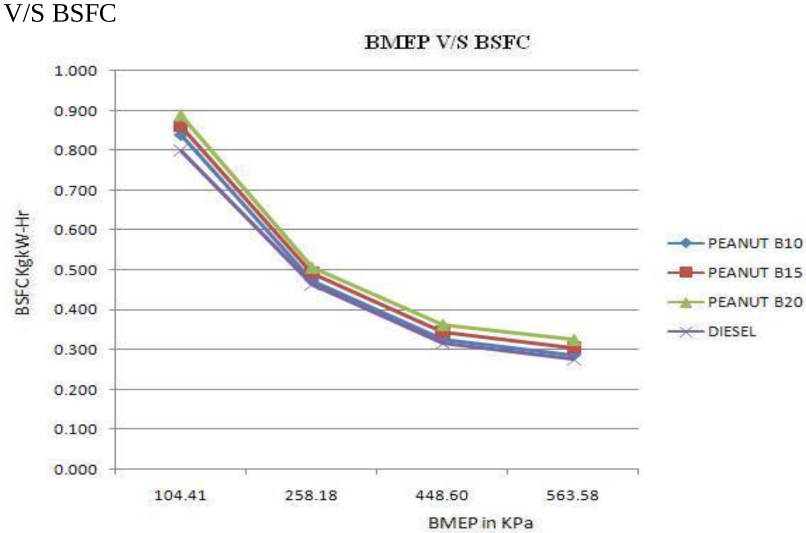


Figure 5.3 BMEP V/S BSFC for POME with Diesel

Figure 5.3 shows the variation of BMEP with respect to BSFC that for Diesel and it is clear that BSFC decreases with increase in BMEP. This variation occurs for the increment loads. The B10 POME has less BSFC at higher loads and pressures. Thus B10 POME is best compare to other blends.

b. BMEP V/S BTE

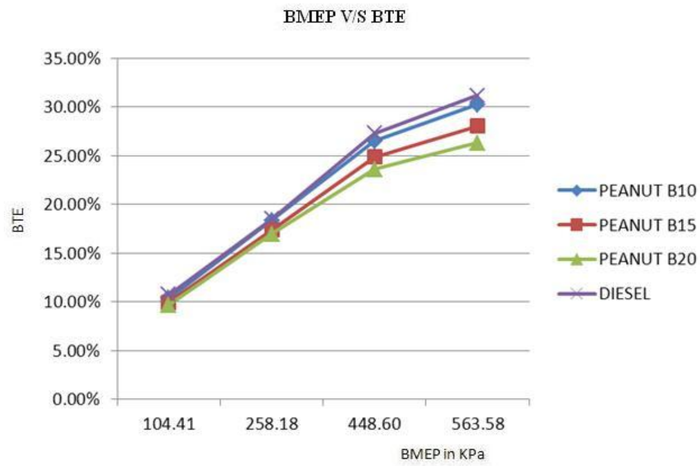


Figure 5.4 BMEP V/S BTE for POME with Diesel

The figure 5.4 shows the variation of BMEP with respect to BTE for various loads of POME blends. From the graph it is clear that BTE increases with increase in brake mean effective pressure. B10 POME slightly greater values of BTE compare to other blends and slightly lesser than diesel at higher loads.

Conclusion

The conclusions deriving from present experimental investigation to evaluate the experimental tests are conducted on 4-stroke, single cylinder, water cooled and direct injection diesel engine by using virgin biodiesel blends of B10, B15, and B20 pure diesel at constant speed of 1500rpm.

From the better efficiency point of view it can be conclude that the blend B10 has given the better performance in the sense of brake thermal efficiency, specific fuel consumption. No engine seizing, injector blocking was found during the entire operation while the engine running with different blends of biodiesel.

The BSFC value obtained for POME at B10 is 0.27 kg/kW-hr and 0.285 kg/kW-hr for pure Diesel fuel. The BSFC of POME B10 blend is comparatively lesser than Diesel at full load condition.

The BTE value for POME is 31.04% which is the maximum BTE obtained for B10 blend compare to all other blends with diesel having BTE 30.03% at full load condition.

The BSFC value obtained for SOME at B10 is 0.28 kg/kW-hr and 0.285 kg/kW-hr for pure Diesel fuel. The BSFC of POME B10 blend is comparatively lesser than Diesel at full load condition

The BTE value for SOME is 30.04% which is the maximum BTE obtained for B10 blend compare to all other blends with diesel having BTE 30.03% at full load condition. The BTE value of B10 SOME is almost equal to that of Diesel

The B10 POME is giving comparatively better performance than other blends. Also B10 POME has greater thermal efficiency and lesser specific fuel consumption than B10 SOME which is optimized blend in case of SOME in comparison with Diesel.

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